Fresh and Salt

A Curriculum Integrating Ocean and Great Lakes Literacy Principles

COSEE Great Lakes

Centers for Ocean Sciences Education Excellence

A Curriculum Integrating Ocean and Great Lakes Literacy Principles

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* ***OL:*** Ocean Literacy Principle
* ***GL:*** Great Lakes Literacy Principle

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Fresh and Salt

Introduction

COSEE Great Lakes—A Regional Project Linking Scientists and Educators to Collaborate on Ocean and Great Lakes Science

The National Science Foundation's Division of Ocean Sciences supports a network of coordinated centers whose mission is to spark and nurture collaborations among research scientists and educators to advance ocean discovery and make known the vital role of the ocean in our lives. COSEE Great Lakes is a member of this network of Centers for Ocean Sciences Education Excellence (COSEE) fostering the integration of ocean and Great Lakes research into high quality educational materials. These centers enable Great Lakes and ocean researchers to gain a better understanding of educational organizations and pedagogy, while providing educators with an enhanced capacity to understand and deliver high-quality educational programs in the ocean sciences.

COSEE Centers also provide material to the public that promotes a deeper understanding of the Great Lakes and the ocean and their influence on quality of life and national prosperity. COSEE's goals include inspiring citizens to become more scientifically literate and environmentally responsible through standards-based science curricula and programs that bridge the ocean and freshwater sciences, while also creating dynamic linkages between the education and research community.

Toward a Fresh and Salt Curriculum

COSEE Great Lakes has continued to meet the challenge of improving today's science education through its professional training for educators and innovative curriculum resources for students and teachers, grades K-16. Our curriculum-based project began with *Greatest of the Great Lakes: A Medley of Model Lessons,* 41 activities for grades 4-10, providing highly relevant and timely lessons. The topics encompass regional fields of science research and at the same time allow us to address the priorities that educators express, those that deal with environmental issues and responsibility.

The culmination of the project includes *Fresh and Salt*, a collection of activities connecting Great Lakes and ocean science topics to enhance teacher capabilities for accessing science information that is vital to maintaining the environmental health and economic benefits of our nation's freshwater and marine systems. This exemplary collection provides teachers with an interdisciplinary approach to ensure students achieve optimum science understanding of both Great Lakes and Ocean Literacy principles. A comprehensive range of instructional modes is offered, including data interpretation; experimentation; simulation; interactive mapping; investigation, and decision-making.

Criteria for Selection

The 14 activities that compose *Fresh and Salt* were selected based on a distinct set of criteria and opportunity to apply the science process skills students need for effective science learning. In seeking recommendations for quality activities, the COSEE Great Lakes educator responsible for this curriculum project contacted other COSEEs, the NOAA Education Office, Sea Grant programs outside of the Great Lakes region, and the National Marine Educators Association through its online website, "The Bridge."

The recommended activities were carefully considered by the COSEE Great Lakes team comprised of education professionals from the

Illinois-Indiana Sea Grant Program, Ohio Sea Grant Program, New York Sea Grant Institute, Pennsylvania Sea Grant Program, Michigan Sea Grant Program, and the Minnesota Sea Grant Program.

To ensure excellence, activities were required to meet the following criteria for selection:

- Enhance learning skills: Inquiry, hypothesis, synthesis, and other essential skills.
- Offer numerous learning applications: Problem-based learning, data gathering and interpretation, and authentic, real world experience.
- Integrate science with other disciplines.
- Provide grade level coverage in elementary, middle, and secondary schools.
- Offer a good representation of activity types, e.g., role playing, decision-making, data interpretation, and experimentation.

Designed to be used by teachers in grades 5-12, these pre-existing materials have been rigorously reviewed and tested in schools. Pilot testers in Great Lakes schools evaluated materials for appropriateness of the grade level, reliability, accessibility, functionality, and relevance to the literacy principles. The final lessons selected were developed by national and regional agencies, institutes, organizations and universities.

Using the alignment tables, educators can see how each activity is matched with State Science Education Standards for Great Lakes states, Great Lakes and Ocean Literacy Principles, and National Geography Standards. This standards-based framework will enable educators to integrate the *Fresh and Salt* curriculum into classrooms and informal learning environments. An Instructional Mode chart is also provided to assist educators in identifying the type of activity and its application to the curriculum.

Using the Fresh and Salt Collection

This curriculum is organized by pairing two activities, typically one freshwater and one saltwater, that are aligned to each of the Ocean Literacy and Great Lakes literacy principles. In each literacy principle section, we have included a preamble that provides an overview of the activity pairs; how they relate to the literacy principle; how they may compare and/or contrast; and comments from teachers who have pilot tested the activities.

Enhancing Great Lakes and Ocean Literacy

Participation in COSEE programs and classroom integration of supplemental curriculum materials provides educators, both formal and informal, with an interdisciplinary means of creating a more scientifically literate work force and citizenry. Educating students about ocean and Great Lakes topics can enhance science, math, geography, and technology skills, as well as foster new understandings about best practices for protecting our local aquatic and marine resources. The new Great Lakes Literacy principles and associated website **www.greatlakesliteracy.net** had its origin in Ocean Literacy, a concise framework for conveying the most important science principles and interconnected concepts that citizens around the globe should know. The Ocean Literacy principles, fundamental concepts, and scope and sequence may be found at **http://oceanliteracy.wp.coexploration.org**.

It is our hope that this new curriculum will engage students in relevant science and help prepare students as responsible decision-makers and future leaders to promote a sustainable society. We now invite you and your students to explore the world of water and spice up your classroom with a little *Fresh and Salt*!

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Density: Sea Water Mixing and Sinking
Adapted by NASA Aquarius Education and Public Outreach based on an original activity by the Maury Project, American Meteorological Society Aquarius.nasa.gov

Going with the Flow
Prepared by the Office of Education and Outreach at the University Corporation for Atmospheric Research and Eastern Michigan University with funding from award #NA07SEC4690004 from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce to Eastern Michigan University. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration (NOAA) or the U.S. Department of Commerce.

Ooze Clues
Written by Lisa Ayers Lawrence, Virginia Sea Grant, Virginia Institute of Marine Science. The Bridge is sponsored by NOAA Sea Grant and the National Marine Educators Association © Virginia Sea Grant Marine Advisory Program, Virginia Institute of Marine Science, College of William and Mary

What Causes the Shoreline to Erode?
Developed from original OEAGLS, with the support of the Great Lakes Protection Fund, Ohio Sea Grant, and The George Gund Foundation, 1993-97.
Modified from the OEAGLS EP-7 "Coastal Processes and Erosion" by Beth A. Kennedy, Ohio and Roseanne W. Fortner, Ohio Sea Grant Education Program, The Ohio State University

Implications of Warming in the Arctic
Lesson is part of Arctic Community Curriculum © 2006, Will Steger Foundation, Elizabeth K. Andre Globalwarming101.com

How is Coastal Temperature Influenced by the Great Lakes and the Ocean
Written by Rosanne W Fortner and Victor J. Mayer
© Fall 2009, Heldref Publications, heldref.org

Bats and Hot Dogs!
Created by Stephany Hannon - Fairhope HS, Alabama; Becky Kapley - Cuyahoga Community College - Ohio Distributed by-MBARI: Monterey Bay Aquarium Research Institute George Matsumoto - Education Research Specialist. February 2006, mbari.org/earth/

Being Productive in the Arctic Ocean
Produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration, NOAA, Oceanexplorer.noaa.gov

Tangled Web
Great Lakes in My World ©2005 by Alliance for the Great Lakes. Curriculum Developers: Anne Richardson and Stephanie Smith; Editor: Sarah Surroz

Sea Connections
Written by Barbara Branca for
Smithsonian Education; Ocean Planet: Interdisciplinary Marine Science Activities

Pollution Solution
Written by Barbara Branca for
Smithsonian Education; Ocean Planet: Interdisciplinary Marine Science Activities

Downeaster Alexa
Produced by the Ohio State University, Co-Directors: Roseanne W Fortner and Victor J. Mayer; Content Advisor: David Bromwich; Curriculum Editor: Tony P. Murphy. © The Ohio State University Research Foundation, 1993

I, Robot, Can Do That!
Produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration, NOAA, Oceanexplorer.noaa.gov

Calling All Explorers
Developed by Kimberly Williams, Miller Place High School, Long Island, New York for the National Oceanic and Atmospheric Administration,
NOAA Oceanexplorer.noaa.gov

Activities by Grade Level

Fresh and Salt Activities - COSEE Great Lakes	Format	Grade Level
Principle 1: The Earth has one big ocean with many features.		
Density: Sea Water Mixing and Sinking	Experiment	6 - 12
Going with the Flow	Experiment/Data	3 - 5
Principle 2: The ocean and life in the ocean shape the features of the Earth.		
Ooze Clues—Diatom Ooze	Data Interpretation	9 - 12
What Causes the Shoreline to Erode	Investigation	6 - 12
Principle 3: The ocean is a major influence on weather climate.		
Implications of Warming in the Arctic	Cooperative learning/ feeback loops	6 - 12
How is Coastal Temperature Influenced by the Great Lakes and the Ocean?	Investigation/ mapping/ graphing	6 - 12
Principle 4: The ocean makes Earth habitable.		
Bats and Hot Dogs!	Real - time Data Interpretation	6 - 9
Being Productive in the Arctic Ocean	Experiment	9 - 12
Principle 5: The ocean supports a great diversity of life and ecosystems.		
Tangled Web	Simulation	5 - 8
Sea Connections	Food Web Card Game	6 - 8
Principle 6: The ocean and humans are inextricably interconnected.		
Pollution Solution	Experiment/Role-play	6 - 8
Downeaster Alexa: A fishery story	Data Interpretation	6 - 9
Principle 7: The ocean is largely unexplored.		
I, Robot, Can Do That!	Technology Investigation/ Decision - Making	7 - 8
Calling All Explorers	Webquest NOAA	5 - 9

Fresh and Salt

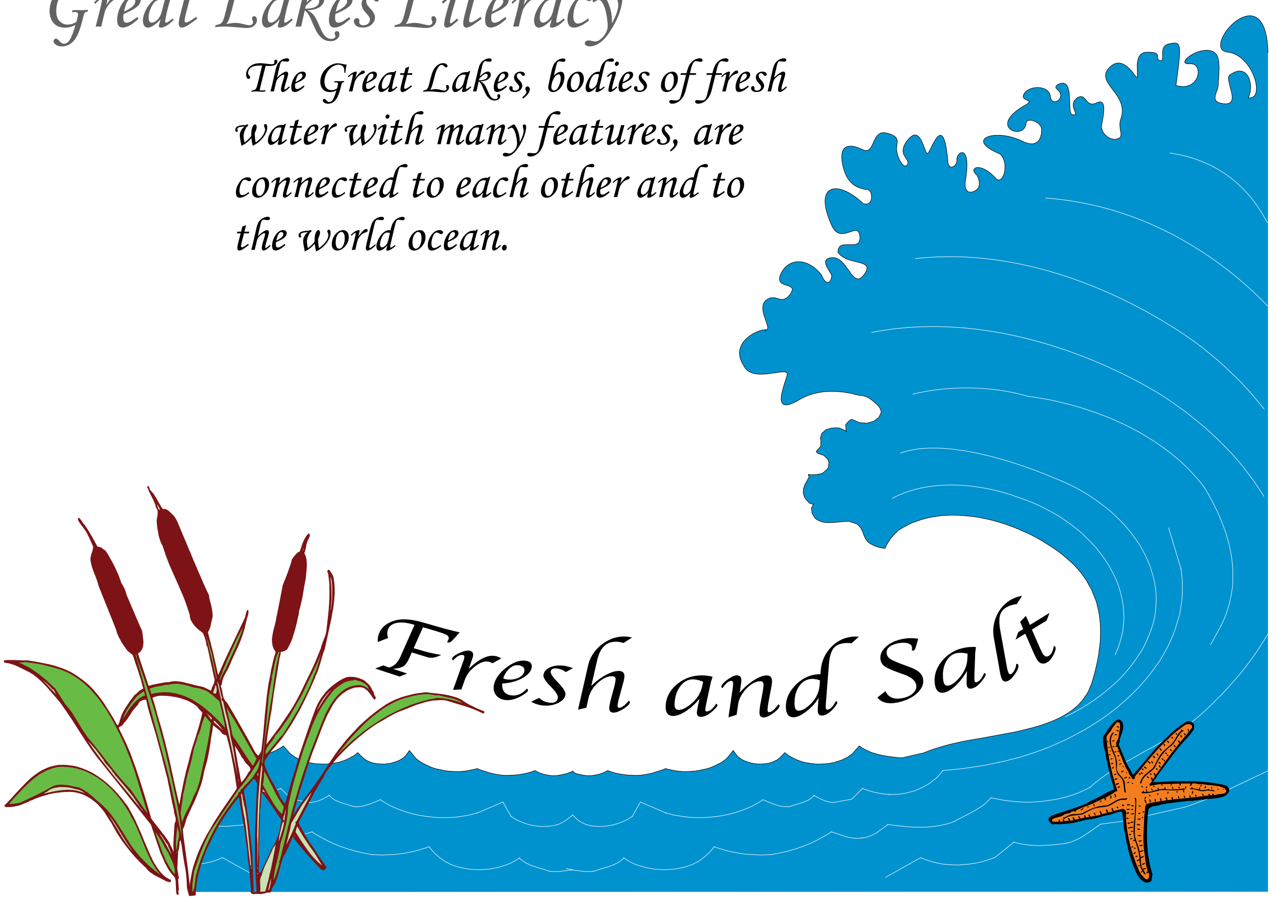
Principle 1

Ocean Literacy

The Earth has one big ocean with many features.

Great Lakes Literacy

The Great Lakes, bodies of fresh water with many features, are connected to each other and to the world ocean.



Fresh and Salt

Principle 1: The Earth has one big ocean with many features. (OL[1])

The Great Lakes, bodies of fresh water with many features, are connected to each other and to the world ocean. (GL[2])

Essential Principle #1 addresses the dominant physical features of the ocean and the interconnected nature of its circulation system powered by wind, tides, and the force of the Earth's rotation, the Sun, and water density differences. Although most of the Earth's water (97%) is in the ocean, as compared with the Great Lakes, it is finite and resources are limited. This principle teaches us that the ocean is connected to all major watersheds on Earth, which drain to the ocean. Both of the included activities incorporate writing and discussion to compare the concept of surface currents in the ocean and fresh water.

Density: Sea Water Mixing and Sinking, from NASA Aquarius Education and Public Out¬reach, is geared towards middle or high school students. This activity explores important characteristic properties that contrast sea water from fresh water. Students learn that two of the most important characteristics of ocean water are its temperature and salinity. Together they help govern the density of seawater, which is a major factor controlling the ocean's vertical movements and layered circulation.

As a class or in small groups, students investigate the role of temperature and salinity in determining seawater density. Students write a brief paragraph describing their observations and results during the experiment. Critical thinking skills are enhanced, including comparison, predicting, and hypothesizing, as students address three questions to assess their level of knowledge and comprehension throughout the activity.

[1] OL: Ocean Literacy

[2] GL: Great Lakes Literacy

Students further investigate the role of temperature and salinity in determining seawater density by using a T-S Diagram, a powerful tool used in studies of seawater density, mixing, and circulation. Such mixing can be a significant factor in causing surface seawater to sink as part of vertical circulation. The use of a laboratory procedure to illustrate the concepts of density, measurement, and graphing provide students with the background and essential information to help understand the concept of ocean salinity. Additional background resources include a concept map, "Properties of Water" from the comprehensive Aquarius Concept Map – *Water & its patterns on Earth's surface*, vocabulary list.

Teacher reviewers offered the following comments:

"I expect my students to use measurement in science. I expect them to use the correct equipment and labels and to fully understand the concept of density. I also expect them to be comfortable using various graphs and tables because the WCKE test is full of this sort of assessment."

"The use of a laboratory procedure makes this extremely interesting to my 8th graders. To me, the use of the graph with the curved lines and the added dimension make this innovative."

"I like this lesson because it reviews concepts like density, volume, and mass. It also has them attempt a new graphing skill. I will use this in the future with all classes. It's a good way to teach a physical science concept through an environmental venue."

Going with the Flow, by the Office of Education and Outreach at the University Corporation for Atmospheric Research and Eastern Michigan University, is a classroom activity based on the book *Ducks in the Flow – Where Did They Go?* Students develop a simple model to discover that air moving over water causes the surface of the water to move horizontally. In writing and in discussion, students relate this concept to surface currents in the ocean and the Great Lakes. Designed to be used in grades 3-5, students work in teams to simulate how wind makes surface water move by transferring energy to the water. Incorporating skills such as observation, simulation, and data interpretation, students are able to address the following key points:

1) Wind makes surface water of the ocean and Great Lakes move.
2) Wind transfers energy to the water. When the wind stops for a brief amount of time, the currents continue to flow because the water still has energy.
3) Objects floating in the ocean or Great Lakes will move with the currents. The ducky in the *Ducks in the Flow, Where Did They Go?* storybook traveled because it floated in surface currents.
4) Surface currents affect the surface water: deep water does not move with the currents.

Educators who reviewed this activity shared these reflective comments:

"The activities had a connected flow and allowed students to investigate concepts about the transfer of wind energy and surface currents through exploration, observation, and group/whole group discussions."

"The student worksheets prompted thinking and required explanations for a student's thoughts. Recording observation notes, using a key to guide drawings, and allowing students to work in cooperative groups added to the quality of the lesson."

"The activity sheets were <u>exceptional</u>. They provided students with enough space to make scientific drawings and write their observations."

"The activities held student interest because they were very 'hands-on.' The kids loved doing the investigations in groups, rather than just following teacher-led demonstrations."

"The relationships of the Great Lakes easily surfaced in Activity 1, as we discussed the movement of the foil balls and related it to water pollution circulating and moving from one body of water to another due to the flow of currents. Students easily made the connections between what happens in the oceans, happens to all bodies of water."

AQUARIUS
Education & Public Outreach

Density: Sea Water Mixing and Sinking

Unit: *Salinity Patterns & the Water Cycle* **I Grade Level:** *Middle or High* **I Time Required:** *two 45 minute class periods* **I Content Standard:** *NSES Physical Science, properties and changes of properties in matter* **| Ocean Literacy Principle 1e:** *Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic.*

Big Idea: *Two of the most important characteristics of ocean water are its temperature and salinity. Together they help govern the density of seawater, which is a major factor controlling the ocean's vertical movements and layered circulation.*

Key Concepts:
- Sea water has characteristic properties (e.g. density) that are independent of sample size.
- There are two main factors that make ocean water more or less dense: temperature and salinity.
- Cold, salty water is denser than warm, fresher water and will sink below the less dense layer.
- Density is defined as the measure of a material's mass (e.g. grams) divided by its volume (e.g. milliliters).
- Mixing of seawater influences the density of seawater thereby affecting ocean circulation. Seawater mixing also has an affect on ocean life.

Essential Questions:
- Can oceans be too salty, or not salty enough?
- What is a pattern? Is ocean salinity a pattern?
- Is salty water heavier than fresh water?
- What is the relationship of salinity to other properties of oceans?
- How do oceans affect climate changes?

Knowledge and Skills:
- Explain the relationship between temperature, salinity, and density.
- Compare the density of salt water and fresh water.
- Measure the density of water and define the units of measurement; a gram is the mass of one milliliter of pure water.
- Demonstrate changes in density through experimentation.
- Compare and contrast results of experimentation with hypotheses.
- Explain the role of mixing of seawater in density-driven vertical ocean circulation.
- Describe the use of a temperature – salinity (T-S) diagram in seawater density studies.
- Read a T-S diagram and an ocean salinity map.

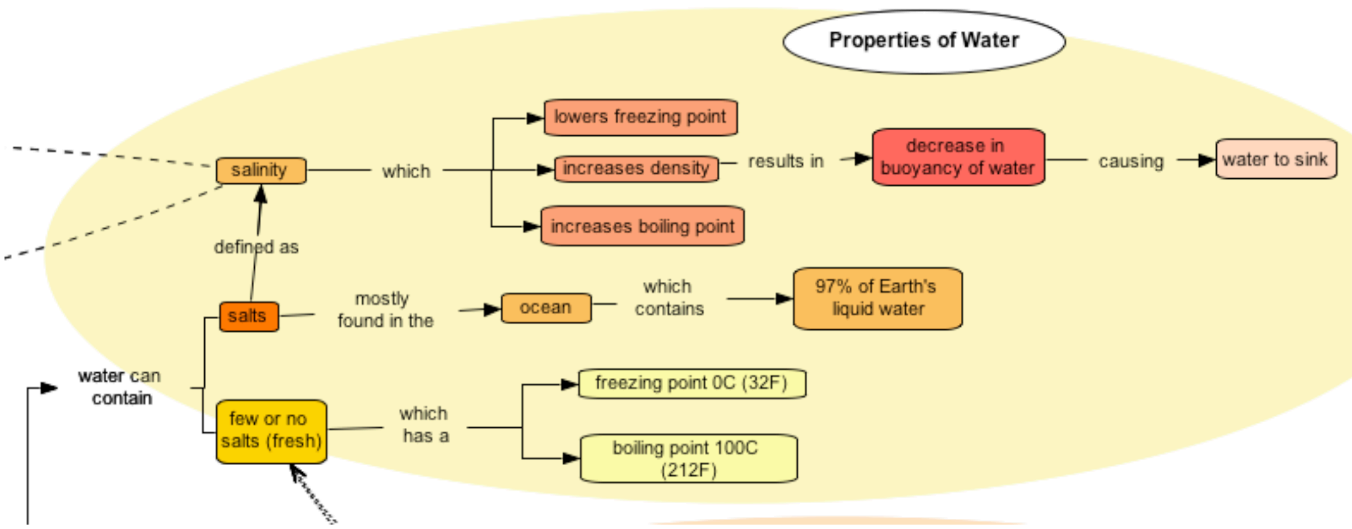
Prior Knowledge:
- The salt in seawater comes from the weathering of earth's land surface.
- Salinity is the measure of the amount of dissolved salts in seawater
- Temperature affects the density of fresh water. Cold water sinks below warm water.

Common Preconceptions:
- Weight and density are not differentiated but are both defined by a sense of "heaviness."
- An object, such as a pebble, is "light for a human, but heavy for water."
- An object floats because it is lighter than water.
- The conception of density is related to the denseness (loose or tight) in the packing of particles; i.e. mass and

volume depend on the conception of the arrangement, the concentration, and the mass of particles.

Concept Map:

This lesson and activity relates to the branch “Properties of Water” from the comprehensive Aquarius Concept Map – *Water & its patterns on Earth’s surface*



Activity 1 Measuring the Density of Water
Background:
Density is weight divided by volume. The density of fresh water is 1 gram (mass) per cubic centimeter (volume). In other words, if you had a cube with the dimensions: 1cm x 1cm x 1cm; and filled it with pure water, that cube of water would weigh 1 gram. This density is expressed as 1 g/cm^3. If you dissolve salt into the water, the salt will increase the fluid’s mass, while its volume will remain the same. Thus, the liquid’s density will increase.

Materials: *Per student group –*
- *graduated cylinders (50 or 100 ml),*
- *4 gm table salt*
- *paper towels,*
- *eyedropper,*
- *scale (0 – 200 gm).*

Preparation: *Distribute materials to student groups.*

Activity 1.
- Determine the density of tap water:
  - Measure the mass of the empty graduated cylinder. Record the weight.
  - Fill the cylinder with water to the 100 ml line. This is the volume.
  - Measure the mass of the cylinder with water.
  - Subtract the mass of the empty cylinder from the mass of the filled cylinder.
  - Divide the mass of the water by its volume. This will yield the density of the tap water. Record your result.
- Determine the density of tap water with salt:
  - Use an eyedropper to remove 2 g (2 ml) of water from the cylinder.
  - While the cylinder is on the scale, add 2 g of salt.

- Read the new water level inside the cylinder. This is the new volume.
- Divide the mass of the water inside the cylinder by its new volume. This is the density of the salt water. Record your result.
- Compare the densities of the salt water and the fresh water.

Activity 1. - Assessment / Questions

- Ask students to write a brief paragraph describing their observations and results during the experiment, in addition to the following questions:
  - When you dissolved the salt into the water the liquid's density **increased, decreased,** or **stayed the same**? (Choose one) Why? *(The salt increases the fluid's mass while its volume remains the same.)*
  - How might the experiment have changed if the temperature of the water had been hot? Cold? Form hypotheses of predictions about temperature and density.
- Discuss whether it will be easier for a person to float in salt water or fresh water. Why? Have any of the students noticed this difference?

Activity 2. Sea Water Mixing and Sinking
Background

In the oceans, the salinity varies over time and from place to place. Typical open ocean salinities vary between 33 and 36 PSU (Practical Salinity Units), equivalent to 33-36 parts per thousand. Two of the most important characteristics of ocean water are its temperature and salinity. Together they help govern the density of seawater, which is the major factor controlling the ocean's vertical movements and layered circulation. The following activity investigates the role of temperature and salinity in determining seawater density. It does so by using a Temperature-Salinity (T-S) Diagram to examine the effect of mixing on density. Such mixing can be a significant factor in causing surface seawater to sink as part of vertical circulation. The T-S Diagram is a simple, but powerful tool used in studies of seawater density, mixing, and circulation. In a T-S diagram, temperature is plotted along the vertical axis in degrees Celsius and salinity is measured along the horizontal axis in PSU. Seawater density is illustrated in the diagram by curved lines of constant density. Surface waters are mixed by winds and deep ocean water mixing is driven by density differences. Circulation in the depths of the ocean is referred to as thermohaline circulation. The deep ocean is layered with the densest water on bottom and the least dense water on top. Water tends to move horizontally throughout the deep ocean, moving along lines of equal density. Vertical circulation is limited because it is easier for water to move along lines of constant density (isopycnals) than across them.

Materials:

- *Pencil,*
- *T-S Diagram (below),*
- *Water Sample Table (below)*
- *Ocean Salinity map*

Preparation: *None (although "Potato Float" is a good activity to acquaint students with the concept of densities of liquids).*

Activity 2

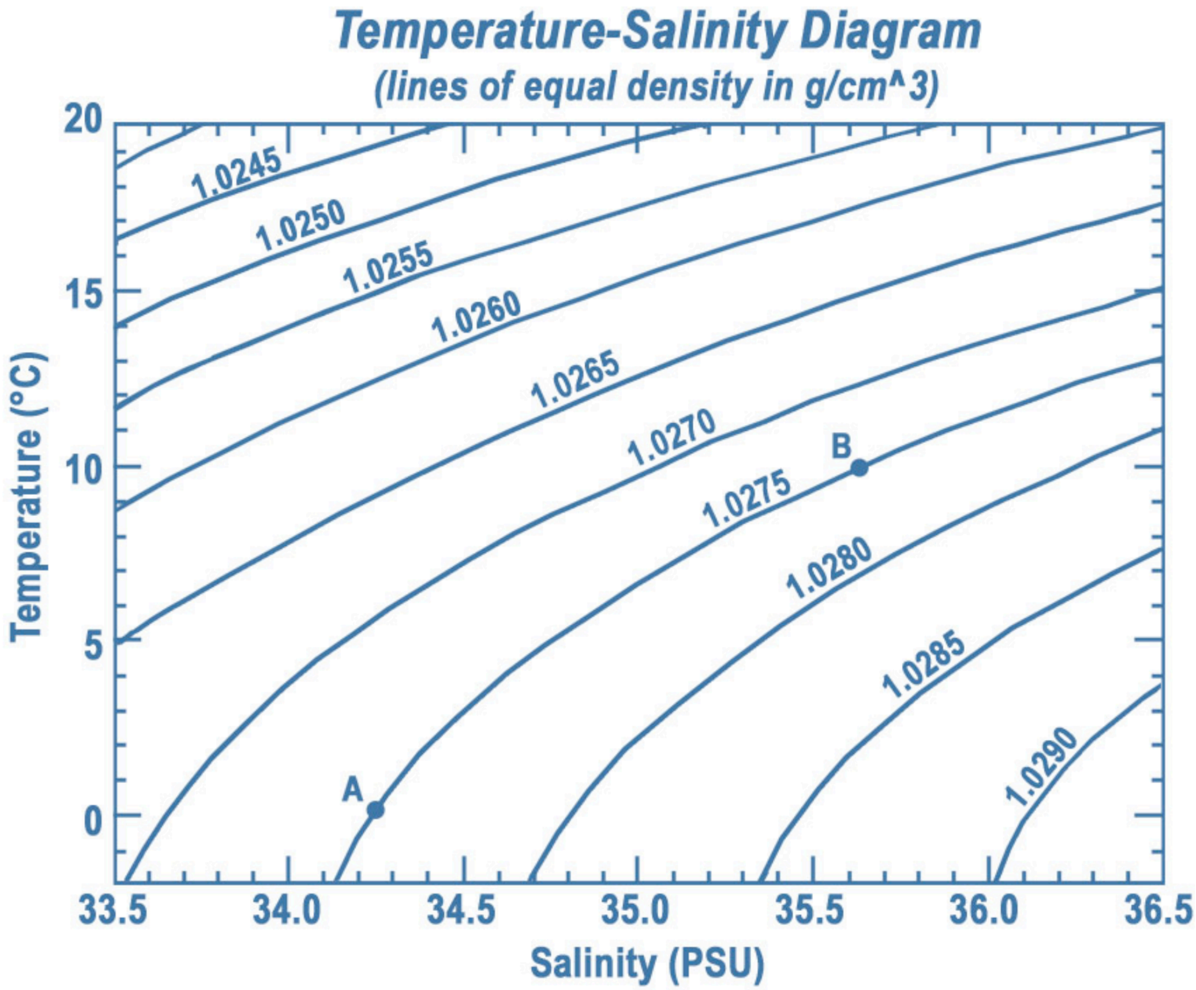
- As a class or in small groups, examine the Temperature-Salinity (T-S) Diagram (below). Temperature is plotted along the vertical axis in degrees Celsius (°C). Salinity is measured along the horizontal axis in Practical Salinity Units (PSU) that is numerically equivalent to parts per thousand (‰). Seawater density, in grams per cubic centimeter (g/cm^3), is shown on the diagram by curved lines of constant density. The value of each curved line appears immediately above each line. Note that temperature and salinity together govern the density of seawater.
- As shown by the T-S Diagram, the density of seawater increases with **increasing** or **decreasing** temperature and with **increasing** or **decreasing** salinity.
- On the T-S Diagram, each seawater sample is plotted as a dot (•) at the point determined by its temperature and salinity. Find the temperature and salinity for the two surface seawater samples

labeled "A" and "B" and record these values in the Water Sample Table (below).
- The density of seawater samples must be determined to several decimal places in order to detect significant differences. Read from the T-S Diagram the densities for the two surface seawater samples labeled "A" and "B" to the fourth decimal place. Record these values in the table. Note that their densities are the same.
- If surface waters of the same density are brought together, they tend to mix. The temperature and salinity of the resulting mixture are somewhere between the temperatures and salinities of the original waters prior to mixing. Record in the table, the temperature and salinity of a water sample "C" that would result if equal volumes of samples "A" and "B" were mixed together. *(Hint: Mixing one liter of 10°C water with one liter of 30°C water produces two liters of water at 20°C.)*
- Comparison of the seawater densities recorded in the table shows that the density of sample "C" is ***less than, equal to,*** or ***greater than*** (choose one) the density of samples "A" and "B" prior to mixing.
- On the T-S Diagram, draw a straight line between the points representing samples "A" and "B". Any possible mixture of these seawater samples, including sample "C," would be represented by a point falling somewhere on the straight line. Regardless of the relative volumes of seawater samples "A" and "B" mixed together, the T-S Diagram shows the resulting mixture will always be **denser** or **less dense** (choose one) than either "A" or "B."
- Comparison of the density of surface seawater samples "A" and "B" with the density of any resulting mixture of these original samples indicate that the mixed water will **remain at the ocean surface** or **sink** (choose one). This can result in broad-scale motions that play significant roles in the layered circulation of the ocean.
- Have students make predications about where high and low salinity water might occur in the world's ocean. Use the Global Ocean Salinity Map to verify predictions and discuss contradictions between the map and student predictions.
- This investigation shows that mixing surface seawaters of the same density, but different temperatures and salinities, produces seawater of **greater, equal,** or **lesser** (choose one) density.

Vocabulary
- **buoyancy:** In physics, an upward force on an object immersed in a fluid (i.e. a liquid or gas), enabling it to float or at least to appear to become lighter. If the buoyancy exceeds the weight, then the object floats; if the weight exceeds the buoyancy, the object sinks.
- **density:** Mass per unit volume of a substance. Usually expressed as grams per cubic centimeter (gm/cm^3).
- **mass:** The property of a body that causes it to have weight in a gravitational field.
- **practical salinity unit (PSU):** Used to describe the concentration of dissolved salts in water, the UNESCO Practical Salinity Scale of 1978 (PSS78) defines salinity in terms of a conductivity ratio, so it is dimensionless. Salinity was formerly expressed in terms of parts per thousand (ppt) or by weight (parts per thousand or 0/00). That is, a salinity of 35 ppt meant 35 pounds of salt per 1,000 pounds of seawater. Open ocean salinities are generally in the range between 32 and 37.
- **salinity:** A measure of the quantity of dissolved solids in ocean water. In general, salinity reflects the total amount of dissolved solids in ocean water in parts per thousand by weight after all carbonate has been converted to oxide, the bromide and iodide to chloride, and all the organic matter oxidized.
- **solute:** A substance dissolved in another substance (the solvent) to create a solution.
- **specific gravity:** The ratio of density of a given substance to that of pure water at 4°C and at a pressure of one atmosphere.
- **volume:** The measure of three-dimensional space occupied by an object.

Activity 1. Original source: *San Juan Institute Activity Series and NASA's "Visit to an Ocean Planet" CD-ROM* **Activity 2. Original source:** *Adapted from the Maury Project, American Meteorological Society*

***Aquarius* Education & Public Outreach URL:** http://aquarius.nasa.gov/



Water Sample Table			
Sample	**Temperature (°C)**	**Salinity (PSU)**	**Density (gm/cm^3)**
A			
B			
C			

Going with the Flow

A Classroom Activity for *Ducks In The Flow - Where Did They Go?*

Summary:

Students use a simple model to discover that air moving over water causes the surface of the water to move horizontally. In writing and in a discussion, students relate this concept to surface currents in the ocean and the Great Lakes.

Student Learning Outcomes:

Students will be able to

- Relate the motion of surface currents (cause) to the motion of objects floating in the ocean and Great Lakes (effect)
- Relate the transfer of energy from wind moving across water (cause) to the horizontal movement of water (effect)
- Use the term "surface current" to explain horizontal movement of surface water caused by wind
- Explain that surface currents affect surface water, not deep water

Standards:

Ocean Literacy Essential Principles and Fundamental Concepts

- The Earth has one big ocean with many features.

National Science Education Standards

- (K-4) Position and motion of objects
- (5-8) Structure of the earth system
- (5-8) Motions and forces
- (5-8) Abilities necessary to do scientific inquiry

Materials: (teams of 2-3 students)

- 5-6 quart clear plastic shoebox (1 per team)
- Water (to fill shoeboxes approximately ¾ full)
- Black construction paper (l per team)
- Bendable straws (1 per student)
- Paper towels (for clean up)
- Newspaper (to cover table/desk)
- *Going with the Flow Data Sheets 1-3* – (1 per student)
- For *Activity 1: Aluminum foil* (Each team crumples 20 one-inch squares into 10 loose balls that will float and 10 tight balls that will sink.)
- For *Activity 2: Rheoscopic fluid* (Dilute 150 ml of rheoscopic fluid in 3 L of water per team; the diluted fluid can be reused.)

Purchase Note: You can purchase rheoscopic (convection) fluid from many online vendors for approximately $10/L:

- Arbor Scientific - www.arborsco.com (# P8-5000)
- Carolina Biological - www.carolina.com (# GEO8450)
- Educational Innovations - www.teachersource.com (# RH-100)
- Fisher Scientific - www.fishersci.com (# S4520 or S4521)

Grade Level: 3-5

Time: 1-2 class periods (45 minutes each)

For more information, please visit:
www.windows.ucar.edu/ocean_education.html

Activity 1 – Directions and Procedure

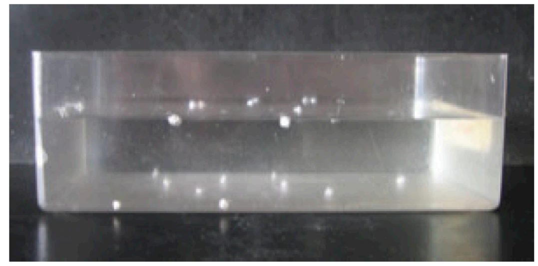


Figure 1: Some of the aluminum balls should sink and some should float.

1. ***Build the model***:

- Fill the ocean basin (shoe box) ¾ full with ocean water (water).
- Add the aluminum balls.
- Make sure that some sink to the bottom (deep water) and some float (surface water) – (Figure 1).
- Place the black paper under the model to improve visibility.

2. Relate the model to reality: Lead the class to complete the following graphic organizer and/or analogy notation on the board or overhead, prior to beginning the activity.

Graphic Organizer:

MODEL	REALITY (students answer)
Box	Ocean Basin or Great Lake basin
Water	Ocean or Great Lakes water
Air moving through the straw	Constant wind
Floating aluminum balls	Objects floating with the surface current or surface water molecules
Sunk aluminum balls	Objects deep in the ocean or deep water molecules

Analogy Notation:

Box : Lake Michigan Basin :: Air moving through straw : _______________
Answer: Constant wind
Box : Lake Michigan Basin :: Floating aluminum balls : _______________
Answer: Objects floating in the ocean or Great Lake or surface water molecules
Box : Lake Michigan Basin :: Sunk aluminum balls : _______________
Answer: Objects deep in the ocean or Great Lake/deep water molecules
Box : Lake Michigan Basin:: water : ________________
Answer: Ocean or Great Lakes Water

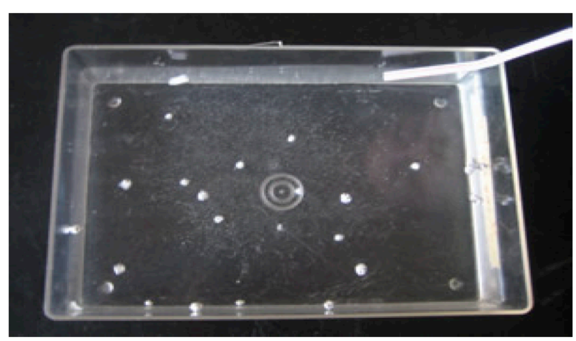


Figure 2: Straw placement while blowing.

3. ***Simulate wind***:

- The water begins still.
- Students place the shorter section of the bendable straws parallel to the surface of the water.
- One student in the team blows through the straw to simulate wind. Students blow horizontally (not down into the water) with the tip of the straw near the surface of the water and near the edge of the basin (shoe box) (Figure 2). The wind (blowing air) should be just hard enough to make ripples. With younger students, demonstrate the proper technique before beginning. The student creates wind in the same direction for 30 seconds.

Content Notes:

This models wind blowing across ocean water. The wind causes both little waves (ripples) and *surface currents. This activity simulates how wind makes surface water move by transferring energy to the water.*

The major ocean currents move in large cyclic patterns. This activity is not a good model for explaining that circulating pattern. The major ocean circulation occurs primarily because of the Coriolis Effect, which will be explained in the Ocean in Motion *activity.*

4. ***Observe the Motion***:

- The student not simulating the wind draws what s/he observes on *Data Sheet – Activity 1, Page 1* (Windy Observation boxes). S/he uses arrows to describe the motion and direction of the aluminum balls and wind (blown air).
- The student should differentiate between observations of floating balls and sunken balls.

Content Note: *The surface currents affect the floating balls but not the sunken balls; similarly, ocean surface currents do not affect deep water.*

5. Students switch roles. The second wind maker blows in the same direction and at the same intensity as the first wind maker. The second observer records his/her observations on his/her copy of *Data Sheet – Activity 1, Page 1* (Windy Observation boxes). Repeat until everyone has a turn at both roles.

6. ***Simulate Calm and Observe the Motion***:

- Students stop blowing and wait 5 seconds to simulate a brief calm (ocean wind stops blowing for a short interval).
- Students draw observations on *Data Sheet – Activity 1, Page 2* (Calm Observation Boxes).

Content Note: *This models short lulls in winds. The water does not immediately stop moving, because the wind transfers energy to the water. The water continues moving until the energy is dissipated as heat or transferred to the side of the basin (shoe box).*

7. ***Relate the model to reality***:

- Guide students to connect their observations of the model to the motion of water in the ocean and wind blowing over the ocean and to the *Ducks in the Flow – Where Did They Go?* storybook. The aluminum balls model objects floating in the ocean, such as the ducky in the storybook. The questions on *Data Sheet – Activity 1, Page 3* guide this discussion.

Key Points:
1) Wind makes surface water of the ocean (and Great Lakes) move.
2) Wind transfers energy to the water. When the wind stops for a brief amount of time, the currents continue to flow, because the water still has energy.
3) Objects floating in the ocean (or Great Lakes) will move with the currents. The ducky in the Ducks in the Flow, Where Did They Go? *storybook traveled, because it floated in surface currents.*
4) Surface currents affect the surface water; deep water does not move with the currents.

Activity 2 – Directions and Procedure

Content Note: *Children may think that the aluminum balls in Activity 1 moved only because the wind blew on the balls, as with the motion of a sailboat. Though not completely untrue, this focuses attention on wind power, not surface currents. In this second activity, children more directly visualize currents using rheoscopic fluid, as opposed to indirectly inferring currents using floating objects.*

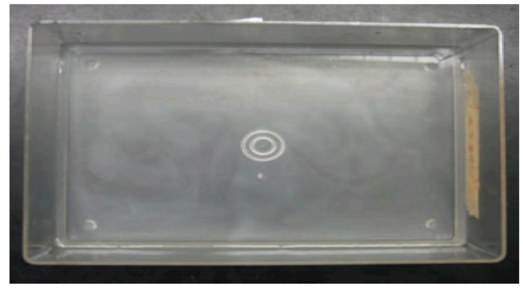


Figure 3: Water with Rheoscopic fluid before the "wind" is applied.

1. ***Build the model***:

- Fill the basin (shoe box) ¾ full with ocean water (diluted rheoscopic fluid) (Figure 3).
- Place the black paper under the model to improve visibility.

2. ***Relate the model to reality:*** Lead the class to complete the following graphic organizer and/or analogy notation on the board or overhead, prior to beginning the activity.

Graphic Organizer:

MODEL	REALITY (students answer)
Water with Rheoscopic fluid	Ocean or Great Lakes water
Box	Ocean Basin or Great Lake basin
Air moving through the straw	Constant wind

Analogy Notation:

For Beginners - Box : Lake Michigan Basin :: Water with Rheoscopic fluid : _______________
Answer: Ocean or Great Lakes Water
For Advanced Students - Box : Air moving through straw :: Lake Michigan Basin : _______________
Answer: Constant wind

3. ***Simulate wind***:

- The water begins still.
- Students place the shorter section of the bendable straws parallel to the surface of the water.
- One student in the team blows through the straw to simulate wind. Students blow horizontally (not down into the water) with the tip of the straw near the surface of the water and near the edge of the basin (shoe box) (Figure 4). The wind (blowing air) should be just hard enough to make ripples. With younger students, demonstrate the proper technique before beginning. The student creates wind in the same direction for 30 seconds.

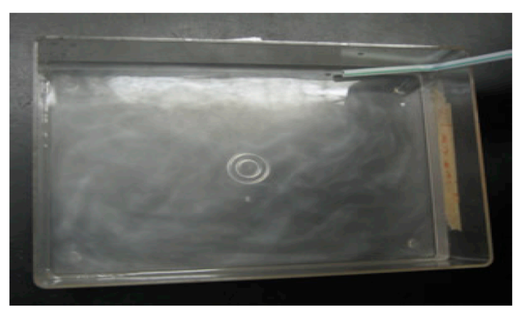


Figure 4: Water 10 seconds after "wind" begins to blow.

Content Notes: *This models wind blowing across ocean water. The ripples are not currents – they are little waves. This activity simulates how wind makes surface water move by transferring energy to the water.*

4. ***Observe the Motion***:

- The student not simulating the wind draws what s/he observes on *Data Sheet – Activity 2, Page 1* (Windy Observation boxes).
- S/he uses arrows to describe the motion and direction of the aluminum balls and wind (blown air).

5. Students switch roles. The second wind maker blows in the same direction and at the same intensity as the first wind maker. The second observer records his/her observations on his/her copy of *Data Sheet – Activity 2, Page 1* (Windy Observation boxes). Repeat until everyone has a turn at both roles.

6. ***Simulate Calm and Observe the Motion***:

- Students stop blowing and wait 5 seconds to simulate a brief calm (*ocean wind stops blowing for a short interval*).
- Students draw observations on *Data Sheet – Activity 2, Page 2* (Calm Observation Boxes).

7. ***Relate the model to reality***:

- Guide students to connect their observations of the model to the motion of water in the ocean and wind blowing over the ocean and to the *Ducks in the Flow – Where Did They Go?* storybook. The questions on *Data Sheet – Activity 2, Page 3* guide this discussion.

  Key points:
  1) Wind makes surface water in the ocean (and Great Lakes) move.
  2) Wind transfers energy to the water. When the wind stops for a brief amount of time, the currents continue to flow, because the water still has energy.
  3) Objects floating in the ocean (or Great Lakes) will move with the currents. The ducky in the Ducks in the Flow, Where Did They Go? *storybook traveled, because it floated in surface currents.*

Scientifically Accepted Explanation

In the classroom model, air blows over the surface water causing the water to move, pushing along more water, and setting up a miniature surface current. When wind blows over the ocean, the wind pushes the water and the water moves.

Some wind blows almost all the time. For example, the “Trade Winds” blow constantly over ocean water near Hawaii, and the “Westerlies” blow constantly over water off the west coast of the United States and Canada. These winds have been blowing in the same direction and fairly constantly for centuries. These constant winds push large, constant surface currents. Like the winds, surface currents are ancient and reliable.

In the model, the children stop blowing to simulate calm. Even if constant winds, like the Trade Winds, slow temporarily, the major ocean surface currents continue to move during these lulls, as in the model. Similarly, the direction of surface winds may temporarily change due to a storm. Nonetheless, the overall average direction and strength of the winds remains very constant, so the large surface currents in the oceans are very consistent.

Sometimes, wind blows and then stops, like a passing breeze or storm; it is inconsistent. Less constant winds can also cause small, short-lived surface currents. For example, if a child is fishing in a lake using a fishing float, and a breeze is blowing across the lake, the breeze may cause a temporary surface current that pushes the fishing float toward shore.

Surface currents are different from waves. Waves may cause floating objects (like the fishing float) to move up and down and back and forth, but the object will not ever progress in any one direction. The fishing float in this example will “bob” in the waves, but it will not be pushed to shore.

In the model, the aluminum balls move with the surrounding water – the water pushes the balls. The aluminum balls model objects such as the toy duck in *Ducks in the Flow – Where Did They Go?* Scientists track surface currents using special floating buoys called “drifters”. In the storybook, the toy ducks and other plastic animals that were lost overboard in a shipwreck served as accidental drifters and were also tracked by scientists to map surface currents.

In the classroom activity, the surface water moves while the deeper water remains still. Surface currents do not extend to the deeper parts of the ocean. In the classroom model, “deep” refers to a few centimeters. In the ocean, “deep” refers to over a hundred meters (in some places more than 200 m!), depending on the location and season. In the classroom activity, the surface currents did not move in a straight line because they bounced off the sides of the container. In the ocean, surface currents also bounce off the sides of the ocean basins. However, the large-scale swirling of surface currents all around the ocean is caused by the Coriolis Effect (see the *Ocean in Motion* activity).

More Advanced Explanation

When wind blows over water, wind transfers kinetic energy to water molecules. The water molecules then transfer kinetic energy to the water molecules in front and just below them, setting up the ocean-wide surface currents. This kinetic energy is the reason why the surface current in the model does not stop immediately, even when the “wind” is calm. It takes a few minutes for the energy to dissipate into heat energy or be transferred to the sides of the “basin”. The aluminum balls, floating plastic duckies, and drifter buoys move in currents because water molecules push against these objects.

The direction of the constant winds over the ocean (Westerlies, Easterlies, or Trade Winds) varies with latitude and depends on the Coriolis Effect. In the Northern hemisphere, the Trade Winds found at the latitude of Hawaii tend to blow south and are curved to the right, or west, due to the Coriolis Effect. The Northern “Westerlies” that affect most of North America tend to blow North and curve to the right, or east. The result of these winds can be seen in the surface current patterns in the ocean.

Connection to the Great Lakes
Surface currents are affected by the direction of the prevailing winds and Coriolis Effect, but they are also affected by the land masses that the moving water bumps into. This is particularly obvious in inland seas like the Great Lakes. Because the Great Lakes are smaller than the ocean, surface currents hit land sooner. Therefore, though Great Lakes’ surface currents resemble the swirls of the ocean surface currents, the patterns are more complicated. Surface currents in the Great Lakes change slightly on a daily, weekly, and monthly basis. Scientists take the average of these motions to discover the general trends in surface currents, which can be very useful for knowing where the surface currents may carry things like nutrients (chemicals that plants and algae need).

Connection to Social Studies
Surface currents have been used since ancient times to speed travelers across the sea, helping ancient Indonesians voyage to Madagascar and speeding the Vikings to Greenland. Did you know that Benjamin Franklin was one of the first to chart the Gulf Stream of the Atlantic Ocean? Mr. Franklin made eight round-trip voyages between North America and Europe.

Activity Extensions

- Imagine a place, where another shipwreck may occur and more plastic duckies may fall into the sea. Using a map of major surface currents in the ocean (gyres), predict possible places where the duckies may land. As a class, research the culture of other children in these imagined ducky landing sites.

- Listen to the song, “Wreck of the Edmund Fitzgerald” by Gordon Lightfoot. Research the location of this shipwreck that occurred in the Great Lakes. Predict where objects from this shipwreck may have moved, based on maps of Great Lakes’ surface currents. In what portion of the lakes would floating objects move faster? Slower?

- Use an encyclopedia to look up the Great Barrier Reef, Australia, and clownfish. If a clownfish managed to find his way into a surface current near the Great Barrier Reef, north of Brisbane, Australia, where might that clownfish end up?

Resources

Surface Currents and Winds in the Ocean

- UCAR's Windows to the Universe "Currents of the Ocean" - http://www.windows.ucar.edu/tour/link=/earth/Water/ocean_currents.html&edu=elem
- Museum of Science "Oceans in Motion" - http://www.mos.org/oceans/motion/currents.html
- NASA's "Ocean Motion and Surface Currents" (currents diagram) - oceanmotion.org/html/background/wind-driven-surface.htm
- NASA's "Ocean Motion" (winds diagram) - oceanmotion.org/html/background/equatorial-currents.htm

The Great Lakes

- Missouri Botanical Garden's "What's it like where you live?" - http://www.mbgnet.net/fresh/lakes/index.htm
- EPA's "Visualizing the Great Lakes" - http://www.epa.gov/glnpo/image/
- GLERL's Mean Circulation in the Great Lakes - www.glerl.noaa.gov/data/char/circ/mean/mean-circ.html

Photographs of Drifter Buoys

- NOAA's "The Global Drifter Program" - www.aoml.noaa.gov/phod/dac/gdp_drifter.html

Social Studies Connections

- "The Gulf Stream" (history) - http://fermi.jhuapl.edu/student/phillips/index.html
- Benjamin Franklin and Surface Currents, PBS Benjamin Franklin Weather Wise - www.pbs.org/benfranklin/l3_inquiring_weather.html
- TERC's "Study of Place (Franklin's map) - http://studyofplace.terc.edu/Activities/Activity.cfm?ActivityId=7&ActivityItemId=79
- Ancient Navigation and Surface Currents NOVA Online "Secret's of Ancient Navigation" - www.pbs.org/wgbh/nova/longitude/secrets.html
- Historical Shipwrecks in the Great Lakes Thunder Bay National Marine Sanctuary – http://thunderbay.noaa.gov/welcome.html
- Gordon Lightfoot: "Wreck of the Edmund Fitzgerald" – Song Lyrics - http://gordonlightfoot.com/wreckoftheedmundfitzgerald.shtml

This activity was developed by Laura Eidietis, Sandra Rutherford, Margaret Coffman, and Marianne Curtis. Parts of the activity were modified from the following sources:

- Tolman, Marvin N. *How are Ocean Currents Affected by Wind? Hands-on Earth science activities for grades K-6*, Second Edition, pp. 120-1, John Wiley & Sons/Jossey-Bass A. Wiley, San Francisco, 2006.
- VanCleave, Janice P., "Movers" in *Janice VanCleave's Earth Science for Every Kid*, pp.198-9, John Wiley & Sons, Inc., New York, 1991.

Illustrations by Lisa Gardiner
Graphic Design by Becca Hatheway

Going with the Flow

Data Sheet - Activity 1, Page 1
(Aluminum Balls Activity)

Name: ____________________________

Directions: Draw and describe what you observe. Imagine that you are looking down into the ocean basin from above.

<u>KEY</u>

→ Direction of movement

○ Floating balls

△ Sunken balls

Windy Observation

Balls in surface water (floating)

____

____

____

____

____

Balls in deep water (sunken)

____

____

____

____

____

Going with the Flow

Name: ____________________________

Data Sheet - Activity 1, Page 2
(Aluminum Balls Activity)

Directions: Draw and describe what you observe. Imagine that you are looking down into the ocean basin from above.

KEY

→ Direction of movement

○ Floating balls

△ Sunken balls

Calm Observation

Balls in surface water (floating)

____

____

____

____

____

Balls in deep water (sunken)

____

____

____

____

____

Going with the Flow

Name: ____________________________

Data Sheet - Activity 1, Page 3
(Aluminum Balls Activity)

What did you observe?

Compare the motion of the balls at the top of the water and at the bottom of the water.

____

____

____

____

What do you think?

Can wind cause currents on the bottom of the ocean?

(Circle One) YES NO Maybe

I think this because…

____

____

____

____

What did you observe?

Compare the motion of the balls when the wind was blowing and when the wind was not blowing.

____

____

____

____

Going with the Flow

Name: ____________________

Data Sheet - Activity 2, Page 1
(Aluminum Balls Activity)

Directions: Draw and describe what you observe.

KEY

Motion of water

Windy Observation

From Above

____

____

____

____

____

From Side

____

____

____

____

____

Going with the Flow

Name: ______________________

Data Sheet - Activity 2, Page 1
(Aluminum Balls Activity)

Directions: Draw and describe what you observe.

KEY

Motion of water

Windy Observation

From Above

____

____

____

____

____

From Side

____

____

____

____

____

Going with the Flow

Name: ______________________

Data Sheet - Activity 3
(Rheoscopic Fluid Activity)

What did you observe?

Compare the motion of the fluid when the wind was blowing to the motion of the fluid when the wind was not blowing.

____

____

____

____

What do you think?

If the wind stopped blowing for a short time, would the ocean currents stop?

(Circle One) YES NO Maybe

I think this because…

____

____

____

____

What do you think?

In *Ducks in the Flow - Where Did They Go?*, what caused the duck to travel so far?

____

____

____

I think this because…

____

____

____

Fresh and Salt

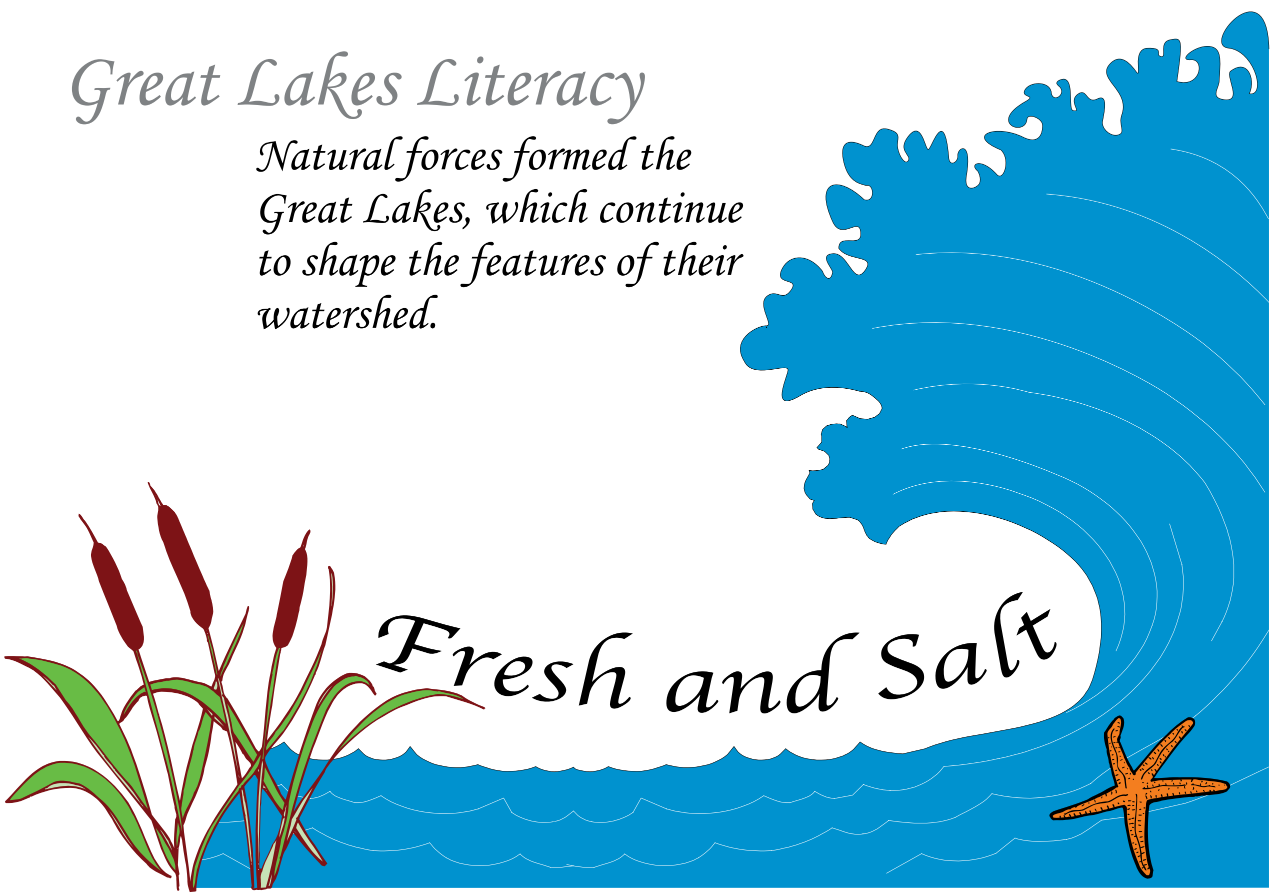
Principle 2

Ocean Literacy

The ocean and life in the ocean shape the features of the Earth.

Great Lakes Literacy

Natural forces formed the Great Lakes, which continue to shape the features of their watershed.



Fresh and Salt

Principle 2: The ocean and life in the ocean shape the features of the Earth. (OL)

Natural forces formed the Great Lakes, which continue to shape the features of their watershed. (GL)

Essential Principle #2 is the one in which much of the geology content of Ocean and Great Lakes Literacy is addressed. The activities in this set represent geological phenomena that can be found in some form in both the ocean and Great Lakes. One activity relates to underwater sediments, how they are formed and how people interpret Earth history with their configuration; the second activity focuses on some dramatic macroscopic shoreline geology. Both lessons address how humans study and interact with the geological phenomena.

Ooze Clues, from the Bridge for Marine Education, describes major types of biogenic ocean sediments and asks students to determine where they occur on the sea floor based on their characteristics and how they react with ocean water. Since the skeletons of diatoms and foraminifera form the silicious and calcareous oozes, and ocean depth affects where these remnants of life are found, the lesson also demonstrates how biology interacts directly with geology. Students will apply and practice skills in data analysis, predicting, map reading and making comparisons.

The lesson is designed for high school and is best done with groups that have already studied plankton and foraminifera. Some teachers who used the lesson on the Atlantic coast added advance information about the plankton and forams in local sediments. The same teachers have commented that the questions in the lesson are fairly low level but do require students to identify the science used to justify their choice of location for the types of sediments. A Great Lakes educator used the lesson as a summative and connective activity across topics, and appreciated the science process applications: *"Science is all about making predictions and looking for answers within data. This activity nicely did both. I used the activity at the beginning of my invertebrate unit as we discussed plankton. They had just learned about diatoms and had drawn them under the microscope, so they knew what they were. We had just finished a unit on the ocean floor so it was good to relate the two units."*

For teachers who are seeking a direct freshwater parallel, a sample activity on lake sediment cores, with pollen instead of plankton, *Paleoclimates and Pollen* is found at **http://www.windows.ucar.edu/tour/link=/teacher_resources/teach_pollen.html.** The use of layers of lacustrine [lake] sediment layers for documenting changes over time is important in showing how climate has changed in different parts of the world. Scientists studying sediments in a Lake Erie pond[1] have data that could be used to construct a lesson that roughly parallel the data use and hypothesizing in *Ooze Clues.*

What Causes the Shoreline to Erode?

This activity originated with Ohio Sea Grant, and the erosion examples are from the Great Lakes. Of course, the same processes occur on ocean shores as well, and impacts are also related to the shoreline composition. In the activity, students simulate the action of waves on shorelines of

(Endnotes)

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[1] Stuckey, Ronald L. and David L. Moore, 1995. Return and Increase in Abundance of Aquatic Flowering Plants in Put-In-Bay Harbor, Lake Erie, Ohio. OHIO J. SCI. 95 (3): 261-266

different composition and anticipate the ways a shoreline will change with continuing erosion. The lesson uses a range of science process skills, including map reading and interpretation, decision making and concept mapping. For the educators who reviewed this lesson, the addition of a lab experience for students to simulate a shoreline model was also a strong engaging component. As one reviewer pointed out in her evaluation, *"The introduction provides an excellent overview of the natural causes of shoreline erosion because all the facts that are needed are stated within three sentences. The shoreline of the Great Lakes is like the ocean shoreline in that both are subject to erosion from external forces. We can compare and contrast the external forces and the rate of shoreline erosion on the Great Lakes and in the ocean. Since both bodies of water are interconnected, it is important to let the students know the important relationship for our existence of these bodies of water."*

For higher grades and an example of how technologies inform scientists about coastal erosion, teachers may want to try *Erosion in the Outer Banks*, at **http://www.lib.unc.edu/dc/ncmaps/erosion_k12.html.**

An ocean of free teacher-approved marine education resources

Bridge DATA Series

Diatom Ooze

Ooze Clues

Written by: Lisa Ayers Lawrence, Virginia Sea Grant, Virginia Institute of Marine Science

Summary

Plot the distribution of various oozes using information from sediment maps.

Grade Level:
9-12

Lesson Time:
1 hr.

Materials Required:
- Global map
- Sediment Distribution Patterns map

Related Resources:
- Geological Oceanography
- Plankton
- Benthos

Objectives

- Describe the characteristics of different types of seafloor sediments and oozes.
- Predict distribution of calcareous and siliceous oozes.
- Compare and discuss locations of sediments and oozes.

Vocabulary

Terrigenous, Biogenous, Hydrogenous, Cosmogenous, Calcareous ooze, Siliceous ooze, Foraminifera, Diatoms, adiolaria, Carbonate compensation depth

Introduction

Just as ocean beaches display a variety of sediment types, the ocean floor may be made of sand, rock, remains of living organisms, or other material. The grains and particles that make up the seafloor sediments are classified by their size and their point of origin. Sediments can come from land (terrigenous), from living organisms (biogenous), from chemical reactions in the water column (hydrogenous), and even from outer space (cosmogenous).

Terrigenous sediments dominate the edges of the ocean basins, close to land where they originated. As you move deeper into the ocean basins, biogenous sediments begin to dominate. Biogenous sediments can consist of waste products or remains of organisms, including those of microscopic phytoplankton and zooplankton. When skeletal remains of microscopic organisms make up more than 30% of the sediment, it is called "ooze."

There are two types of oozes, calcareous ooze and siliceous ooze. Calcareous ooze, the most abundant of all biogenous sediments, comes from organisms whose shells (also called *tests*) are calcium-based, such as those of foraminifera, a type of zooplankton. Foraminifera are one of the most abundant types of zooplankton and are widely distributed throughout the surface of the world's oceans.

Siliceous oozes are made up of the remains of diatoms, a microscopic phytoplankton, and radiolaria, a microscopic zooplankton. Diatoms are one of the most important primary producers in the ocean. Because they are primary producers, diatoms are found in nutrient-rich areas of the ocean especially in areas of upwelling like the polar seas. As you move from continental shelf to open ocean areas, the number of diatoms present decreases. Radiolarians, the other source of siliceous ooze, feed on phytoplankton and thus are also more abundant in nutrient-rich water. However, radiolaria favor the equatorial upwelling zones as opposed to the polar upwelling zones.

Another factor that affects where biogenous sediments will occur is the depth of the ocean floor. Calcium carbonate dissolves readily under pressure and in cold water, therefore deeper ocean floors will have less calcareous ooze. At a depth of about 5 km, the rate of dissolution (how quickly calcium carbonate dissolves) is faster than the rate at which calcium shells are raining down from above. This depth is called the carbonate compensation depth or CCD.

Data Activity

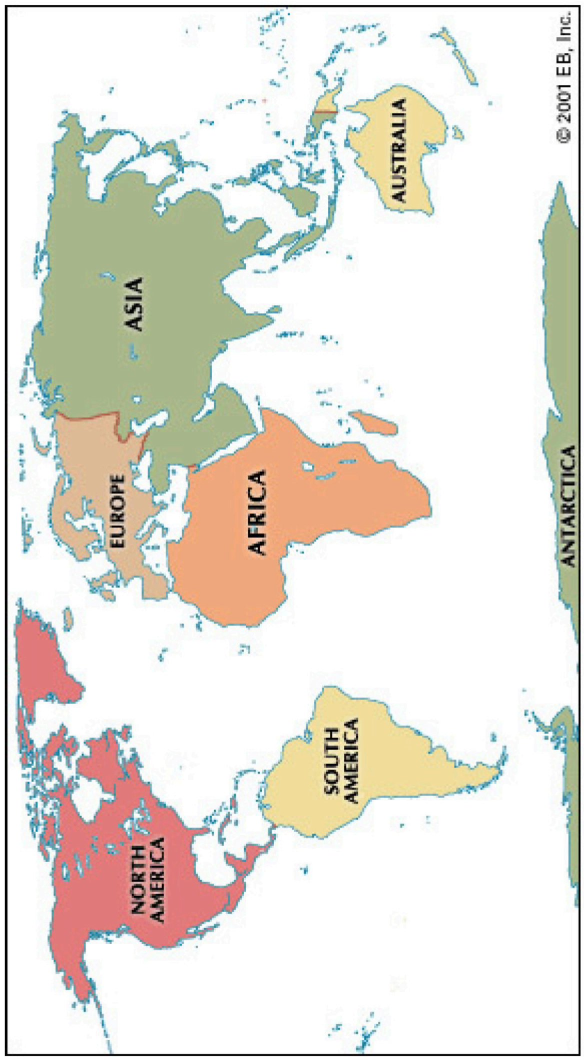
Using what you've learned about the distribution of diatoms, radiolaria and foraminifera and about the carbonate compensation depth, predict where you think you would find calcareous and siliceous oozes. Print a global map, and mark your predictions on it.

Next, print the General Sediment Distribution Patterns map. This map shows the general location of biogenous sediments. Compare your map to the sediment distribution map.

QUESTIONS

- Were your predictions close to where calcareous and siliceous oozes actually occur?
- How does your map compare with the sediment distribution map?
- Which type of ooze dominates the ocean sediments, calcareous or siliceous? Why?
- What parts of the oceans do not have calcareous ooze? What might be some reasons for this? (Hint: depth, distribution of organisms)
- Where are large deposits of siliceous diatom ooze? Are these deposits mostly near the edges of continents or in the middle of the ocean basins? Why? (Hint: areas of upwelling/high nutrient levels)
- Where do you see large deposits of siliceous radiolarian ooze? Why?

The Bridge is sponsored by NOAA Sea Grant and the National Marine Educators Association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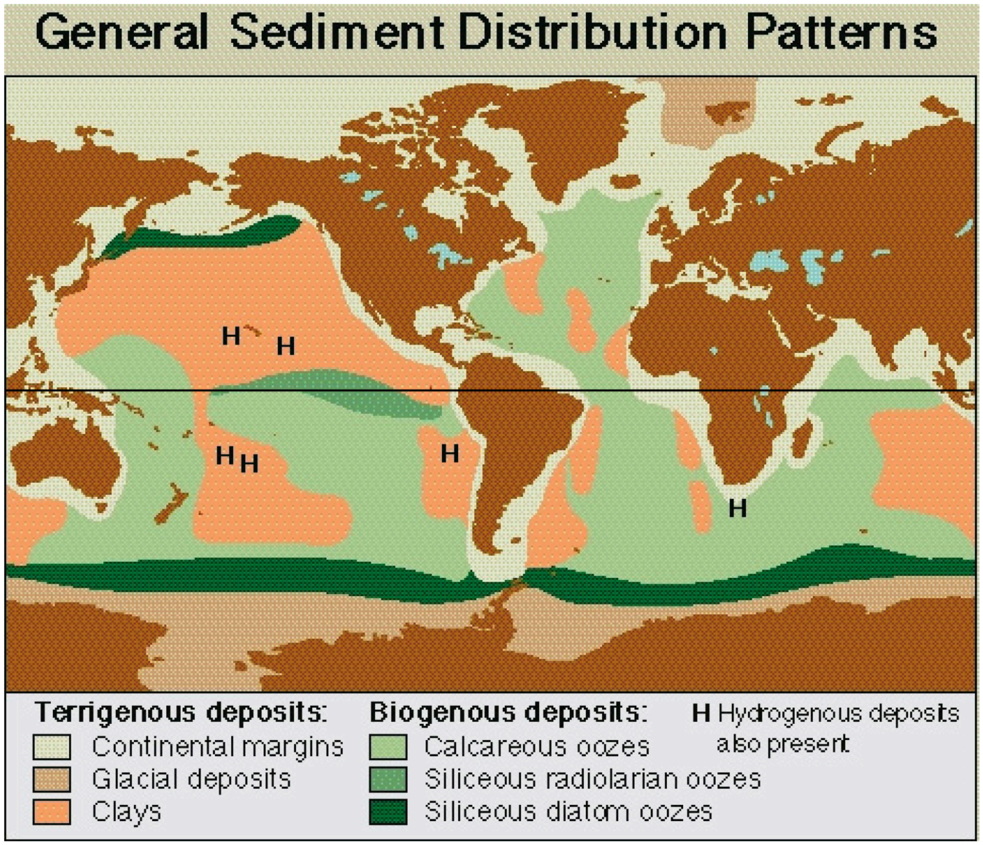


Siliceous pelagic sediments

Consist **of clay-silt-sand sized particles derived from phytoplankton or zooplankton in the photic zone. Siliceous sediments occur mostly below the CCD or under coastal or oceanic upwelling systems**

Siliceous-Pelagic sediments are rich in the remains of diatoms, silicoflagelattes and radiolaria. They occur most commonly below the CCD and in areas around the Antarctic and tropical and coastal upwelling zones where extremely high production of siliceous organisms occurs resulting in great export production of siliceous microfossils. Note that there is no such area in the GIN Seas or the North Atlantic because the diluting effects of large amounts of terrigenous and carbonate material in sedimentary water depth that are above the CCD here.

What causes the shoreline to erode?

Shorelines along the Great Lakes vary in the nature of their sediments and erodibility. Natural causes of erosion include waves, currents, and effects of wind and storms on shoreline processes. We can simulate the processes of shoreline erosion for an understanding of the ongoing changes that occur in coastal areas.

Objectives

When you have completed this investigation you will be able to:

- List major natural forces of erosion along the lake shore.
- Describe how the rate of erosion differs with different materials.

Procedure

In teams of three, follow the procedure below.

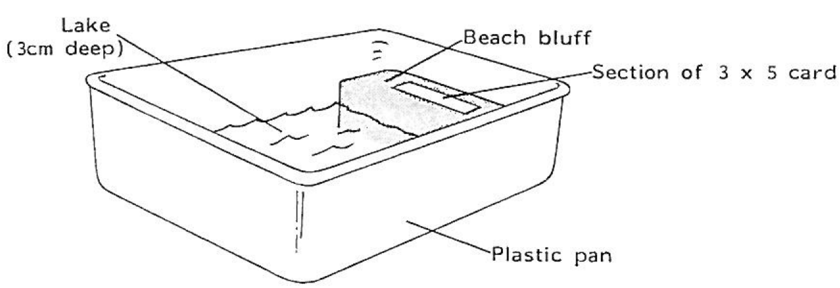
A. In the end of one of the plastic pans, place three handfuls of wet sand.

B. Using a piece of board, mash the sand up against the end of the pan and flatten the top. Make this "beach bluff" about as wide as it is high.

C. Repeat Steps A and B with a second pan, building a beach bluff made of wet soil.

D. In one end of the third pan make a stack of rock pieces that will represent a rocky shoreline about the same size as the other bluffs.

Figure 1. Shoreline Model.



Source

Modified from OEAGLS EP-7, "Coastal Processes and Erosion," by Beth A. Kennedy, Newark Public Schools, Ohio, and Rosanne W. Fortner, Ohio Sea Grant Education Program, The Ohio State University.

Earth Systems Understandings

This activity explores ESU 4 and 5 (the impact of land and water interactions on shorelines over time). Extensions address stewardship of coastal resources using ESU 2 and 3 (scientific methods and planning). Using ESU 6 students can consider how coastal processes relate to Earth's position in a larger universe.

Materials

Divide the class into teams of three, giving each team the appropriate materials. Each lab team should be supplied with

- Three rectangular plastic dishpans or plastic shoe boxes.
- One piece of board (2 x 4 or plank) as long as the width of the dishpan's floor.
- One piece of board half as long as the width of the pan.
- About 1 liter of sand per team.
- 1 liter of potting soil per team.
- Several pieces of rock 5-10 cm long.
- 3 x 5 note card cut in three long strips.
- Ruler to measure wave heights.
- Access to a supply of water.
- Each student will need a pencil or pen for recording data and answering questions.

Teacher's Overview

Students examine how shoreline geology affects the rate and amount of erosion that occurs along the edges of oceans or lakes. They conduct an experiment comparing the stability of three geologically different beach bluffs as they are attacked by waves.

In recording data, it is suggested that the number and height of waves be recorded only once for each shore type, when the bluff collapses.

Additional Method

Students can use a fan to generate wind and produce waves, simulating actual conditions on a lake.

Suggested Approach

To help cut down on the amount of equipment needed, the activity could be done in large groups or by a single group of students acting as demonstrators. Stress that the water used in Step E be poured in slowly; otherwise beach bluffs may begin to collapse before waves are generated.

Be sure to provide an appropriate place to dispose of the muddied water, preferably outdoors away from the school building.

You should now have three "beach bluffs" of various types and sizes of material. The three pans represent lakes.

E. Hold the pieces of board up against the sand bluff to protect it while you slowly add water to the empty end of the pan. Create a lake about 1-1.5 cm deep. Remove the board gently when the lake water is still.

F. Repeat Step E to create lakes in front of the soil and rock bluffs.

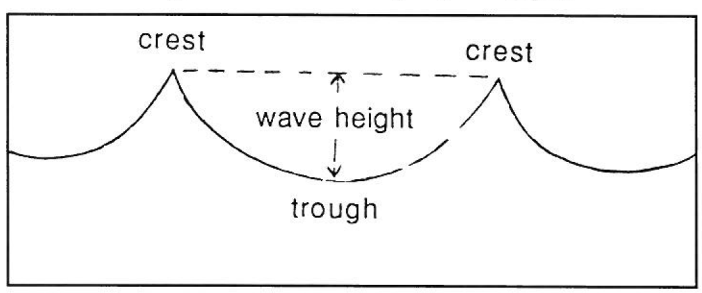
G. Gently place a strip of note card flat on top of each bluff.

H. You are now ready to act as the wind, making waves and causing erosion on the shoreline. Using a ruler or the pieces of board, make waves that move toward the beach bluff from the opposite end of the lake. Start gently, counting the number of waves you produce. Then gradually increase the strength of your waves as if the wind were becoming stronger. Record what happens to the beach bluffs as you repeat this process in each lake. Put your information in a Data Table that shows the number of waves before bluff collapse, size of waves, and effects on the bluff for each type of shore material.

I. When the section of note card slips toward the water, your bluff has collapsed. If collapse has not occurred after 100 waves, stop and record your observations of the bluff's condition. Put this information in the Data Table.

NOTE: To estimate the height of waves, find the distance from the top (crest) of the wave to the lowest part (trough) of the wave. Do not measure from the bottom of the "lake" basin unless the bottom is actually exposed as the wave passes by. Refer to Figure 2.

Figure 2. Determining Wave Height.



Answer the following questions based on your results.

1. Which beach bluff is the least stable (collapsed first)?

2. Which beach bluff is the most stable (withstood the most waves)?

Some beach bluffs around the Great Lakes shore are actually made of sand and some of clay similar to the soil bluff you constructed. The rocky bluffs of the lake shore may be of limestone or a soft shale.

3. What type of beach bluff would you choose if you were building a cottage on the shoreline? Why?

4. Map 1 shows Lake Erie's shoreline. Cover the top half of the page. Based on what you have discovered about how different materials erode, answer the following questions using the lower map provided.

   a. Put X's on the sections of shoreline that are probably made of rock.

   b. Put O's on the sections of shoreline that are probably made of sandy material.

(You do not have to cover the shoreline with either X's or O's. The shape of the shore may not give you any clues about the type of material it has.)

   Uncover the top half of the page and check your predictions using the map of shoreline deposits.

5. Some points of land sticking out into the lake may be made of sand. What process is probably responsible for carrying the sand and depositing it there? (You may need to reread the introduction at the beginning of this activity.)

Answers

1. The sand bluff is the least stable. The small and fairly uniform grain size produces a permeable surface that is quickly penetrated and disrupted by the water. On the board, record wave heights and number of waves from different lab teams. Note that higher waves erode the bluff more quickly (fewer waves are needed).

2. The rock beach is the most stable because of the resistant nature of the rocks. Students may want to discuss which types of rocks would be more resistant to erosion. An interesting experiment could be designed by the class using small rock polishers (tumblers) loaded with different kinds of local rocks and processed simultaneously for the same number of days. Students should choose rocks depending on the lake region of study. Comparing the mass of rocks before and after the erosion would indicate which rock types were more resistant. However, you should mention that shale, though a rock, is quite erodible and would not be a good site for construction.

3. When erodible characteristics are considered, students should choose the rocky bluff as a building site. However, you should mention that shale, though a rock, is quite erodible and would not be as good a site for construction. At the end of the activity are transparency masters for use in illustrating the types of shorelands and beaches around the Great Lakes and a discussion of the possible uses made of these areas. Students who have completed the activity should be able to identify areas of potential erosion problems using the outline maps.

4. See the accompanying map for approximate locations of sandy and rocky shorelines. Student maps should be accepted if an attempt has been made to label shoreline sections. Points of land projecting into the lake are often labeled "X" by students, and cut away sections of shore may be labeled "O." A discussion of students' responses and the transparencies can lead to consideration of Question 5.

Answers

5. The lake's longshore current, or littoral drift, is responsible for creating many of the points of land projecting into the lake. The "spits," as they are called, are made of sediments carried from other areas. The current direction produced by the prevailing winds determines which way a spit curves.

6. The points of land that form smooth curves out into the lake are generally sandy. Those with ragged or angular shapes usually have a rock base. The two lakeward projections surrounding the mouth of Sandusky Bay illustrate these differences. The Marblehead area to the west of the bay is limestone, and Cedar Point to the east is a sandy deposit.

7. In predicting future shoreline characteristics, it is hoped that students will apply what they have learned about coastal processes. Answers will vary, and the differences between predictions can furnish material for class discussion of erosion and deposition rates, the future of lake shore property, and how the shore could be protected. An outline map of all lakes is found at the back of this volume. Enlarge sections as needed.

Lake Erie's Pelee Island is an interesting case in point. The island is rocky, but has a spit at its southern tip. Changes in the direction of the longshore current cause the spit to curve eastward at some times and westward at others. People sailing on the lake have referred to Pelee island as "the island that wags its tail."

6. How could you tell from their appearance which points of land might be sandy instead of rocky?

Erosion of coastal areas, as you have seen, occurs at different rates depending upon the material making up the shoreline. The same processes act upon the ocean as upon large lakes. Some of the coast of England, for example, has been worn back more than 3 km since the time of the Romans. The shore of Cape Cod retreats at the rate of 25 to 150 cm each year. These coasts are composed of relatively weak material, but the same process takes place more slowly in the hardest rock.

7. On the map on your work sheet, draw your prediction of how the Lake Erie shoreline will be shaped 100 years from now if the present rates of erosion and deposition continue. Select another of the Great Lakes and repeat steps 4-7 using the lake outline provided.

Review Questions

1. Explain how natural forces cause erosion along the Great Lakes. How do you think human actions contribute to coastal changes?

2. What types of shore materials erode faster? Slower?

3. Use a concept map to illustrate the present day land/water interactions along the Great Lakes coastline showing relationships between the factors involved in coastal processes.

Extensions

1. Do research to locate the largest cities along the Great Lakes. Also determine where the population densities are the greatest. Begin your search with GLIN on the Internet, or with the Great Lakes Atlas. What effect would these factors have on erosion rates along the shores?

2. How should decisions be made about potential shoreline uses and devices designed for shoreline protection? What interests should be considered in the decision-making process? What would you do if you could decide on the best way to use a section of shoreline? Draw a picture of what it would look like.

3. Extend your thinking to construct a concept map relating this activity with the position and action of Earth in space, i.e., the effect of the rotation of the Earth on wind generation, the seasons and their influence on storms, temperature, and coastal processes. Work in teams to create ideas to share with the class.

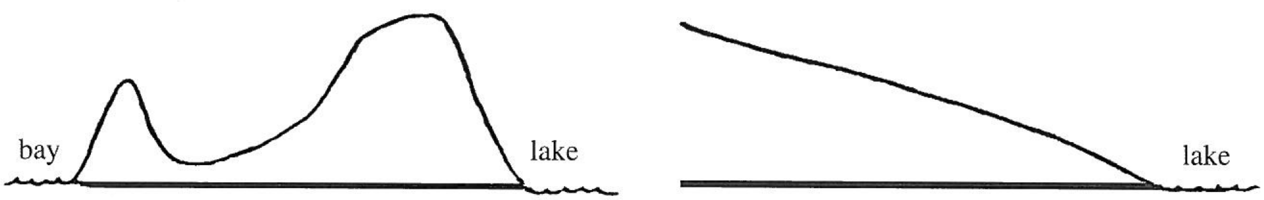
Teacher's Page

Example of student data table:

	Number of Waves	Height of Waves	Effects on Bluff
SANDY BLUFF			
SOIL BLUFF			
ROCKY BLUFF			

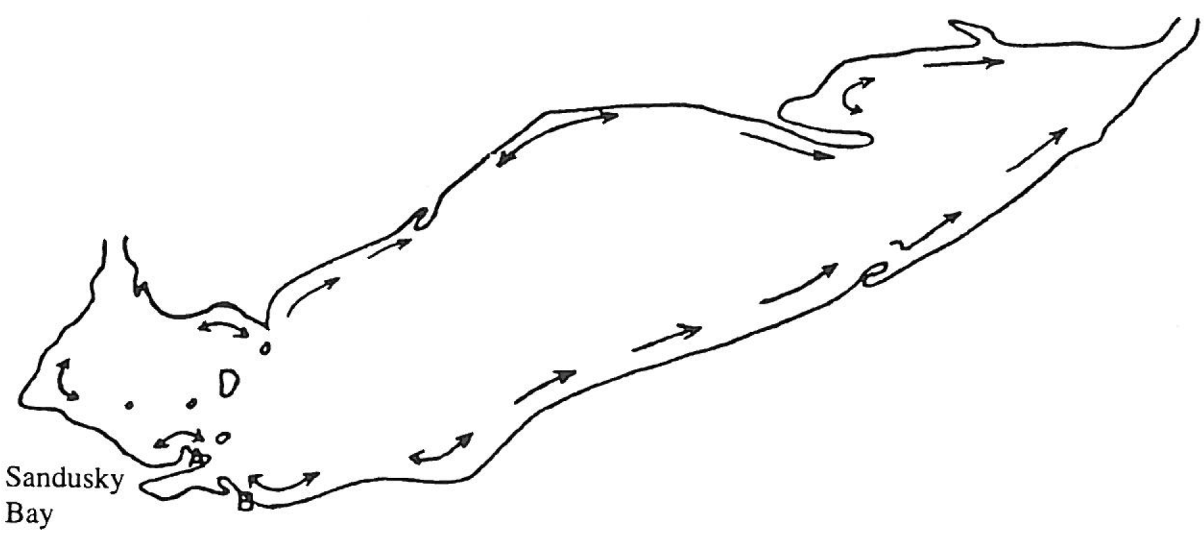
Figure 1. Comparison of Lake Erie Coastline Features.

Figure 1 shows how the rocky and sandy bluffs look in cross section. Rocky areas are generally steep and angular, while sandy bluffs have a gentle slope. The cross sections shown were taken at areas marked A and B on Figure 2.

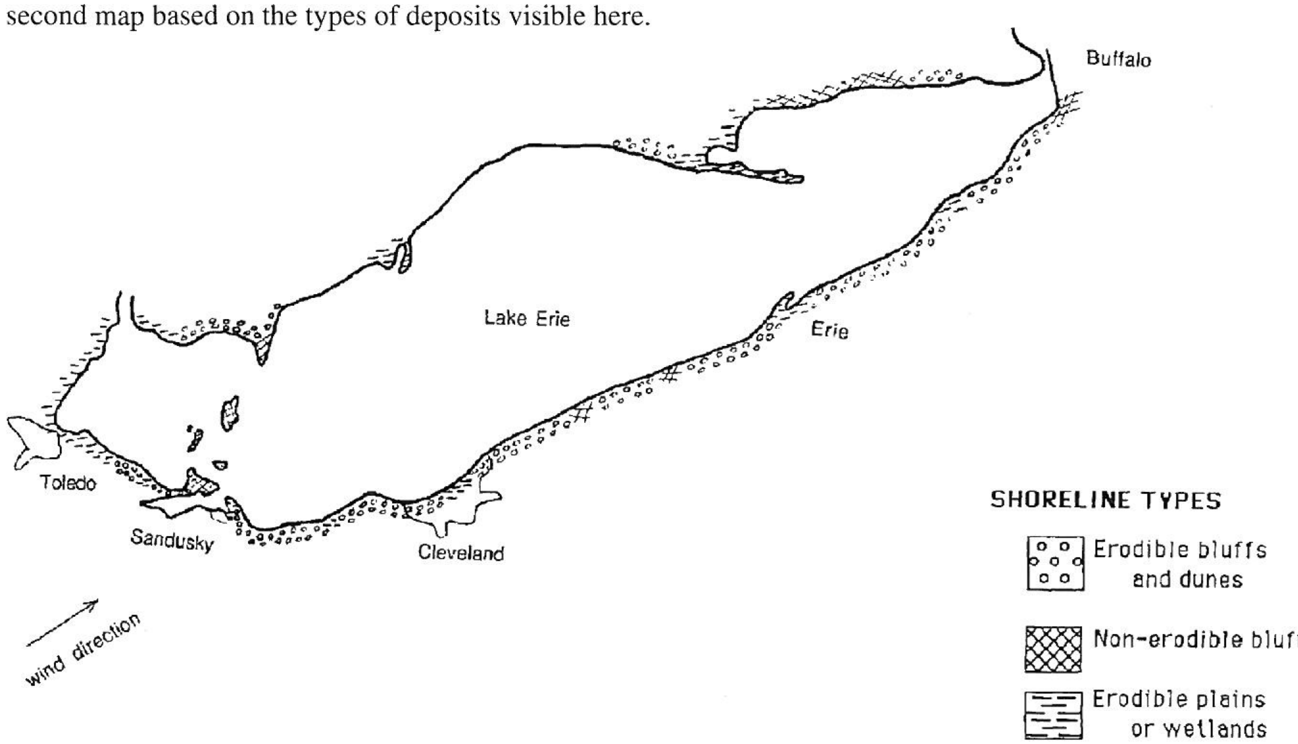


A. Rocky bluff profile (Eastern end of Marblehead). B. Sandy bluff profile (West of Huron, Ohio).

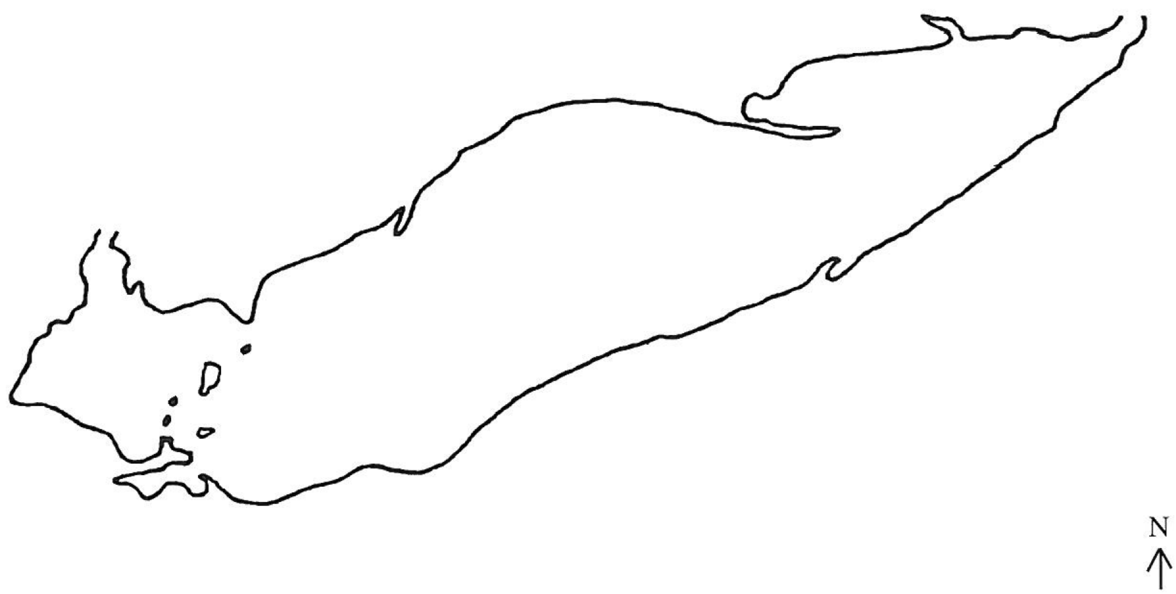
Figure 2. Net Direction of Littoral Transport, and Curvature of Spits in Lake Erie.



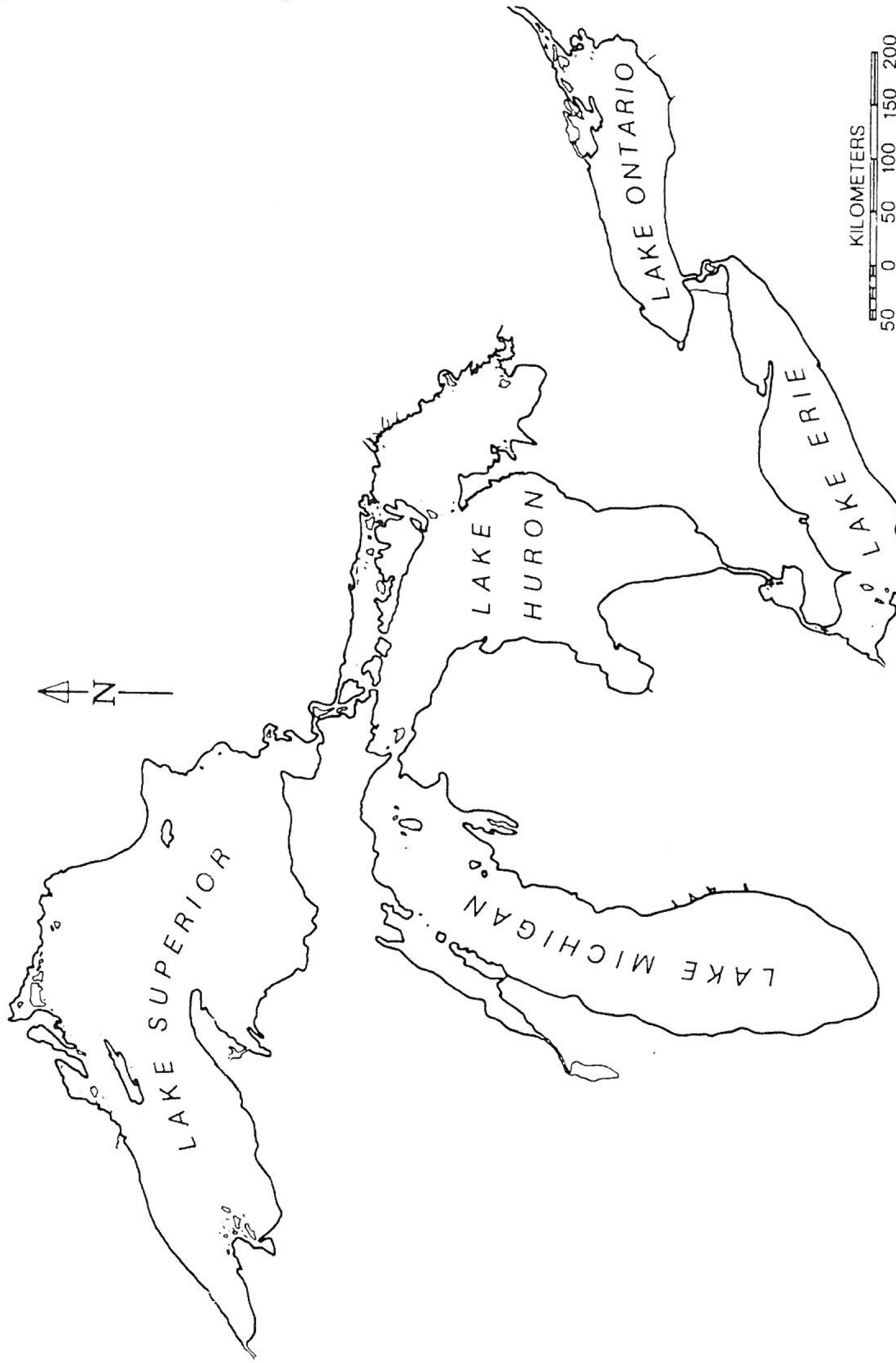
Map 1. Lake Erie Shoreline.
Below are the shoreline types surrounding Lake Erie. Make your prediction of the future shoreline on the second map based on the types of deposits visible here.



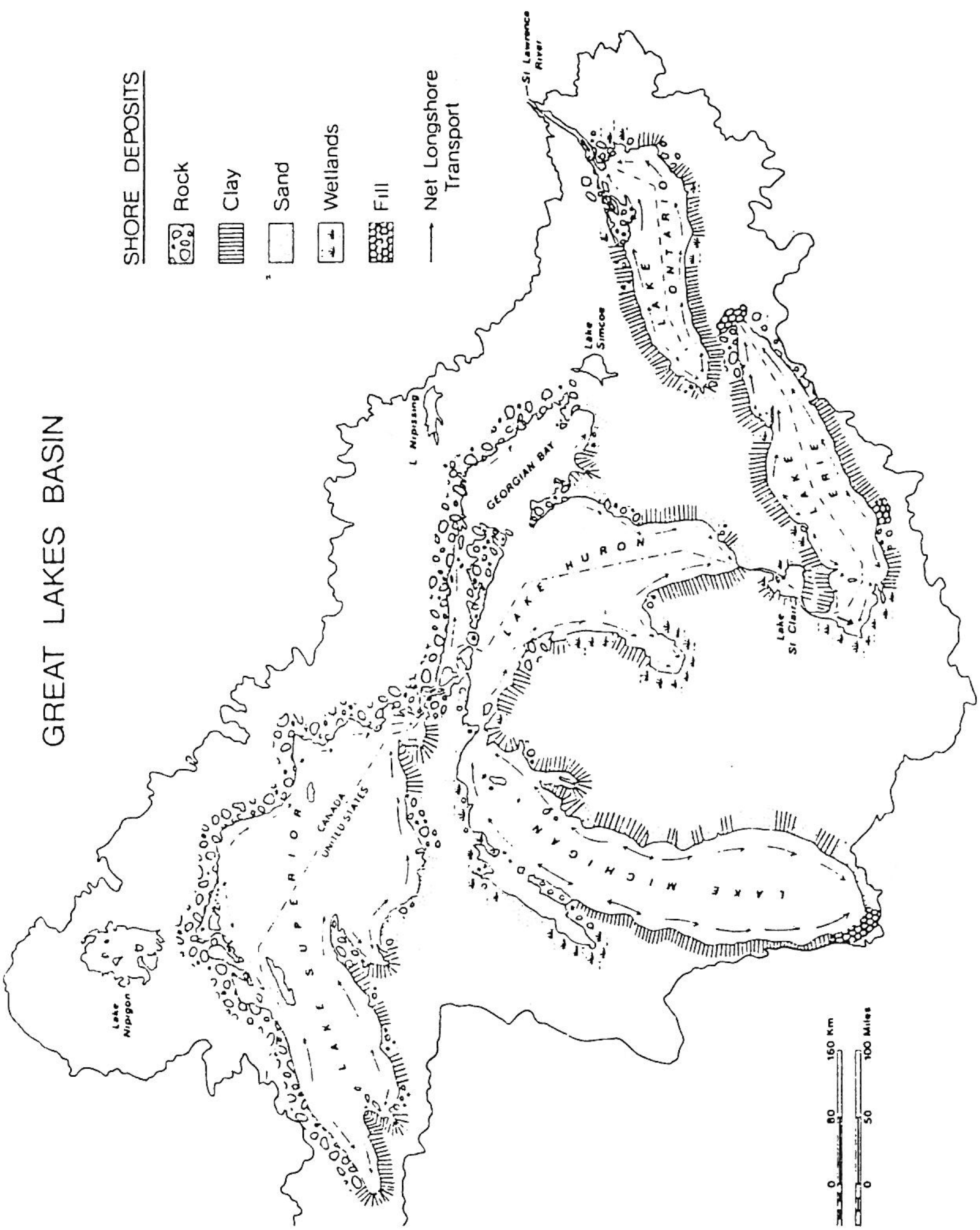
Predicted Shoreline of Lake Erie 100 Years From Now (Present Shape Given).



Map 2. Great Lakes Outline Map.



Map 3. Shoreline Deposits of the Great Lakes Region.



Source: Carter, Charles. 1993. *The Great Lake Erie*.

Fresh and Salt

Principle 3

Ocean Literacy

The ocean is a major influence on weather and climate.

Great Lakes Literacy

The Great Lakes influence local and regional weather and climate.

Fresh and Salt

Principle 3: The ocean is a major influence on weather climate. (OL) The Great Lakes influence local and regional weather and climate. (GL)

Essential Principle #3 describes how the development of climate patterns is a complex set of processes. Learning about coastal weather conditions serves as a step toward understanding how the atmosphere and ocean interact to create a maritime climate. Oceans influence the world's climate by storing solar energy and distributing it around the planet through currents and atmospheric winds. The Great Lakes also have a big influence on the climate. Acting as a giant heat sink, the lakes moderate the temperatures of the surrounding land, cooling the summers and warming the winters.

Both activities in this set use a cooperative learning approach to help students develop an understanding of how lakes and oceans can have a direct effect on weather and climate. The first activity relates to rising Arctic temperatures and how this can impact the global climate and have other worldwide implications, including sea level rise. The second activity focuses on how soil and water differ in their ability to absorb and release heat energy and describes how this difference, in heat absorbed or released, affects the atmosphere immediately above the land and the water.

Implications of Warming in the Arctic, from the Will Steger Foundation, focuses on how the Arctic responds more rapidly and more dramatically than the rest of the world to the early effects of global warming. In the past few decades, Arctic average temperature has risen almost twice as quickly as the average temperature in the rest of the world. This makes the study of the Arctic interesting and important for several reasons, from climate impacts to its huge resources of oil, gas, and fish that supply the rest of the world. In addition, effects of global warming in the Arctic are easily recognizable and often dramatic.

Students in grades 6-12 investigate three positive feedback loops, including surface reflectivity, ocean circulation, melting permafrost releasing heat-trapping gasses, and melting ice contributing to rising sea levels. Working in pairs, students cooperatively read, plan, and practice their lessons, as well as present their lessons to each other. Although the earth will continue to warm for centuries due to heat-trapping gasses already in the atmosphere, students will learn that it is not too late for the public to take action to slow that process and prevent some of the most extreme effects.

For more information on other topics presented in this lesson, as well as expedition resources linked to this lesson plan, visit: **http://willstegerfoundation.org/index.php/programs/k-12-education-program.**

How is Coastal Temperature Influenced by the Great Lakes and the Ocean? In this Ohio Sea Grant lesson, middle school teachers can help their students build an understanding of how large bodies of water serve as a heat source or sink at different times. Students investigate how proximity to water moderates climate along the coast. The activity's combination of laboratory investigation, map study, and graphing applies different learning styles and provides practice in several important science processes.

Activity 1 examines the principles behind changes in temperature of water vs. changes in temperature of land or the air. Working in teams, students construct a lab to investigate (1) how soil and water differ in their ability to absorb and release heat energy and (2) describe how the difference in heat absorbed or released affects the atmosphere immediately above the land and the water.

Activity 2 demonstrates how the role of energy in temperature change plays out in modifying coastal temperatures. Students work in pairs to synthesize information about the effects of the ocean and Great Lakes on the temperature of the surrounding land.

As one teacher reviewer commented, *"I really like that the students have to become accustomed to new types of maps and reading those maps based on the information provided. There was higher level questioning going on with the compare/contrast questions. I think those are extremely powerful."*

This "Coastal Temperature" activity is adapted from *Earth Systems Education Activities for Great Lakes Schools: Great Lakes Climate and Water Movement* (V. J. Mayer et al., 1996).

Lesson 4: Implications of Warming in the Arctic

Why should we learn about global warming in the Arctic?

Question	Besides being a "canary in the coal mine," why should we learn about global warming in the Arctic?
Objective	Students will be able to explain feedback loops including surface reflectivity (albedo), ocean circulation, melting permafrost releasing heat-trapping gasses and melting ice contributing to rising sea levels. Students will be able to explain how warming in the Arctic affects the rest of the world.
Time Needed	40 minutes
Materials	Feedback #1: Surface Reflectivity (Albedo) Feedback #2: Ocean Circulation (Thermohaline circulation) Feedback #3: Melting permafrost

Directions:

Explain to your students that the Arctic responds more quickly and more dramatically than the rest of the world to the early effects of global warming. In the past few decades, Arctic average temperature has risen almost twice as quickly as the average temperature in the rest of the world. This makes study of the Arctic interesting and important for several reasons including:

- Effects of global warming in the Arctic are easily recognizable and often dramatic.
- The Arctic supplies oil, gas and fish to the rest of the world and these supplies will be affected by climate change.
- Studying the Arctic can give us an early indication of the environmental and societal significance of global warming.
- Warming in the Arctic can impact the global climate and have other worldwide implications including sea-level rise.

Explain that one of the ways that Arctic warming can impact the global climate is through **feedback loops**. A positive feedback loop is a process that creates conditions that make that process quicken or intensify. A negative feedback loop is a process that creates conditions that make that process slow or diminish. Let students know that they are about to learn about three positive feedback loops in the Arctic that can affect the global climate. ***(5 min)***

Have students count off from one to three. Each student must then find another student who has the same number. In these pairs, the students cooperatively read the following passages:

Feedback #1: Surface Reflectivity (Albedo)
Feedback #2: Ocean Circulation (Thermohaline circulation)
Feedback #3: Melting permafrost
(5 min)

Then have each pair plan a way to teach their topic to other students. Their lesson will need to include an explanation of the major concepts in the passage and an explanation of the visuals that accompany the passage. ***(5 min)***

Lesson 4: Implications of Warming in the Arctic

Why should we learn about global warming in the Arctic?

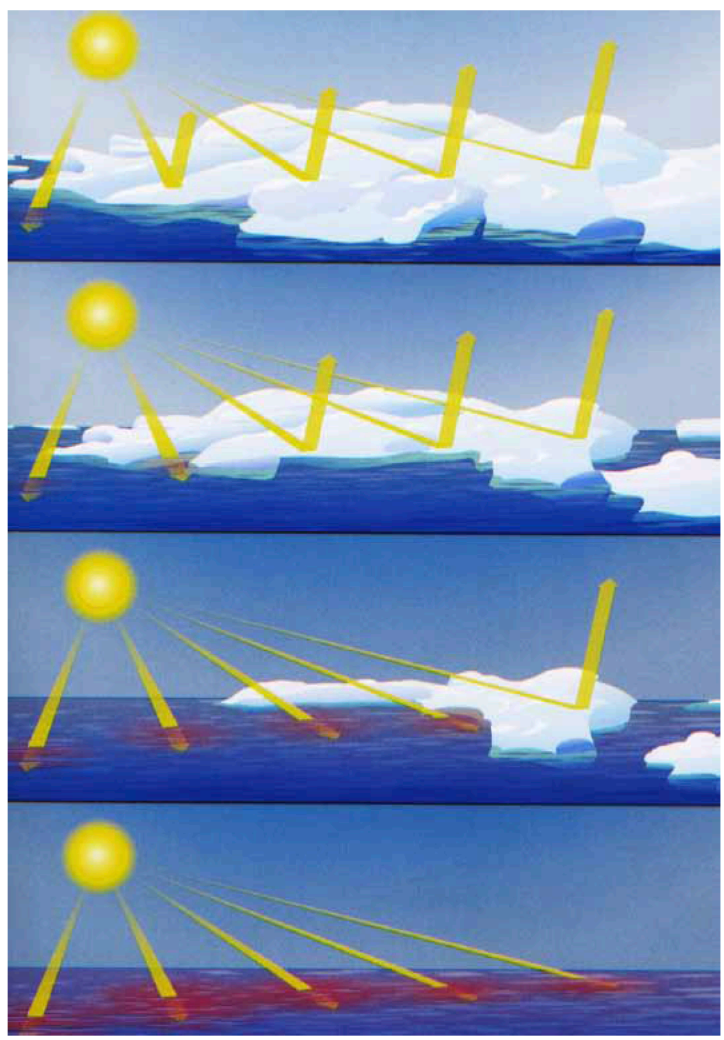
If you are interested in seeing animation of a **positive feedback**, visit: ***www.willstegerfoundation.org/resources***

These pairs will then split and each student will find another student who also has the same number. For example, a student with the number one will find a different student who is also a number one. These new pairs will then share with each other the lesson they prepared with their first partner, including the analogy and original visual. These new partners give each other feedback on aspects of their lesson that were especially good. Students can then decide to incorporate certain aspects of their partner's lesson into their lesson to strengthen it. *(5 min)*

Next, students find new groups that comprise a student with each number. For example, a student with the number one would find a student with the number two and also a student with the number three. Starting with the student with the number one, the students teach their lessons to the other two students in their group. *(5 min)*

The teacher will then ask students to explain and summarize feedback loops including **surface reflectivity** (albedo), **ocean circulation** (thermohaline circulation) and **melting permafrost.** *(5 min)*

Ask the students what another global effect will be of melting glaciers. If they do not mention sea-level rise, ask them to imagine a glass of water that is 4/5 full. Imagine what would happen if you kept adding more and more ice cubes (the water would spill over the rim of the glass). This is the analogy for icebergs calving off land-based glaciers directly into the sea and raising sea level. Also ask your students to imagine a bathroom sink full of water with a rim that slopes to drain excess water down into the basin. Imagine placing ice cubes next to the faucet handles. When the ice cubes melted, the water would run into the sink basin and raise the water level in the sink. This is the analogy for melting land-based mountain glaciers with streams that eventually flow into the ocean.



Explain to your students that as melt-water accumulates on top of ice sheets like the Greenland Ice sheet or the Western Antarctic Ice sheet, water can tunnel down through the ice in rivers called **moulins** that lubricate the bottom of the ice sheet where it rests on the rock. This water can make the ice sheet unstable and it can slide into the ocean. Recent studies have shown when ice sheets begin to disintegrate, sea level can rise as quickly as a few meters per century (Hansen, 2005). *(5 min)*

Lesson 4: Implications of Warming in the Arctic

Why should we learn about global warming in the Arctic?

Let your students know that although the earth will continue to warm for centuries due to heat-trapping gasses already in the atmosphere, it is not too late for us to act to help slow that warming and prevent some of the most extreme effects.

Ask your students to recall actions from Lesson Three that they can take as individuals to help reduce heat-trapping emissions. *(5 min)*

Homework:

Ask your students to write a journal entry about some aspect of this topic that interests them. Suggested topics include how global emissions of heat-trapping gasses affect the Arctic and how changes in the Arctic in turn affect the global climate, thoughts about what our society's response should be to these changes, how the student can respond to this issue on a personal level, etc.

For more information on **positive feedback loops** and other topics presented in this lesson, as well as expedition resources linked to this lesson plan, visit: *www.willstegerfoundation.org/resources*

Notes to Teachers:

- Before dividing the students into groups, explain the entire activity to them and let them know how much time they will have for each section of the activity.
- As the students are cooperatively reading, planning and practicing their lessons and presenting their lessons to each other, circulate between the groups and listen at each group for a few moments to gauge the progress of the groups and to make certain that students are focusing their efforts on the task.
- Inform students that you will circulate between the groups during this activity and that you may ask any student at any time to explain any aspect of the passages. Let them know that it is the responsibility of each group to make sure that each member understands all the concepts and would be ready to explain any of the topics.
- Students may ask why the Arctic warms more quickly than the rest of the world. In addition to the effect of albedo explained in this lesson, there are three additional factors. First, in the tropics much of the extra energy from the heat trapped at the surface goes into evaporation. By contrast, in the Arctic, a much higher percentage of that extra heat goes directly into warming the atmosphere. Second, in the Arctic the layer of the atmosphere that has to warm in order to warm the surface is much thinner than that same layer in the tropics (~5 miles in the Arctic versus ~9 miles in the tropics). Third, alterations in the circulation patterns of the atmosphere and oceans can bring more heat to the Arctic.
- This lesson did not illustrate any negative climate feedback loops. Cloud cover is an example of a negative feedback loop. As the atmosphere warms and as more water vapor evaporates, there will be more clouds. Clouds have a cooling effect and thus slow global warming. As discussed earlier, clouds (water vapor) is short lived in the atmosphere. Scientists are actively studying clouds to assess their net effects during the warming of the planet.
- One additional negative climate feedback loop is increased plant growth. Plants use carbon dioxide to photosynthesize and higher concentrations of CO_2 can make plants increase production, thereby incorporating more carbon from the atmosphere and temporarily storing it in plant tissue. Some have hoped that this increased carbon-storing capacity of plants will remove enough carbon dioxide from the atmosphere to solve the problem of global warming. Recent studies, however, show that plants will not be able to increase production enough to compensate for human-caused emissions. This is due to a number of factors including limited available nitrogen, land use changes and other plant stressors.
- Scientists have found no negative-feedback loops that would be significant enough to compensate for increasing atmospheric concentrations of heat-trapping gasses.

References:

Hansen, J. E. (2005). Is There Still Time to Avoid 'Dangerous Anthropogenic Interference' with Global Climate? Presentation on December 6, 2005 at the American Geophysical Union, San Francisco, California.

Hassol, S. J., Correll, R., Prestrud, P., Weller, G., Anderson, P.A., Baldursson, S., et al. (2004). Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, England.

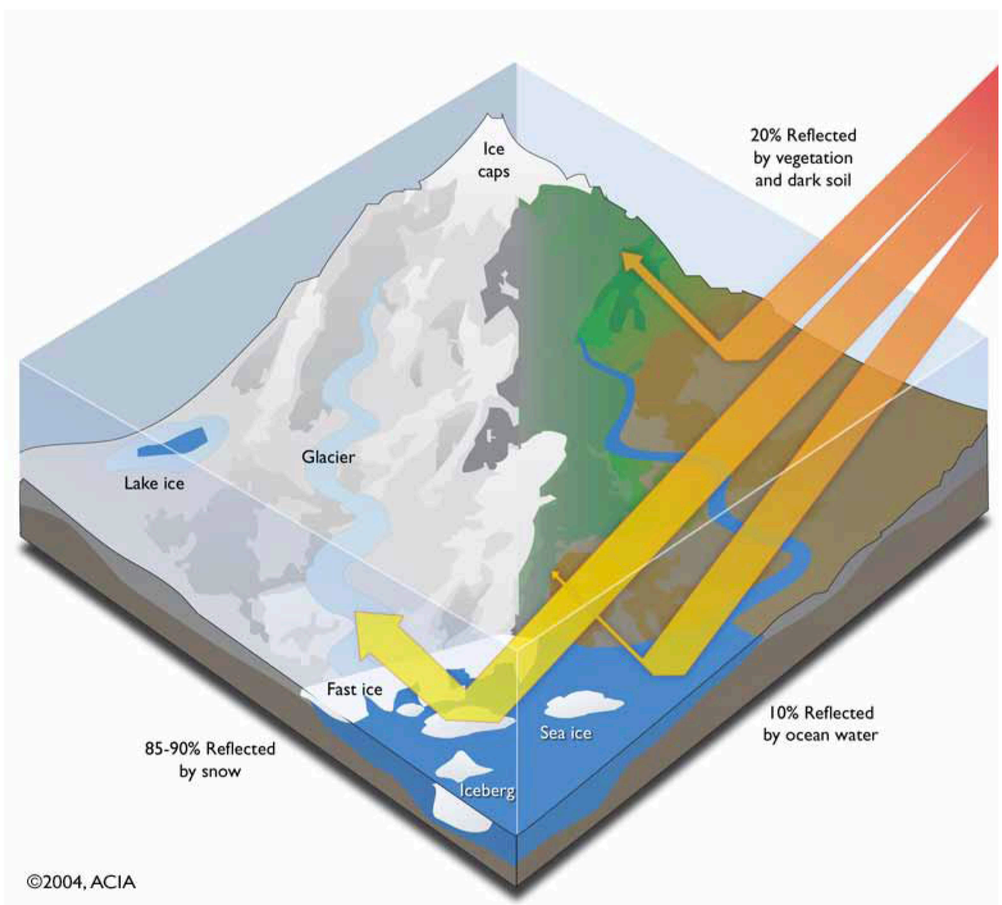
Lesson 4: Implications of Warming in the Arctic

Why should we learn about global warming in the Arctic?

Feedback #1: Surface Reflectivity (Albedo)

One amplification cycle or "feedback loop" in the Arctic that will have an impact on global climate is surface reflectivity (also called albedo). Light-colored objects reflect more heat than dark-colored objects. This is why wearing black clothes on a sunny day feels so much warmer than wearing white clothes.

Snow and ice covers much of the Arctic land and ocean. Because snow and ice is bright white, as much as 90% of the solar energy that hits them reflects back into space. When warmer temperatures melt the snow and ice, the darker-colored vegetation or ocean water below absorbs up to 90% of the incoming solar radiation. When this extra energy is absorbed instead of being reflected, it further heats the oceans, land and surrounding air which in turn causes more melting. Thus, it is a positive feedback loop because the process of melting snow and ice creates conditions that melt even more snow and ice. The graphic below illustrates the surface reflectivity/albedo feedback loop. This feedback loop is one of the reasons that the Arctic is warming more quickly than the rest of the world. The effects are not limited to just the Arctic, however, because Arctic warming increases warming on a global scale.



Lesson 4: Implications of Warming in the Arctic

Why should we learn about global warming in the Arctic?

Feedback #2: Ocean Circulation (Thermohaline circulation)

Ocean circulation is a feedback loop through which changes in the Arctic can make larger changes in the rest of the world. Global ocean currents are like giant conveyor belts that move warm water from the tropics up to the higher latitudes and cold water from the polar areas down towards the tropics. This process helps cool the warm parts of the world and warm the cold parts of the world. For example in western Europe, countries like England and France are as far north as Newfoundland and Labrador off the east coast of Canada. In that section of Canada, the climate is very cool and winters are long and cold. By contrast, in the United Kingdom and France, the climate is mild in the winter. Tropical plants can grow in England and there is hardly ever any snow at lower elevations. Part of what keeps the climate in western Europe so mild in the winter is an ocean currents called the Gulf Stream and the North Atlantic Drift that bring warm water north from the tropics. Look at the graphic below. The red lines represent warm water on the surface and the blue lines represent cold, deeper water. See how a red line goes north past western Europe and a blue line comes down past the east coast of Canada? These currents are largely responsible for that part of Canada being cold and western Europe, at the same latitude, being mild.

These ocean current "conveyor belts" are driven by two factors: temperature and salinity (saltiness). The entire system is called thermohaline circulation. *Thermo* means "temperature" and *haline* means "salt." Warm water is less dense than cold water. Fresh water is also less dense than salt water. Warm, salty water travels from the tropics towards the poles on the surface. When it gets to the polar regions it cools and becomes more salty as some of the water turns to ice and rejects its salt which then goes into the water around it, making that water more salty. This colder and saltier water sinks and then travels along the bottom back towards the tropics. Along the way it gets warmer and fresher (less salty) from the discharge of rivers along the way.

As the Arctic warms, so does the water there, making it less dense. It is also becoming less dense because ice is melting and river discharge is increasing, pumping more fresh water into the Arctic ocean and ultimately the North Atlantic Ocean. These two factors slow the global thermohaline circulation. This affects the global climate.

Besides affecting global climate, ocean circulation also carries carbon dioxide (CO_2) into the deep ocean. Carbon dioxide can be incorporated into colder ocean surface waters at a greater rate than into warm surface waters. As the ocean continues to warm, its ability to uptake carbon dioxide from the atmosphere will decrease. Also as the ocean circulation slows, less carbon is stored in the ocean, letting more of it build up more quickly in the atmosphere, hence increasing global warming.

Lesson 4: Implications of Warming in the Artic

Why should we learn about global warming in the Arctic?

Feedback #3: Melting Permafrost

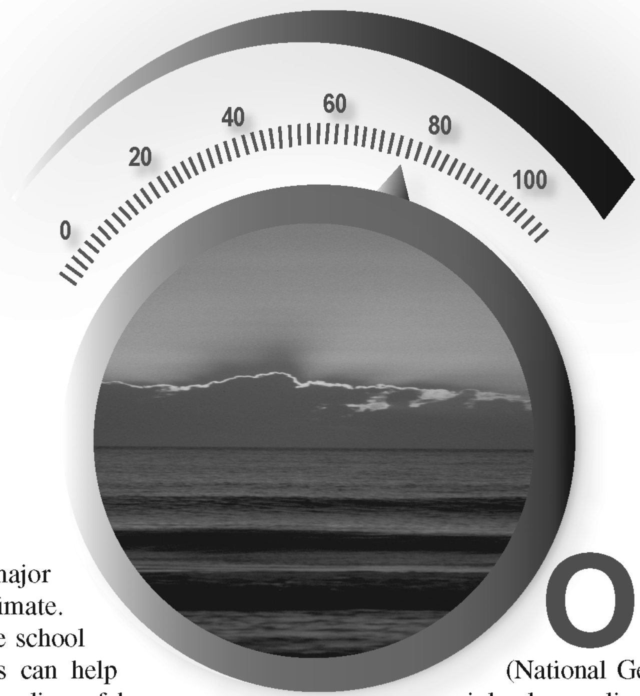
Melting permafrost is a feedback loop through which warming in the Arctic can have an affect on global climate. One third of the carbon stored in the soil of the earth is stored in the Arctic, much of it frozen in permafrost. The reason there is so much carbon in the Arctic is that for much of the year, the temperature is so cold that when plants and animals die, they do not readily decompose. Consequently, the carbon (which is the building blocks of life forms) stays frozen in the soil. Over years as living things continue to die, more and more carbon accumulates in the frozen ground.

As the soil warms, the dead material begins to decompose (rot). Decomposition releases both methane (CH_4) and carbon dioxide (CO_2) into the atmosphere. Both methane and carbon dioxide are heat-trapping gasses, meaning they trap energy in the atmosphere and keep it from radiating back into space.

These emissions of methane (a gas which lingers in the atmosphere for about 12 years) and carbon dioxide (which lingers in the atmosphere for over a century) further contribute to global warming. This is a positive feedback loop because melting permafrost releases heat-trapping gasses, which make conditions that melt even more permafrost and release even more heat-trapping gasses.

How Is Coastal Temperature Influenced by the Great Lakes and the Ocean?

Rosanne W. Fortner and Victor J. Mayer



Abstract. The ocean is a major influence on weather and climate. With this set of lessons, middle school Earth systems science teachers can help their students build an understanding of how large bodies of water can serve as a heat source or sink at different times and how proximity to water moderates climate along the coast. The activity's combination of laboratory investigation, map study, and graphing applies different learning styles and provides practice in important science processes. The activities are adapted from *Earth Systems Education Activities for Great Lakes Schools: Great Lakes Climate and Water Movement* (V. J. Mayer et al. 1996).

Keywords: heat sink, heat source, lake effect, maritime climate, temperature

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Ocean literacy essential principle 3 states that the ocean is a major influence on weather and climate (National Geographic et al. 2006). The principle also applies to the Great Lakes region of the United States, where weather is influenced by proximity to the lakes. The development of climate patterns is a complex set of processes, but learning about coastal weather conditions serves as a step toward understanding how the atmosphere and ocean interact to create a maritime climate.

It takes far more energy to change the temperature of water than the temperature of land or air. For this reason, temperatures over inland areas exhibit greater extremes and ranges than temperatures near large bodies of water. Activity 1 examines the principles behind such changes, and activity 2 demonstrates how the process plays out in modifying coastal temperatures.

Activity 1: What Happens to Heat Energy Reaching Water and Land?

Even as far back as the log cabin days, American pioneers would place a large container of water in a room to prevent foods from freezing on cold nights. The pioneers understood that water absorbs a great deal of heat energy and can, in turn, release this heat. In the first investigation, middle school students explore how bodies of water can affect the surrounding areas. This activity simulates the effects of sunlight on water and land.

Objectives

When students have completed this activity, they should be able to (1) describe how soil and water differ in their ability to absorb and release heat energy and (2) describe how this difference in heat absorbed or released affects the atmosphere immediately above the land and the water.

Materials for Each Lab Group

- Four thermometers
- One container of dark soil and one container of water (The containers should hold equal amounts, and the soil and water should be left out overnight to come to room temperature.)
- Two 30-cm rulers
- Masking tape
- Ring stand
- Lamp (at least 150 W) with reflector
- Safety goggles for each group member
- Graph paper

Setup

Teams should set up the materials according to the following directions. (See Figure 1 for a completed setup.)

1. Place the containers of soil and water about 3 cm apart. Lay one ruler across each container, resting it on the container's rim.
2. Place one thermometer in the soil, with the bulb just barely covered. Use masking tape to attach the thermometer to the ruler to hold it upright. Place another thermometer close to the first one, with the bulb about 1 cm above the soil. Attach it to the ruler, too.
3. In the water container, position the remaining two thermometers the same way, placing one just above and one just below the water surface. Attach both to the ruler above the water container.
4. Place the lamp on the ring stand, with the reflector pointing down. Position the lamp 30 cm above the containers and centered between them, being careful to shield the thermometer bulbs from the direct rays of the lamp. Containers may face each other for more even distribution of light, as long as the thermometers can be read.

With this apparatus, one can simulate alternate periods of heating and cooling and observe how temperature changes in and above the water and land. The situation might represent either light and darkness on a single day or seasons of heating and cooling with annual changes in insolation.

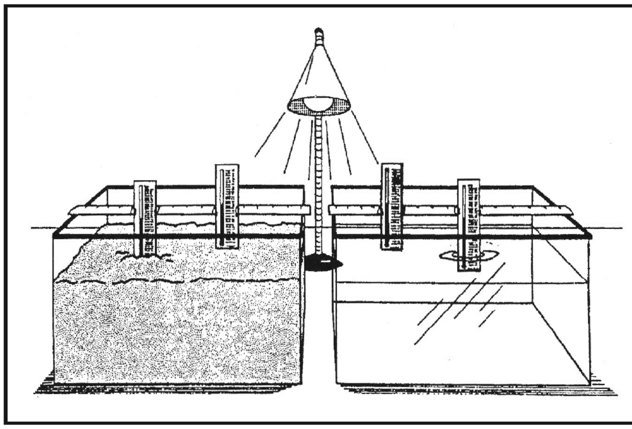


FIGURE 1. Setup for activity 1 investigation. Source: V. J. Mayer et al. 1996.

Procedure for Students

1. Construct a data table to show the temperatures of the four thermometers each minute for at least 24 minutes.
2. Wear safety goggles for this investigation.
3. The teacher should examine the setup before the lamp is turned on.
4. Turn on the lamp. At 1-min intervals, record the temperatures on each of the four thermometers. Continue for 12 min.
5. After 12 min, turn off the lamp. Continue recording temperatures at 1-min intervals for 12 min more.
6. Plot the data on a time–temperature graph. Use a different color for the data from each thermometer. Use the data to answer the following questions.
   a. When the light is on, does air heat up faster over the soil or over the water? (Answer: *over soil*)
   b. When the light is on, which changes more, the temperature of the soil or the temperature of the water? (Answer: *The soil heats more rapidly. Soil has a lower specific heat, and it absorbs all radiation close to the surface. Specific heat is the amount of heat in calories required to raise the temperature of 1 g of substance by 1°C. The specific heat of water is 1. All other common liquids and solids have a specific heat of less than 1.*)
   c. Which absorbs more energy, soil or water? (Answer: *water*) Students may have difficulty understanding this answer. The clue is in the air temperature curves. The air over the soil heats up much more rapidly than the air over the water because soil cannot hold on to the heat energy and returns it to the atmosphere. The difference in the curves, therefore, implies that the water has a greater capacity for storing heat energy.
   d. In the second 12-min interval, when the light is off, which changes more, the temperature of the soil or the temperature of the water? (Answer: *After the*

light is turned off, the soil cools more rapidly than the water because of its lower specific heat.) See Figure 2 to further explore this idea. Note that the curves for soil and water now show a drop at different rates in section B of the graph.

e. Which changes most after the light is off, the temperature above the soil or the temperature above the water? (Answer: *above the soil*) Notice how the air lines on the graph cross at about 19 min and continue to diverge after that. This shows that water is acting as a source of heat energy for the atmosphere.
f. Which loses heat faster, soil or water? (Answer: *soil*)
g. Which keeps heat energy longer, soil or water? (Answer: *water*)
h. Anything that adds heat energy to the atmosphere is called a *heat source*. A *heat sink* takes and stores energy from the atmosphere. Discuss whether soil or water could be considered a heat sink while the light is on. (Answer: *Normally, soil functions very briefly as a heat sink after the light is turned on. Shortly, however, it begins radiating energy back to the atmosphere—becoming a heat source—as indicated by the heating of the air above the soil. Water remains a heat sink and produces only a minimal rise in temperature of the air above.*)
i. After the light is turned off, is the soil a heat source? Is the water a heat source? Why? (Answer: *After the light is turned off, soil functions briefly as a heat source. Because the air temperature above the water remains higher than that of the water itself, it continues to act as a heat source for the entire recording period, until the surface water is the same temperature as the air over it.*)

Technology Application

Use temperature probes in a local environment to collect daily water, air over water, land, and air over land temperature data for mornings and afternoons for several weeks in the spring. Have the class develop graphs that represent how the local soil, water, and air temperatures change during the day, as in activity 1. Cloud cover and passage of fronts will affect these data, so it may take several days for students to be able to generalize from their observations.

If outdoor data collection is not possible, the Internet can be a data source. For example, the Web site http://weather.unisys.com/surface/previous/sfc_con_24temp-10.html provides a 24-hr map of atmospheric conditions for the current day, and the isotherms (in degrees Celsius) can be observed across periods of daylight and darkness over both land and water. Students can graph the range of temperatures in coastal areas to see if they can detect how the sea or Great Lakes are serving as heat sources or sinks for the atmosphere. Note that the general movement of air across the continental United States is west to east. Ask students to determine which coast of a lake or ocean is more likely to show effects of the water on air temperature. (Answer: *The air temperature over a coastal area downwind of water will likely show more effects of the water as a heat source or sink.*)

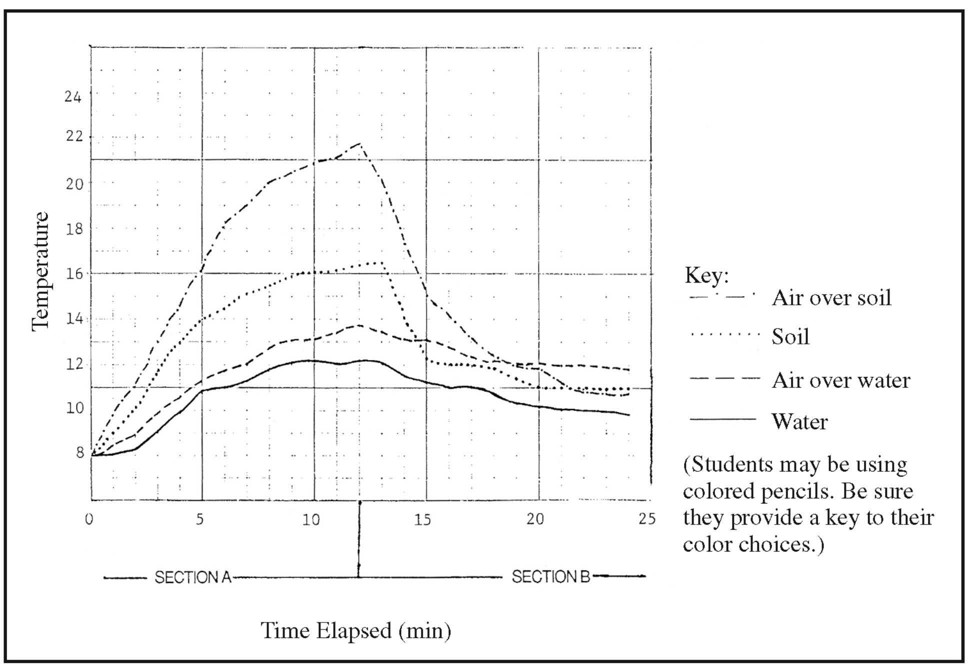


FIGURE 2. Sample of student graph results. Source: V. J. Mayer et al. 1996.

Assessment

Accuracy in graphing will be necessary for appropriate interpretation of results. Teachers should observe graphing techniques as one component of assessment. Answers to the questions are a second component, although class discussion may be necessary to bring out the principles involved in interpreting the data. Finally, ask students to apply what they have learned by answering the question discussed in the first paragraph of activity 1: Why would pioneers put a barrel of water in the apple shed to prevent fruit from freezing on a chilly night?

Activity 2: How Do the Ocean and the Great Lakes Affect Temperature?

In activity 1, students learned that a pan of water is a good heat sink when the lamp is on and a good heat source when the light is off. Soil also acts as a heat sink and source, but its capacity to hold energy is much lower than that of water. Therefore, soil becomes a heat sink soon after the light is turned on and stops acting as a heat source not long after the light is turned off.

Water in the ocean and Great Lakes tends to increase in temperature all summer. This indicates that it is storing up extra energy from the atmosphere and acting as a heat sink throughout the summer. In the winter, however, there is less radiation from the sun. Then, oceans and lakes become heat sources, giving up their stored energy to the atmosphere.

Objectives

When students have completed this activity, they should be able to synthesize information about the effects of the ocean and Great Lakes on the temperature of the surrounding land.

Students should work in pairs on this activity. Each pair will need copies of Figures 3–6.

Procedure for Students

1. Figures 3 and 4 are maps of Ohio with isotherms drawn on them. An *isotherm* is a line that connects points of equal temperature. The National Weather Service reports temperatures in Fahrenheit, so the temperatures on this map are in Fahrenheit. Average temperatures in July and January are shown in the figures, and the body of water north of Ohio is Lake Erie. Have the students answer the following questions using this pair of maps.
   a. What happens to the average temperature along line AB in Figure 3 as you approach Lake Erie from the west? (Answer: *Temperatures go up a little, then decrease as you approach the lake.*)
   b. What happens to the average temperature along line CD in Figure 4 as you approach Lake Erie from the

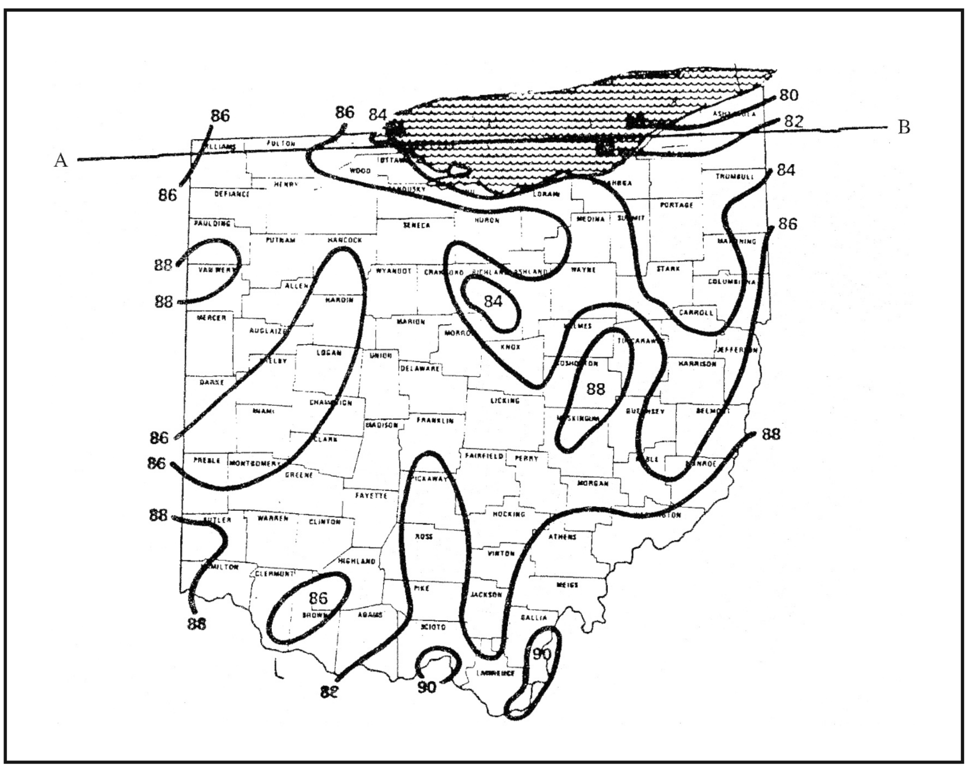


FIGURE 3. Mean maximum temperature of an average July in Ohio (°F). Source: V. J. Mayer et al. 1996.

west? (Answer: *Temperatures increase nearer to the lake.*)

c. Explain the differences in temperature patterns between July and January. (Answer: *During the summer, the lake absorbs energy, but the land reradiates energy to the atmosphere. Therefore, the air over land is warmer than air over the water. In the winter, the energy absorbed by the lake water is gradually released to the atmosphere, making the air over the water warmer than the air over the land.*)

d. Is Lake Erie a heat source or sink? Discuss. (Answer: *Lake Erie is both a heat source and a heat sink, depending on the season. In the late spring and summer, it is a heat sink; in the fall and winter, it is a heat source.*)

e. Describe the effects of Lake Erie on the temperature of northern Ohio. (Answer: *Lake Erie acts as a moderator for northern Ohio's climate. It keeps the air cooler in the early summer and warmer in the rest of the fall and the winter than in other parts of the state.*)

2. The ocean affects temperatures in much the same way as large lakes. Figures 5–6 are maps of the world that show isotherms representing average temperatures in July and January. On these maps, the temperatures are in degrees Celsius.

a. Follow parallel 60°N across Figure 5. How is temperature affected by the continents and by the ocean? (Answer: *As you follow 60°N across the map for July, the temperature rises over the continents and falls over the oceans.*) If students are familiar with how to make a topographic profile, they could make a temperature profile here to answer this question graphically. Teachers might also wish to look at other latitudes for examples of temperature differences.

b. Follow parallel 60°N across Figure 6, just as in Figure 5. Describe the differences in average temperature. (Answer: *As you follow the line of latitude 60°N across the map for January, the temperature falls over the continents and rises over the ocean.*) For color maps showing similar data, see http://www.mapsofworld.com/world-maps/world-weather-map.html.

3. The ocean affects the temperature of the Great Lakes region, too. When the Great Lakes region has warm winter temperatures, it is under the influence of air that starts over the oceans. The cold frigid winter air comes from northern Canada, where the ocean does not have an effect.

a. Do oceans act as heat sources or sinks? How do you know? (Answer: *Oceans act as heat sources in winter and heat sinks in summer, just as the Great Lakes do.*)

b. Do continents ever act as heat sources? Explain. (Answer: *The continents act as heat sources in*

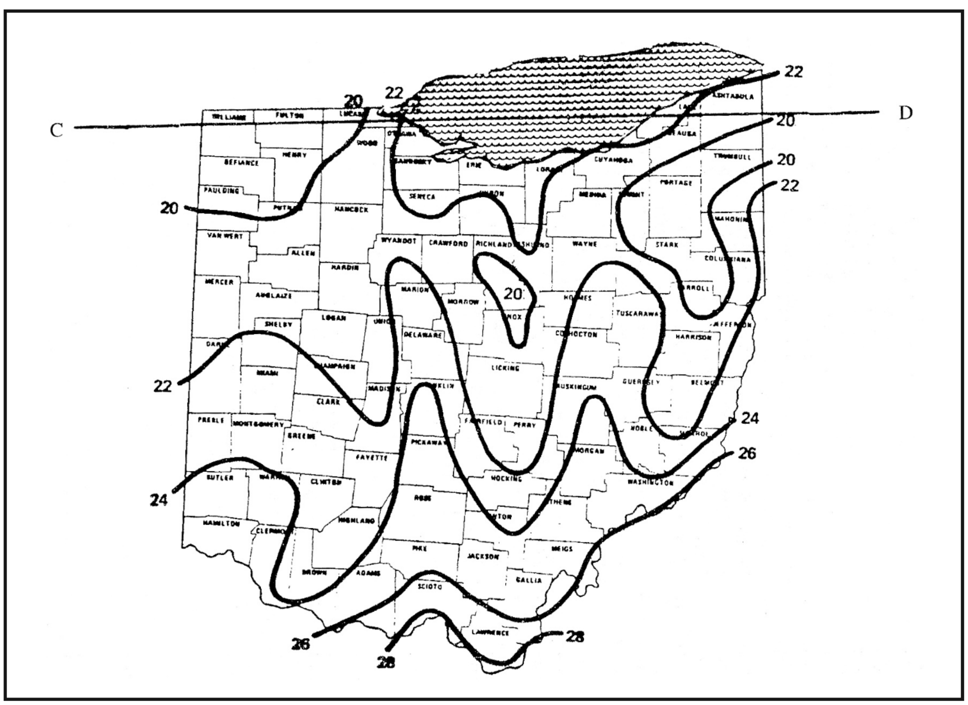


FIGURE 4. Mean maximum temperature of an average January in Ohio (°F). Source: V. J. Mayer et al. 1996.

summer and heat sinks in winter, just like the land in Ohio does.)

Technology Application and Extension

The Smithsonian Ocean Planet Web site (http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_4.html) has a world map with 11 world cities marked. Have small groups of students examine the location of each city and hypothesize whether and how the ocean affects its temperatures. The Web site provides high and low temperatures for cities so students can evaluate their hypotheses. In some cases, the heat source–heat sink principles can explain the data, but ocean currents are also

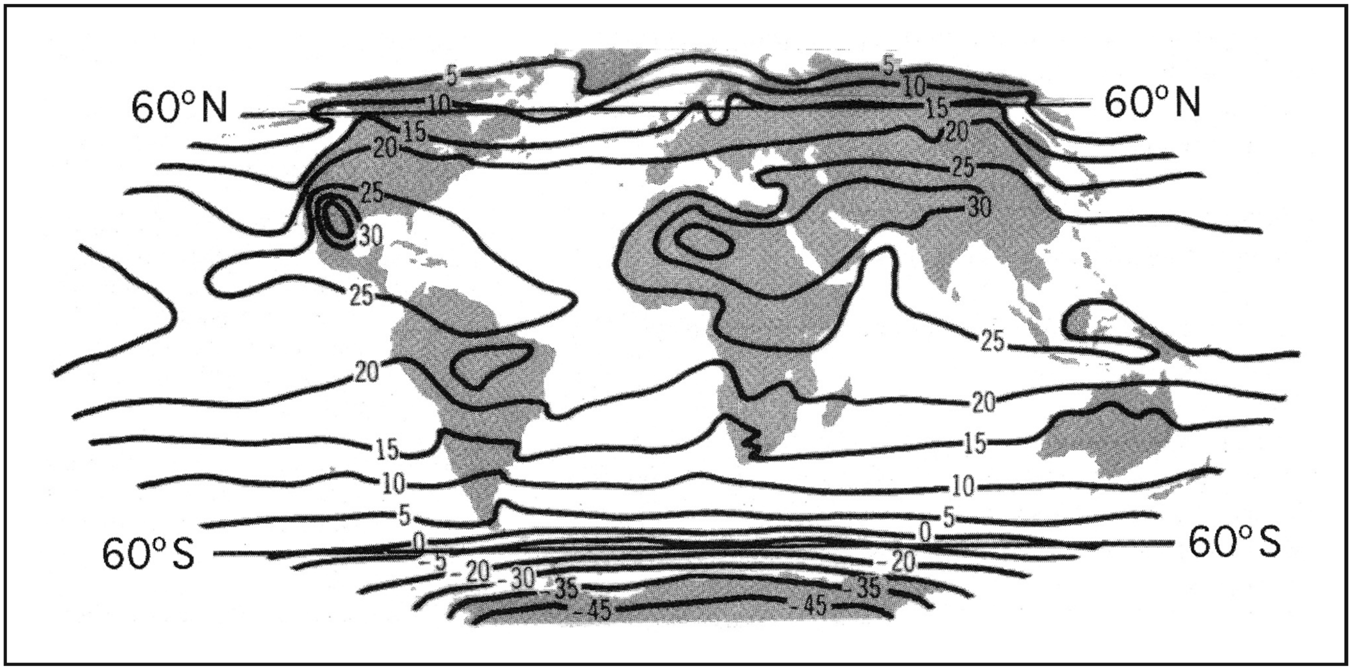


FIGURE 5. World map of average temperatures in July (°C). Source: V. J. Mayer et al. 1996.

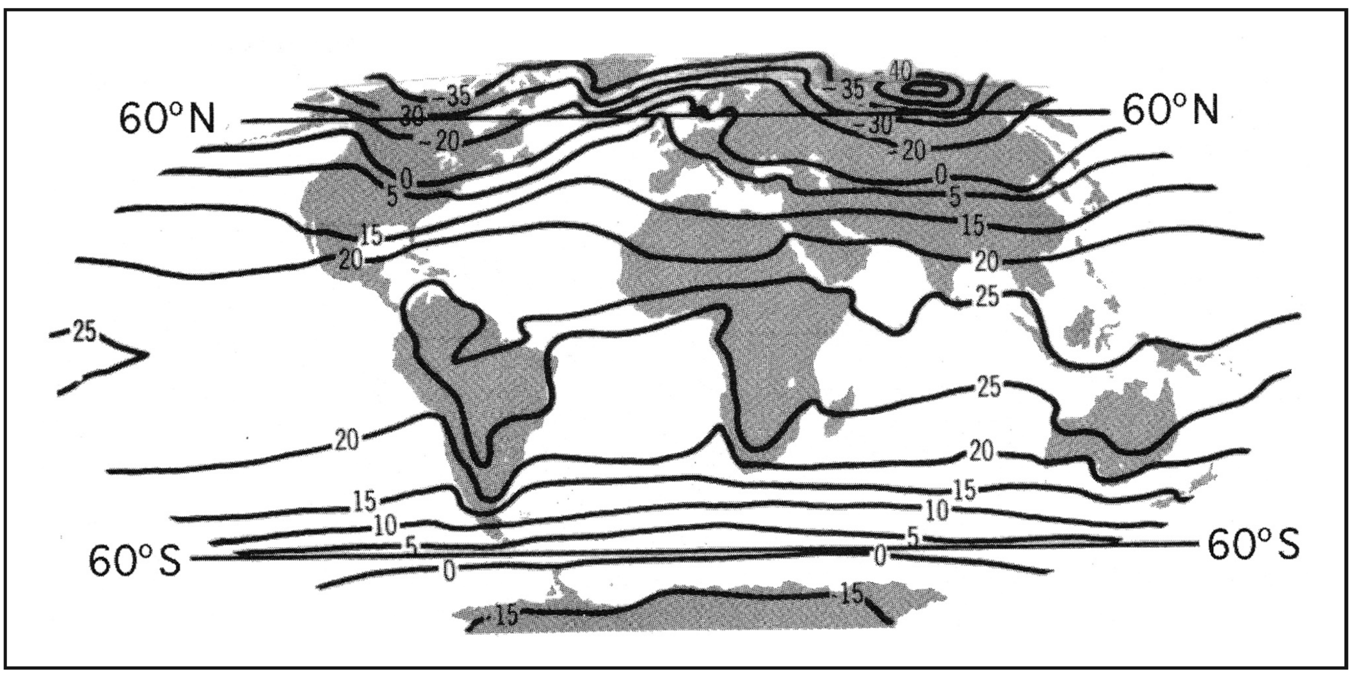


FIGURE 6. World map of average temperatures in January (°C). Source: V. J. Mayer et al. 1996.

involved. This exercise demonstrates that ocean–climate interactions are much more complex than one can illustrate in a single lesson.

Assessment

Student understanding can be assessed by having small groups develop an advertising campaign for a coastal area in a particular season. Students may use a video, brochure, or other medium to convey their advertising message. Ads should synthesize information about seasonal effects of the nearby ocean or Great Lake and apply the information to a new situation.

Meeting Standards

These activities address not only ocean literacy essential principle 3, but also numerous national science education standards (National Research Council 1996) for content in grades 5–8. These include the following:

- science as inquiry: abilities related to scientific inquiry, understanding about scientific inquiry;
- physical science: properties and changes of properties in matter, motions and forces, transfer of energy;
- Earth and space science: structure of the Earth system (Oceans have a major effect on climate, because water in the oceans holds a large amount of heat), Earth in the solar system (The sun is the major source of energy for phenomena on the Earth's surface); and
- unifying concepts and processes: evidence, models, and explanation; change, constancy, and measurement.

Acknowledgments

The authors are indebted to Ohio teachers James Meineke and Beth Kennedy, who originated the lessons presented in this article.

Resources

Bigelow Laboratory's Web site explores sea surface temperatures, climate moderation by currents, day–night temperature changes, and related phenomena at http://www.bigelow.org/virtual/sst_sub1.html (accessed April 30, 2009).

Centers for Ocean Sciences Education Excellence (COSEE) Ocean Systems has an award-winning ocean climate interactive Web site linked to http://cosee.umaine.edu/tools/oci/ (accessed April 30, 2009).

Great Lakes Coastal Forecasting System has nowcast maps of water temperatures, available at http://www.glerl.noaa.gov/res/glcfs/ (accessed April 30, 2009).

The National Oceanographic Data Center makes U.S. coastal water temperatures, including some monthly data, accessible at http://www.nodc.noaa.gov/dsdt/cwtg/all.html (accessed April 30, 2009).

References

Mayer, V. J., R. W. Fortner, H. Miller, and A. L. Sheaffer, eds., 1996. *Earth Systems Education Activities for Great Lakes Schools: Great Lakes Climate and Water Movement.* Ohio Sea Grant Education EP-083. Columbus: Ohio State University.

National Geographic Society, National Oceanic and Atmospheric Administration (NOAA), Centers for Ocean Sciences Education Excellence (COSEE), National Marine Sanctuary Foundation, National Marine Educators Association, College of Exploration. 2006. Ocean literacy: The essential principles of ocean sciences grades K–12. http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf (accessed March 1, 2009).

National Research Council. 1996. *National Science Education Standards*. Washington DC: National Academy Press.

Fresh and Salt

Principle 4

Ocean Literacy

The ocean makes Earth habitable.

Great Lakes Literacy

Water makes Earth habitable;
fresh water sustains life on land.

Fresh and Salt

Principle 4: The ocean makes Earth habitable. (OL) Water makes Earth habitable; fresh water sustains life on land. (GL)

Essential Principle #4 describes how life is thought to have begun in the ocean. The earliest evidence of life is found in the ocean as fossils. Activities by photosynthetic organisms in the ocean initially produced much of the atmospheric oxygen. In modern times oxygen levels and other physical and chemical properties affect production in both the ocean and the Great Lakes, often to the point that they become limiting factors. Limiting factors, e.g., inadequate amounts of oxygen, can constrain the productivity of organisms and communities.

Being Productive in the Arctic Ocean and BATS and Hot Dogs both discuss productivity, one in the Atlantic/Pacific Oceans and the other in the Arctic Ocean. Both lessons use data collected by research facilities and ask students to analyze that data. *BATS and Hot Dogs* uses real time data from ocean observatory websites. For classrooms that don't have internet access *Being Productive in the Arctic Ocean* provides the data on data cards.

Being Productive in the Arctic Ocean, from NOAA Ocean Explorer, focuses on factors that limit primary productivity in the Arctic Ocean. It lists and describes the three realms of the Arctic Ocean and discusses how microscopic algae use photosynthesis to provide energy for the other organisms in this environment. The lesson includes ten data sets that represent samples that could have been taken at ten different times of the year. Students use this data to determine why certain days were more 'productive' than others. Variables include ice cover, photosynthetically active radiation, chlorophyll a, nitrate, and primary productivity.

This activity is geared towards high school students who do not have access to the internet in their classroom. It familiarizes students with the concept of productivity and allows them to use data to infer what might be the limiting factor on productivity on a given day.

Similar processes are at work in the Great Lakes and can limit production there. The Dead Zone, for example, is a phenomenon in western Lake Erie where oxygen is depleted by decomposition of large amounts of plant matter. This process is amplified by zebra mussel activity as they filter out the smallest particles in the lake, allowing more light to penetrate and thus more plant growth at depth. As decomposing plants deplete the oxygen, fish and other organisms in the area must either relocate or perish.

BATS and Hot Dogs from EARTH, (Education and Research: Testing Hypotheses), uses real-time data to compare nitrate and phosphate concentrations at two ocean sites. Students retrieve data from these sites, analyze the data, construct graphs and compare their data with other students. Variables in this lesson include phosphorous, nitrate, salinity, temperature, and depth. These physical and chemical properties impact production in the world's oceans. The lesson also stresses interactions between the atmosphere and the ocean, and introduces students to Ocean Observation Systems.

There are several parallels to the Great Lakes system. Many of the same physical and chemical properties exist in a freshwater environment. The oceanic and atmospheric interaction is also similar. This lesson asks students to take what they've learned to the next level by hypothesizing what the impacts of global climate change might be on primary productivity. Impacts may be different in the ocean and Great Lakes environments.

Education and Research: Testing Hypotheses

Lesson Plan—BATS & HOT DOGS

Summary

This activity allows students, working individually or in small groups, to retrieve information from pre-assigned web sites, retrieve real-time data to compare nitrate and phosphate concentrations at two open ocean monitoring sites, and construct an EXCEL graph using data from two different sites. Each student or group will retrieve data for a specific time frame from public data generated at an ocean observatory and generate a graph for each variable. After graphing the data, students will analyze their graphs, discuss and compare their findings with the class. In conclusion, the students will predict how future Global Climate Changes might affect these nutrients in the open ocean. Student assessment will be based on accuracy of content in a lab summary and active participation in the data collection process and class discussion.

Key Concepts

- Identify patterns and relationships determined from collected data.
- Solve for unknown quantities by manipulating variables.
- Discuss physical and chemical properties of saltwater.
- Describe physical characteristics and processes of oceans.
- Recognize interactions between the atmosphere and the ocean.

Objectives

Students will be able to:

- ***Locate*** and ***describe*** the Great Ocean Conveyor Belt
- ***Explain*** the importance of primary productivity and nutrient regeneration by bacteria in the World's oceans
- ***Explain*** how the ocean conveyor belt affects both of these processes
- ***Identify*** physical and chemical properties of ocean water that affect primary productivity in the ocean
- ***Collect data*** (phosphorus, nitrate, depth) from the HOT and BATS ocean observatory Web sites
- ***Analyze the data*** to identify trends Predict the effect global climate changes may have on primary productivity in open ocean waters

Materials

- Computers with Internet access, printers
- HOT DOGS and BATS Data Visualization instruction pages
    - http://www.mbari.org/earth/mar_tech/buoys/HOT_DOGS.html
    - http://www.mbari.org/earth/mar_tech/buoys/BATS.html

- HOT DOGS and BATS Graphing instruction pages
  - http://www.mbari.org/earth/mar_tech/buoys/BHD_graph.html
- Access to additional resources (posters, paper for brochure, blog, power point)

Procedure

1. Read the following background information describing the Great Ocean Conveyor Belt
   a. David Suzuki Foundation—The Great Ocean Conveyor
   http://www.davidsuzuki.org/Climate_Change/Science/Conveyor.asp
   b. The Environmental Literacy Council—The Great Ocean Conveyor Belt
   http://www.enviroliteracy.org/article.php/545.html
   c. Windows to the Universe—Transfer and Storage of Heat in the Oceans
   http://www.windows.ucar.edu/tour/link=/earth/Water/ocean_heat_storage_transfer.html

2. Read the following background information describing ocean primary productivity
   a. Oregon State University—Ocean Productivity
   http://www.science.oregonstate.edu/ocean.productivity/
3. Read the following background information describing nutrient cycles
   a. e-subjects—Nutrient Cycles
   http://e-subjects.co.uk/mod/resource/view.php?id=2042
   b. The Encyclopedia of Earth—Marine Nitrogen Cycle
   http://www.eoearth.org/article/Marine_nitrogen_cycle
   c. Chemgapedia—Simplified Marine Nitrogen Cycle
   http://www.chemgapedia.de/vsengine/vlu/vsc/en/ch/16/uc/vlus/nitrogen.vlu/Page/vsc/en/ch/16/uc/chemicalcycles/nitrogen/simplenitcycle.vscml.html
   d. The Environmental Literacy Council—Phosphorus Cycle
   http://www.enviroliteracy.org/article.php/480.html
4. Read the following information on physical and chemical properties of ocean water that affect primary productivity
   a. espere—Phytoplankton and nutrients in the oceans
   http://www.atmosphere.mpg.de/enid/1f85756ba5113dcb47a225ee0813c5aa,0/2__Oceanic_nutrients/-_Phytoplankton_and_nutrients_1vf.html
   b. espere—Seasonal cycle of phytoplankton growth
   http://www.atmosphere.mpg.de/enid/1f85756ba5113dcb47a225ee0813c5aa,0/2__Oceanic_nutrients/-_Phytoplankton_growth_1vg.html
5. Answer the following questions on a sheet of paper
   a. What is the correlation, if any, between nutrient concentrations in open ocean waters and ocean primary productivity?
   b. In what ways are phytoplankton blooms beneficial to the health of the open ocean ecosystem?
   c. In what ways are phytoplankton blooms detrimental to the health of open ocean ecosystem?
   d. How might they impact the economic activity of the region?
6. Use the HOT DOGS and BATS Data Visualization instruction pages to download and import nutrient data from each location into Excel
7. Use the HOT DOGS and BATS Graphing instruction pages to produce graphs of the data using Excel
8. Answer the following questions on a sheet of paper

a. Looking at the nutrient data, were their concentrations uniform through out the water column at both the HOT and BATS sites? If not, describe any differences.
b. What was the maximum concentration of each nutrient for each site?
c. At what depth were the highest nutrient concentrations found at each site?
d. Why are maximum concentrations of each nutrient found at this depth?
e. What oceanic factors might contribute to the differences found in nutrient concentrations between the HOT site in the Pacific Ocean and BATS site in the Atlantic Ocean?

9. Read the following information about global climate change
   a. espere—Consequences of global warming on ocean circulation http://www.atmosphere.mpg.de/enid/fe3c53b548f5dad9a8f4a5da78be90ea,0/1__Oceans_and_climate/-_Oceans_and_climate_change_1vr.html
   b. WHOI—The Once and Future Circulation of the Ocean http://www.whoi.edu/page.do?pid=12455&tid=282&cid=17906
10. On a sheet of paper, write a paragraph predicting the effect global climate changes might have on primary productivity in open ocean waters (Be sure to support your prediction with information from the data and/or readings)
11. Students will present their predictions in the form of a poster, Power Point presentation, skit or blog

Assessment

- **Performance**— Did students accurately follow the directions in the activity? Did students' answers to the questions demonstrate an understanding of nutrient data? Did students successfully create and print an EXCEL graph of defined data sets?
- **Product**—Did students' presentations clearly communicate their predictions? Did students' predictions reflect an understanding of nutrient processes?

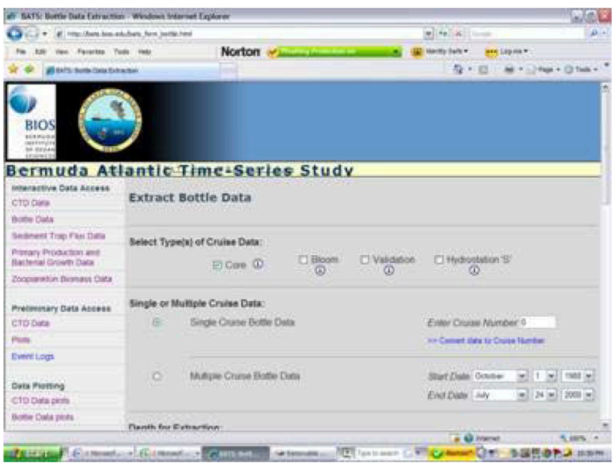
Marine Technology

BATS: Data Visualitzation

The Bermuda Atlantic Time-series Study (BATS) was established to uncover mysteries of the deep by analyzing important hydrographic and biological parameters throughout the water column. Pursuing this goal has enabled BATS scientists—and oceanographers worldwide—to completely revise their perspective on the ocean's physical, chemical and biological processes. Sustained time-series data collection has challenged longstanding paradigms and has begun to uncover exciting new observations about the ocean.

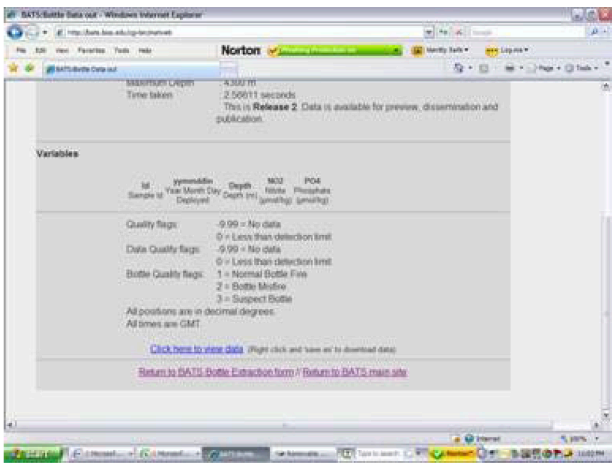
Data visualization

1. Navigate to http://bats.bios.edu/

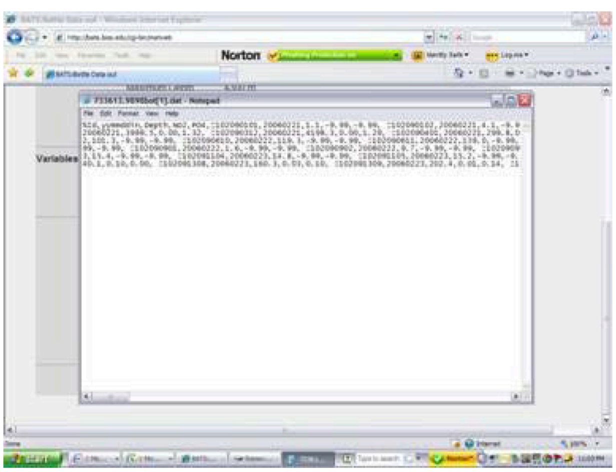


2. In the left-hand menu, click on "**Bottle Data**"
3. Select the following:
    1. Type of Cruise: "**Core**"
    2. Choose "**Single Cruise Bottle Data**"
    3. Enter Cruise Number: "**10209**"
    4. In the Discrete Data section, check all of the following:
        1. "**Sample Identification Number**"
        2. Deployed: "**Year Month Day**"
        3. "**Depth**," "**Nitrate+Nitrite**," "**Phosphate**"
    5. Output Format: "**CSV**"
    6. Click "**Get Bottle Data**
4. A table called "***Details of Extrated Bottle Data***" will come up

5. At the bottom of the page, click on "**Click Here To View Data**"

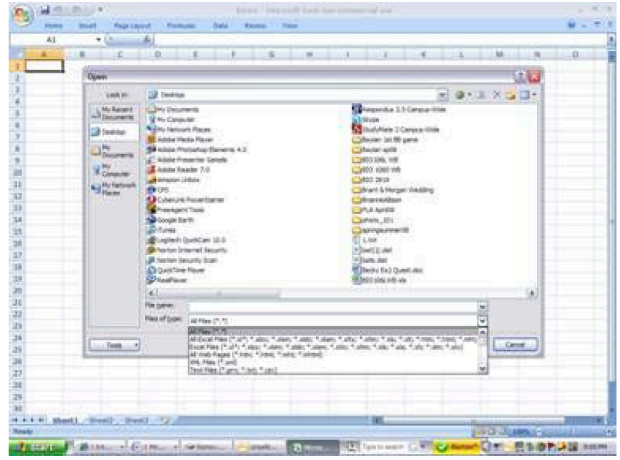


6. If a dialog box appears, click "Open;" data will appear in Notepad
7. Save the file on the desktop or in an easy-to-find folder

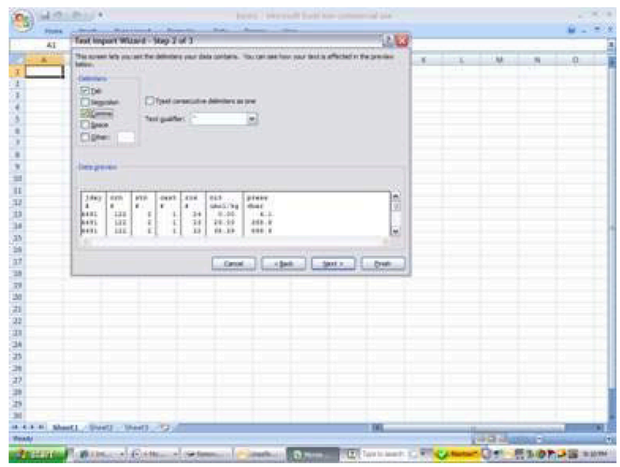


Importing the data into Excel

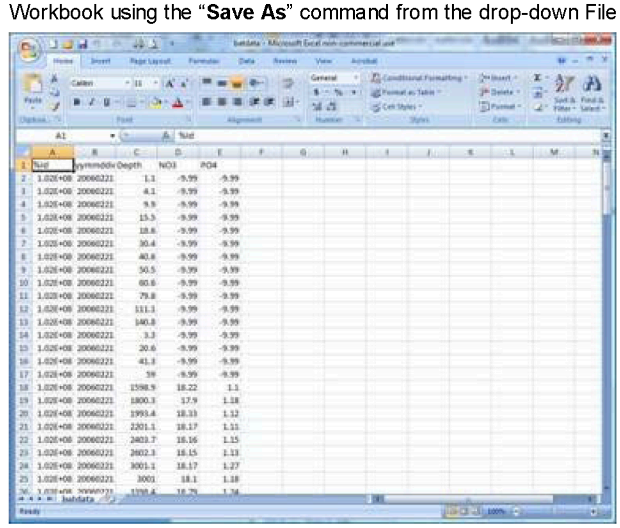
1. Open Excel and click "**Open**" in the drop-down File menu
2. In the "Open" dialog box, select "**All files**" in the "Files of type" field
Locate your Notepad document and select it, then click "**Open**"



3. Click on the bubble "**Delimited**", then click "**Next**"
4. Add the "**Comma**" as a delimiter by clicking on the box next to it, then click "**Finish**"

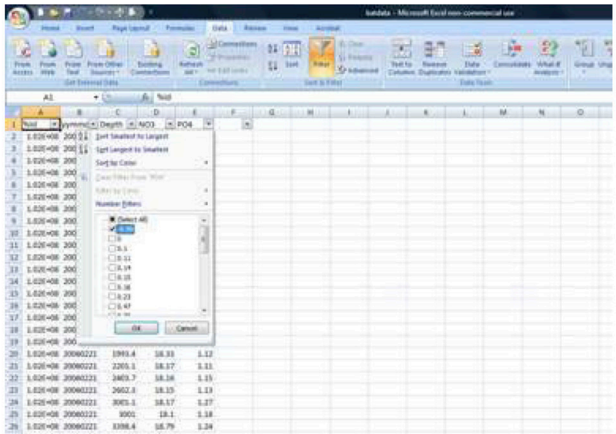


5. Once the data have been imported, be sure to save the file as an Excel Workbook using the "**Save As**" command from the drop-down File menu

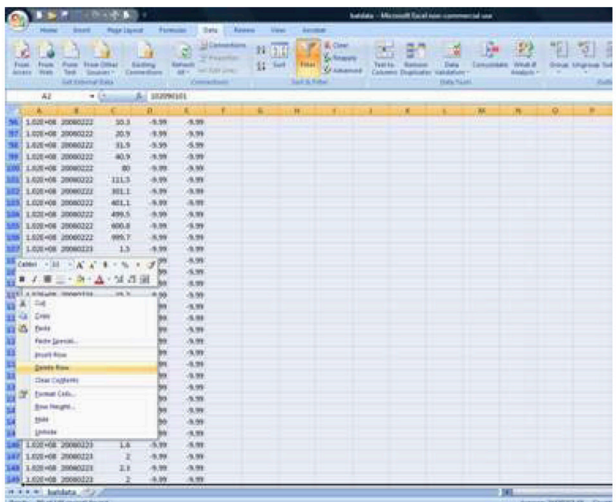


Before the data can be used, the depths without nutrient data need to be removed. When no nutrient data is available, BATS reports it at "-9.99"

1. Return to your Excel spreadsheet
2. Click on **Data > Filter**
3. Click on the arrow next to "**PO4**"
4. In the dialog box, click on "**Select All**," then select **"-9.99**;" click "**OK**"



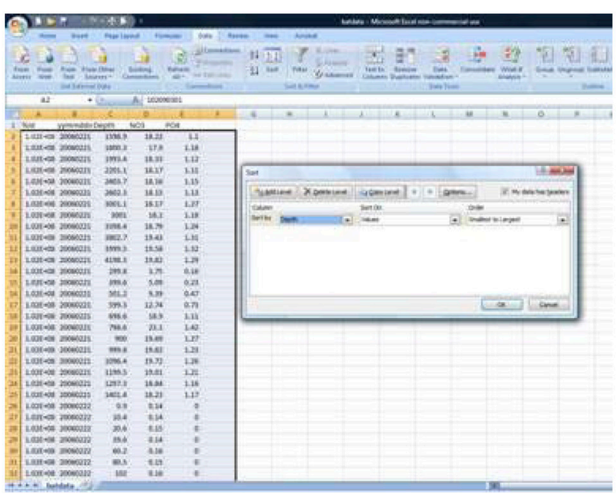
5. Delete rows 2 through 149:
    a. Click on row 2 (the number 2 on the left-hand side) and drag the cursor down to highlight all rows below
    b. Right click on the row labels (the numbers on the left-hand side)
    c. Select “**Delete Row**”



6. Click on the arrow next to “**PO4**”
7. In the dialog box, click on “**Select All**,” then click “**OK**”

xt, sort the data by depth.

1. Click on **Data > Sort**
2. In the “Sort by” drop box, click on “**Depth**;” click on “**OK**”



3. **Don’t forget to save your file!**

Marine Technology

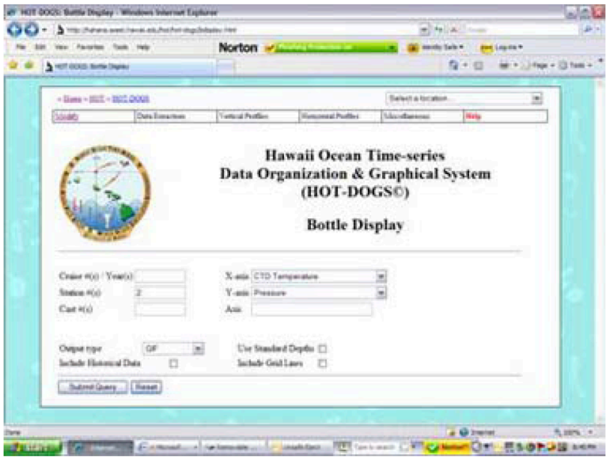
HOT DOGS: Data Visualitzation

Watch this video to learn what HOT-DOGS is all about.

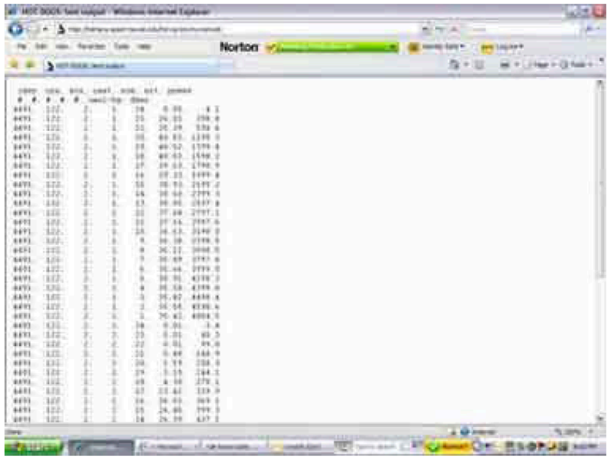
Station ALOHA is a multidisciplinary hydrostation situated in the North Pacific subtropical gyre. A host of biological and chemical variables have been measured at this site on a near-monthly basis since October 1988. Such data sets provide a rare and valuable opportunity to analyze fundamental geophysical dynamics and ecosystem processes. Fortunately, these data are available for online public access and can be downloaded for students to explore a wide range of research questions.

Data visualization

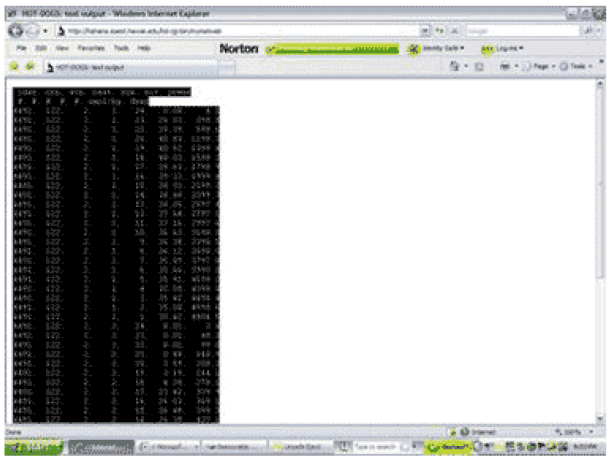
1. Navigate to http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html



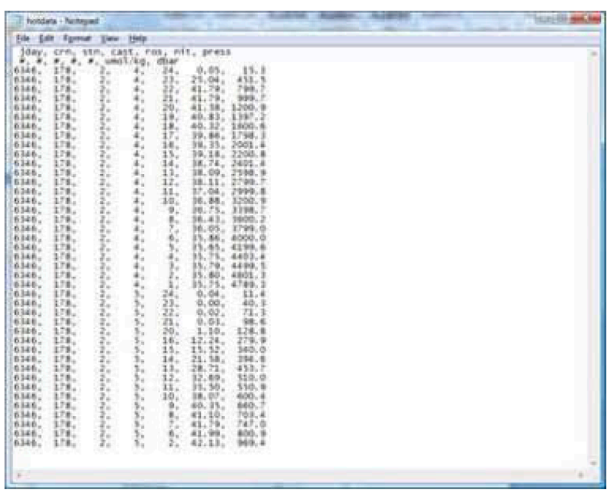
2. From the menu at the top of the screen, go to **Vertical Profiles > Display > Bottle**
3. Enter cruise number (**178**, for February 2006), station (**2**, for ALOHA); leave cast numbers blank
4. Enter axis variables:
    a. X-axis: "**Nitrate + Nitrite**
    b. Y-axis: "**Pressure**"
    c. C-axis: leave blank
5. Set Output type as a "text"
6. Click "Submit Query;" The data will be displayed as follows:



7. Highlight the displayed data (CTRL+A) and copy it (CTRL+C)



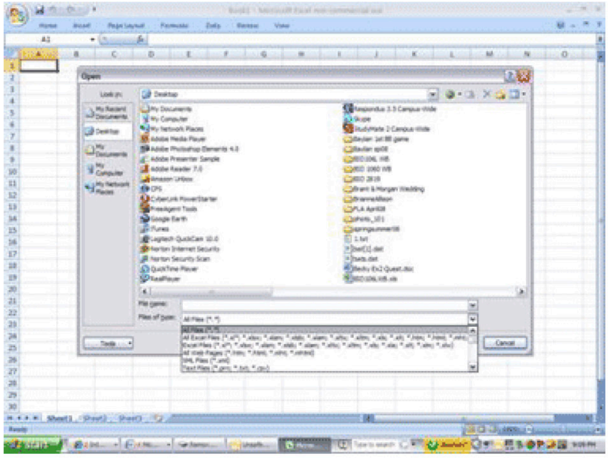
8. Open a Notepad document *(to find Notepad, go to Start>All Programs>Accessories>Notepad)*
9. Paste the data into Notepad (CTRL+V).
10. Save the file on the desktop or in an easy to find folder



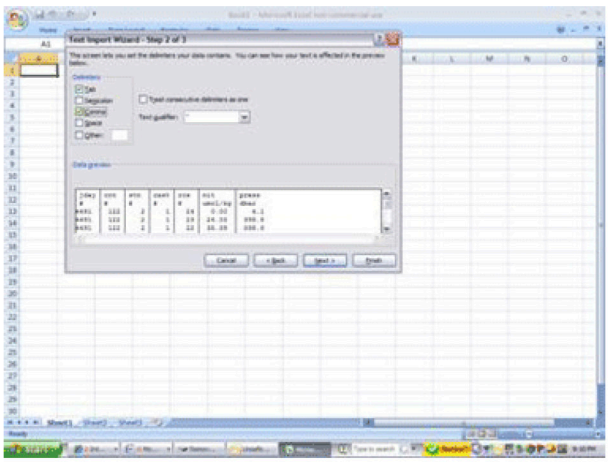
11. Repeat this procedure for Phosphate *(Choose "Phosphate" for the X-axis in Data Visualization step 4-a)*

Importing the data into Excel

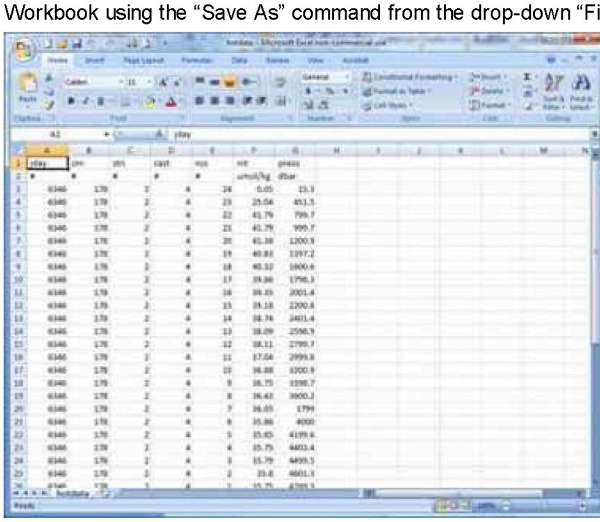
1. Open Excel and click "Open" in the drop-down File menu
2. In the "Open" dialog box, select "All files" in the "Files of type" field
   Locate your Nitrate Notepad document and select it, then click "Open"



3. Click on the bubble “Delimited”, then click “Next”
4. Add the “Comma” as a delimiter by clicking on the box next to it, then click “Finish”



5. Once the data have been imported, be sure to save the file as an Excel Workbook using the “Save As” command from the drop-down “File” menu



6. Repeat this procedure for Phosphate data

Back to top

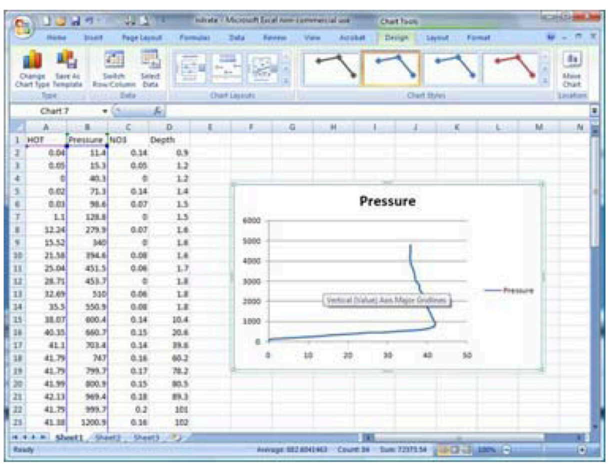
BATS & HOT DOGS: Graphing data in Excel

Note: These directions provide step-by-step instructions for creating graphs in Excel 2007. Procedures for older versions of Excel will be similar, but menu items may be located in different places. Instructions for older verisons will be posted soon.

1. Open a new Excel worksheet. Save it as "Nitrate."
2. Return to your HOT Nitrate spreadsheet. Copy the following columns: "nit" (Nitrate+Nitrite) and "press" (Depth):
    a. Select both columns by placing your cursor over the letter at the top of column F, then click and drag to highlight both columns F and G
    b. Copy the columns (CTRL+C) , then move to your new spreadsheet, select the first two columns, and paste the data (CTRL+V)
3. Remove the cells with the units in them:
    a. Select cells 2A-2B (click and drag to highlight both cells)
    b. Click Home>Delete
4. Rename the columns "HOT" and "Pressure"
5. Return to your BATS spreadsheet. Copy the following column: "NO3" (Nitrate+Nitrite):
    a. Select the column by placing your cursor over the letter at the top of column D
    b. Copy the column (CTRL+C) , then move to your new spreadsheet, select column C, and paste the data (CTRL+V)
6. Rename the column "BATS"
7. Copy the "Depth" column (column C in your BATS spreadsheet) and paste into column D in your Nitrate spreadsheet.
8. Open a new Excel worksheet. Save it as "Phosphate."
9. Repeat steps 2 through 7 for the phosphate ("phos" and "PO3") and depth columns in your HOT and BATS phosphate files

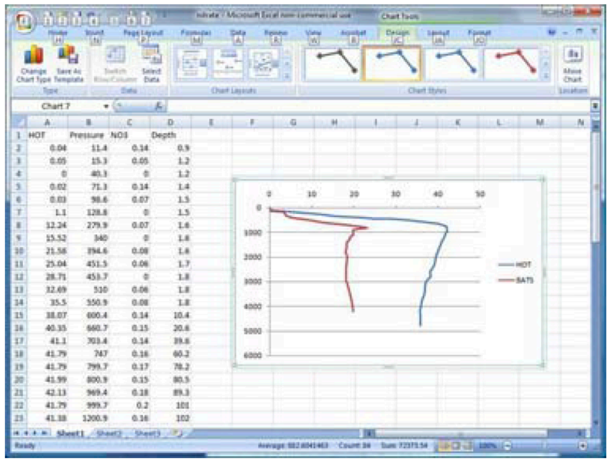
Now you are ready to make a graph!

1. First, sort your data according to depth:
    a. Select columns A and B and select Home>Sort and Filter>Custon sort…
    b. Select the check box by "My data has headers"
    c. Under "Sort by," choose "Pressure" and select OK
2. Select columns A and B (the HOT data) and select Insert>Scatter>Scatter with Straight Lines. Your graph should look like this:

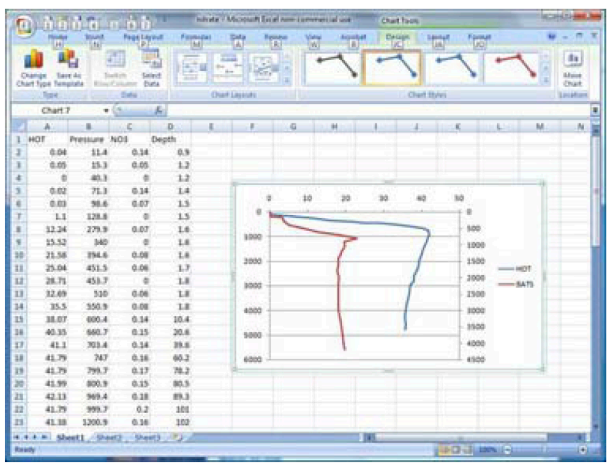


3. In order for the y-axis to show depth from top to bottom, you'll need to reverse the order of the values:
    a. Select Layout>Axes>Primary Vertical Axis>More Primary Vertical Axis Options…
    b. Check the box in front of "Values in reverse order" and click OK
4. Now, you need to add the BATS data to your graph:
    a. Select Design>Select Data
    b. Under the "Legend Entries (Series)" box, click "Add"
    c. In the "Series Name" box, type "BATS"
    d. In the "Series X Values" box, select the icon with the red arrow, then go to your spreadsheet and click and drag to select cells C2-C59; click on the arrow icon again

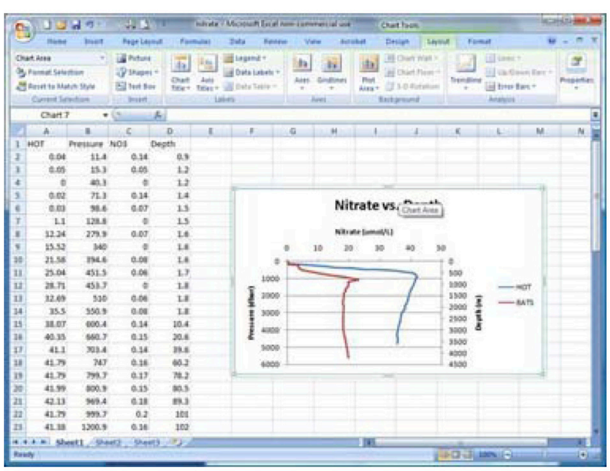
   e. Repeat this procedure for the "Series Y Values" box, selecting cells D2-D59; click OK
5. While you have the "Select Data Source" box open, you can change the name of your HOT data series :
   a. Under the "Legend Entries (Series)" box, click on the "Pressure" series and click "Edit"
   b. In the "Series Name" box, type "HOT" and click OK; click OK again
6. Your graph should now look something like this:



7. Now, you have to give the BATS data it's own axis:
   a. Click on the red BATS line, then right click to bring up the Data Series menu; select "Format data Series..."
   b. Click the button in front of "Secondary Axis" and click "Close"
8. Use the procedure in step 3 to reverse the values on the Secondary Vertical Axis
9. Your graph should now look like this:



10. Finally, use the Chart Layout tools to add chart and axis titles. Your final graph should look something like this:



11. Use these same procedures to create a graph comparing HOT and BATS phosphate data.

oceanexplorer.noaa.gov

Arctic Ocean Exploration

Being Productive in the Arctic Ocean

Focus
Primary productivity and limiting factors

Grade Level
9-12 (Chemistry/Biology)

Focus Question
What factors limit primary productivity in the Arctic Ocean?

Learning Objectives
Students will be able to identify the three realms of the Arctic Ocean, and describe the relationships between these realms.

Students will be able to identify major factors that limit primary productivity in the Arctic Ocean, and will be able to describe how these factors exert limiting effects.

Given data on potentially limiting factors and primary productivity, students will be able to infer which factors are actually having a limiting effect.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the vocabulary list.
Benthic
Pelagic
Zooplankton
Phytoplankton
Sympagic
Primary productivity
Continental shelf
Diatoms
Algae
Photosynthesis
Chemosynthesis
Primary production

The words listed as key words are integral to the unit and will be used in the first step of the Learning Procedure. They are really the material that will become the basis of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lip-read. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. In addition, Steps 3 and 4 in the procedures should be reversed so that a brief discussion occurs prior to handing out the data cards.

Materials
- ❐ Five sets of Sample Data Cards, one set of ten cards for each student group
- ❐ Blank "Data Summary Sheet" (copy master included in this activity)

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Five groups

Maximum Number of Students
25

Key Words

Pelagic
Benthic
Sympagic
Zooplankton
Primary productivity
Phytoplankton
PAR
Chlorophyll a

Background Information

The Arctic Ocean is the smallest of the world's four ocean basins with a total area of about 5.4 million square miles or 14 million square kilometers (roughly 1.5 times the size of the United States), and is bordered by Greenland, Canada, Alaska, Norway, and Russia. The Arctic Ocean has the widest continental shelf of any ocean, extending 750 mi (1,210 km) from the coast of Siberia, but also has areas that are quite deep (the average depth is 12,000 ft (3,658 m) and the maximum depth is 17,850 ft (5,441 m). The Chukchi Sea provides a connection with the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is with the Atlantic Ocean via the Greenland Sea.

The floor of the Arctic Ocean is divided by three submarine ridges (Alpha Ridge, Lomonosov Ridge, and the Arctic Mid-Oceanic Ridge) one of which (the Lomonosov Ridge) creates a relatively isolated area known as the Canadian Basin. This area is particularly interesting to scientists because its isolation could mean that it contains unique life forms that are found nowhere else on Earth. But the Arctic Ocean is not easily explored; it is almost entirely covered with ice for eight months of the year, a drifting polar ice pack covers the central and western portions year-round, and sea temperature seldom rises above 0°C. Although the Arctic is still the world's least explored ocean, new expeditions are about to give us much greater knowledge of the mysteries of this polar frontier.

At this point, we know that there are at least three distinct biological communities in the Arctic Ocean. The Sea-Ice Realm includes plants and animals that live on, in, and just under the ice that floats on the Arctic Ocean's surface. Because only 50% of this ice melts in the summer, ice flows can exist for many years and can reach a thickness of more than six ft. (2 m). Sea ice is not usually solid like an ice cube, but is riddled with a network of tunnels, called brine channels, that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biological material through photosynthesis. Bacteria, viruses, and fungi also inhabit the channels, and together with diatoms and algae provide an energy source (food) for flatworms, crustaceans, and other animals. This community of organisms is called sympagic, which means "ice-associated." Partial melting of sea ice during the summer months produces ponds on the ice surface that contain their own communities of organisms. Melting ice also releases organisms and nutrients that interact with the ocean water below the ice.

The Pelagic Realm includes organisms that live in the water column between the ocean surface and the bottom. Melting sea ice allows more light to enter the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. Through photosynthesis, these algae provide energy for a variety of floating animals (zooplankton) that include crustaceans and jellyfishes. Zooplankton, in turn, are the energy source for larger pelagic animals including fishes, squids, seals, and whales.

When pelagic organisms die, they settle to the ocean bottom as detritus, and become the energy source for inhabitants of the Benthic Realm. Sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians are common members of Arctic benthic communities. These animals provide energy for bottom-feeding fishes, whales, and seals.

Most of our knowledge about biological communities in the Arctic Ocean comes from studies on portions of the Ocean near the continental shelves. Very little research has been done on the sea ice, pelagic, and benthic realms in the deepest parts of the Arctic Ocean. These areas are the focus of the Arctic Ocean Expedition.

This activity is focused on primary productivity in the Pelagic Realm. Primary productivity refers to the amount of organic matter (usually expressed as grams of carbon per square meter per day) produced by organisms that are able to manufacture food from simple inorganic substances using energy from sunlight (in the case of photosynthesis) or chemical reactions (in the case of chemosynthesis). As far as we know, primary productivity in the Arctic Ocean occurs only through photosynthesis, and most of that photosynthesis takes place in microscopic floating algae (phytoplankton). As general principles, we know that photosynthesis requires photosynthetic plants, light, carbon dioxide, water, and nutrients; and that the availability of plant material, light, and nutrients can all limit the amount of photosynthesis that occurs. But we do not know which of these factors limit primary production in the Arctic Ocean, or how much primary production actually occurs there.

Learning Procedure

1. Review the Background Information on the Arctic Ocean and its three known biological realms with your students. Emphasize that the three realms are coupled, and that photosynthesis by microscopic algae (phytoplankton) provides the energy for other organisms in these realms (i.e., the algae are the "base of the food chain"). You may want to mention that other marine systems (such as those in the vicinity of hydrothermal vents) are not dependent on photosynthesis for energy, but rely on chemosynthesis instead (see http://oceanexplorer.noaa.gov/explorations/02galapagos/galapagos.html and http://oveanexplorer.noaa.gov/explorations/02fire/welcome.html for lesson plans and background information on these systems). If necessary, review the basic concepts of photosynthesis. Be sure students understand that photosynthesis can be limited if one or more of the necessary components is in limited supply.

2. Tell students that they will be examining data on primary productivity and factors that may limit this production in the Arctic Ocean. 10 data sets will be examined, representing samples that might have been taken at 10 different times of the year. As each sample is examined, students will be asked to explain the results in terms of what factors seem to be limiting primary productivity.

3. Distribute the five sets of sample data cards to the student groups. One group should receive the "Ice Cover" cards, a second group should receive the "Chlorophyll a" cards, a third group should receive the "PAR" cards, a fourth group should receive the "Nitrate" cards, and the fifth group should receive the "Primary Productivity" cards. Each set should contain one card for each of the 10 "Sampling Days."

4. Briefly discuss the meaning of each set of cards:

"Ice Cover" cards describe the percent of the sea surface that is covered with ice.

"PAR" cards describe the amount of photosynthetically active radiation (i.e., sunlight that is useable for photosynthesis) available as a percentage of the maximum radiation that occurs during the year.

"Chlorophyll a" cards describe the amount of chlorophyll a (which is a measure of the amount of photosynthetically-capable plant material present) in the surface seawater.

"Nitrate" cards describe the amount of nitrogen-containing nutrients present.

"Primary Productivity" cards describe the amount of organic matter that has been produced through photosynthesis at the sea surface.

5. Have each group read their cards for Sample Day #1. List the readings on the Blank Data Summary Sheet. When each group has read their cards, discuss the results. Repeat this process for the remaining nine Sample Days. The first few Sample Days should give the students a feel for what levels of the various factors may limit primary production. Refer to the "Teacher's Master Data Summary" and use the following guide as needed to aid these discussions.

Sample Day #1: This is a fairly high rate of Primary Productivity. Students should note that there is no ice to block sunlight, and PAR is fairly high. The significance of Chlorophyll a and Nitrate concentrations will become apparent as other days are examined.

Sample Day #2: 50% of the sea surface is covered with ice, and this limits Primary Productivity to less than half the value on Sample Day #1, even though the PAR and Nitrate levels are actually higher, and there are only slightly fewer algae (as indicated by Chlorophyll a) than on Sample Day #1. Reduction of sunlight by sea ice can be a major limiting factor for primary productivity in the Arctic Ocean.

Sample Day #3: Primary Productivity again is much lower than on Sample Day #1. A combination of ice cover and reduced PAR (perhaps it was a cloudy day!) are probably responsible, since Nitrate and Chlorophyll a levels are similar to previous days.

Sample Day #4: Primary Productivity is lowest yet, and the obvious cause is the greatly- reduced level of Nitrate.

Sample Day #5: Everything seems favorable here, but Primary Productivity is low. Let the students speculate on the cause. They should notice that PAR is nearly 100% (i.e., close to maximum), and may wonder whether there is such a thing as too much light. In the Arctic Ocean, photosynthetic algae can be adapted to rather low light conditions, and it is possible for photosynthesis to be inhibited if these algae are exposed to too much light.

Sample Day #6: Low Primary Productivity again; students should have no problem figuring out that extensive ice cover is the likely cause.

Sample Day #7: Time for inferences! When would you expect ice to cover 100% of the sea surface? Winter, of course! So, PAR would be zero because night lasts 24 hours in the polar winter. We would expect Chlorophyll a and Primary Produc-tivity to be pretty close to zero as well.

Sample Day #8: Reviewing the preceding data sets, students should notice that Nitrate does not appear to limit Primary Productivity except when it is in very limited supply. Since Primary Productivity is relatively high, and there is 30% ice cover, students could reasonably infer that Nitrate is not limiting in this case, so it could be any of the previous levels except 0.2.

Sample Day #9: Low PAR is the key here. It is probably early winter, so students could conclude that ice cover is probably fairly high (above 70%) and Primary Productivity is probably quite low.

Sample Day #10: Since all other factors seem pretty favorable, yet Primary Productivity is low, students should suspect that Nitrate levels are low enough to be limiting.

6. Have students write individual summaries of factors that limit Primary Productivity in the Arctic Ocean.

The BRIDGE Connection

www.vims.edu/bridge/polar.html
www.vims.edu/bridge/plankton.html

The "Me" Connection

Have students write a short essay or prepare a brief oral presentation on how knowledge of Primary Productivity in the Arctic Ocean might benefit them personally, and/or why they think this knowledge is (or is not) important. Ask students to share their thoughts with the class.

Connections to Other Subjects

English/Language Arts, Mathematics

Evaluation

Have students write their own interpretations of Sample Days #6 – 10 before these are discussed as a group.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov to keep up to date with the real-time exploration of the deep Arctic Ocean, and to find out what organisms researchers actually find in the three realms.

2. Have students research primary productivity in temperate and/or tropical ocean waters, and compare these data with primary productivity in the Arctic Ocean.

Resources

http://oceanexplorer.noaa.gov – Follow the Arctic Ocean Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at this site.

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

http://photoscience.la.asu.edu/photosyn/education/learn.html – Links to many sites and activities about photosynthesis

Smith, Jr., W. O. 1995. Primary productivity and new production in the Northeast Water (Greenland) Polynya during summer 1992. Journal of Geophysical Research 100: 4357-4370. – The scientific journal article upon which this activity is based.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Chemical reactions

Content Standard C: Life Science

- Interdependence of Organisms

Content Standard D: Earth and Space Science

- Energy in the Earth system

For More Information

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843.762.8737 (fax)
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Acknowledgements

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http://oceanexplorer.noaa.gov

Student Handout

ICE COVER DATA

Sample Day #1

Ice Cover = 0%

ICE COVER DATA

Sample Day #2

Ice Cover = 50%

ICE COVER DATA

Sample Day #3

Ice Cover = 50%

ICE COVER DATA

Sample Day #4

Ice Cover = 10%

ICE COVER DATA

Sample Day #5

Ice Cover = 0%

ICE COVER DATA

Sample Day #6

Ice Cover = 70%

ICE COVER DATA

Sample Day #7

Ice Cover = 100%

ICE COVER DATA

Sample Day #8

Ice Cover = 30%

ICE COVER DATA

Sample Day #9

Ice Cover = GUESS!

ICE COVER DATA

Sample Day #10

Ice Cover = 15%

Student Handout

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #1

PAR = 75% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #2

PAR = 78% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #3

PAR = 45% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #4

PAR = 76% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #5

PAR = 98% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #6

PAR = 79% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #7

PAR = GUESS!

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #8

PAR = 82% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #9

PAR = 10% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #10

PAR = 79% of maximum

Student Handout

CHLOROPHYLL a DATA

Sample Day #1

Chlorophyll a = 87 µg/l

CHLOROPHYLL a DATA

Sample Day #2

Chlorophyll a = 76 µg/l

CHLOROPHYLL a DATA

Sample Day #3

Chlorophyll a = 73 µg/l

CHLOROPHYLL a DATA

Sample Day #4

Chlorophyll a = 82 µg/l

CHLOROPHYLL a DATA

Sample Day #5

Chlorophyll a = 85 µg/l

CHLOROPHYLL a DATA

Sample Day #6

Chlorophyll a = 71 µg/l

CHLOROPHYLL a DATA

Sample Day #7

Chlorophyll a = GUESS!

CHLOROPHYLL a DATA

Sample Day #8

Chlorophyll a = 76 µg/l

CHLOROPHYLL a DATA

Sample Day #9

Chlorophyll a = 5 µg/l

CHLOROPHYLL a DATA

Sample Day #10

Chlorophyll a = 73 µg/l

Student Handout

NITRATE DATA

Sample Day #1

Nitrate = 6.2 µmol/l

NITRATE DATA

Sample Day #2

Nitrate = 8.4 µmol/l

NITRATE DATA

Sample Day #3

Nitrate = 11.3 µmol/l

NITRATE DATA

Sample Day #4

Nitrate = 0.2 µmol/l

NITRATE DATA

Sample Day #5

Nitrate = 7.1 µmol/l

NITRATE DATA

Sample Day #6

Nitrate = 6.7 µmol/l

NITRATE DATA

Sample Day #7

Nitrate = 5.2 µmol/l

NITRATE DATA

Sample Day #8

Nitrate = GUESS!

NITRATE DATA

Sample Day #9

Nitrate = 7.6 µmol/l

NITRATE DATA

Sample Day #10

Nitrate = GUESS!

Student Handout

PRIMARY PRODUCTIVITY DATA

Sample Day #1

Surface Primary Productivity =
9.3 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #2

Surface Primary Productivity =
4.3 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #3

Surface Primary Productivity =
5.1 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #4

Surface Primary Productivity =
3.4 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #5

Surface Primary Productivity =
4.3 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #6

Surface Primary Productivity =
3.4 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #7

Surface Primary Productivity =
GUESS!

PRIMARY PRODUCTIVITY DATA

Sample Day #8

Surface Primary Productivity =
6.5 mg C/m^2/day

PRIMARY PRODUCTIVITY DATA

Sample Day #9

Surface Primary Productivity =
GUESS!

PRIMARY PRODUCTIVITY DATA

Sample Day #10

Surface Primary Productivity =
2.6 mg C/m^2/day

Student Handout
Teacher's Master Data Summary

Sample Day	Ice Cover (% of surface)	PAR* (% of maximum)	Chlorophyll a (μg/l)	Nitrate (μmol/l)	Primary Productivity (mg C/m^2/day)
1	0	75	87	6.2	9.3
2	50	78	76	8.4	4.3
3	20	45	73	11.3	5.1
4	10	76	82	0.2	3.4
5	0	98	85	7.1	4.3
6	70	79	71	6.7	3.4
7	100	GUESS	GUESS	5.2	GUESS
8	30	82	76	GUESS	6.5
9	GUESS	10	5	7.6	GUESS
10	15	79	73	GUESS	2.6

* photosynthetically active radiation

Student Handout

DATA SUMMARY SHEET

Sample Day	Ice Cover (% of surface)	PAR* (% of maximum)	Chlorophyll a (µg/l)	Nitrate (µmol/l)	Primary Productivity (mg C/m²/day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

* photosynthetically active radiation

DATA SUMMARY SHEET

Sample Day	Ice Cover (% of surface)	PAR* (% of maximum)	Chlorophyll a (µg/l)	Nitrate (µmol/l)	Primary Productivity (mg C/m²/day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

* photosynthetically active radiation

Fresh and Salt

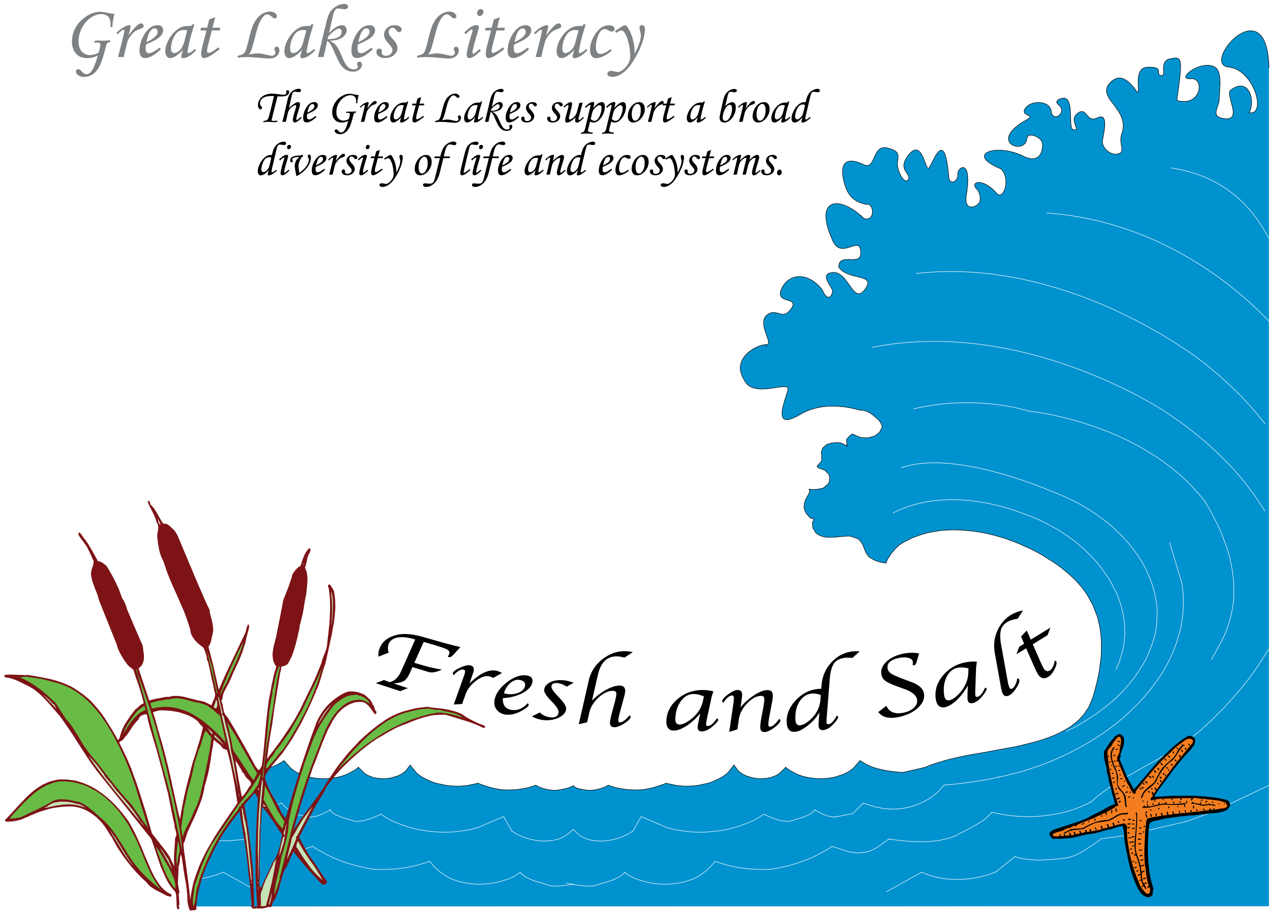
Principle 5

Ocean Literacy

The ocean supports a great diversity of life and ecosystems.

Great Lakes Literacy

The Great Lakes support a broad diversity of life and ecosystems.



Fresh and Salt

Principle 5: The ocean supports a great diversity of life and ecosystems. (OL) The Great Lakes support a broad diversity of life and ecosystems. (GL)

Essential Principle #5 addresses the life sciences, especially biology and ecology. The two activities in this set focus on life forms that live in the ocean or Great Lakes environment, and further, on the interactions among those "critters" that define the ecosystem. In *Dr. Art's Guide to Planet Earth*, a reference publication cited at the end of this overview, the author takes a systems approach to the earth and defines three principles – Matter Cycles, Energy Flows, and Life Webs. Both of the included activities clearly demonstrate "life webs." With a bit of discussion they both also show how "energy flows" through the system. The *Tangled Web* activity includes critters that are decomposers, illustrating how "matter cycles." These are basic concepts applicable to all ecosystems, and very important for students to understand.

In *Tangled Web*, from *Great Lakes in My World* by the Alliance for the Great Lakes, students have at least one "creature card" from a supplied set of sixty that is used to develop a yarn web showing the connections among the critters that inhabit the Great Lakes. The students discuss how complex the interactions in the web are and the significance of that complexity. And they discover how impacts to a small portion of the web may generate larger-scale changes, perhaps extending throughout the system. Students become actively involved in constructing the web based on listening skills and building on the input of other students. Once the web is built, students are asked to consider specific perturbations to the web and what the effects might be. Tugging on the web in a single location results in most, or all, feeling the connection. Students may also break connections in the web to discover and discuss the effects. Upon concluding the group activity, students are asked to create a food web diagram, and then to write a brief essay about how his/her critter fit into the food web and to show the effects of changes. An assessment rubric is provided.

The activity is designed for grades 4–8; students benefit from prior participation in several other lessons from the overall set of 80 activities. The set of creature cards packaged with the overall curriculum, or a facsimile, is also necessary to build the web. Teachers who used the lesson provided very positive comments, including:

"The activity engaged students right from the beginning and held their attention."

"The lesson required students to work cooperatively."

"This provided a very concrete example of how humans impact ecosystems."

"The activity was very hands-on and interactive. Students remained engaged and interested throughout."

"The lesson utilizes multiple learning strategies."

The *Sea Connections* activity is one of the Smithsonian's Ocean Science Interdisciplinary Marine Science Activities. A very informative essay provides superb background on the four ocean ecosystems – kelp forests, coral reefs, hydrothermal vents, and polar oceans—investigated in the lesson. Students identify producers and consumers from each system and construct a food web (or chain) illustrating one of the systems. They recognize the delicate balance that exists in each, and the potential disruptions caused by human activities.

The activity is built around a card game that includes critters from each of the four ecosystems. Working in groups of four or fewer, students play the game until one is able to collect all five of the cards in one of the four ecosystem "suits." The rules of the game are provided to the student in an easily-understood summary. "Disconnect" and "reconnect" cards add the impacts of natural and human perturbations to the rounds of play. Once one student in a group has collected a "winning hand," the remaining players can trade to fill out each of the remaining suits. Once all the hands are assembled, the students are asked to complete a data sheet about the ecosystem cards collected. Then they build a food web/chain that includes producers, primary consumers, and predators. A guided discussion about the perturbations and impacts helps students to recognize the delicate balance in these often-fragile ecosystems.

Teachers from the Great Lakes region who reviewed this activity and used it in their classrooms appreciated the introductory material, and recognized the parallels between these ocean ecosystems and the Great Lakes.

Specific comments included:

"The game was very creative and enabled the students to see the consequences of actions in a very real way."

"Playing a game is always a great way to teach students."

"The activity does a wonderful job of showing the need for environmental stewardship."

"The construction of a food web was a great way for students to demonstrate understanding of the food web relationships within an ecosystem."

"The closing activity encourages awareness and knowledge of how human activities can affect organisms living in the marine ecosystem. High school students could go on to develop action plans."

"The background information was excellent."

Sussman, Art, 2000. *Dr Art's Guide to Planet Earth*. Chelsea Green Publishing Company, White River Junction, VT, 122 pages. ISBN: 1-890132-73-X

EXPLORE

10 | Tangled Web

GRADE LEVEL

4-8

45 minutes

summary

Students make a yarn web of connections between Great Lakes species, discuss the significance of the complexity of the web and discover the impacts of changes to the web.

subjects

Ecology, Environmental Science

standards

IL
Science: 11.A.2c, 12.B.2a, 13.B.2f
Language Arts: 3.A.3, 3.C.2a, 5.C.2a

IN
Science: 2.6.2, 3.4.4, 4.4.1, 4.4.2, 4.4.3, 4.4.6, 4.6.2, 4.6.3, 6.4.2, 6.4.9, 7.4.2, 7.4.8, 7.4.9
Language Arts: 4.4.2, 7.5.7, 8.5.7

MI
Science: SCI.II.1.E.2, SCI.II.1.E.4, SCI.II.1.MS.3, SCI.III.5.MS.2, SCI.III.5.MS.3
Social Studies: SOC.11.2.LE.1
Language Arts: ELA.2.LE.1

WI
Science: C.8.2, F.4.4
Language Arts: C.4.2

objectives

- List five to eight connections between Great Lakes organisms in a food web.
- Explain the impacts of changes in a Great Lakes food web.
- Diagram a small food web.

prerequisite

Lake Connection, Eco-Language, Fish Observation, A Closer Look

vocabulary

Food web: the whole group of interacting food chains in a living community

resources

Food Web sites:
Environmental Protection Agency
www.epa.gov/glnpo/atlas/images/big05.gif
Michigan Sea Grant
www.miseagrant.umch.edu/education/foodweb.html
Michigan Tech
www.techalive.mtu.edu/meec/module08/FoodWeb.htm

setting

INDOORS OUTDOORS

materials

- Creature Cards with asterisk (*)
- Ball of yarn
- Masking tape

background

Information on the eating habits of the organisms can be found on the backs of the Creature Cards. Food chains that show feeding relationships in an ecosystem are part of large and complex food webs. By exploring these relationships, students become familiar with the concept of food webs, as well as the different plants and animals that inhabit the Great Lakes. Information on eating habits can be found on the backs of the Creature Cards.

procedure

1. Have students brainstorm a list of species in the lake. Use the Creature Cards to help guide their responses. Give each student one Creature Card. Using those from the aquatic ecosystem will work best (with asterisks). *Include organisms students have learned about in the two previous activities.*
2. Have students hold the cards or attach them to their shirts with masking tape so that everyone can see the pictures. Have students sit in a circle and announce the names of their organisms.
3. Holding the ball of yarn, tell students that you represent the sun. You will give your energy to one of the plants, e.g., algae, by holding onto the end of the yarn and passing the ball to a student with a plant card. When a student receives the ball of yarn, she or he should hold onto one end, and pass the ball to a student with the card of an organism that his/her organism could eat OR be eaten by. For example, the algae could pass the yarn to a zooplankton, who could pass it to a forage fish or vice versa. Students should look at the backs of their Creature Cards to determine what the organism eats or is eaten by. Continue passing the yarn until it has reached everyone at least once. Continue the game as long as you can find new connections. Since each student is holding onto a piece of the yarn, a web should be forming between the students.
4. It is very important that each time the yarn is passed, students realize that it can go to the organism that eats their creature OR to an organism their species eats. Otherwise, a food web will not be created. Some creatures may be included more than once. Make sure all creatures become part of the web. This may involve some problem-solving.
5. At this point, give a hypothetical situation (positive or negative) that affects a species. For example, if the lake trout have been over-fished, have the "lake trout" give a light tug on his/her piece of the yarn. Have students "tug back" when they feel the tug, raising their hands as they tug for a visual of the web interconnections. For each species, at least two others will feel a tug on the yarn. Soon all students will be gently. You can also have the "lake trout" drop the yarn and have the rest of the class readjust the web to account for the change. Other scenarios could include: (+) a comeback in the yellow perch population, wetland habitat restoration, or (-) a wetland is filled, impacting species who spawn in the wetland; mercury has entered the lake, causing aquatic birds to die; or zebra mussels have entered the food web, reducing the amount of food available for native fish.
6. Discuss:

- What did the yarn look like after it had been passed to everyone? *A web.*
- Why did it look like this instead of a straight line or circle? *The food web connections are complex, like a web.*
- What happened when one organism dropped the yarn? Did the web stay the same, fall apart completely, or something else? *The rest of the web had to readjust. Other organisms were impacted, but the whole web did not collapse because it is complex enough that it can change and still survive.*

7. What would happen if more and more scenarios were introduced, eliminating more parts of the food web? *The food web would ultimately look a lot different from the way it looked originally, and would be more simplified. Food webs that lack complexity are not as resilient to change as those with a diverse group of organisms.*

Satisfy Your Curiosity QUESTION IDEAS

- *Where does my species fit into the food web?*
- *What eats my species?*
- *What does my species eat?*
- *What other organisms does my species impact?*

wrap-up

Use the journal pages for the following:

1. Food Web Diagram: Have each student create a food web diagram that includes five to eight organisms. The food web should include several food chains. Use arrows to indicate who eats who, and include all types (decomposers, producers, herbivores, omnivores, carnivores, scavengers). Students may need to ask questions of others who had different Creature Cards.
2. Have each student write a brief essay that articulates how his/her organism fits into the food web. In the essay, the student should explain the effect of changes in the food web, and begin to draw conclusions about what happens to a food web when species are eliminated.

assessment

Rubric on page 86

10 | Tangled Web

GRADE LEVEL
4-8

journal pages

FIRST NAME																				
LAST NAME																				

[1] Draw a picture of a lake food web. Include 5-8 species in your picture, and arrows to show how they are connected.

[2] Write about how your organism fits into the food web. Explain the impact changes have on the food web. Draw conclusions about what happens to a food web when species are reduced or increased.

APPROVED BY	

EXPLORE 10 | Tangled Web

ELEMENTS	☆☆☆☆	☆☆☆	☆☆	☆
PARTICIPATION: Student actively participates in both the food web activity and class discussion. Student references knowledge gained from the activity and makes connections to his/her organism. Student uses active listening skills (eye-contact, confirming or referencing others' comments, affirmative gestures or comments).	Addresses all of the components	Missing one component	Missing two components	Missing three or more components
FOOD WEB DIAGRAM: Student includes at least eight organisms in his/her food web. The food web includes several food chains, used arrows to indicate who eats whom, and includes all levels (decomposers, producers, herbivores, omnivores, carnivores, scavengers).	Addresses all of the components	Missing one component	Missing two components	Missing three or more components
ESSAY: Student was able to articulate how his/her organism fits into the food web. Student is able to explain the impact changes have in the food web. The student is able to draw conclusions about what happens to a food web when organisms are eliminated.	Addresses all of the components	Missing one component	Missing two components	Missing three or more components

Great Lakes in My World

Creature Cards

Over 60 illustrated information cards featuring Great Lakes plants and animals

Name: Species' common and scientific names are provided.
*: Indicates that this card can be used in the activities Tangled Web and Web of Life.

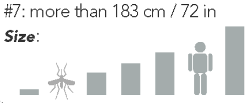
who? *description*

A description of the species that includes type, physical characteristics and species status (endangered, invasive, etc.)

Scale: A scale conveys the relative size of the species. A darkened column indicates the species place in the size range. The sizes for each column are as follows:

#1: less than .6 cm / .25 in
#2: .6 cm / .25 in – 6.3 cm / 2.5 in
#3: 6.6 cm / 2.6 in - 30 cm / 12 in
#4: 31 cm / 12.1 in - 61 cm / 24 in
#5: 63.5 cm / 25 in - 122 cm / 48 in
#6: 123 cm / 48.5 in - 183 cm / 72 in
#7: more than 183 cm / 72 in

Size:



where? *environment*

An explanation of the species' general environment and specific habitat

what? *characteristics*

Facts about the species role in the food web, reproduction and other distinguishing habits

Interesting Fact *

Characteristics that make this plant or animal unique

Creature Card Definitions

Carnivore: a flesh-eating animal

Colony: a population of plants or animals in a particular place that belong to one species

Consumer: a plant or animal that preys on other living things or eating particles of organic matter

Crustacean: any of a large class of mostly water-dwelling arthropods (as shrimps, wood lice, water fleas, and barnacles) having an exoskeleton of chitin

Decomposer: an organism that lives on and breaks down dead organisms

Detritus: particles of decaying organic material

Diurnal: active in the daytime

Endangered species: a species in immediate danger of extinction

Flock: a group of birds or mammals assembled together

Forage fish: fish that primarily eat phytoplankton and zooplankton (especially diporeia); they are prey for larger predators such as lake trout and whitefish; they include smaller fish such as herring, alewives, chubs, and smelt.

Herbivore: animal that eats only plants

Invasive species: plant or animal that enters an ecosystem to which it is not native and competes with one or more species for food, shelter, and/or reproductive opportunities.

Larva: a young wingless, often wormlike, form (grub or caterpillar) that hatches from the egg of many insects

Migrate: to pass from one region or climate to another usually on a regular schedule for feeding or breeding

Creature Card Definitions

Mollusk: any of the category (phylum: mollusca) of invertebrate animals (as snails, clams, and mussels) with a soft body lacking segments and usually enclosed in a shell

Nocturnal: active in the night

Omnivore: feeds on both animal and plant matter

Phytoplankton: very small, freely floating plant that drifts with water currents

Plankton: small water organisms that exist in a drifting, floating state; is the base of freshwater ecosystems, provides food for larger animals and indirectly for humans, whose fisheries depend on phytoplankton and zooplankton

Predator: an animal that lives by killing and eating other animals

Prey: an animal hunted or killed by another animal for food

School: group of fish that swim together; generally of the same species for protection, feeding and other reasons

Solitary: growing or living alone; not forming part of a group or cluster

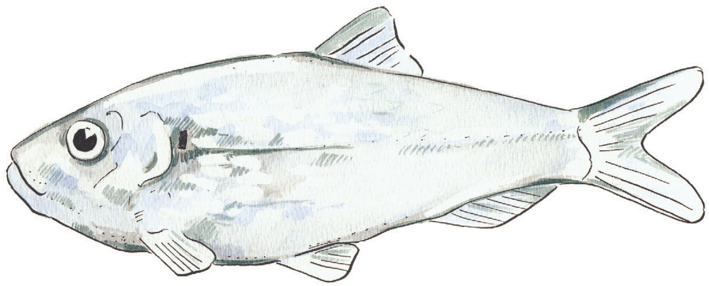
Spawn: to produce or deposit eggs

Species of concern: a plant or animal that may become threatened

Threatened species: a plant or animal needing special action to protect it from becoming endangered

Toxin: a substance produced by a living organism that is very poisonous

Zooplankton: Very small floating or swimming animals that drift with water currents



Alewife*

Scientific Name: *Alosa pseudoharengus*

who? *description*

Type: fish

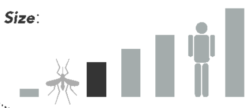
Length: 15 cm / 6 in

Weight: 113 g / .25 lbs

Coloring: silver with blue or blue green luster on back

Invasive Species

Size:



where? *environment*

Habitat: lakes and oceans

Interesting Fact ★

Alewives are usually a salt-water fish, but they spawn in freshwater. After laying their eggs, many die and wash up along the lake shoreline in the spring and summer.

what? *characteristics*

Feeding:

Who eats me? lake trout, salmon

What do I eat? phytoplankton, zooplankton and small crustaceans

Role: consumer, omnivore

Reproduction: lay eggs in summer in water, near the shore

Grouping: swim in schools

Activity: year-round

Bald Eagle*

Scientific Name: *Haliaeetus leucocephalus*

who? *description*

Type: bird

Length: 76-94 cm / 30-37 in

Weight: 7 kg / 15 lbs

Coloring: dark brown body, white head and tail

Body Features: yellow eyes, beak, and feet

Size:

where? *environment*

Habitat: forested backdune, lakeshore and seacoast, nests in trees (especially conifers) or on cliffs near water; nests are 182 cm / 6 ft wide and 91 cm / 3 ft high

Interesting Fact ★

Bald eagles can see 3 or 4 times as far as humans and eat one pound of fish in four minutes. They have a 182 cm / 6 ft wingspan!

what? *characteristics*

Feeding:

Who eats me? scavengers eat dead eagles

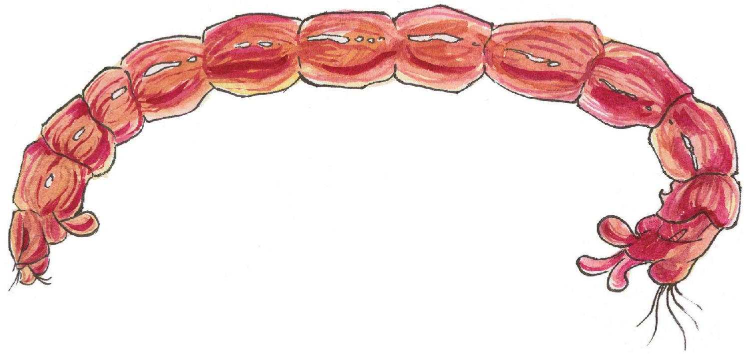
What do I eat? dead or wounded fish, aquatic birds, and mammals

Role: consumer, carnivore

Reproduction: 2 eggs in spring

Grouping: solitary or in pairs, live in groups in winter

Activity: diurnal



Bloodworm*

Scientific Name:
Family: Chronomidae

who?
description

Type: insect (in larval stage)

Length: 2.5-3.8 cm / 1-1.5 in

Coloring: red

Body Features: distinct head, segmented abdomen, prolegs (leg-like projections), and gills

Size:

where?
environment

Habitat: muddy, bottom areas of ponds, lakes and rivers; the worms build tubes of mud around themselves that are attached to objects in the water

Interesting Fact ★

A bloodworm is in the larval stage of its lifecycle. When it becomes an adult, it turns into a midge, an insect that looks like a mosquito. Freshwater blood-worms and humans both have hemoglobin which allows red blood cells to carry oxygen.

what?
characteristics

Feeding:

Who eats me?
fish, aquatic insects

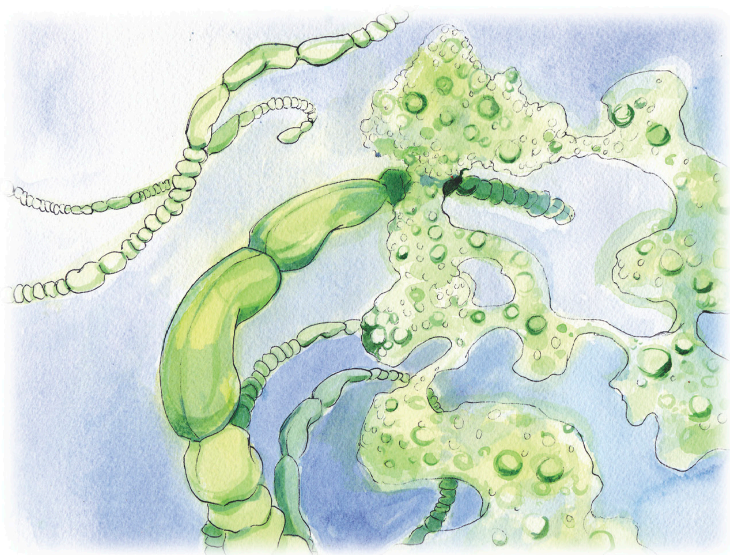
What do I eat?
phytoplankton, detritus

Role: consumer, omnivore

Reproduction: lay eggs as adults

Grouping: often found in groups

Activity: mainly nocturnal



Blue-Green Algae (cyanobacteria)*

Scientific Name:
Anabaena, Microcystis

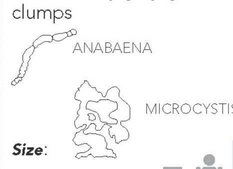
who?
description

Type: bacteria

Size: microscopic

Color: some, but not all are blue-green; can be yellow-green, green, grey-green, grey-black, and even red

Other: microcystis colonies look like tiny grey-green clumps



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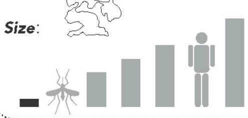


where?
environment

Sunlight: varies - direct and dim sunlight

Habitat: water; attach to surface of rocks, stones and plants in water, or on the bottom sediment of lakes

Interesting Fact ★

Blue-green algae movements can be seen under a micro-scope as they glide, rotate and jerk. Their fossils have been identified as over three billion years old!

what?
characteristics

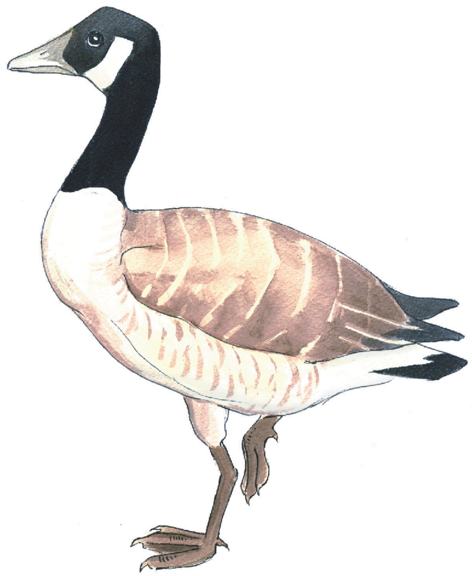
Feeding:

Who eats me?
daphnia, copepod

What do I use to make food?
sunlight

Role: producer

Reproduction: can grow individually as single cells or in colonies; when algae reproduces quickly it is called a "bloom"



Canada Goose*

Scientific Name: *Branta canadensis*

who? *description*

Type: bird

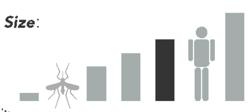
Length: 63.5-114 cm / 25-45 in

Weight: 1-8 kg / 2-17 lbs

Coloring: black head and neck, white cheek patches, mottled grey-brown body

Body Features: brown webbed feet

Size:



where? *environment*

Habitat: interdunal pond, freshwater lakes, wetlands, ponds; builds a nest on the ground, near water

Interesting Fact ★

Canada geese fly in a "V" formation during migration. They use their large, strong wings as weapons when protecting their young.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** coyotes eat geese; eggs are eaten by fox, raccoons and coyotes

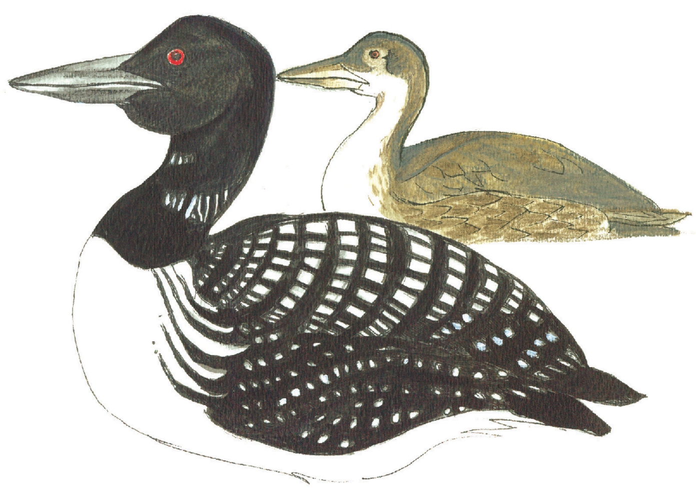
➲ ***What do I eat?*** Plants and insects

Role: consumer, omnivore

Reproduction: lays 5-7 eggs

Grouping: pairs and flocks

Activity: diurnal, migrate south in the winter



Common Loon *

Scientific Name: *Gavia immer*

who? *description*

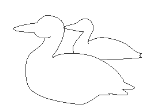
Type: bird

Length: 91 cm / 3 ft

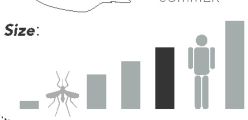
Weight: 3-6 kg / 6-13 lbs

Coloring: black and white checkered body, black head, white belly and underwing, white collar

Body Features: large webbed feet



Size:



where? *environment*

Habitat: freshwater lakes, sleep on deep water areas away from land; nest on small islands

Interesting Fact ★

Many bones of the loon's body are solid, rather than hollow like those of other birds. These heavy bones help loons dive for food.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** large fish, snapping turtles, gulls, eagles, crows

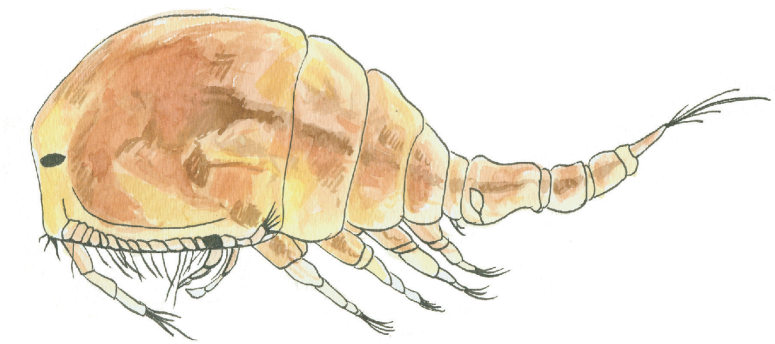
➲ ***What do I eat?*** fish, crayfish, frogs, snails, salamanders, leeches

Role: consumer, carnivore

Reproduction: 2 eggs in summer

Grouping: pairs

Activity: diurnal



Copepod (cyclops)*

Scientific Name: *Cyclops strenuus*

who? *description*

Type: zooplankton, crustacean

Length: 2-3 mm / .08-.1 in

Coloring: clear, tan

Body Features: single eyespot and curved body

Size:

where? *environment*

Habitat: quiet waters of ponds, lakes, and rivers

Interesting Fact ★

Copepods are difficult for scientists to catch to study because they dart so quickly! It is sometimes called a cyclops because the single eyespot reminds people of the one-eyed monster in Greek mythology.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** insects and small fish

➲ ***What do I eat?*** algae, bacteria, dead plant and animal matter

Role: consumer, omnivore

Reproduction: females carry twin egg sacs

Daphnia*

Scientific Name: *Daphnia pulex*

who? *description*

Type: zooplankton, crustacean

Length: less than 3 mm / .1 in

Coloring: clear body tissue shows organs inside

Body Features: 5 pairs of legs used to capture food, large antennae are pushed downward for swimming

Size:

where? *environment*

Habitat: near the surface of lakes, ponds, and quiet streams

Interesting Fact ★

Dozens of daphnia can fit on a single fingernail.

what? *characteristics*

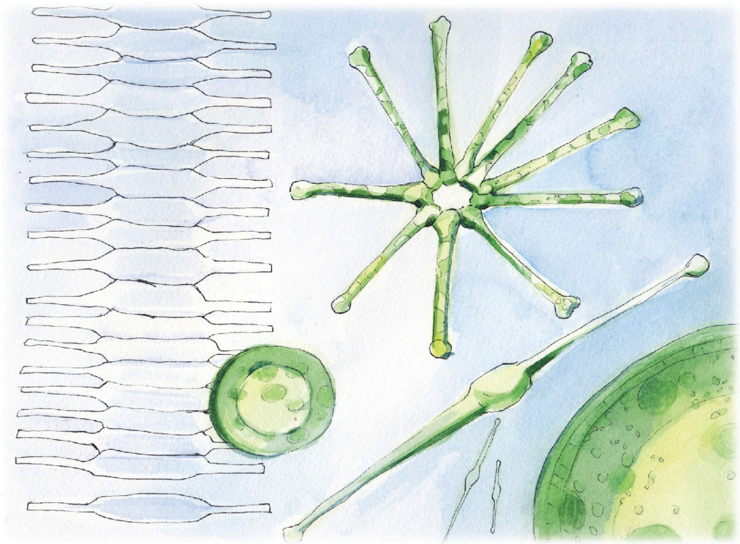
Feeding:

➲ ***Who eats me?*** fish

➲ ***What do I eat?*** phytoplankton

Role: consumer, herbivore

Reproduction: lays eggs in lake bottom sand, young hatch in spring



Diatoms*

Scientific Name: *Asterionella, Cyclotella, Fragilaria, Synedra*

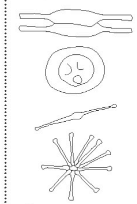
who? *description*

Type: phytoplankton

Height: microscopic – less than 1 mm / .04 in

Color: golden brown

Other: no leaves or flowers; single-celled organism



Size:

where? *environment*

Sunlight: direct sunlight

Habitat: freshwater lakes and pond, and on the surface of oceans

Interesting Fact ★

More than 8000 kinds of diatoms exist. They are a major food source for fish. Diatoms have a shell or cell wall that has a pattern that lets scientists know what type of diatom it is.

what? *characteristics*

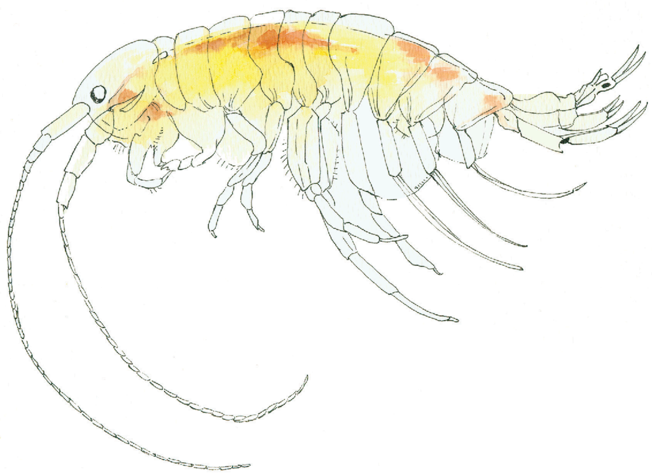
Feeding:

➲ ***Who eats me?*** zooplankton, water fleas, copepods, snails, mollusks, fish

➲ ***What do I use to make food?*** sunlight

Role: producer

Reproduction: divide in half (cell division)



Diporeia*

Scientific Name: *Diporeia hoyi*

who? *description*

Type: crustacean

Length: 1.27 cm / .5 in

Weight: .1 oz / 2.8 g

Coloring: clear, yellow

Body Features: 5 pairs of legs

Size:

where? *environment*

Habitat: freshwater lakes, spends time in the water column, lives in mud on lake bottom

Interesting Fact ★

Diporeia is a very important food source for forage fish. Even though they are small, they are high in fat and calories when eaten by fish.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** whitefish, chub, sculpin

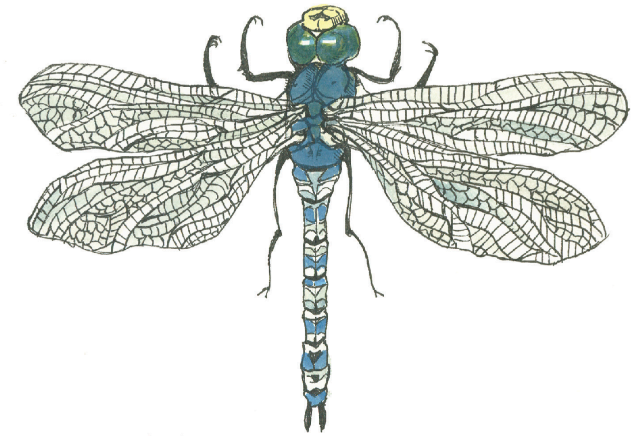
➲ ***What do I eat?*** algae and bacteria

Role: consumer, herbivore

Reproduction: lay eggs

Grouping: colonies

Activity: nocturnal



Dragonfly (blue darner)*

Scientific Name:
Aeschna constricta

who?
description

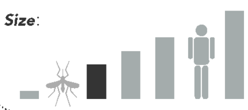
Type: insect

Length: 5-8 cm / 2-3 in wing-span

Coloring: primarily blue and green

Body Features: four wings operate independently

Size:



where?
environment

Habitat: interdunal pond, in and around wetlands; under-water for first stage of life

Interesting Fact ★

Dragonflies are a living fossil; they have not changed for over 300 million years. They can hover, fly backwards, loop, and speed up to 56 km / 35 mi per hour.

what?
characteristics

Feeding:

Who eats me?
fish

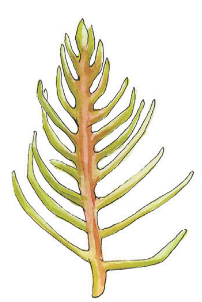
What do I eat?
mosquitoes, midges and other small, flying insects

Role: consumer, carnivore

Reproduction: lay eggs in water; first stage of life under-water; adult stage on land and in flight

Grouping: solitary

Activity: diurnal



Eurasian Milfoil*

Scientific Name:
Myriophyllum spicatum

who?
description

Type: plant

Height: up to 91 cm / 3 ft

Leaves: 1.5-4 cm / .6-1.5 in long, have a feather-like outline, in groups of 4; stem is leafless towards the base, but branches out, the top often turns red

Flowers: lower ones are female, upper ones are male

Invasive Species

Size:

where?
environment

Sunlight: moderate

Habitat: lives in water from 1-3 m / 3-9 ft deep

Interesting Fact ★

Eurasian milfoil is an invasive species brought to North America from Europe in the 1940's. It competes with native plants and can impair water quality.

what?
habits

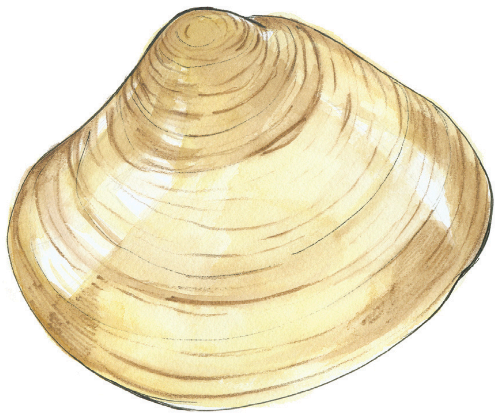
Feeding:

Who eats me?
water birds

What do I use to make food?
sunlight

Role: producer

Reproduction: stems release fragments that develop roots, new stems and leaves, then sink and grow from the bottom; can also be pollinated



Fingernail Clam*

Scientific Name:
Sphaeriidae

who?
description

Type: mollusk

Length: 1.3 cm / .5 in

Coloring: cream, orange, white

Body Features: fine rows of concentric, raised lines

Size:

where?
environment

Habitat: sandy bottom of freshwater lakes and streams

Interesting Fact ★

Fingernail clams do not have eyes, a nose, or antennae, but they do have a foot they push out of the shell to help them to move.

what?
characteristics

Feeding:

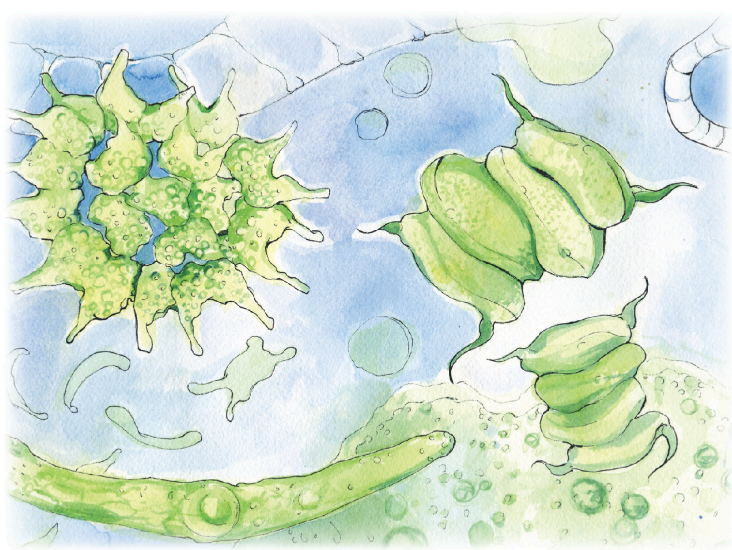
➲ Who eats me?
bottom feeding fish

➲ What do I eat?
plankton, bacteria

Role: consumer, omnivore

Reproduction: young emerge from parents in adult form

Activity: year-round



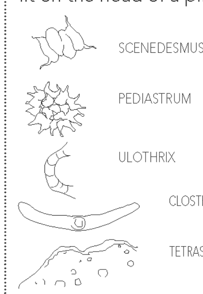
Green Algae*

Scientific Name:
Closterium, Pediastrum, Scenedesmus, Tetraspora, Ulothrix

who?
description

Type: phytoplankton

Size: microscopic - 1000 could fit on the head of a pin



Size:

where?
environment

Sunlight: direct sunlight

Habitat: mostly freshwater, found in all 5 Great Lakes

Interesting Fact ★

Algae is the base of the lake food web. It produces more oxygen than all of the plants on Earth combined. Of the more than 7,000 types of green algae in the world, cladophora is one type found in clumps along Great Lakes beaches.

what?
characteristics

Feeding:

➲ Who eats me?
water fleas, copepods, snails, mollusks, fish

➲ What do I use to make food?
sunlight

Role: producer

Reproduction: can grow individually as single cells or in colonies; some have spores; when algae reproduce quickly, this is called a "bloom"

Human*

Scientific Name: *Homo sapien*

who? *description*

Type: mammal

Length: adults average 152-182 cm / 5-6 ft

Weight: adults average 50-91 kg / 110-200 lbs

Coloring: skin shades range including, white, pink, beige, tan, light-dark brown

Body Features: 2 arms, 2 legs, 10 digits on hands and feet

Note: rely on sense organs (eyes, ears, mouth, nose) and opposable thumb

Size:

where? *environment*

Habitat: homes in a variety of ecosystems, rural-urban; homes vary in shape, size, and material depending on culture and location

Interesting Fact ✶

Humans do not have natural predators and are able to live in many different types of environments.

what? *characteristics*

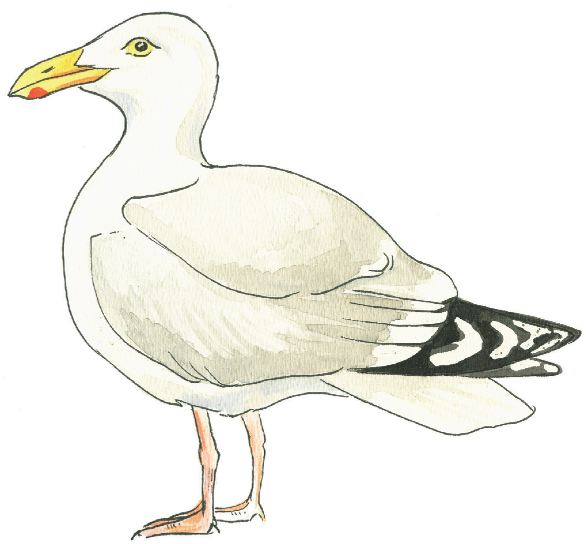
Feeding:

Who eats me?
not a primary food source for animals, but may be eaten by large carnivores

What do I eat?
depends on culture - various vegetables, fruits, nuts, fish (including lake trout and yellow perch), cows, pigs, chickens

Role: consumer, omnivore

Reproduction: live young which is generally raised by both parents



Herring Gull*

Scientific Name: *Larus argentatus*

who? *description*

Type: bird

Length: up to 61 cm / 24 in

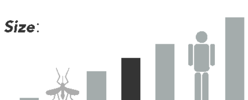
Weight: 1.1 kg / 2.5 lb average

Coloring: white, grey wing backs, yellow bill with red spot

Body Features: pink legs

Note: The ring-billed gull is also commonly found in the Great Lakes region. It has a black line around its beak and has similar characteristics to the herring gull.

Size:



where? *environment*

Habitat: beach, lakeshore and seacoast, grass nests on flat ground

Interesting Fact ✶

Herring gulls will travel up to 40 miles from home for food.

what? *characteristics*

Feeding:

Who eats me?
other gulls, eagles eat young

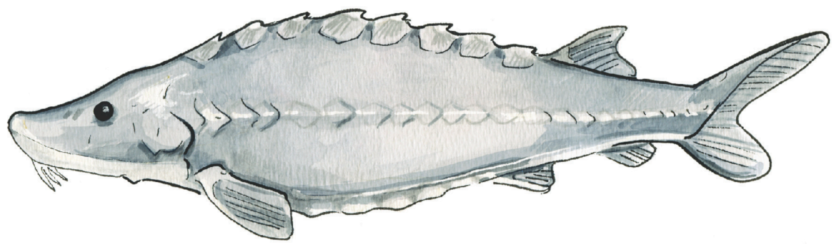
What do I eat?
clams, small fish, small mammals, garbage, birds, dead animals

Role: consumer, omnivore, scavenger

Reproduction: 3 eggs in spring

Grouping: colonies

Activity: diurnal



Lake Sturgeon*

Scientific Name: *Acipenser fulvescens*

who?
description

Type: fish

Length: 91-183 cm / 3-6 ft

Weight: 4-91 kg / 10-200 lbs

Coloring: olive brown to grey, white belly

Body Features: long, pointed snout with four barbels, or feelers, under the front of the snout

Endangered in Illinois, Indiana, and Michigan

Size:

where?
environment

Habitat: freshwater lakes, lives on lake bottom

Interesting Fact ★

The female sturgeon takes 20 years to mature and can live for 100 years. The sturgeon uses its barbels to find food on the lake bottom.

what?
characteristics

Feeding:

Who eats me? humans and other fish eat eggs

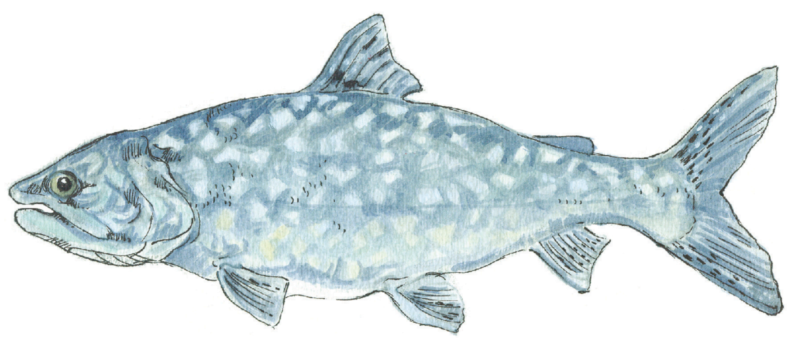
What do I eat? crustaceans, mollusks, insects

Role: consumer, omnivore

Reproduction: eggs; spawns every 4-6 years in swift water

Grouping: solitary

Activity: diurnal



Lake Trout*

Scientific Name: *Salvelinus namaycush*

who?
description

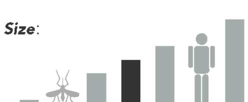
Type: fish

Length: 43-69 cm / 17-27 in

Weight: 1344-4032 g / 3-9 lbs

Coloring: light spots on dark background, color van vary greatly from fish to fish

Size:



where?
environment

Habitat: freshwater lakes, in cold, clear, deep water

Interesting Fact ★

Lake trout are a popular food for humans and the invasive sea lamprey. This has caused overfishing and reduced fish population. The United States and Canada worked together to reduce lamprey numbers. Namaycush is a Native American word that means "dweller of the deep."

what?
characteristics

Feeding:

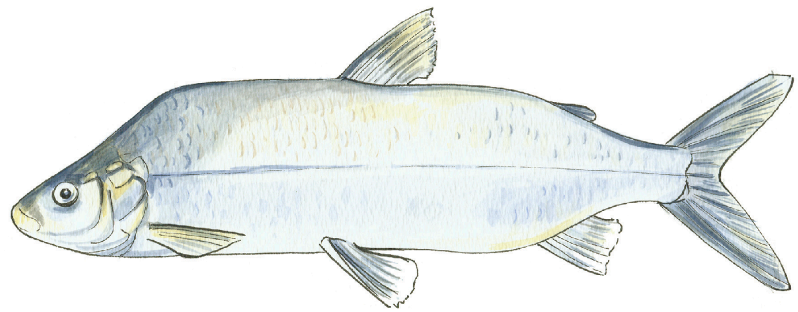
Who eats me? sea lamprey, humans

What do I eat? chub, sculpin, smelt, alewives

Role: consumer, carnivore

Reproduction: female lays up to 15,000 eggs; spawns in shallow areas

Activity: year-round



Lake Whitefish*

Scientific Name: *Coregonus clupeaformis*

who? *description*

Type: fish

Length: 43-56 cm / 17-22 in

Coloring: silver sides, greenish brown back

Body Features: two clear fins on the back and a blunt nose

Size:

where? *environment*

Habitat: found in all five Great Lakes; prefer deep waters of up to 61 m / 200 ft, deeper in hot weather

Interesting Fact ★

The whitefish population seems to be making a comeback after years of over-fishing and bad environmental conditions had reduced their population.

what? *characteristics*

Feeding:

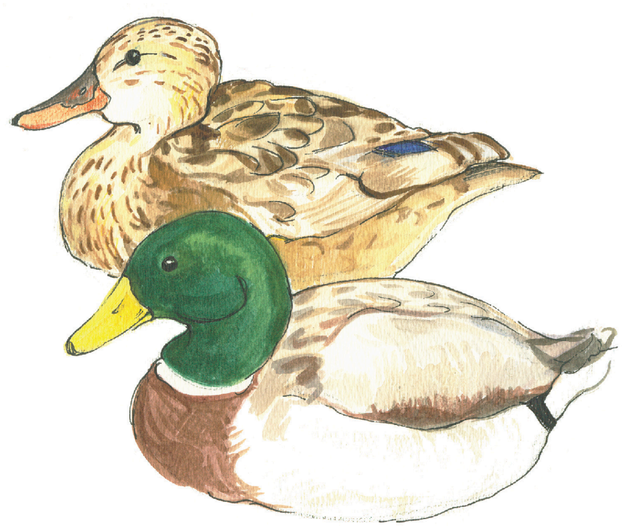
Who eats me? lake trout, walleye, pike, humans; eggs eaten by other fish

What do I eat? diporeia, insects, freshwater shrimp, small fish, fish eggs

Role: consumer, carnivore

Reproduction: eggs laid in early winter in shallow sandy or rocky water 7 m / 25 ft deep; young hatch in spring

Grouping: swims in schools



Mallard Duck*

Scientific Name: *Anas platyrhynchos*

who? *description*

Type: bird

Length: 50-60 cm / 19-23 in

Weight: 1.24 kg / 3 lbs

Coloring: male-green head, white neck ring, brown breast, yellow bill; female-all brown/ white mottled, greenish bill, white patch around wing

Body Features: orange webbed feet

Size:

where? *environment*

Habitat: interdunal pond, freshwater lakes, ponds, swamps, grass nest on the ground

Interesting Fact ★

The mallard is the most commonly recognized wild duck in the world.

what? *characteristics*

Feeding:

Who eats me? muskellunge, humans, coyotes, snapping turtle

What do I eat? emergent weeds, small invertebrates, larval insects, grains

Role: consumer, omnivore

Reproduction: 8-12 eggs in spring

Grouping: pairs or flocks

Activity: diurnal

Muskellunge*

Scientific Name: *Esox masquinongy*

who? *description*

Type: fish

Length: up to 152 cm / 5 ft

Weight: 18-31 kg / 40-70 lbs

Coloring: silver green to light brown with dark bars, cream belly with small brown spots

Body Features: long head and snout, and a large mouth

Size:

where? *environment*

Habitat: freshwater lakes, near weed beds and shore

Interesting Fact ★

Muskies were often caught by fishermen as prize fish, but now fishing of muskies is regulated to protect the population.

what? *characteristics*

Feeding:

Who eats me? humans

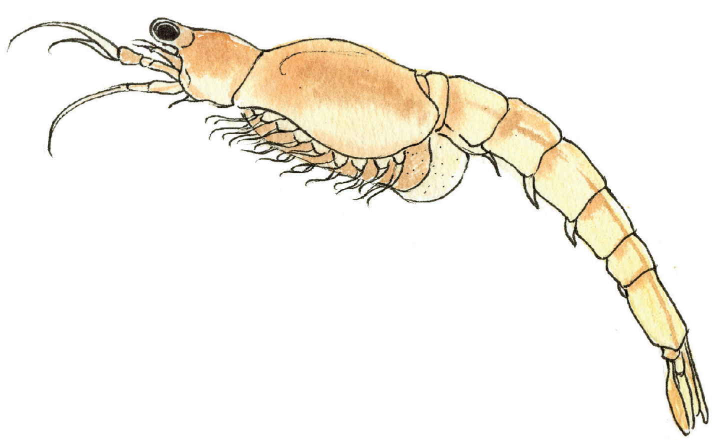
What do I eat? other fish, ducklings, frogs, rodents

Role: consumer, carnivore

Reproduction: lay eggs in shal-low water

Grouping: solitary

Activity: most active in warm weather



Opossum Shrimp*

Scientific Name: *Mysis relicta*

who? *description*

Type: crustacean

Length: 2-3 cm / .8-1 in

Coloring: clear, beige

Body Features: 10 pairs of jointed legs

Size:

where? *environment*

Habitat: freshwater lakes, deep cold water

Interesting Fact ★

Opossum shrimp look like a miniature crayfish. They are not actually shrimp.

what? *characteristics*

Feeding:

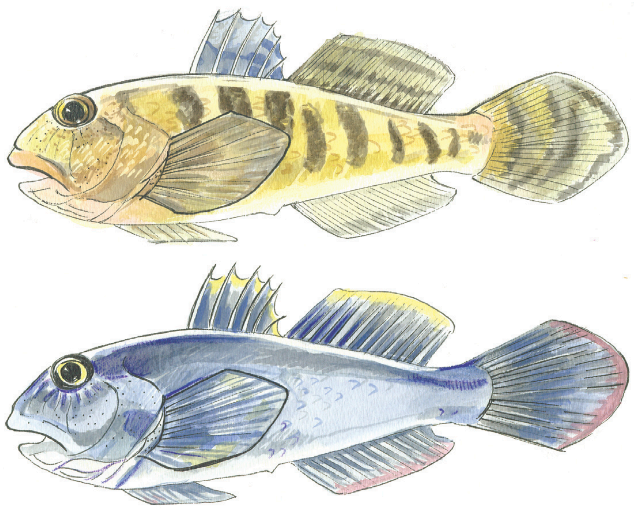
Who eats me? lake trout, alewife

What do I eat? Phytoplankton, zooplankton, copepods, detritus

Role: consumer, omnivore

Reproduction: female carries eggs in a pouch

Activity: diurnal movement and nocturnal feeding



Round Goby*

Scientific Name: *Neogobius melanostomus*

who?
description

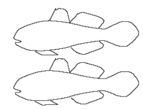
Type: fish

Length: under 18 cm / 7 in

Coloring: slate gray or black body with black or brown spots

Body Features: raised, frog-like eyes; have thick lips, front fin has a black spot, body is covered with fine scales

Invasive Species



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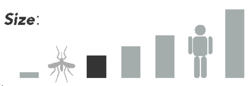


where?
environment

Habitat: lake bottom, found in all the Great Lakes and some nearby lakes

Interesting Fact ★

The round goby has a very active sensory system which allows it to find prey and also avoid becoming prey. They have become too numerous to bring under control.

what?
characteristics

Feeding:

Who eats me?
bass, pike, walleye

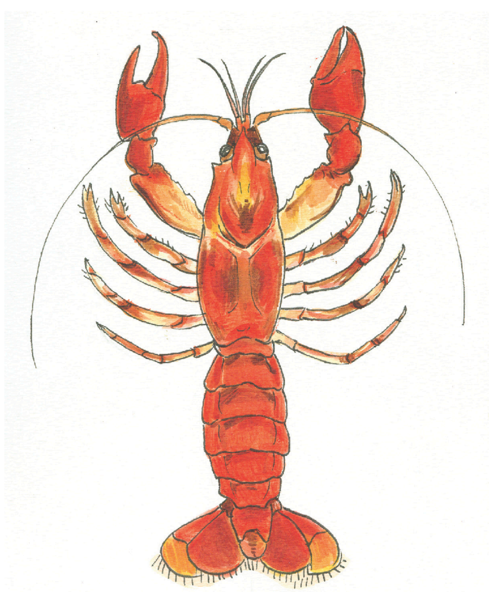
What do I eat?
small fish, zebra mussels, and fish eggs

Role: consumer, carnivore

Reproduction: spawns up to five times per mating season; builds nests in rocky areas for eggs

Grouping: found in dense populations

Activity: diurnal



Rusty Crayfish*

Scientific Name: *Orconectes rusticus*

who?
description

Type: crustacean

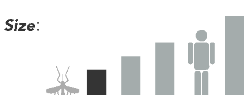
Height: 8-10 cm / 3-4 in

Coloring: red / brown color

Body Features: large claws and rusty colored spots on each side of the main body section

Invasive Species

Size:



where?
environment

Habitat: lakes, ponds, and streams in areas where there is debris on the bottom

Interesting Fact ★

Rusty crayfish are an invasive species that have been spread when used for bait by fishermen. They have also been spread by science classes who have released them after being classroom pets.

what?
characteristics

Feeding:

Who eats me?
predator fish, birds, raccoons

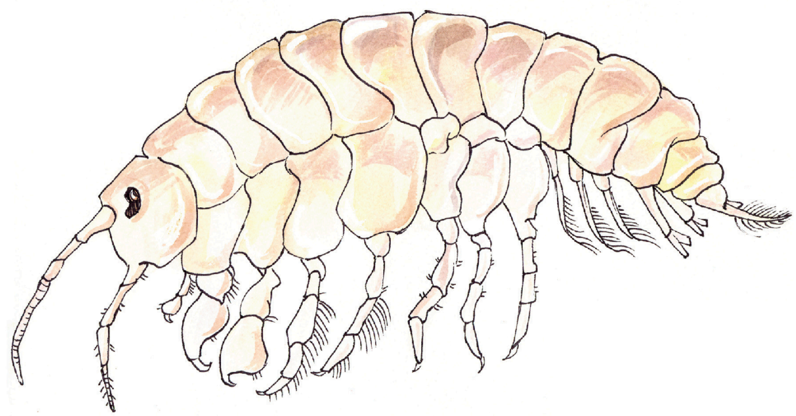
What do I eat?
aquatic plants and insects, fish eggs and small fish

Role: consumer, omnivore and scavenger

Reproduction: eggs are usually laid in the spring by the female

Grouping: young crayfish stay with their mother for several weeks. After, they tend to live independently

Activity: nocturnal



Scud*

Scientific Name: *Gammarus*

who? *description*

Type: crustacean

Length: 2.54 cm / 1 in

Coloring: most are gray and tan; some are shades of green, blue, orange, and purple

Body Features: shrimp-like with an arched, flat body; two pair of antennae and nineteen paired legs

Size:

where? *environment*

Habitat: shallow water in lakes, ponds, and slow moving rivers with abundant vegetation and debris on the bottom

Interesting Fact ★

Scud populations may be declining because of competition with the zebra mussel for phytoplankton.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** insects, amphibians, shore birds and fish like sculpin, smelt and chub

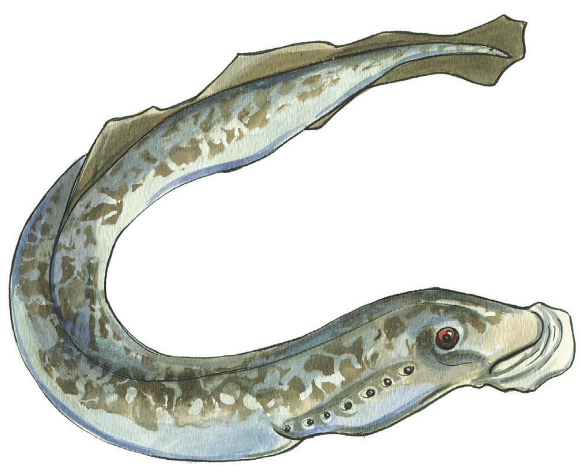
➲ ***What do I eat?*** algae, dead plants and animals

Role: consumer, omnivore

Reproduction: reproduces after 5-8 years

Grouping: colonies

Activity: mainly nocturnal



Sea Lamprey*

Scientific Name: *Petromyzon marinus*

who? *description*

Type: fish

Length: 30-50 cm / 12-20 in

Weight: 226-363 g / .5-.8 lbs

Coloring: grey-blue, metallic purple, and silver

Body Features: long, slender body, mouth with sharp teeth enables it to suck out the fluid and tissue of fish, especially the lake trout

⚠ ***Invasive Species***

Size:

where? *environment*

Habitat: freshwater lakes and oceans

Interesting Fact ★

Sea lampreys naturally live in saltwater, but came into the Great Lakes through canals. There are efforts to control the lamprey population because they do not have natural predators in the Great Lakes.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** none in Great Lakes

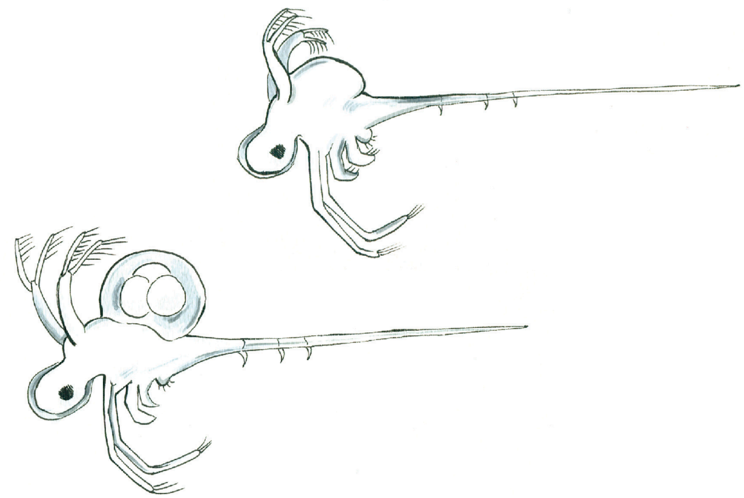
➲ ***What do I eat?*** fish, including lake trout

Role: consumer, carnivore

Reproduction: lay eggs

Grouping: solitary

Activity: year-round



Spiny Water Flea*

Scientific Name: *Bythotrephes cederstroemi*

who? *description*

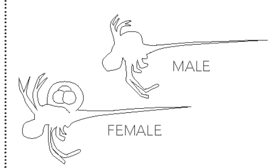
Type: zooplankton, crustacean

Length: less than 1.3 cm / .5 in

Coloring: clear

Body Features: crustacean with long, sharp, barbed tail spine

Invasive Species



Size:

where? *environment*

Habitat: throughout the Great Lakes and some inland lakes

Interesting Fact

This creature is not a flea, but a crustacean. Only some larger fish can eat it because the sharp tail spine is hard for smaller fish to swallow. It competes with fish for plankton.

what? *characteristics*

Feeding:

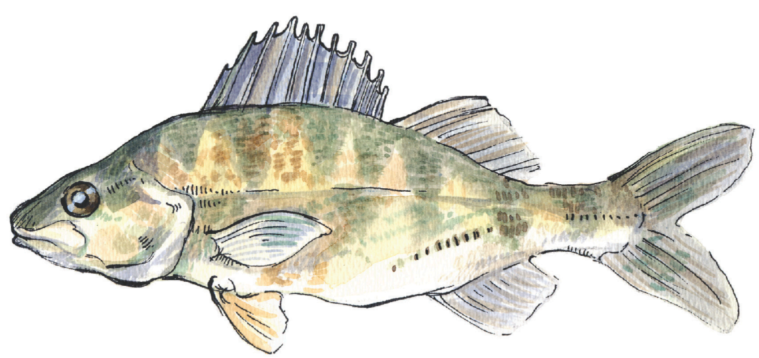
Who eats me? some large fish

What do I eat? plankton

Role: consumer, omnivore

Reproduction: reproduce rapidly; during warm summer temperatures each female produces 10 offspring every 2 wks

Grouping: form clusters with each other



Walleye*

Scientific Name: *Stizostedion vitreum*

who? *description*

Type: fish

Length: 33-63 cm / 13-25 in

Weight: .4-2 kg / 1-5 lbs

Coloring: brown to yellow

Body Features: The young usually have dark blotches across their backs and down their sides

Size:

where? *environment*

Habitat: freshwater lakes, lives in deep water, near the bottom of the lake in weeds or rocks

Interesting Fact

Walleyes have large, marble-like eyes that help them see well in dim light.

what? *characteristics*

Feeding:

Who eats me? humans, muskellunge, largemouth bass

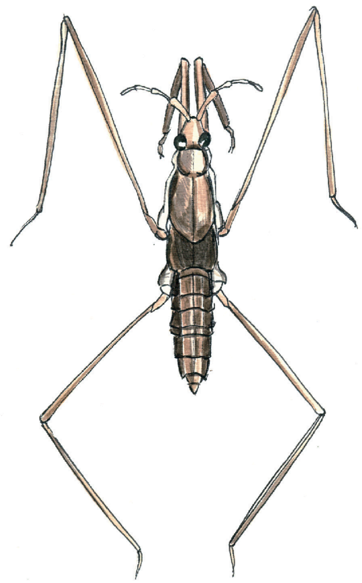
What do I eat? yellow perch, aquatic insects, crayfish

Role: consumer, carnivore

Reproduction: occurs in spring/early summer, females release up to 612,000 eggs

Grouping: loose but distinct schools

Activity: feeds at dusk



Water Strider*

Scientific Name: *Gerris remigis*

who? *description*

Type: insect

Length: 1.2 cm / .5 in

Coloring: dark brown to black

Body Features: long legs, two legs can fold under front of body

Size:

where? *environment*

Habitat: interdunal pond, freshwater lakes and wetlands, live under leaves, spend time on surface of water

Interesting Fact ★

Water striders communicate with each other through ripples on the surface of the water.

what? *characteristics*

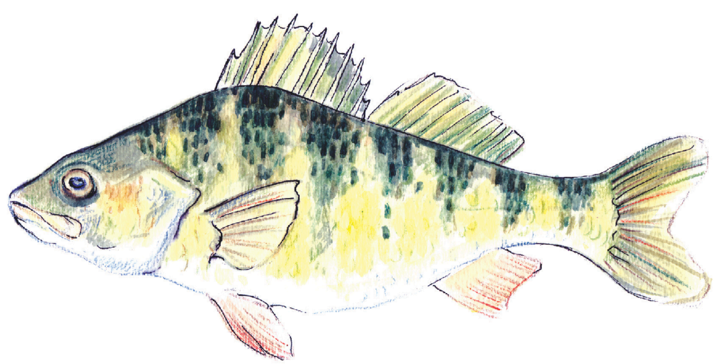
Feeding:

➲ ***Who eats me?*** birds, fish, dragonflies

➲ ***What do I eat?*** Insects from water and land, plants

Role: consumer, omnivore

Reproduction: lay eggs at water's edge



Yellow Perch*

Scientific Name: *Perca flavescens*

who? *description*

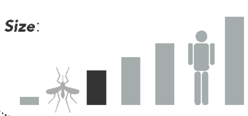
Type: fish

Length: 15-25 cm / 6-10 in

Weight: 168-448 g / 6-16 oz

Coloring: back is bright to olive green or golden brown, sides are yellow-green; grey to milk-white belly

Size:



where? *environment*

Habitat: lake bottom, less than 30 feet depth, feeds near the shore and rests on the bottom

Interesting Fact ★

Yellow perch are a popular food for humans, but have been overfished and the population has decreased. They lay their eggs in long, jelly-like ribbons.

what? *characteristics*

Feeding:

➲ ***Who eats me?*** alewife (feed on larva), humans

➲ ***What do I eat?*** minnows, insect larvae, plankton, worms

Role: consumer, carnivore

Reproduction: lay eggs April-May

Grouping: swims in schools

Activity: diurnal, year-round

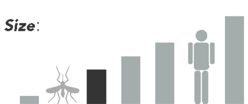
Zebra Mussel*

Scientific Name: *Dreissena polymorpha*

who? *description*	where? *environment*	what? *characteristics*
Type: mollusk ***Length:*** up to 5 cm / .75 in ***Coloring:*** tan and blackish stripes (like a zebra) ***Body Features:*** two connected shells hold a small mussel between them, they attach to hard surfaces with byssal threads ***Invasive Species*** ***Size***:	***Habitat:*** freshwater, native to the Caspian and Black Sea, but now in all Great Lakes and some inland lakes; depths of 2-7 m / 6-23 ft	***Feeding:*** ***Who eats me?*** round goby ***What do I eat?*** algae ***Role:*** consumer, omnivore ***Reproduction:*** eggs expelled by females and fertilized outside of the body by males in spring / summer ***Grouping:*** colonies

Interesting Fact ★

Zebra mussels are commonly found around the Great Lakes. They compete with native fish for plankton, which causes problems for the fish. Because they are filter feeders, zebra mussels can increase water clarity.



Sea Connections

Some people go whale watching. Some people long to swim with dolphins. Others earn their livelihood fishing for giant tuna in a vast ocean. These marine animals capture our attention and our imagination. We have a connection to all the living things of the ocean, from the microscopic floating plants that supply us with the oxygen we breathe to the huge blue whale that fills its belly with a ton of krill. Microscopic or oversized, plant or animal, from muddy shoreline to deep ocean floor, the ocean's living things attest to its endless variety, its biodiversity. Scientists say that there may be millions more species than we know swimming, floating, and crawling in the deep oceans and as yet unseen by human eyes. With the aid of submersible technology, entire new ecosystems are being discovered. Each ecosystem consists of a community of living things that interact with one another in complex relationships in unique conditions of water temperature, salinity, chemical composition, and currents. Far below the surface of the ocean, where no sunlight reaches, hot water laced with chemicals spews out of cracks in the ocean floor. These cracks (hydrothermal vents) occur most often along the mid-ocean ridge, where Earth's crustal plates are spreading apart. Water reaching temperatures of four hundred degrees Celsius and chemical compounds such as hydrogen sulfide billow out from the vents. At certain vents, as the hot, sulfide-rich water comes in contact with cold seawater, metal sulfides precipitate out. The chemicals pile up into structures that resemble chimneys, which scientists call "black smokers." Scientists have found one black smoker that is as tall as a fifteen-story building. Can living things survive in such a place? The answer is yes. In 1977, scientists aboard the submersible *Alvin*, exploring five thousand feet below the surface of the Pacific, saw large, four-foot-tall tube worms, some with bright red plumes, living around a hydrothermal vent. Later laboratory investigation revealed that the unusual worms had no digestive system but instead contained about 285 billion bacteria per ounce of tissue! In this sunless world, a type of sulfur-loving bacteria was the worms' food source. Clouds of bacteria, appearing white in the lights of the sub, were able to use hydrogen sulfide as an energy source. In most other food chains, plants convert carbon dioxide into food using sunlight during *photosynthesis*. These peculiar bacteria were able to convert hydrogen sulfide into food during *chemosynthesis*. Also found around the vents, feeding on the water rich in chemosynthetic bacteria, were certain kinds of clams and mussels. At this great depth and pressure, some species of octopus prey upon these shelled invertebrates. But when the hot water and chemicals coming from the vent slow down to a trickle, the animals disappear. In the past twenty years, more than three hundred species have been identified in this unique environment. Similar vent organisms have been discovered at the base of the continental shelf, where the ocean water is sulfide-rich but not hot, as in the hydrothermal vents. These "cold seeps," as they are called, illustrate how little we know about the productivity of the ocean bottom. As far as scientists can tell, hydrothermal vents and cold seeps have not yet been affected by human activities. Far away in a tropical ocean is another distinctive marine ecosystem. One in four marine species on our planet lives in a coral reef, an underwater world like no other with its colorful variety of swimming and floating animals making their way among the branching corals. The food chain of the coral reef begins with photosynthetic algae, microscopic organisms that use sunlight to make food. Most of the algae live in harmony within the tiny coral animals themselves. Reef-building corals secrete a hard, stony shell of calcium carbonate that builds up over time and provides the habitat for reef animals. Colorful invertebrates such as the coral shrimp feed on algae and detritus around the coral, where they in turn may become dinner for small fish. Large, sleek, and silvery barracuda patrol the outer reef, preying on smaller fish such as the butterfly fish. However, there is trouble in this paradise: pollution from pesticides, sewage, and soil run-off has damaged many reefs in the Caribbean and Pacific. The practice of dynamite fishing to stun fish and capture them for the aquarium trade has devastated reefs in parts of Asia, the South Pacific, and Africa. Perhaps not as familiar to us is the frigid water of the polar ocean. The food chains of the polar ocean also begin with algae, including symmetrically shaped diatoms with hard silicate shells. Algae are eaten by tiny invertebrate animals, including shrimplike krill. In the ocean around Antarctica, krill are an important food source, eaten by a diverse group of animals including fish, baleen whales, and Adélie penguins. The penguins are in turn preyed upon by leopard seals. The top predator of the Antarctic is the killer whale, which eats penguins and seals. Thus overfishing of krill in polar waters may jeopardize not only krill, but whales, seals, and penguins too. Along more temperate seacoasts, kelp forests form another unique ecosystem. Kelp are brown algae that can grow as much as sixty centimeters in one day, ultimately reaching as long as eighty meters. Tiny crustaceans called copepods are among the animal plankton that feed on the floating algae and detritus in the Pacific along the California coast. Larger invertebrates, such as sea urchins and abalone, graze on the kelp and are in turn eaten by sea otters. The overharvesting of kelp and a decrease in water quality have impaired the productivity of these ecosystems. Discharge from nuclear power plants on the California coast raises the water temperature just enough so that more sea urchins and abalone survive and grow, eating kelp and diminishing the size of kelp beds. Understanding the various marine ecosystems helps us to better understand the important connections among marine organisms and suggests how much we still have to learn about the oceans.

This understanding also raises warning flags about the necessity of monitoring human activity to keep these connections from being severed and to protect marine biodiversity.

Sea Connections

Lesson Plan

Objectives

Identify producers and consumers from four marine ecosystems.

Describe the delicate balance among organisms in each environment.

Construct a food chain or web from a marine ecosystem.

List some of the human activities that can upset the balance in marine environments.

Materials

Student Page

Globe or world map

Playing cards to be copied and cut out

Heavy stock paper for photocopying or pasting cards

Scissors

Subjects

biology, geography, oceanography, political science, art

Procedure

1. Motivate students by rapidly spinning a globe and asking them to approximate how much of Earth is covered by ocean. Ask them to think about the variety of marine organisms and habitats that must exist on our watery planet, which is over three-quarters ocean. Then have students locate each of the following on a globe or world map: the Great Barrier Reef in Australia (coral reef); the Weddell Sea, Antarctica (polar ocean); Monterey Bay, California (kelp forest); and the Mid-Atlantic Ridge (hydrothermal vent). (If the Mid-Atlantic Ridge is not shown on your globe or world map, approximate its location by connecting Iceland and the Azores with a large letter C, or look at the map on page 11, the Sea Secrets Student Page.)

2. Using the introduction as a guide, describe to your students some of the amazing biodiversity of ocean life, including marine organisms in hydrothermal vents, coral reefs, kelp forests, and polar oceans. Challenge students to match each of the four ecosystems you have described with the correct location on the globe. Ask them to name the producers and consumers from each ecosystem. Producers always begin the food chain and, in the ocean, are generally algae, although chemosynthetic bacteria are the producers near hydrothermal vents. All the other organisms are consumers.

3. In advance, photocopy the three pages of playing cards and paste copies onto heavy stock paper. Cut each sheet into nine cards along the guide lines. Each complete deck will have twenty-seven playing cards and is suitable for a group of up to four players. After cards are cut out they may be laminated or stored in plastic sleeves designed to hold trading cards.

4. Divide students into groups of four or fewer. Pass out a deck of cards to each group and the Rules of the Game Page to each player. Read through the directions together. Make sure that students understand that they will be trying to collect all five cards from one ecosystem in order to see how they connect to each other. Tell students that only five organisms have been chosen from each ecosystem for the game, but that these representative organisms are part of much bigger food webs from each ecosystem. Read through the Disconnect and Reconnect cards to make sure students understand how they are used in the game.

5. As students start playing, circulate among the groups. As a player is carrying out the directions on a Disconnect card, have that student explain to you the relationship of the organisms within that ecosystem and tell in his or her own words the impact of the card.

6. As a student from one group wins, you might interrupt play to let that student describe the winning hand to the class. Use this as a jumping-off point to talk about how food chains and food webs connect the producers and consumers in an ecosystem. As the students resume playing, tell them that the winner from each group should lay out the winning cards to form a food web for other players to see. Then they can divide and trade the remaining cards so that each player has all five cards of one ecosystem—a winning hand.

7. Ask students to fill in their charts using their cards. Spot check the diagrams of each marine ecosystem. Student food chains and food webs should show a pattern of producers first, then primary consumers (those that eat producers directly), followed by predators. If students use arrows to connect the organisms, the arrow's point should mean "eaten by."

8. When students have finished their pages, discuss which of the Disconnect cards prevented them from winning. This can lead to a discussion of the international problem of overfishing. Explain to students that when too many people haul their fishing nets and cast their lines in the same waters, too few fish are left to reproduce. In addition, some fishing grounds have become polluted, so the overall result is a dramatic drop in the fish population. The overfishing problem is so great in some areas that the government has to limit or halt fishing until certain populations recover. Among those on the "hardest hit list" are the Pacific king crab and the Atlantic

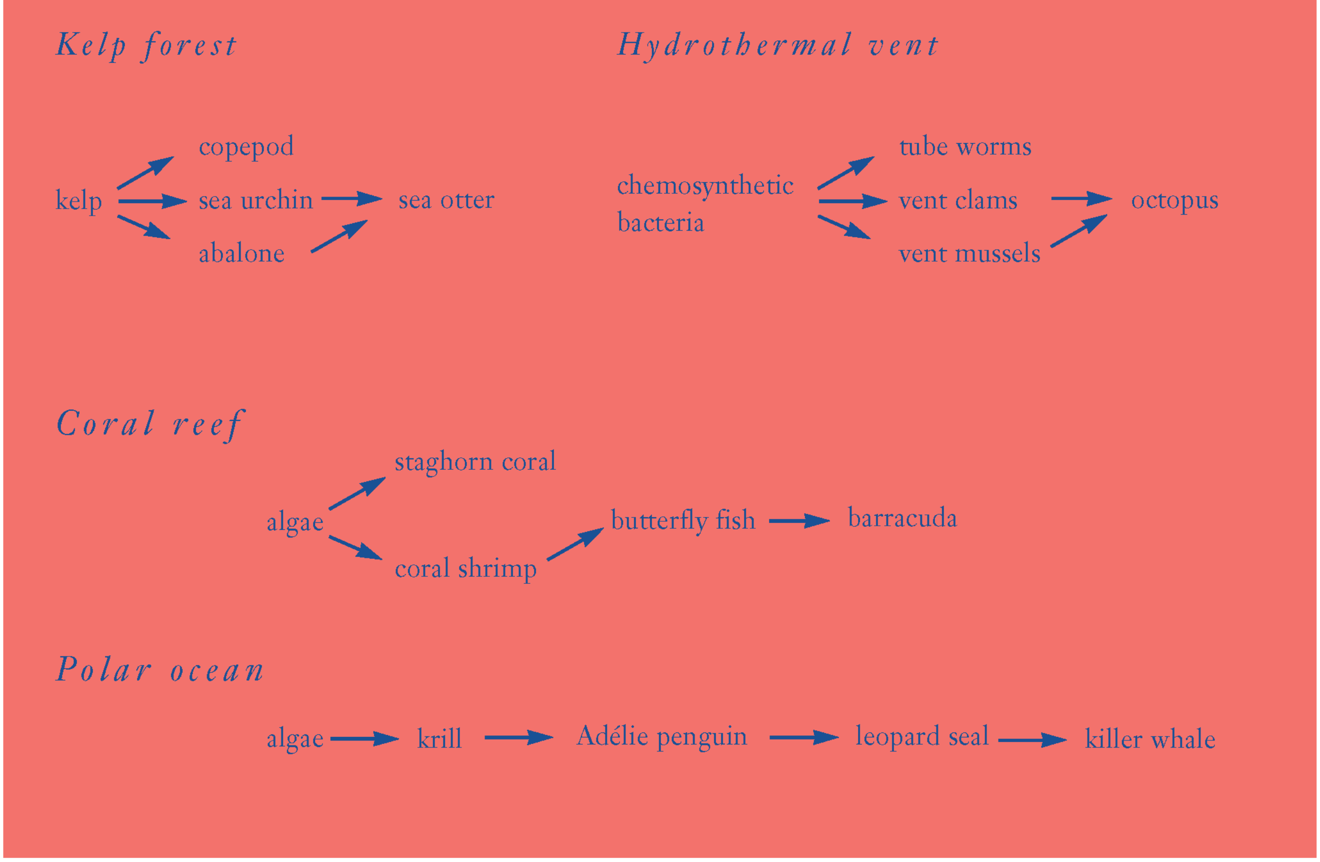
cod and haddock. In 1991 the American Fisheries Society announced that about half the nation's stock of salmon was at risk. Even the mighty bluefin tuna, which can weigh fifteen hundred pounds and swim as fast as a speeding car, is down to only 10 percent of its 1980s population.

Commercial fishing practices of the past have also harmed nontarget species. In some places enormous driftnets up to sixty kilometers long were set over huge areas of ocean. The fine filaments would catch thousands of fish by the gills, but many other animals would get caught, too. Turtles, birds, sharks—even whales and dolphins—drowned in these nets. Loud cries from conservationists and governments brought about a ban on these driftnets, although shorter nets are still used close to shore. Other fishing gear still in use catches and kills young fish and other unwanted animals by mistake.

9. Ask students to imagine that they make their living catching fish, as some of their parents and grandparents did. Ask them to think about how they would feel if the government set a limit on their catch. Their first reaction might be to the loss of income; however, over the long term they should be concerned with finding ways to prevent the disappearance of the species.

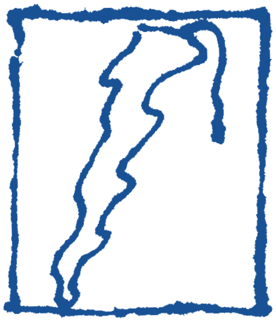
10. Ask students if they've ever played the card game Go Fish. Then ask them why the game they have just played could be called Don't Go Fish. They might answer that overfishing causes the reduction or loss of desirable and profitable species of fish and shellfish. It also disturbs the delicate balance of producers and consumers in each marine ecosystem. The purpose of the card game is to show how both natural events and human activities, such as overfishing, can disturb this balance and break the links that connect species in an ecosystem.

Sea Connections—Sample answers to food webs



kf

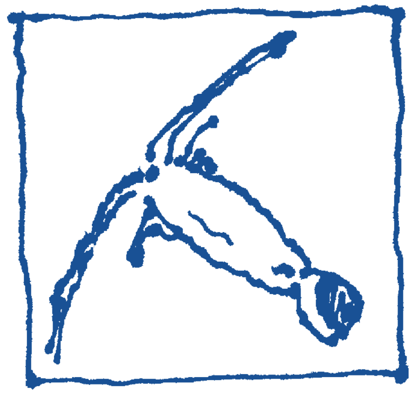
Kelp



produces food

kf

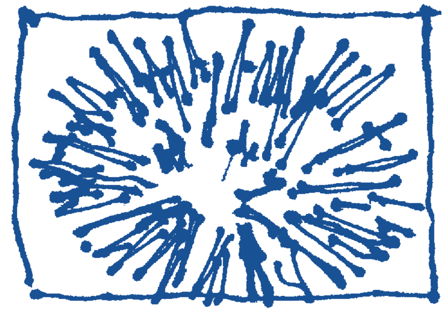
Copepod



eats kelp and other algae

kf

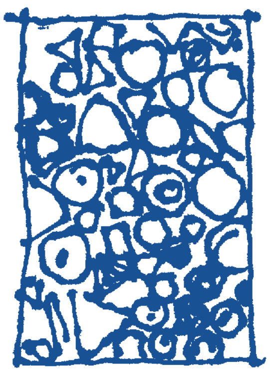
Sea urchin



eats kelp

cr

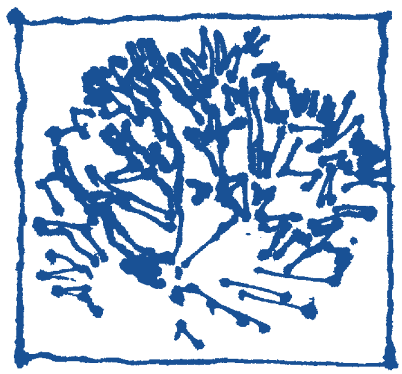
Algae



produce food

cr

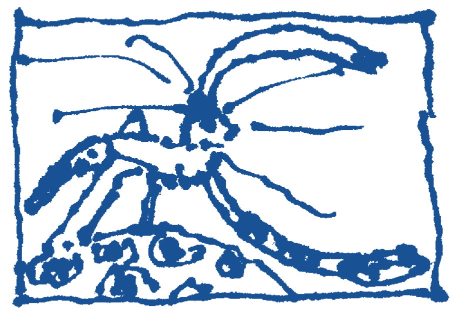
Staghorn coral



feeds on algae, other organisms

cr

Coral shrimp



feeds around coral

hv

Bacteria

produce food from chemicals

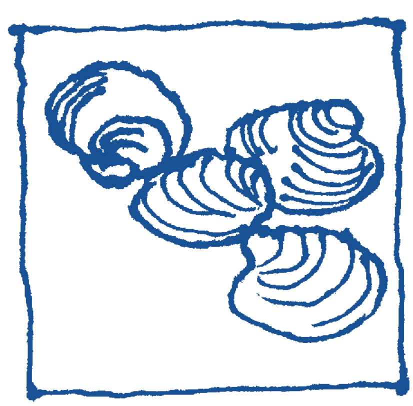
hv

Tube worms

feed on bacteria

hv

Clams



feed on bacteria

kf

Abalone

eats kelp

kf

Sea otter

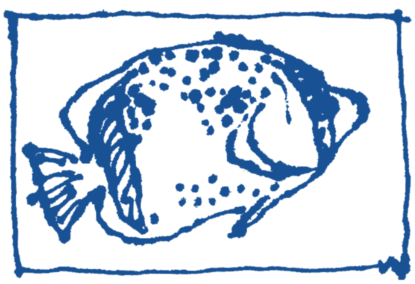
eats sea urchins and abalone

Disconnect

Kelp over-harvested!
Too much kelp has been harvested for use in industry. If you have any kelp forest cards, lose your next turn until the kelp forest recovers.

cr

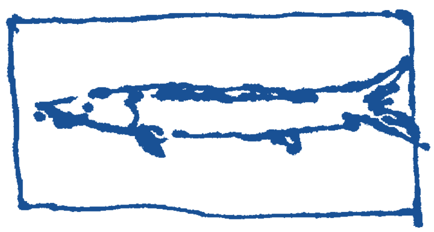
Butterfly fish



feeds around coral

cr

Barracuda



eats other fish

Disconnect

Blast fishing!
Dynamite blows up a coral reef. Coral is destroyed and the fleeing fish are captured. If you have any coral reef cards, discard them and take new ones.

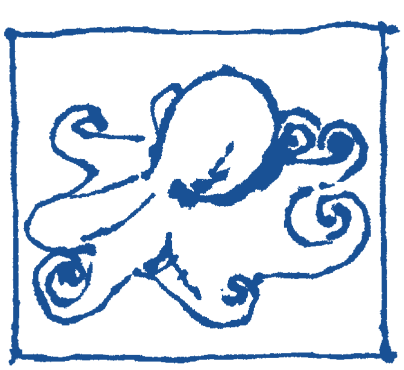
hv

Mussels

feed on bacteria

hv

Octopus

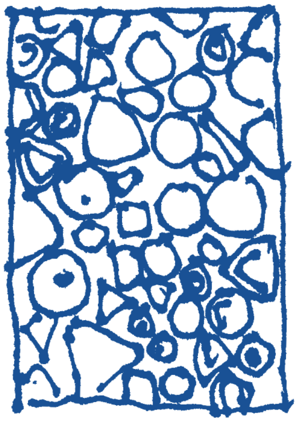


eats clams and mussels

Disconnect

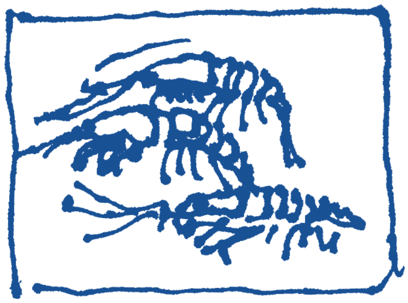
Smoker stops smoking!
A smoker stops spewing hydrogen sulfide. Few bacteria survive. The entire food chain is affected. If you have any smoker cards, keep them, but you lose your next turn.

Diatoms



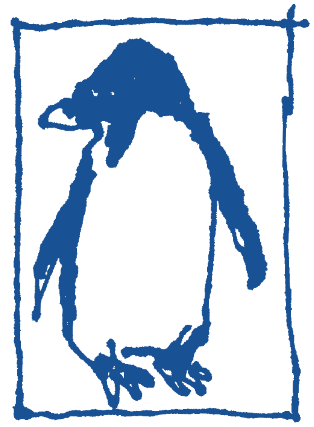
make food

Krill



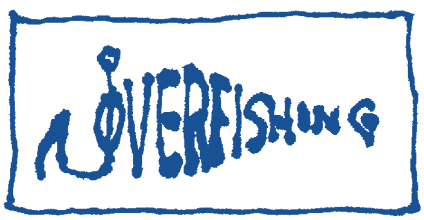
eat algae

Adélie penguin



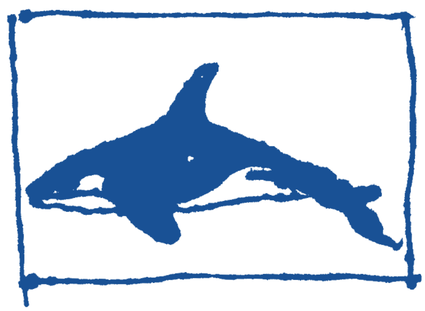
eats krill

Disconnect



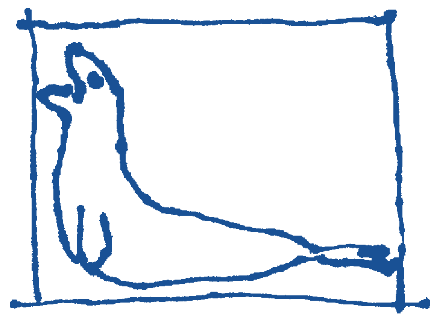
Overfishing of krill!
As a result, whales, penguins and seals are also in danger. If you have any polar ocean cards, discard them and take new cards.

Killer whale



eats penguins and seals

Leopard seal



eats Adélie penguins

Disconnect

Ocean pollution!
Pollution from pesticides, and sewage harms all ecosystems. Whatever cards you are collecting, you lose two turns until the ocean recovers.

Reconnect

Good news!
Because of international agreements on overfishing, give the player that went before you a needed card from your hand. Ask for and receive one card that you need from any other player.

Reconnect

Good news!
Because of international agreements on overfishing, give the player that went before you a needed card from your hand. Ask for and receive one card that you need from any other player.

Sea Connections Student Page

In Sea Connections, you and your team will play a card game. The playing cards represent some of the plants and animals that are connected together in the food webs of four very different marine ecosystems. The cards show how these ocean producers and consumers depend on one another. The objective of the game is to collect all five cards from one ecosystem. What will get in your way are Disconnect cards. These cards describe events that harm ocean ecosystems and interrupt the connections among the living things that are found there.

Rules of the Game

1. Decide who will be the dealer in your group. The dealer shuffles the pile and deals each player five cards face down, then places the remaining cards in a pile face down. The dealer turns the first card up next to the rest of the deck to start a discard pile.
2. Group your cards by the icon in the top left corner. The icons represent:

kf kelp forest

cr coral reef

hv hydrothermal vent

po polar ocean

The object is to collect five cards in one suit, which will include all the animals and plants from one ecosystem. For example, if you were dealt two cards from the coral reef, you may wish to collect all the cards from that ecosystem. (There are four suits, so each player should be trying to collect a different suit.)

3. When it is your turn, pick up the top card from the pile. If you don't need it, place it face up on the discard pile. If you wish to keep it, discard a different card from your hand. If you pick up a Disconnect card, use it during that turn. If you are dealt a Disconnect card, use it during your first turn. If you are dealt more than one Disconnect card, use one at each turn. You may use a Reconnect card at any time. Make sure that you finish each turn with five cards.
4. If the player before you discards a card that you want, you may pick it up instead of drawing from the face-down pile.
5. The first person to collect five cards in one suit wins. If no one wins the first time through the deck, the dealer shuffles the cards in the discard pile and you continue playing.

Sea Connections Data Chart

What suit did you collect?

What are the some of the living things found in this marine ecosystem?

Draw a food chain or food web that shows how the producers and consumers in this ecosystem are related. Use arrows to mean "eaten by . . ."

Resources

Resources for students

Online resources

Visit Ocean Planet online at **http://seawifs.gsfc.nasa.gov/ocean_planet.html**

Using the Exhibition Topic Outline, choose Ocean Planet Marine Life Facts, Creatures of the Thermal Vents, The Living Reef, and Aliens Among Us (under Educational Materials in the Ocean Planet Floor Plan); and Threatened Habitats and Fishing Issues (under Oceans in Peril). Click on "Resource Room" to link to such resources as the Electronic Zoo.Visit the Marine Biodiversity Sculpture (under Ocean Science) or use the Image Catalog (under Resource Room) for photographs of organisms from each of the marine ecosystems mentioned in the preceding activity.

Brower, Kenneth. *Realms of the Sea*. Washington, D.C.: National Geographic Society, 1991.

Cerullo, Mary M. *Coral Reef: A City That Never Sleeps*. New York: Cobblehill Books, 1996.

Charton, Barbara. *The Facts on File Dictionary of Marine Science*. New York: Facts on File, 1986.

Fodor, R. V. *The Strange World of Deep-Sea Vents*. Springfield, New Jersey: Enslow Publishers, 1991.

Resources for teachers

Duxbury, Alyn C., and Alison B. Duxbury. *An Introduction to the World's Oceans*. 4th ed. Dubuque, Iowa: William C. Brown, 1994.

Earle, Sylvia A. *Sea Change, A Message of the Oceans*. New York: G.P. Putnam's Sons, 1995.

Fresh and Salt

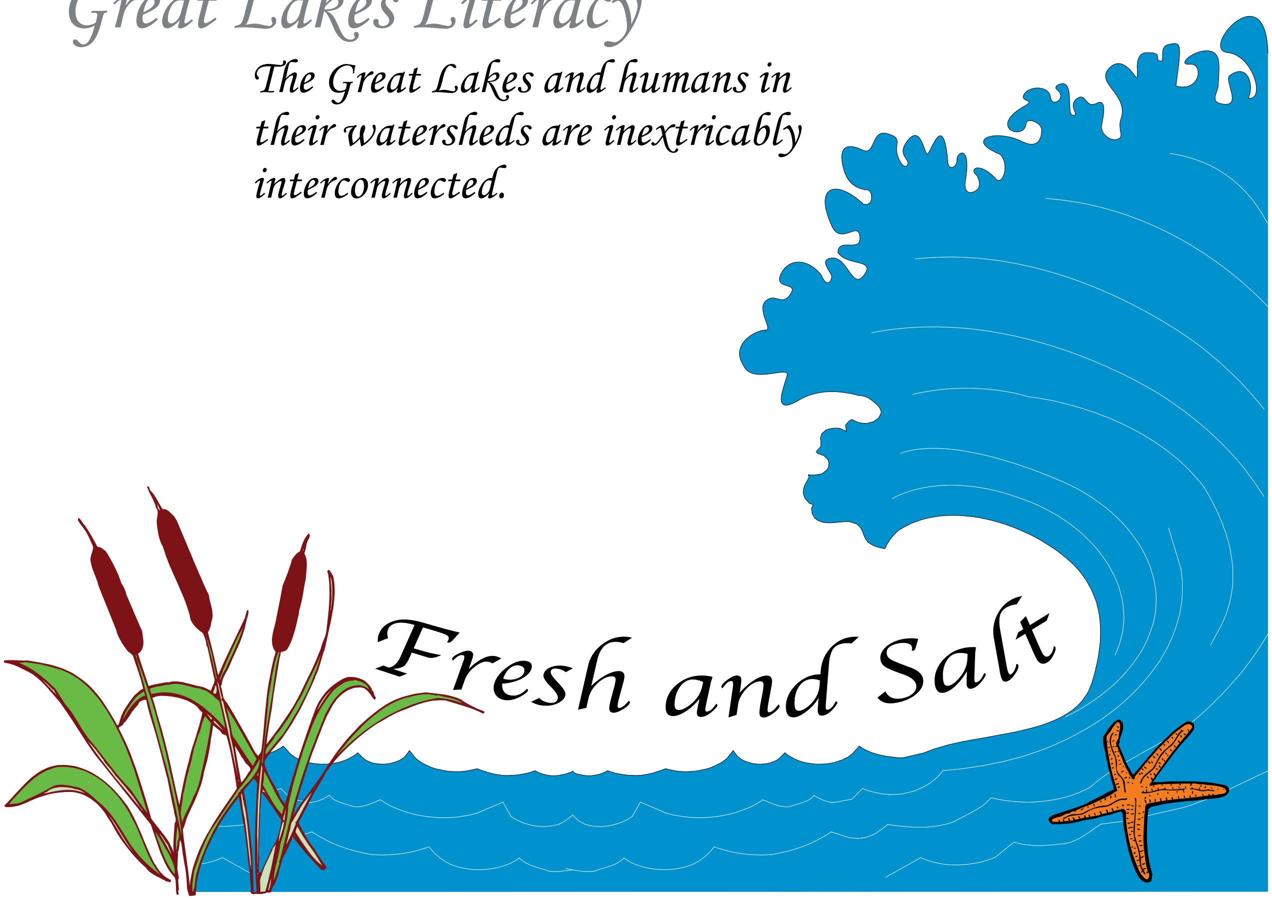
Principle 6

Ocean Literacy

The ocean and humans are inextricably interconnected.

Great Lakes Literacy

The Great Lakes and humans in their watersheds are inextricably interconnected.



Fresh and Salt

Principle 6: The ocean and humans are inextricably interconnected. (OL) The Great Lakes and humans in their watersheds are inextricably interconnected. (GL)

Essential Principle #6 covers the human-environment connection; i.e., people's dependence and impact on the oceans and Great Lakes as well as the resources provide by oceans and Great Lakes, which sustain our quality of life. This principle teaches us about the many foods, medicines, minerals, and energy resources provided by these waters. The Great Lakes also provide a significant source of drinking water to populations living near the lakes. In addition, residents in coastal areas are impacted by land use decisions and natural hazards. These human hazards may include tsunamis, hurricanes, changes in water levels, and storm surges. Conversely, people can make physical modifications to the shoreline and beaches, which can result in problematic erosion, storm surges, and in the Great Lakes, can increase or reduce lake levels.

A central stewardship theme expressed throughout this principle is that the ocean and the Great Lakes sustain life on earth and humans must live in ways that sustain these waters. Individual and collective actions are needed to effectively manage these vital water resources.

Pollution Solution and Downeaster Alexa: A fishery story examine environmental changes to both an ocean and Great Lakes system that lead to impacts affecting not only marine ecosystems, but also people's lives and livelihoods. In both activities, students examine these changes and also learn about mitigation strategies including an oil spill cleanup, as well as needing to make changes in the fish catch.

Pollution Solution is geared towards high school students and creates awareness and knowledge about the cost of using materials to clean up a spill, but also the cost of disposing of those materials. In addition, students build an understanding of how expensive an environmental clean-up operation would be. This activity, published by the Smithsonian Center for Education and Museum Studies, helps students understand the ecological impacts of an oil spill as well as impacts on human populations. It's not all gloom and doom, however; the lesson notes that "ecologists revisiting oil spill sites have found marine population recovering better than they had predicted." This glimmer of hope doesn't negate the fact that it will often take decades for this to happen.

Similar hazards have occurred in the Great Lakes, including events such as hazardous substance releases, hazardous ice conditions, and oil spills in Great Lakes watersheds.

Educators who reviewed this activity offered these important reflections:

"Could a massive oil spill happen in the Great Lakes? What is the history of these accidents in the Great Lakes?"

"These two situations can be investigated by students, creating an excellent Great Lakes comparison."

"The introduction provided a nice way to introduce the topic of oil pollution."

"The experience of causing the oil spill and cleaning it up, and keeping track of the expenses."

"The procedure is very clear and concise and user-friendly!"

"I like the idea of using trade books to introduce a topic, especially colorful children's books." regarding resources suggested in the activity

"I used the website links provided in the activity to show the pictures of animals and the environment with oil on them."

Downeaster Alexa: A fishery story from *The Changing Earth System* (The Ohio State University) takes a look at events and people of a struggling North Atlantic striped bass fishery. It incorporates learning skills such as interpreting song lyrics, graphing, analyzing data, map reading, and collecting historical records. Students describe a major fishery of the North Atlantic; interpret the offshore characteristics of an area using a bathymetric chart; identify human and natural environmental reasons for changes in fish catch; and analyze the relationship of global environmental changes to fish population changes.

A teacher, eloquently described the flow: *"The students were hooked on the lesson with singing the song. After that they immediately started to discover both sides of the ecological equation by studying why the fishermen had to limit their striper catch as a means to re-establish the striper population. But, they also saw that there is a great deal of personal sacrifice on the part of the fisherman to attain ecological goals. This was a component that I was glad to see included. Too many times we present ecology to students as a one-way street. In other words, ecology trumps all industrial endeavors, which simply can't be the case."*

There are several parallels to the Great Lakes system. A Pennsylvania teacher suggested that it would be a natural connection for students to author a subsequent lesson on the freshwater fisheries industry on Lake Erie and similar problems it has faced. Students can also look at unique problems experienced by anglers on the Great Lakes.

Teacher reviewers provided these significant comments on the benefits of the activity and suggested extensions and modifications:

"The single most creative portion of this lesson was its global approach. The students were able to see the struggle between maintaining a healthy fisheries stock and securing the future of an industry that we all depend on."

"These lessons were very well-developed and geared for the students to see the bigger ecological connections. The dependency between a successful fisheries industry and the need for catch limits was undoubtedly delivered in this lesson."

"This strategy [in the Procedure section] allowed for me to approach this in a differentiated pedagogy. I had some students in groups moving independently with mini-conference time with me. Others required a more direct instructional approach."

"I found my students completely engaged throughout this lesson and its activities. I teach in a 42-minute block, which is conducive to this format [mini activities embedded in the lesson]."

"Use of the Billy Joel song as an introduction to this activity was effective, although I augmented the set-induction by finding the 1989 MTV video of the song and allowed the students to actually sing along and view the message that the composer was trying to deliver. The students quickly related to the plight that the fisherman were encountering."

Pollution Solution

More than 60 million gallons of oil enter the oceans every year, but it's not reported on the news. That's because this oil seeps from oil-bearing rock layers into the ocean as part of a natural process. When tankers running aground spill oil, that's news, and currently these accidents deposit about 37 million gallons of oil into the ocean every year. The largest amount of oil entering the ocean through human activity is the 363 million gallons that come from industrial waste and automobiles. When people pour their used motor oil into the ground or into a septic system, it eventually seeps into the groundwater. Coupled with industrial waste discharged into rivers, oil becomes part of the run-off from waterways that empty into the ocean. All of this oil affects ocean ecosystems. When an oil spill occurs in the ocean, the oil may spread across miles of open water and up onto beaches, littering them with tar balls. The intertidal zones—

coastal areas that are the habitat for fish, birds, and other wildlife—are often the most vulnerable. Animals may perish when the oil slicks their fur or downy feathers, decreasing the surface area so they are no longer insulated from the cold water. Or the animals may ingest the oil, then become sick or unable to reproduce properly. When an oil spill occurs along a coastline, it affects the human population as well as wildlife. Emergency equipment and personnel must be rushed to the scene. The responsible party must be identified to determine who will pay for the cleanup. Usually the cleanup is a group effort by oil companies, government agencies, local groups, and volunteers. People rescue and clean birds and animals and painstakingly scrub the oil from the rocky shores with brushes and detergent. Coming in by sea and by air, crews skim the spreading oil from the water's surface. Oil that cannot be skimmed is emulsified—that is, droplets of oil are scattered into tiny particles that will then float away and disperse out to sea. Sometimes microscopic helpers are put to work. Genetic engineers have developed oil-eating bacteria that can be used to ingest the oil, to clean up long after the crews and volunteers have left. The experience gained from several well-publicized oil spills has ushered in an era of greater understanding and international cooperation with regard to containing spills and avoiding environmental disasters that affect our global ocean. One bright spot of news is that ecologists revisiting oil spill sites have found marine population recovery better than they had predicted.

Pollution Solution

Lesson Plan

Step 1

Objectives

Predict the effects of an oil spill on a marine environment.

Establish a list of solutions to avoid unnecessary oil pollution.

Materials

Copies of Student Page A

Optional: additional photographs or articles about oil spills

Subjects

biology, chemistry, social studies

Possible answers, page 38:

1. Problems: Currents and wind may carry the oil over a huge area of the sea.

Strategies: Bring in equipment by air or boat to skim the oil from the water's surface before it spreads.

Problems: Rocks will get covered with oil; animal habitats will be harmed.

Strategies: Have crews scrub the rocks with brushes and detergent.

Problems: The oil will wash up on shore, making cleanup difficult and affecting wildlife.

Strategies: Have crews take away or sift through oily sand and rescue wildlife.

2. These agencies have information about winds, currents, tides, and weather patterns affecting the area.

This agency has information about which species of fish and wildlife need protection.

3. Water is denser, so oil floats on it.

4. The oil will probably spread out away from the spill, staying on top of the water rather than sinking.

Procedure

1. Introduce the topic of oil pollution and how it affects the global ocean. Make a pie chart to show the actual small percentage of oil (5 percent) that enters the ocean through oil spills. Then discuss oil spills with which students may be familiar, such as the spill off the coast of Rhode Island in January 1996 and the one in Prince William Sound in Alaska in 1989. You may wish to check your library or online sources for magazine and newspaper articles about actual oil spill events, perhaps an incident that occurred close to your region to make the topic more relevant to students.

2. Explain to students that crude oil is taken directly from its rocky source below ground or under the sea. It is often transported in huge tankers across vast distances to oil refineries. There the crude is distilled and refined into many familiar petroleum products. During the distillation process, petroleum is heated to extremely high temperatures to separate it into various components such as gasoline and kerosene. Students may not know that petroleum is used for waxes contained in petroleum jelly, lipstick, and many personal care products. Each of these petroleum products has different chemical characteristics. In general, the molecules that make up oils and waxes adhere to one another and are less dense than water; thus, they float on the water's surface without mixing. However, the currents and wind out on the open ocean cause the oil in an oil spill to spread and travel away from the spill site.

3. After an initial discussion, hand out Student Page A. In this page students can use problem-solving skills to decide what strategies they would use if they were actually cleaning up an oil spill. They can work in small groups and brainstorm to come up with answers cooperatively.

Pollution Solution

Student Page A

Suppose you are in the business of cleaning up oil spills in the ocean. Your team has just received word of a tanker leaking oil in the Pacific Ocean. How will you use your resources to effectively clean up the oil and prevent it from spreading? Brainstorm in a small group to predict what will happen during the oil spill, then plan your cleanup strategies.

1. What special problems arise if an oil spill occurs in the open ocean, on a rocky coast, or near a sandy beach? (Hint: You might think about things like currents, surface area, and habitat for wildlife.) List the kinds of equipment and vehicles you might need to do the cleanup at each site in the data chart below.

Oil Spill Site	*Special Problems*	*Possible Strategies for Cleanup*
Open ocean		
Rocky coast		
Sandy beach		

2. What kind of information would be important to find out from these government services?

Weather Service or Coast Guard ____________________

____

U.S. Fish and Wildlife Service ____________________

____

3. Which do you think is denser, oil or water?

____

4. What do you think will happen to the oil (or other petroleum product) as it spills out of a tanker into the ocean? ____________________

____

Pollution Solution

Lesson Plan Step 2

Objectives

Make a model of an ocean oil spill.

Evaluate the efficiency of oil spill cleanup methods.

Materials

For each group of four students, a shallow oblong pan, water, vegetable oil, cotton balls, teaspoon, medicine dropper, timer, plastic container for wastewater, and plastic bag for discarded cotton balls.

Student Page B

Optional: liquid detergent, brush, bird feather, wire whisk, pebbles

Subjects

physics, mathematics

Procedure

1. Advise students of the activity the day before so they can wear washable clothing. Divide students into groups of four. Each group can carry out the simulated oil spill and cleanup cooperatively. Arrange to have all the materials students need at each workstation. Guide students as they read through the directions on how to make an oil spill and then clean it up. Advise them to use their resources wisely, as they will be "charged" for each piece of equipment and the disposal of the oil.

2. In carrying out the activity, limit the "disaster" to a portion of the classroom or lab where surfaces can be wiped dry. Use clear plastic bags to collect the oil-soaked cotton balls so that students can count them and be charged accordingly. Use quart-sized, wide-mouthed plastic containers for the wastewater, which can then be carried to a sink for disposal. Have paper towels on hand to clean up spilled water and advise students of slippery floors.

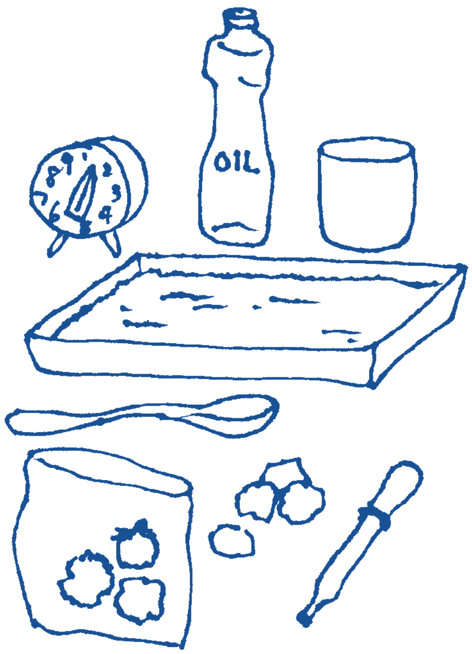
3. Options: Before students begin, demonstrate that "oil and water don't mix" by pouring some oil into a clear container of water. Have students observe how the oil forms a layer on top of the water. Then use a wire whisk to stir up the oil and water. Students will see how oil can be made into smaller and smaller droplets that will disperse in the open ocean where there is room to spread out. This is similar to one of the techniques used in cleanup operations. If students use the whisk in their pans, it will make skimming the oil much more difficult, but you might challenge some students to do it anyway. Another interesting demonstration is to dip a bird feather in oily water and have students try to clean the feather using liquid detergent and a brush.You can also challenge one group to simulate an oil spill that hits a rocky coast by using pebbles at one end of the pan. Have students compare the amount of surface area for that cleanup with an oil spill on the open ocean.

4. After the groups have worked on their oil spills for twenty minutes, have them tally the cost of their efforts and clean up their spill sites. Students can then answer the discussion questions and compare their results.

Pollution Solution

Student Page B

In this activity you will make your own "ocean" in a pan of water. You can simulate your own very limited environmental disaster—and then clean it up! Work with your group to set up the materials shown below.



1. Use the shallow pan filled halfway with water as your model ocean. Add a teaspoon of vegetable oil to the middle of the pan to simulate a leaking oil tanker.
2. While one group member releases the oil in the center of your ocean, another begins timing.
3. After one minute has passed, observe what happens to the oil. See how the oil is affected as another team member blows on the oil, simulating the wind.
4. Begin the cleanup of the oil using the available materials. You may take twenty minutes.
5. Try to do the cleanup efficiently because you will be "charged" for the use of each piece of equipment. No cleanup effort is free! Keep track of the time each technique is used. Use the chart below to calculate the cost of your efforts.

Pollution Solution Cost Sheet

Equipment and Techniques	*Cost*	*Minutes of Use or Number Used*	*Total Cost*
Medicine dropper "skimmer"	$100/minute		
Cotton ball	$20/piece		
Waste disposal:			
Discarded cotton ball	$50/each		
Container for wastewater	$1,000/each		
Labor	$1,000/person/minute		
Total cost			

Pollution Solution

Student Page B

Use the back of this page or a separate sheet to answer these discussion questions.

1. Did you clean up your oil spill within twenty minutes? Did everyone agree on how clean the pan was?

2. Which technique seemed to work best?

3. Make a chart of your class results. Which group cleaned its ocean at the lowest price?

4. What importance does immediate response have in cleanup efforts?

5. Suppose class members used different kinds of oil. Would their results be the same? Do you think all petroleum spills behave the way vegetable oil does? Why or why not?

Pollution Solution

Lesson Plan Step 3

Objectives

Identify the problems caused to the environment and society by an oil spill and the subsequent cleanup operations.

Materials

List of fictitious characters (on page 44)

Optional: newspaper or magazine articles about oil spills

Subjects

social studies, language arts

Procedure

1. To get a sense of the impact of an oil spill, have a role-playing discussion. Ask students to play the parts of some or all of the fictitious characters listed here. Have each character write some notes that would be taken to a press conference held to find out what happened when a tanker went aground and caused an oil spill along a coastline. Some members of the class can be reporters, directing questions to any of the participants. Other members of the class can record the discussion in writing or videotape it.

Fictitious characters

Captain Shipley: captain of the tanker that went aground

Ms. Petrol: spokesperson for the Giant Oil Corporation

Mr. Swab: head of cleanup operations

Ms. Cirrus: spokesperson for the U.S. Weather Service

Mr. Marchand: president of the local merchants' association

Ms. Greene: spokesperson for a national conservation group

Mr. Hook: spokesperson for the local fishing community

Ms. Wright: president of the Town Council

Mr. Labb: scientist at Innovate Corp., a bioengineering firm

Ms. Ivory: salesperson for Kleen-Up Supplies, Inc.

Mr. Byrd: conservationist from the U.S. Fish and Wildlife Service office

Ms. Goodley: spokesperson for volunteers

2. The reporters should ask questions about (a) the chain of events that led to the oil spill, (b) how each party helped with the cleanup operation, and (c) how the spill affected their lives. Student responses will vary widely but should be consistent with the attitude and professional knowledge suggested by each fictitious character's name and position. Students should be able to conclude that the responsibilities for cleanup must be shared and that local people are affected by the oil spill long after the cleanup crews have left.

3. Optional: Have students use their library to access articles about recent oil spills. Encourage students to become aware of local or regional events that are similar, if not as large.

Resources

Resources for students

Anderson, M. K. *Oil Spills*. New York: Franklin Watts, 1990.

Carr, Terry. *Spill! The Story of the Exxon Valdez*. New York: Franklin Watts, 1991.

Resources for teachers

Benchley, Peter. *Ocean Planet: Writings and Images of the Sea*. Edited by Judith Gradwohl. New York: Harry Abrams, in association with the Smithsonian Institution, 1995.

Bulloch, David K. *The Wasted Ocean*. New York: Lyons and Burford, 1989.

Earle, Sylvia A. *Sea Change, A Message of the Oceans*. New York: G.P. Putnam's Sons, 1995.

Keeble, John. *Out of the Channel: The Exxon Valdez Spill in Prince William Sound*. New York: HarperCollins, 1991.

"Rescuers Create a MASH Unit for Hundreds of Stricken Animals." *New York Times*, 4 April 1989.

Online resources

Visit Ocean Planet online at **http://seawifs.gsfc.nasa.gov/ocean_planet.html**

Using the Exhibition Topic Outline, go to Oil Pollution under Oceans in Peril for graphs showing oil pollution data. Under Resource Room, go to the Image Catalog to get photographs and illustrations of specific images suggested by the topics in the activity.

Downeaster *Alexa*:

A fishery story.

We can learn a great deal about the sea, our planet and its people by listening to songs about ships and the sea. The sea has captured the human imagination and stirred its observers to art, literature and song. People across the centuries have recorded their feelings about the sea through these art forms. You may recall looking at Winslow Homer's paintings, or reading *Island of the Blue Dolphins*, or listening to the ballad that tells of "The Wreck of the *Edmund Fitzgerald*."

In this activity we will examine a 1989 song by Billy Joel, exploring its meaning for the singer and its ability to reveal to listeners some information about humans and environmental change. The maps, fisheries data, and sea temperature information were provided by the National Oceanic and Atmospheric Administration (NOAA) to give you an idea of the variety of important subjects this agency studies and how all the information must be considered at once when important issues are addressed. The concepts studied in this activity include: *use of historical data; population; impact of human technology on a population and it's use as a food source.*

Figure 1. - A fishery scene, illustrating a downeaster boat.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

Objectives: When you have completed this set of activities, you should be able to:

1) describe a major fishery of the North Atlantic (Activity A).
2) interpret the offshore characteristics of an area using a bathymetric chart (Activity A).
3) identify human and natural environmental reasons for changes in fish catch (Activity B).
4) analyze the relationship of global environmental changes to fish population changes (Activity C).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 1, 2, 3 and 7, however the following ESUs are covered in the Extensions — 4 and 5. Refer to the Framework for ESE for a full explanation of each ESU.

Activity A: What does the "Downeaster Alexa" reveal about a fishery issue?

Popular singer Billy Joel wrote "Downeaster Alexa" as part of his personal support for the struggling fishing industry of Long Island. Joel worked on an oyster boat there when he was young. The words of the song can give us a great deal of information about the events and people of the North Atlantic striped bass fishery. Apparently the singer sees problems with the system. Are these problems related to global environmental change? How can we tell?

Materials: lyrics of "The Downeaster Alexa"; recording from Joel's *Storm Front* album; NOAA map 13003 *(Cape Sable to Cape Hatteras, 1986)*.

Procedure:
Read the words of the song as you listen to the recording. On your worksheet answer the following questions about the geography, culture and fishery conditions.

<u>Geography</u>
1) What places did the Alexa visit? List them in order; locate these on the worksheet map and connect them in order of travel.

2) Examine the map of oceanic characteristics and observe the depths of the places described in the song. How deep is the vessel's home port in Gardiner's Bay? What kind of feature is Atlantis? How deep is it? How far is it from the vessel's home port?

3) What kind of area is the singer fishing now compared to where he used to fish?

Culture and Fishery Conditions

A typical "downeaster" (downeast work boat) is shown in Figure 1. There are several types, but most are of the same general shape and size.

4) Does the song indicate the size of the Alexa's crew? If there are others aboard, how would you describe the singer's position among them (that is, is he the captain, a crew member, navigator, or what)?

5) Is the Alexa crew fishing for fun or for a trophy size fish to mount and display (sport fishing) or fishing for a livelihood (commercial fishing)?

6) Analyze the financial status of the fisher who is singing. For example, does he make much money? How do you know? What things does he value in his life? What are his responsibilities?

7) According to the song, what influenced the fisher to choose this occupation? How likely is he to be successful in it? Why doesn't he give up fishing for some other line of work?

Fish and Fishing

Three kinds of fish are named in the song. Figure 2 contains some information about them that may be useful.

8) What kind of fish had the singer apparently been catching? Why doesn't he catch them now? What is his alternative?

9) Where are the alternative kinds of fish found (using your map)? Why does each fish pose a problem for the fisher?

10) According to the singer, how does fishing at present compare with previous years?

The Downeaster Alexa

by Billy Joel

Well I'm on the Downeaster Alexa
And I'm cruising through Block Island Sound
I have charted a course to the Vineyard
But tonight I am Nantucket bound.

We took on diesel back in Montauk yesterday
And left this morning from the bell in Gardiner's Bay
Like all the locals here I've had to sell my home
Too proud to leave I worked my fingers to the bone

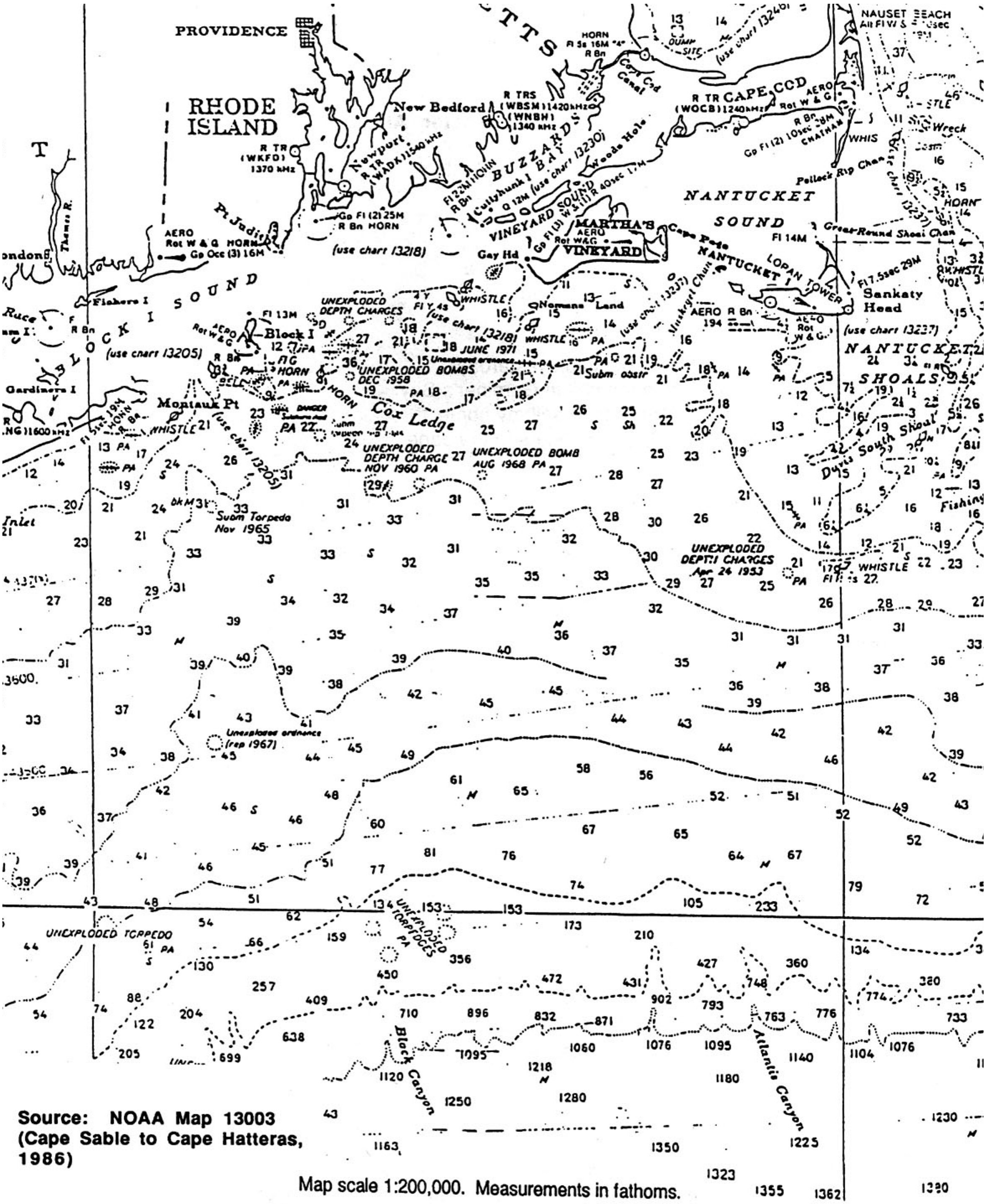
So I could own my Downeaster Alexa
And I go where the ocean is deep
There are giants out there in the canyons
And a good captain can't fall asleep

I've got bills to pay and children who need clothes
I know there's fish out there but where God only knows
They say these waters aren't what they used to be
But I've got people back on land who count on me

So if you see my Downeaster Alexa
And if you work with the rod and the reel
Tell my wife I am trolling Atlantis
And I still have my hands on the wheel

Now I drive my Downeaster Alexa
More and more miles from shore every year
Since they told me I can't sell no stripers
And there's no luck in swordfishing here

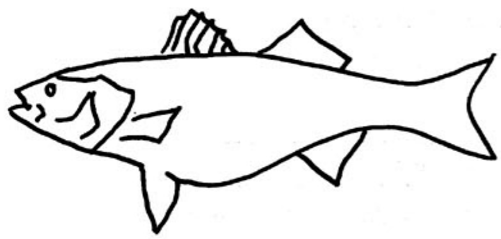
I was a bayman like my father was before
Can't make a living as a bayman anymore
There ain't much future for a man who works the sea
But there ain't no island left for islanders like me



Source: NOAA Map 13003 (Cape Sable to Cape Hatteras, 1986)

Map scale 1:200,000. Measurements in fathoms.

Striped Bass ("striper")

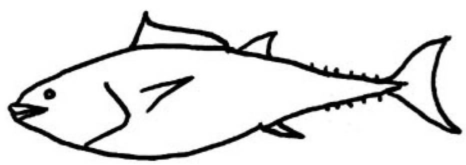


Size: adults 20-100 lb.; most bass of 30lb or more are females

Range: nearshore waters (to 4 miles) of eastern U.S; concentrations in Chesapeake Bay and Cape Cod/Gulf of Maine; temperature dependent, 19 - 23°C

Value: a leading game fish in North Atlantic; Commercial catch regulated since 1982.

Bluefin Tuna ("giants" in the song)

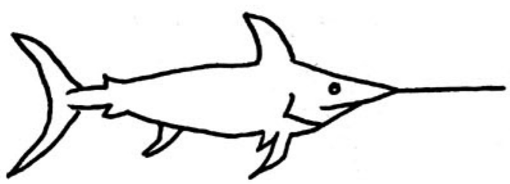


Size: adults up to 10 feet, 2000 lb.;

Range: mostly deep offshore waters; ranging as far north as Newfoundland in summer.

Value: prized by commercial and sport fishers: edible fighting fish.

Swordfish



Size: 6 - 15 feet, up to 1200 lb.

Range: lives in all warm seas.

Value: Prized by sport fishers for trophy; harpooned commercially as food fish.

Figure 2. - Three types of fish named in the song 'The Downeaster Alexa." (Mariners still use English measures rather than metric.)

Activity B: What causes the decline of a fishery?

Materials: data in Table 1; graph paper, pencil and pen or two colored pencils.

Procedure:
Make a graph of the total number of pounds of striped bass caught in U.S. waters of the North Atlantic since 1965. Answer the following questions.

1) In what year were the most stripers caught in US waters? When was the catch the lowest? Describe the general trend of the graph up to the present. What does this suggest about the size of the striper population in these waters?

2) Make a list of possible factors that can cause fish populations to change as they do in the graph. You may be able to get some ideas from the activity called *Yellow Perch in the Great Lakes.* Consider climatic effects, human impacts, water characteristics, predator-prey interactions, etc., and suggest specifically how each factor would contribute to fish population changes.

[See Teacher Information page following the Activity.]

3) If possible, collect historical records of the factors you have identified. Do their trends relate to those of the striper catch?

	A	B	C	D
1	YEAR	Total Catch	MA Catch	NY Catch
2	1960	8550	129	731
3	1961	9461	210	910
4	1962	8611	589	657
5	1963	9288	480	673
6	1964	8557	522	995
7	1965	7710	463	740
8	1966	9075	585	1050
9	1967	10469	662	1630
10	1968	11104	874	1551
11	1969	12397	1038	1535
12	1970	11134	1344	1338
13	197	7821	749	1184
14	1972	10105	1174	836
15	1973	14733	1368	1741
16	1974	11017	1258	1409
17	1975	8833	1360	1184
18	1976	6536	1360	851
19	1977	5520	1185	766
20	1978	4589	860	1122
21	1979	3458	695	570
22	1980	4652	887	598
23	1981	4262	708	822
24	1982	2429	643	471
25	1983	1674	230	296
26	1984	2933	107	595
27	1985	1232	119	469
28	1986	337	96	
29	1987	431	78	
30	1988	407	80	
31	1989	205	172	
32	1990	823	148	82

Table 1. - Striped bass commercial landings (thousands of pounds), 1960-1990.

Dr. Charles Coutant of the Oak Ridge National Laboratory has used general circulation models to predict changes in striped bass numbers and range if CO_2 were doubled and the earth's climate warmed. The "thermal niche" of adult striped bass is about 19 - 23°C. Juveniles are usually found in warmer water, but adults avoid 25°C and higher. Bass migrate up and down the coast as seasonal temperatures change.

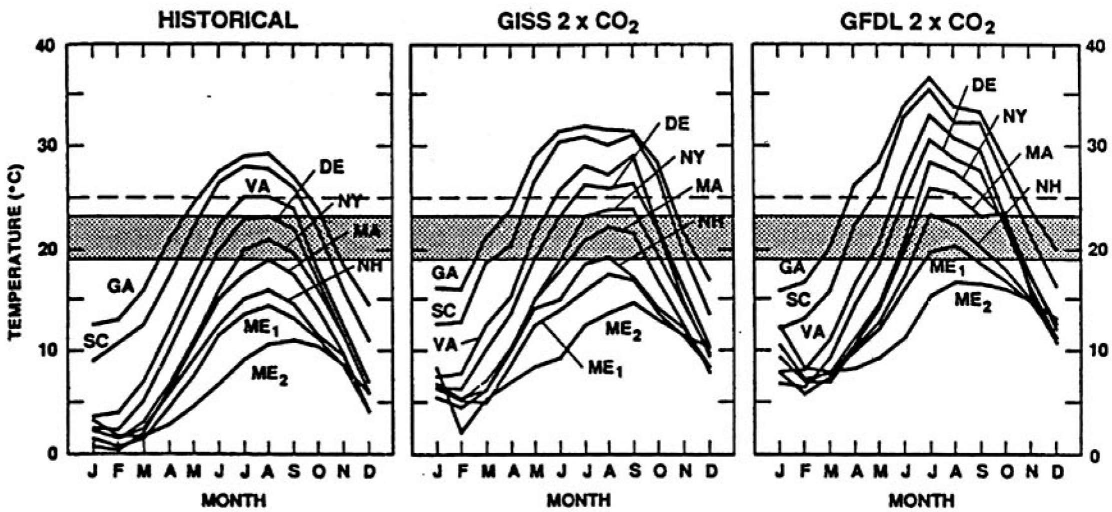


Figure 3. - Atlantic coastal water temperatures, historical and as projected by two general climate models (GISS, GFDL) that simulate a climate with a doubled CO_2 concentration. Dashed line indicates the upper avoidance temperature for adult striped bass (25°C); shaded area is the striped bass thermal niche (19 - 23°C). (Source: Coutant, *Transactions of the American Fisheries Society*, 119 (2) : 240 - 253, 1990)

4) Climate models predict a northward shift of water temperatures (Figure 3) and this can be used to forecast where the fish will be found in the future. Study the model predictions. (Also refer to 'Understanding Climate Models' fact sheet, available in the back of this book.) If a fisher goes out from Long Island in the year 2020, what is the possibility of a good catch of striped bass, compared with today's catch?

5) Look at the graph of striped bass catch from 1930 - 1960 (Figure 4) and compare it with the one you constructed from Table 1. Is the current trend an unexpected one? What forces are acting on the bass population now that were probably not as important earlier?

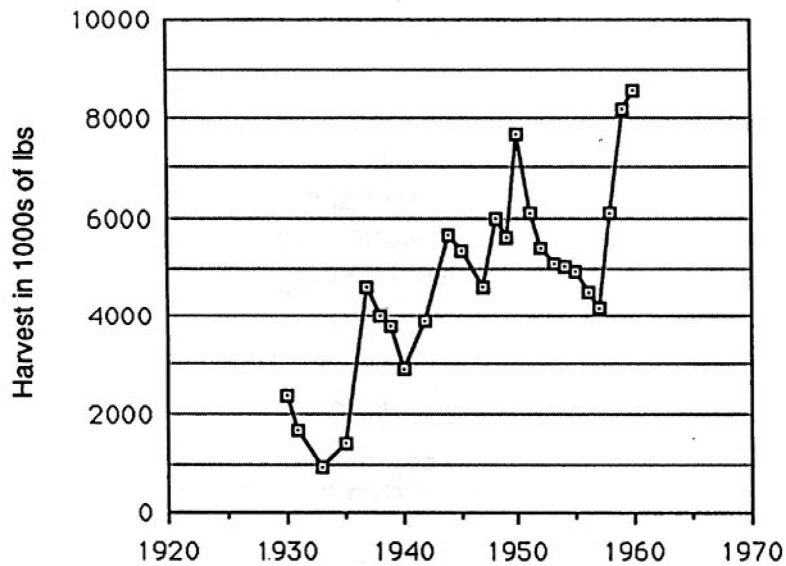


Figure 4. - Striped bass landings in the U.S., 1930 - 1960.

6) At present, striped bass are not found in the Great Lakes, although their physiology would allow them to live in fresh water. Look at a map of North America and note where the Great Lakes empty into the sea. From what you have learned in Activity B, discuss why striped bass haven't entered these waters yet. If climate changed to warmer, predict what could happen. Compare your prediction with what has happened with other Great Lakes invading species.

Activity C: How many fish should be caught?

All of the fish named in *The Downeaster Alexa* song are being **regulated**; in other words, rules have been made so that fish catches can only reach a specified quota. This will ensure that enough fish are left to continue the population. Fishery managers call this a **sustainable yield** of fish. Coastal states can make rules for fish caught within three miles of land. The federal government regulates fishing from three miles to 200 miles offshore (the Fisheries Conservation Zone, FCZ).

Materials: graph constructed in Activity B; Figures 5 - 6; Chart A; pencil or pen; fishery regulations in Table 2.

Procedure:
Answer the following questions on your worksheet:

1) Some fishers would say that regulations on fishing are responsible for the decline in fish catch, not a decreasing number of fish available in the water. Fishery managers say low catches prove the population is in need of protection (regulation). Who is correct? Describe the kinds of evidence you would need to decide which was the more correct interpretation of the declining catch.

2) On the graph you did for Activity B, plot the New York or the Massachusetts catch. Does the graph of the state catch show the same trend as the US graph? Describe how they are related or different.

3) If you were a commercial fisher in New York or Massachusetts, could you use this graph to argue for less regulation of your catch? Why or why not?

Though the magnitude of change is not so dramatic in the states, New York and certain other states have closed the fishery for some years and reopened in others. Examine Table 2, a summary of the fishery regulations in 1990.

4) Look at the graph of bass landings by distance from shore (Figure 5). Does it appear that commercial fishers would benefit if they were to go farther from shore to catch stripers? Besides sailing farther, what other changes would probably be required for offshore fishing? Which of the 3 kinds of fish in Activity A are most likely to be caught farther offshore (in deeper waters)?

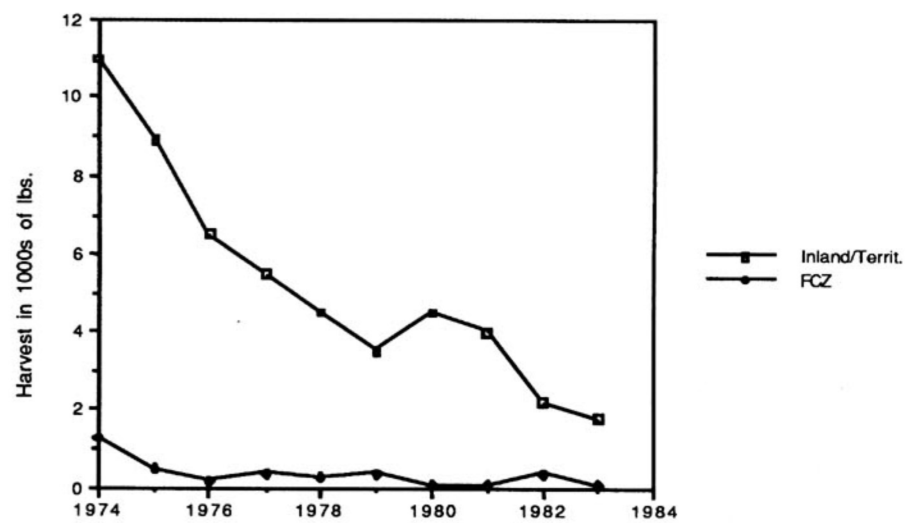


Figure 5. — Striped bass harvest by year for inland waters and FCZ (200 mile zone).

The regulations on striper fishing are based on the size of the fish and the age at which they become sexually mature (able to spawn). Female striped bass differ from males in size. Males rarely exceed 11 years and 30 pounds. A female at 16 years could weigh more than 40 pounds. Complete Chart A as follows to compare the impact of fish sizes on the potential for population growth.

5) If a day's catch is 100 stripers, half male and half female, all about 12 inches long, what proportion of males will have had a chance to spawn? What percentage of females might have spawned? At what fish size and age would most of the males have had a chance to spawn? At what age would most females be spawning?

6) Assume that in one spawning, 1 million eggs are produced and 0.5 million fry emerge. If only larger, therefore older, fish can be caught, how will the fishers

ultimately benefit from letting the fish grow larger? Fill in Chart A to demonstrate this.

7) Since most males are mature before females, the continuation of the population is based on how big the females are when they are caught. Review the regulations for the Atlantic states in Table 2. What do the differences suggest about the health of the fisheries in these states?

8) Analyze the benefits of regulating the striped bass fishery, both to the fishers and to the fish population. Identify any drawbacks that might emerge from such regulation.

Age of fish at catch	Size of Female	% of Fs spawning	# spawns per female X	# young per age per year	Fishery benefit X 0.5 = (fish added to pop.)
2	12"	0			
3	16"	0			
4	20"	25			
5	10 lb	75			
6	18 lb	95			
7	25 lb	100			
8	35 lb	100			

(NOTE: Striped bass are known to live to be 30 years old!)

Chart A. - Contribution to striped bass population by adults of different sizes

State	Size Limits	Cap (1,000 lb)	Seasons[1]
ME	no fishery		
NH	no fishery		
MA	36" minimum	160	1 Jul - 30 Sep
RI	18" minimum 26" maximum (40" maximum for gear other than trap net)	35[2]	
CT	no fishery		
NY	24" minimum 28" maximum	128[2]	1 Sep - 15 Dec
NJ	no fishery		
PA	no fishery		
DE	28" minimum	34	18 Mar - 31 Mar
MD			
Bay & River	18" minimum 36" maximum	319	12 Nov - 31 Jan[1] (includes all gears)
Ocean	28" minimum	25	2 Jan - 31 Jan
PRFC	18" minimum 36" maximum	156	various weeks during Sep, Oct, Nov, & Dec (total of 52 days)
DC	no fishery		
VA			
Bay & River	18" minimum 36" maximum	211	5 Nov - 9 Nov
Ocean	28" minimum 36" maximum		
NC			
Ocean	28" minimum	96	12 Feb 19 Feb - 23 Feb 26 Nov - 23 Dec

Note: More detailed information may be found in the text under state regulations.

[1] All seasons are calendar year 1990, except for Maryland Bay and River, which extended into 1991.

[2] Caps were reduced by ASMFC to offset the effects of slot limits with minimum size limits less than 28" on coast.

Table 2. - Summary of state harvest regulations on the commercial fishery for striped bass for 1990. (Source: NOAA, *Emergency Striped Bass Research Study Report for 1990.*)

9) Compare the history of whaling with the problem of what size of striped bass can be caught (Figure 6). What has happened to the largest species of whales? How could we prevent similar problems with striped bass?

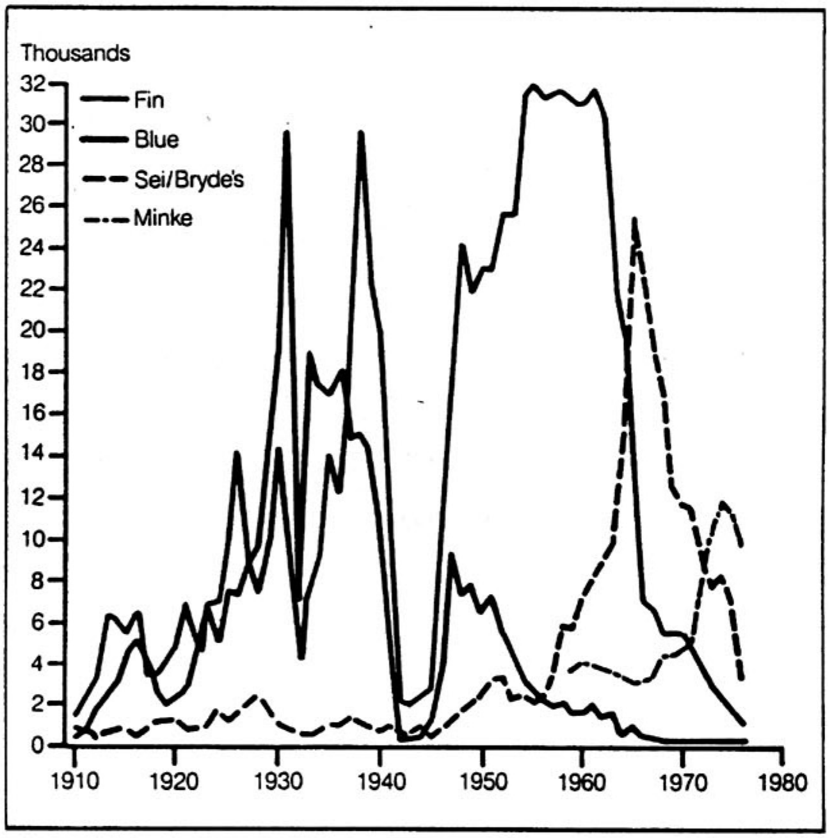


Figure 6. – World catches of five whale species, 1910-1976. (Source: Frost, *Whales and Whaling*, 1978.)

Review the Downeaster *Alexa* lyrics in light of what you now know about the striped bass fishery. Consider how much can be learned from a well-constructed art form such as this song. In the plight of a bass fisher we have found information connecting all the Earth systems: hydrosphere, atmosphere, lithosphere, and biosphere. Draw a concept map illustrating the relationships important to the *Downeaster Alexa.*

Is there a fishing industry (commercial or recreational) in your area? Examine the industry in your locality in light of what you have learned from this activity.

Extensions:

1) Fish are dependent on the interaction of the different subsystems of air, land, ice, water and life to live. Select one of the three species of fish from this activity and investigate its life cycle. Show how an alteration in one of the systems (besides global climate change) would impact the life cycle of the selected fish species.

2) Compare what you have learned in this activity, particularly that knowledge concerning the fisher's career, with a fisher on a large trawler or floating fish factory. What are the economics involved in these two different types of fishing? Compare the daily catch of each. Do you think that fishers like those in the song will survive economically? (The *National Geographic* article "Bering Sea" can be used in this extension.)

3) Commercial fishing is another industry that is dependent on a natural resource. Is this resource being used wisely? How is it regulated? Many people wonder if it is safe to eat fish because of the various chemicals flowing into rivers and eventually pouring into the sea. Is it any less safe than eating vegetables that have been sprayed or meat that has been produced on a factory farm? Like all systems on this planet, life has evolved over a long period of time, many millions of years. Different life forms have adapted to their environment. Is modern technology changing the environment so fast that species, such as fish, cannot adapt to this altered environment? Support your answer with evidence.

4) Many inland fishing areas are threatened by pollution, while other areas have been over-fished. Such areas may be re-stocked by the Fish and Game Divisions of the Department of Natural Resources of those states. How can you relate what you have learned in this activity concerning over-fishing, regulation of catch size, etc., to this situation?

5) Commercial fishers use drift nets. These nets catch large numbers of fish, but they also catch other marine species, such as dolphins, sharks, turtles, which become entangled in the netting and die. Investigate the damage that is caused by these nets and what has been done to try and stop their use.

Additional Teacher Notes:

Hypothesis	Research	Summary
Contaminants	*In situ* and onsite bio-assays in spawning rivers.	
	Maryland Nanticoke 1984-90 C & D Canal 1985-90 Choptank 1987-90 Potomac 1986, 1989-90	Toxic conditions in some rivers in some years. No single contaminant is consistently responsible for mortality. Point source discharge has been implicated.
	Virginia Rappahannock 1989-90 Mattaponi 1989-90 Pamunkey 1989-90 James 1989-90	Survival generally high. Metals concentrations much lower than in Choptank and Nanticoke Rivers
	Laboratory experiments: pH, aluminum and metals for various life stages	Highly sensitive to pH below 6.0 and aluminum concentrations. Salinity and organic acids ameliorate effects.
Starvation	Laboratory studies	Limited evidence of impact except perhaps in Potomac R.
Fishing Mortality	Extensive management changes. Simulation modeling.	Strong evidence of over-exploitation that reduced recruitment. Difficult to distinguish from effects of other factors.
Predation/ Competition (Larval Stage)	Exposed larvae to variety of predators in laboratory.	Numerous potential predators, but evidence in field data is lacking.
Climatic Events	Evaluated historical data on pH trends in major spawning rivers.	No evidence of systematic decrease in pH or increased frequency of low pH events. Historical information is insufficient to detect small changes.
Water Use Practices	Evaluated flow conditions invicinity of Cape Cod Canal	Evidence of transport out of Bay and entrainment of larvae. Overall impact is uncertain. Canal may serve as major egress for juveniles and adults from Chesapeake Bay.
Disease	Laboratory studies of IPN virus	Nonlethal, but striped bass can act as carriers. Potential disease problems in intensive culture, but much lesser problem in nature.

Summary of Emergency Striped Bass Study research on factors responsible for the decline of striped bass in Chesapeake Bay. (Source: NOAA, *Emergency Striped Bass Research Report for 1990.*)

Teacher Background Information:

Deuel, D., McDaniel, D. and Taub, S. 1989. *Atlantic coastal striped bass road to recovery.* Washington, D.C.: NOAA and US Fish and Wildlife Service.
This is the most concise and easily understood of the references.

Phillips, J. H. c1991. *They're Back.* Maryland Department of Natural Resources, Tidewater Administration — Fisheries Division Tawes State Office Building Annapolis, Maryland 21401.
This brochure from the Maryland DNR documents the history of the striped bass in the area. It examines the life history of the fish, its spawning habits, growth rates, food sources and schooling habits. The author traces the decline of the fishery, the measures used to halt this decline and the current status of this fish species.

Bigelow, H. B. and Schroeder, W. C. 1953. *Fishes of the Gulf of Maine.* Fishery Bulletin 74, Vol. 53 : 389 - 404.
This is a more technical bulletin but is useful as various characteristics of the striped bass are outlined. The historical records of habits of this fish species are also documented. One section examines the periodic fluctuations in the distribution of the bass, using different historical sources.

References:

Coutant, C. C. 1990. "Temperature-oxygen habitat for freshwater and coastal striped bass in a changing climate." *Transactions of the American Fisheries Society.* 119 (2) : 240 - 253.

Fortner, R. W. and Leach, S. 1986. *Yellow Perch in Lake Erie.* OEAGLS Activity #9. Ohio Sea Grant Education Program. (Available from The Ohio Sea Grant Program, 1314 Kinnear Rd., Columbus, OH. 43212-1194.)

Frost, S. 1978. *Whales and Whaling. Volume 1.* Canberra: Australian Government Publishing Service. 32 - 33.

Hodgson, B. 1992. "Hard Harvest on the Bering Sea." *National Geographic.* 182 (4) : 72 - 103.

Rago, P. J., Dorazio, R. M., Richards, R. A. and Deuel, D. G. 1992. *Emergency striped bass research study report for 1990.* Washington, D.C.: US Fish and Wildlife Service and NOAA. USGPO: 1992-313-153:60019.

Richkus, W. A. 1990. *Source document for the supplement to the Striped Bass FMP. Fisheries Management Report #16.* NOAA Atlantic States Marine Fisheries Commission.

Setzler, E. M. and others, 1980. *Synopsis of biological data on striped bass, Morone saxatilis, (Walbaum).* NOAA Technical Report. NMFS Circular 433.

VIDEO: Government of Canada, Department of Fisheries and Oceans, and Department of External Affairs. 1992. *Fragile Fishery.*
While not specifically dealing with the American Fishing Industry, this video does deal with many of the issues outlined in this activity and the concept of declining fish stocks.
Available from Department of External Affairs, Ottawa, Canada (613 992-1344).

Fresh and Salt

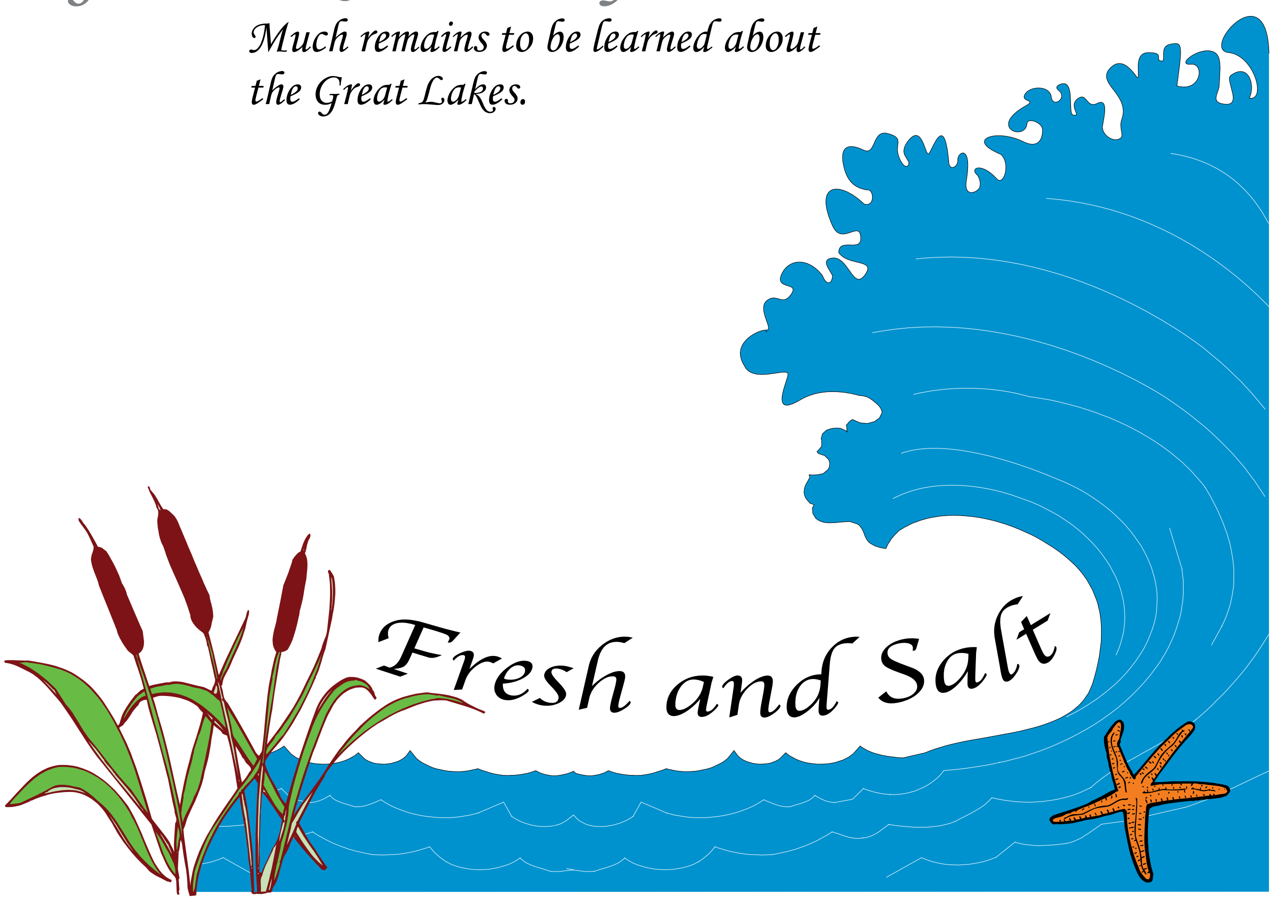
Principle 7

Ocean Literacy

The ocean is largely unexplored.

Great Lakes Literacy

Much remains to be learned about the Great Lakes.



Fresh and Salt

Principle 7: The ocean is largely unexplored. (OL) Much remains to be learned about the Great Lakes. (GL)

Essential Principle #7 addresses exploration, inquiry, and study of the ocean systems and processes. Over the last few decades, the use of ocean and Great Lakes resources has significantly increased. Therefore, it is vital to the future sustainability of our oceans and the Great Lakes to build an understanding about those resources and their potential limitations.

Technological innovations are expanding our ability to conduct exploration using tools such as satellites, unmanned submersibles, and mathematical models. Explorers of the past read journals published upon the return of an expedition. Weather was recorded from instruments by hand. Scientists can now rely on underwater robotic vehicles and real-time data for information.

The Great Lakes, the largest bodies of fresh water in the world, in addition to our oceans, are vast resources for biologists, zoologists, historians, and humanitarians. They provide a wealth of information and underwater cultural resources and hold many secrets yet to be discovered.

Both of the activities in this set focus on the history and modern exploration of ocean discoveries and explore innovative ways to improve the literacy of learners with respect to Great Lakes and ocean issues.

I, Robot, Can Do That!, from NOAA Ocean Explorer, is designed for grades 7–8 engages students in small group work to describe and contrast several types of underwater robots. Each student group is assigned an underwater robot that can be used to perform various tasks that support scientific exploration of the deep ocean. Each group provides a brief oral report of the features of their robot and completes an "Underwater Robot Capability Survey" to record details about the special advantages and capabilities of their vehicle.

In addition, students learn about a series of mission trips for which an underwater robot is needed and then discuss whether their robot is capable of the mission. Mission descriptions include expeditions such as: studying fish communities around deep water coral reefs; exploring the wreck of a Spanish galleon; and studying an unexplored chain of underwater volcanoes. This lesson investigates important learning concepts including hydrothermal vents, plate tectonics, and ecosystems.

Educators who reviewed this activity offered the following reflective comments:

"Great Lakes relationships could be introduced or reinforced by having students design a robot vehicle that would go into the lake and also describe what it would be used for. In that process, they would learn about Great Lakes relationships."

"This lesson requires students to perform research and collect data, as well as organize the data and present it orally or otherwise."

"The materials are accessible because you could use the internet, print-outs from the internet, or you could even make information cards. It's quite adaptable for use."

"One can incorporate visualization [in the Resources section] with the background information and see what scientists see from real life submersible robots—make real feed."

"The activity gets students to practice their skills of problem solving and experimental design."

"It initiates much debate among students as to which vehicle would best solve the problem scenario at hand."

Calling all Explorers, from *Ocean Explorers,* takes students, in grades 5-9, along with them through the NOAA Ocean Exploration (OE) website as they research and write about what it means to be an ocean explorer, both modern and historical. This activity investigates the history of ocean exploration with emphasis on recent explorers of deep-sea environments. Students are asked to reflect and write about differences and similarities between explorers of the past and modern day explorers, as well as to describe the nature of oceans and ocean exploration.
This lesson is designed to enable students to move at their own pace, in self-directed exploration of the Ocean Exploration site. Working in small groups at the computer, students navigate the OE site to locate the "Deep East" ocean explorers via the Cooperative Explorers Web Quest Data sheet. Using updates and logs from the manned submersible Alvin, during the "Deep East" Expedition, students investigate scientists' research including: video footage from the bottom of the Atlantic; data of the biological, geological, and chemical features of the surrounding areas; and examinations of deep-sea water corals and methane hydrates.

In addition, students visit the *Reading for Ocean Explorers* collection, a digital library of complete documents and excerpts from letters, autobiographies, federal government reports, science articles, and reminiscences. This collection illustrates the history, science, and extraordinary personal stories of those involved in the exploration of the oceans. Students also have an opportunity to meet science mentors and role models online during their journey.

Educators who reviewed this activity shared these comments:

"Two full pages of background information on the history, expeditions and agencies related to ocean exploration are provided."

"They learned about [the submersible] Alvin and some of the scientists who have participated in ocean explorations. They also learned that scientists study many aspects of the ocean and have specialized studies."

"This reinforced aquatic biodiversity with another web quest lesson on the Great Lakes [important for comparing/contrasting with Great Lakes concepts]."

"You need one computer for every two students and two sessions to finish this web quest on a grade 6-8 level." (helpful tip for educators as they plan for this activity)

"Seeing the pictures of ocean exploration was interesting to my students."

ocean explorer
oceanexplorer.noaa.gov

Aegean and Black Sea 2006 Expedition

I, Robot, Can Do That!

(adapted from the 2005 Lost City Expedition)

Focus
Underwater robotic vehicles for scientific exploration

Grade Level
9-12 (Life Science/Earth Science)

Focus Question
How can underwater robots be used to assist scientific explorations?

Learning Objectives
Students will be able to describe and contrast at least three types of underwater robots used for scientific exploration.

Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific exploration.

Given a specific exploration task, students will be able to identify robotic vehicles best suited to carry out this task.

Materials
None

Audio/Visual Materials
None

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Six groups of students

Maximum Number of Students
30

Key Words
ABE
ROPOS
Remotely Operated Vehicle
Hercules
Tiburon
RCV-150
Robot

Background Information
The geographic region surrounding the Aegean and Black Seas has been the stage for many spectacular performances in Earth's geologic and human history. Human activities on the region's stage began during Paleolithic times; artifacts discovered near Istanbul are believed to be at least 100,000 years old. Well-known Aegean cultures include the Minoans (ca 2,600 – 1,450 BC), Mycenaeans (ca 1,600 – 1,100 BC), Ancient Greeks (776 – 323 BC), and Hellenistic Greeks (323 – 146 BC). Istanbul—"the only city that spans two continents"—has been a crossroads of travel and trade for more than 26 centuries. Mariners have traveled the Aegean and Black Seas since Neolithic ("Stone Age" times; 6,500 – 3,200 BC), probably for a combination of purposes, including trading, exploration, and warfare.

Interactions between these cultures and many others were often violent and destructive. So, too, were interactions with geological processes. Some of these processes are directly related to the same forces that are believed to have caused the breakup of Pangaea (see "Volcanoes, below). One of the most dramatic and destructive events was the eruption of a volcano in a small group of Aegean islands called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. Estimated to be four times more powerful than the Krakatoa volcano of 1883, the eruption left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climactic impacts. Accompanied by earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization on the island of Crete, 110 km to the south. On Thera, the largest of the Santorini islands, the ancient city of Akrotiri was completely buried beneath the ash. Excavation of the city began in 1967, and is ongoing. The Bronze Age eruption of the Santorini volcano was by no means its last. In fact, the volcano erupted at least 12 times between 197 BC and 1950 and most geologists agree that a violent eruption will happen again.

Interactions with other geological processes may have been equally disastrous. In 1997, geologists William Ryan and Walter Pitman published a theory in which the Black Sea was inundated around 5,600 BC by flood waters from the Mediterranean passing through the Straits of Bosporus at Istanbul. Such a deluge, if it occurred, would have been disastrous for human settlements along the Black Sea shoreline and might have provided an origin for accounts of cataclysmic floods in Christianity and other cultures. Subsequent research has neither proved nor disproved the Black Sea deluge theory, but in 2000, Robert Ballard discovered remains of a wooden structure that may have been part of an ancient seaport 95 meters below the surface of the Black Sea (see http://news.nationalgeographic.com/news/2000/12/122800blacksea.html). This may be one of the best places in the world to look for remains of ancient civilizations, because the deep waters of the Black Sea contain almost no oxygen, so the biological organisms that normally attack such relics cannot live in this environment.

Finding well-preserved archaeological sites, studying ancient maritime trade, and exploring the history of the Theran volcano are the primary goals of the Ocean Explorer Aegean and Black Sea 2006 Expedition. Explorations to pursue these goals are divided into two segments. In the first segment, side-scan sonar, subbottom profiling, and multibeam bathymetric technology are used to survey selected portions of the Aegean, Black, and Eastern Mediterranean Seas. The second segment uses remotely operated vehicles (ROVs) for direct visual observation of promising sites located during the first segment. Increasingly, robotic vehicles are becoming essential tools of modern ocean exploration. In this lesson, students will investigate underwater robots and how ocean explorers use them.

Learning Procedure

1. To prepare for this lesson:
   - Review the background essays for the Aegean and Black Sea 2006 Expedition at http://oceanexplorer.noaa.gov/explorations/06blacksea/; and
   - Review the Ocean Explorer Web pages on underwater robotic vehicles, indexed at http://oceanexplorer.noaa.gov/technology/subs/subs.html.

   If students do not have access to the internet, make copies of relevant materials on underwater robotic vehicles from the Web site referenced above.

2. Briefly introduce the Aegean and Black Sea 2006 Expedition emphasizing ways in which underwater robots will be used by the Expedition. You may want to show video clips

from some of the sites referenced in Step 1 to supplement this discussion.

3. Tell students that their assignment is to investigate underwater robots that can be used to perform various tasks that support scientific exploration of the deep ocean. Assign one of the following robots to each student group, and provide each group with a copy of "Underwater Robot Capability Survey:"
   Autonomous Benthic Explorer (ABE)
   Hercules
   Remotely Operated Platform for Ocean Science (ROPOS)
   General Purpose Remotely Operated Vehicles (ROVs)
   RCV-150
   Tiburon

   You may want to direct students to the Ocean Explorer Web pages on underwater robotic vehicles (see above). If students do not have access to the internet, provide copies of the relevant materials to each group.

4. Have each student group present a brief oral report of the capabilities of their assigned robot. The following points should be included:

Autonomous Benthic Explorer (ABE)

- capable of operating to depths up to 5,000 meters
- autonomous vehicle; no tether to support ship
- tools: video cameras, conductivity and temperature sensors, depth recorder, magnetometer, sonar, wax core sampler, navigation system
- developed to monitor underwater areas over a long period of time
- follows instructions programmed prior to launch; data are not available until robot is recovered
- operates independently during missions, but requires technicians and engineers for maintenance, as well as data managers to retrieve information stored in computer memory

Remotely Operated Platform for Ocean Science (ROPOS)

- capable of operating to depths up to 5,000 meters
- 5,500 m of electrical-optical cable tether
- tools: two digital video cameras; two manipulator arms that can be fitted with different sampling tools (stainless steel jaws, manipulator feedback sensors, rope cutters, snap hooks, core tubes); variable-speed suction sampler and rotating sampling tray; sonar; telemetry system
- can also be outfitted with up to eight custom-designed tools such as a hot-fluid sampler, chemical scanner, tubeworm stainer, rock-coring drill, rock-cutting chainsaw, laser-illuminated, range gated camera, and downward-looking digital scanning sonar
- wide variety of observation tools provides scientists with exceptional flexibility so they can quickly respond to new and unexpected discoveries
- a "typical" dive requires at least four people (and sometimes more): the "Hot Seat" scientist, pilot, manipulator operator, and data/event logger

General Purpose Remotely Operated Vehicles (ROVs)

- depth capability varies
- operated by one or more persons aboard a surface vessel
- linked to the ship by a group of cables that carry electrical signals back and forth between the operator and the vehicle
- tools: most are equipped with at least a video camera and lights
- additional equipment may include a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration, and temperature
- also used for educational programs at aquaria and to link to scientific expeditions live via the internet
- range in size from that of a bread box to a

small truck
- often kept aboard vessels doing submersible operations for safety, and so the ROV can take the place of the submersible when it cannot be used because of weather or maintenance problems
- can also be used to investigate questionable dive sites before a submersible is deployed to reduce risk to the submersibles and their pilots

Hercules

- capable of operating to depths of 4,000 meters
- pilots operate Hercules via a long fiber-optic cable
- designed primarily to study and recover artifacts from ancient shipwrecks
- tools: High-Definition (HD) video camera; pair of still cameras to accurately measure the depth and area of the research site and to create "mosaics;" sensors for measuring pressure, water temperature, oxygen concentration, and salinity
- hydraulic thrusters—propellers in fixed ducts—control the ROV's movements
- yellow flotation package makes Hercules slightly buoyant in seawater
- components that are not in pressure housings are immersed in mineral oil, which does not compress significantly under pressure
- operates in tandem with tow sled "Argus"
- 30-meter (100 foot) tether connects Hercules to Argus
- Argus carries an HD video camera similar to the one on Hercules, as well as large lights that illuminate the area around Hercules
- generally operates 24 hours a day while at sea, different teams called "watches" take turns operating the vehicle
- six watch-standers on each watch:
  – Watch Leader makes sure that the scientific goals of the dive are being addressed
  – Pilot operates Hercules, controlling its thrusters, manipulator arms, and other functions
  – Engineer controls the winch that moves Argus up and down, as well as Argus' thrusters and other functions, and assists the Pilot
  – Navigator monitors the work being done and the relative positions of the vehicles and ship and communicates with the ship's crew to coordinate ship movements
  – Video and Data watch-standers record and document all the data that the vehicles send up from the deep
- Little Hercules replaces Hercules for some missions; Little Hercules has no arms or tools, only gathers video images

Tiburon (ROV)

- capable of operating to depths 4,000 meters
- controlled from a special control room on board its tender vessel, the R/V Western Flyer.
- tether contains electrical wires and fiber-optic strands
- electrical thrusters and manipulators, rather than hydraulic systems, allow vehicle to move quietly through the water, causing less disturbance to animals being observed
- variable buoyancy system allows the vehicle to float motionless in the water without the constant use of the thrusters
- lower half of the vehicle is a modular toolsled, which can be exchanged with other toolsleds to carry out specific missions: benthic (or bottom) toolsled has an extra manipulator arm and extensive sample-carrying space for geological and biological samples; "midwater" toolsled used to explore the biology of open ocean creatures; rock coring toolsled has been used to take oriented rock cores from the sea floor

RCV-150

- capable of operating to depths of 914 m
- tethered to support ship via a double armored electro-optical umbilical
- tools: color video camera, 1500 watts of lighting, micro conductivity/temperature/depth sensor, sonar, manipulator with a six inch cutoff wheel

- controlled by a single pilot from a control console located in the tracking room of the support ship
- small size compared to a submersible allows ROV to have high maneuverability; can get close to the bottom and allow the cameras to peer under ledges and into nooks and crannies
- much easier to launch and recover than a manned submersible so it can be used at night while the submersible is being serviced
- primary data collected is in the form of video
- has been used to conduct surveys of bottom-fish in Hawai'i
- In the event of a submersible emergency with one of the Pisces submersibles in water depths less than 3000 ft, the first action after notifying rescue assets would be to deploy the RCV-150 to evaluate the nature of the emergency and if entangled, try to free the submersible with the radial cutter

5. Tell students that you are going to describe a series of missions for which an underwater robot is needed. After they hear each mission description, each group should decide whether their robot is capable of the mission, and then discuss which of the candidate robots is best suited for the job.

   Read each of the following mission descriptions:
   (a) We are planning an expedition to study an unexplored area of the Arctic Ocean with a maximum depth of 3,000 meters. We are particularly interested in geological formations, and want to collect rock cores and samples of biological organisms that may be living on these formations.
   [ROPOS and Tiburon can be fitted with a rock-coring drill and biological sampling equipment.]

   (b) As part of the ongoing study of the Santorini volcano, we want to survey selected underwater areas around the islands that may show evidence of sunken cities. This will require a robot that can travel back and forth across a survey area, maintaining a distance of about 5 meters from the bottom, with continuous depth recordings and video images taken every 10 meters.
   [Several robots have the capability to do this work, but ABE is best suited for this type of survey since it can operate independently while humans do other work.]

   (c) We are studying fish communities around deep water coral reefs off the coast of Florida (depth 500 – 700 m). We need video records of fish species in a variety of habitats, particularly under coral ledges near the bottom.
   [RCV-150 and some General Purpose ROVs could do this work. RCV-150 has been used specifically for fish surveys, and its small size allows it to work close to the bottom and record images under ledges.]

   (d) We are developing an educational program for our city aquarium, and want to show some of the capabilities of underwater robots. What kind of robot would be most practical for this purpose?
   [A small General Purpose Remotely Operated Vehicle would be most cost effective.]

   (e) Our expedition is studying the linkages between pelagic (mid-water) and benthic (bottom) communities associated with a hydrothermal vent in the Gulf of Mexico (depth is approximately 2,500 meters). We want to collect biological samples from both areas, as well as geological samples (including rock cores) from the benthic areas.
   [ROPOS and Tiburon are capable of collecting the benthic and rock core samples. Tiburon also has a dedicated toolsled specifically for studying midwater organisms.]

(f) We are exploring the wreck of a Spanish galleon that lies in a deep canyon 3,000 meters below the surface. We need a complete, detailed photographic survey of the area around the ship, and also want to be able to recover artifacts that may be discovered.
[Hercules was designed specifically for the study of ancient shipwrecks and recovery of artifacts, and is capable of high-definition photographic surveys.]

(g) A Pisces submersible has become tangled in the rigging of a sunken freighter in 1,500 feet of water. We need a robot to survey the situation and cut the rigging to free the submersible.
[All of the robots could respond to this emergency – if they were in the immediate area and had the necessary cutting attachments available. RCV-150 is specifically designed to support Pisces operations and would most likely be carried as part of emergency response equipment on support vessels.]

(h) We are exploring a series of underwater caves approximately 300 meters deep. The entrances to some of these caves is only about 300 cm square. We need video images of the interior of these caves to plan further explorations.
[General Purpose Remotely Operated Vehicles can be as small as a bread box, and could provide the video images needed for this work.]

(i) Our research team is studying an unexplored chain of underwater volcanoes. We want to sample geological formations as well as biological communities, but won't know exactly what types of samples will be needed until we can see the area. Depths in our study area will be between 1,500 and 4,500 meters.
[ROPOS can be fitted with a wide variety of observation tools that could give these scientists the flexibility they need to respond to new and unexpected discoveries]

(j) Our scientific team needs to monitor the water temperature around a newly erupting underwater volcano two miles below the surface of the ocean. We need samples taken every hour for a month.
[ABE is the only robot in the group capable of autonomous operations and long-term monitoring.]

(k) We are studying the biological communities of a deepwater (1,000 – 2,000 meters depth) coral reef, and want a complete photographic record of the study area (approximately 10,000 square meters). We also need to collect samples of unknown organisms for identification.
[ROPOS, Hercules, Tiburon, and some General Purpose ROVs could do this work. This is an opportunity to discuss the advantages and disadvantages of the different systems. You may want to ask what additional details about the mission would help in making the best choice.]

6. Briefly discuss the disadvantages of underwater robots compared to submersibles. The major drawback is that the human presence is lost, and this makes visual surveys and evaluations more difficult. Tethered robots also are constrained to some extent by their cabled connection to the support ship.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Human Activities," then "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay describing how robots are (or may be) of personal benefit.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics

Assessment

Reports and discussions in Steps 4 and 5 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/06blacksea to keep up to date with the latest Aegean and Black Sea 2006 Expedition discoveries.

2. Build your own underwater robot! See books by Harry Bohm under "Resources."

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 1, 2, and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

Other Relevant Lessons from the Ocean Exploration Program

What's Eating Titanic?

http://oceanexplorer.noaa.gov/explorations/04titanic/edu/media/Titanic04.Rusticles.pdf
(5 pages, 408k) (from the Titanic 2004 Expedition)

Focus: Biodeterioration processes (Physical Science/Biological Science)

In this activity, students will be able to describe three processes that contribute to the deterioration of the Titanic, and define and describe rusticles, explaining their contribution to biodeterioration. Students will also be able to explain how processes that oxidize iron in Titanic's hull differ from iron oxidation processes in shallow water.

Designing Tools for Ocean Exploration

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l1.pdf
(13 pages, 496k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will understand the complexity of ocean exploration; learn about the technological applications and capabilities required for ocean exploration; discover the importance of teamwork in scientific research projects; and develop the abilities necessary for scientific inquiry.

Submersible Designer (4 pages, 452k) (from the 2002 Galapagos Rift Expedition)
[http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf]

Focus: Deep Sea Submersibles

In this activity, students will understand that the physical features of water can be restrictive to movement; understand the importance of design in underwater vehicles by designing their own submersible; and understand how submersibles such as ALVIN and ABE, use energy, buoyancy, and gravity to enable them to move through the water.

Mapping the Canyon

http://oceanexplorer.noaa.gov/explorations/deepeast01/background/education/dehslessons2.pdf
(10 pages, 72k) (from the 2001 Deep East Expedition)

Focus: Hudson Canyon Bathymetry (Earth Science)

In this activity, students will be able to compare and contrast a topographic map to a bathymetric map; investigate the various ways in which bathymetric maps are made; and learn how to interpret a bathymetric map.

Finding the Way

http://oceanexplorer.noaa.gov/explorations/deepeast01/background/education/dehslessons4.pdf
(10 pages, 628k) (from the 2001 Deep East Expedition)

Focus: Underwater Navigation (Physical Science)

In this activity, students will describe how the compass, Global Positioning System (GPS), and sonar are used in underwater explorations; and understand how navigational tools can be used to determine positions and navigate in the underwater environment.

Other Resources and Links

http://oceanexplorer.noaa.gov/explorations/06blacksea – Web site for the Aegean and Black Sea 2006 Expedition

http://www.immersionpresents.org/ – Immersion Presents Web site; click on "Ancient Eruptions!" for more information about the Aegean and Black Sea 2006 Expedition, images, and educational activities

http://www.ngdc.noaa.gov/paleo/ctl/clihis10k.html –Timeline for last 10,000 years from NOAA's Paleoclimatology Web site

http://pubs.usgs.gov/pdf/planet.html – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml – Web page from NASA about "Creeping Dead Zones," including SeaWIFS satellite imagery

http://news.nationalgeographic.com/news/2000/12/122800blacksea.html – National Geographic Web site, "Ballard Finds Traces of Ancient Habitation Beneath Black Sea"

http://blacksea.orlyonok.ru/blacksea.shtml – Web site of the Living Black Sea Marine Environmental Education Program in the Russian Federal Children Center Orlyonok

Friedrich, W. L.. 2000. Fire in the Sea. The Santorini Volcano: Natural History and the Legend of Atlantis. Translated by Alexander R. McBirney. Cambridge University Press. 258 pp.

Ryan, W. and W. Pitman. 1999. Noah's Flood: The New Scientific Discoveries About the Event That Changed History. Simon and Schuster. New York.

Yanko-Hombach, V. 2003. "Noah's Flood" and the late quaternary history of the Black Sea and its adjacent basins: A critical overview of the flood hypotheses. Paper presented at the Geological Society of America Annual Meeting, November 2–5, 2003, Seattle, WA (abstract available online at http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_58733.htm).

http://ina.tamu.edu/ub_main.htm – Web site with information about the excavation of a Bronze Age shipwreck at Uluburun, Turkey

http://projectsx.dartmouth.edu/history/bronze_age/ – Dartmouth University Web site, "Prehistoric Archaeology of the Aegean," with texts, links to other online resources, and numerous bibliographic references

Bohm, H. and V. Jensen. 1998. Build Your Own Programmable Lego Submersible: Project: Sea Angel AUV (Autonomous Underwater Vehicle). Westcoast Words. 39 pages.

Bohm, H. 1997. Build your own underwater robot and other wet projects. Westcoast Words. 148 pages.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in society

Content Standard G: History and Nature of Science

- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 6.

The ocean and humans are inextricably interconnected.

- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- *Fundamental Concept c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept f.* Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
- *Fundamental Concept g.* Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.

The ocean is largely unexplored.

- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

Student Handout

Underwater Robot Capability Survey

Name of Robotic Vehicle ____________________

Maximum Operating Depth ____________________

Tethered or Autonomous ____________________

Minimum Number of Crew Required for Operation ____________________

Tools ____________________

Special Capabilities or Advantages ____________________

Other Details ____________________

ocean explorer
oceanexplorer.noaa.gov

Learning Ocean Science through Ocean Exploration

Section 1

Ocean Exploration

Ocean Exploration

Ocean exploration has been a human endeavor for as long as humans have designed boats and been able to put to sea. Ocean exploration is not the province of any single culture. Polynesians, Phoenicians, Norsemen—all were fabulous sailors and explorers. Humans managed to reach islands and continents isolated by oceans—sometimes by relatively shorter island hops as in the population of Australia, sometimes by sailing into the unknown across whole oceans to reach distant places like the Hawaiian Islands. In the process they invented technologies that enabled them to explore more effectively and safely—better vessels and navigation systems based on the position of the sun and stars.

Humans are by nature record keepers and collectors of information and materials because knowledge enhances survival. If the explorers returned home, they brought new knowledge as well as materials such as metals, plants and animals. Much of that new information would be called science today.

Most United States students take American history. Hence, their knowledge of ocean exploration may be focused on the discovery and exploration of the New World by Europeans. Portuguese, Spanish, and English explorers from the second half of the last millennium are most familiar to them. These explorers kept journals and records that we still read today. They took artists and natural historians with them to document what they found. For example, Vancouver explored the west coast of the United States with a science illustrator. Sir Walter Raleigh employed John White to draw species from the Chesapeake and Virginia area. Mark Catesby was sent from England in 1724 to explore the East coast of the colonies for Sir Hans Sloan in England. He water colored over 220 plates and sent back countless specimens during his four-year collecting journey. During the Lewis and Clark Expedition, Merewether Lewis recorded his discoveries though his own scientific illustrations. The work of these men and their artists remains interesting today. They were the first explorers to chart and draw the natural history of what is now the United States.

Challenger Expedition of 1874

Modern ocean science exploration started with the *Challenger* Expedition of 1874—the first focused ocean science expedition. It was much longer than modern expeditions and very expensive. Victorian Great Britain had a fascination with science and scientific discovery that is reflected in their public funding of and interest in natural history museums. The United States' own Smithsonian Institution was funded by an Englishman and named for him. The *Challenger* Expedition was funded by the British government. Its explorers were charged with studying and mapping the oceans of the world. This four-year research expedition produced 50 volumes of scientific writing and illustrations over a 10- year period. Its specimen collections are still archived and studied, its publications still referenced and read.

Technological innovations since the *Challenger* have constantly improved the quality and quantity of scientific information produced by ocean explorers. Victorians' views of ocean creatures were limited to drawings and specimens in jars. Where once water samples were collected in bottles and weather was recorded from instruments by hand, oceanographers now have satellite data and remote sensing from ocean drifting or fixed equipment arrays, and these same data appear on the evening news. The lead line that measured how deep the water was has been replaced by sonar that is available to recreational boaters. Today we see fabulous video footage of underwater discoveries on television, as IMAX films and in print media. Where Victorians read journals published upon the return of an expedition, we can now follow scientists along in real time on the expedition over the Internet, seeing what they see, discovering what they find. And yet our ocean remains less explored than the backside of the moon. Amazing new discoveries are still waiting to be made.

The National Oceanic and Atmospheric Administration's creation of the Office of Ocean Exploration (OE) launched a new era of ocean exploration. NOAA recognizes that there are many exciting discoveries waiting to be made. Ocean explorers are taking us along with them through the Ocean Explorer (OE) web site and the associated CD. This is your chance to share the excitement of ocean science discoveries with your students.

Classroom Activities about Ocean Exploration in this Section

This section includes:

- *Calling All Explorers* from Deep East 2001.

Where to Find More Activities on Ocean Exploration

Additional exercises related to ocean explorers and the theme of exploration are found on the OE web site or OE CD. They are:

- *Why Do We Explore?* from Deep East 2001 and Galapagos Rift in 2002
- *Journey to the Unknown* also found on Deep East 2001 and Galapagos Rift in 2002

Lesson Plan 1

Calling All Explorers

Focus
The history of ocean exploration with emphasis on recent explorers of deep-sea environments

Focus Question
Who are some past and present ocean explorers and what are their accomplishments?

Learning Objectives
Students will research and write about what it means to be an ocean explorer, both modern and historic.

Students will describe the nature of oceans and ocean exploration.

Students will meet science mentors and role models on-line.

Additional Information for Teachers of Deaf Students
The words listed as Key Words should be introduced prior to the activity. This activity allows the students to do their own research but in the process they will likely encounter many words unfamiliar to them. It might be helpful to review the student handout with the students prior to sending them to explore the Web site.

Students may need some assistance with the questions that ask for their own opinion or ideas. Prior to the individual exploration activity, it would be helpful for teachers to discuss role models in general and then share a story of their own role model(s) in science.

Materials
- ❒ Web Quest NOAA Site: http://oceanexplorer.noaa.gov/explorations/deepeast01/deepeast01.html on-line or an OE CD

For each student:
- ❒ Part I: Team Exploration – *Cooperative Explorers Web Quest Data Sheet*
- ❒ Part II: Individual Exploration – *Individual Explorers Reflection Sheet*

Audio/Visual Materials
Internet connection for student use

Teaching Time
Two 45 minute periods, one each for two parts

Seating Arrangement
Part I: groups that work with your computer arrangement

Part II: individual work in a place that lends itself to reflection

Key Words
Exploration
Documentation
Science role models
Biodiversity
Extreme environments

Background Information
The National Oceanic and Atmospheric Administration's Office of Ocean Exploration launched a new era of ocean exploration. Its creation recognizes that there are many exciting discoveries waiting to

be made. Ocean explorers are taking us along with them through the OE web site and the associated CD. This exercise introduces your students to the OE web site (or CD) and to the people who are the modern ocean explorers. It is designed to enable them to move at their own pace, in self-directed exploration of the OE site.

Learning Procedure

Part I: Team Exploration

1. Assign students to computers in small groups with one *Cooperative Explorers Web Quest Data Sheet* per student and let them work through the sheet as a group.

Part II: Individual Exploration

1. Provide copies of *Individual Explorers Reflections Sheet*. This individual work may be assigned as homework rather than done in class. Be sure to have a class discussion after the work is turned in to get your student's reactions to modern vs. historic explorers.

The BRIDGE Connection

www.vims.edu/bridge

The "Me" Connection

All of Part II: Individual Exploration is the "Me" Connection

Connection to Other Subjects

English/Language Arts, Physical Earth, Life Sciences, Art/Design

Evaluation

Use Student Evaluation Sheets. See *Teacher Key, Part I and Part II*

Extensions

Ask students to investigate career opportunities as ocean explorers, ocean scientists, and others whose careers support ocean science and exploration. Visit the Ocean Exploration Web Site at: www.oceanexplorer.noaa.gov

Resources

http://oceanexplorer.noaa.gov/library/readings/welcome.html
Readings illustrating the history, science, and personal stories of those involved in ocean exploration

http://oceanexplorer.noaa.gov/history/history.html
A comprehensive look at NOAA's 200 year history of ocean exploration

National Science Education Standards

Content Standard G – History & Nature of Science

- Science as a human endeavor
- The nature of science

Activity developed by Kimberly Williams, Miller Place High School, Long Island, New York

Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut

Student Handout

Part I: Cooperative Explorers Web Quest Data Sheet

Welcome, Ocean Explorers! Please proceed to the following web site:
www.oceanexplorer.noaa.gov/explorations/deepeast01/deepeast01.html
or use the Ocean Exploration CD to find Deep East ocean explorers

Your first mission is to find the link to the deep-sea explorers.
1) Write that link here: ______________________________

2) List three places in the deep sea where ocean explorers have done their recent research:
  a) ______________________________
  b) ______________________________
  c) ______________________________

3) There are many individuals studying the deep sea. List at least five here and describe their field of research.
  a) ______________________________
  ____
  b) ______________________________
  ____
  c) ______________________________
  ____
  d) ______________________________
  ____
  e) ______________________________

4) Describe what your day might be like if you were a marine chemist:
If I were a marine chemist, I would. . . .

____
____
____
____
____
____
____

Student Handout

5) In some ways, deep-sea explorers of modern times are similar to historic explorers. They are brave, curious people who are at the cutting edge of their field of interest. They are very unique individuals. One major difference is that women are an important part of ocean science research in modern times. For example, one of the scientists shown in your Web Quest is the only woman certified to pilot the deep sea submersible known as the *Alvin*. Find her name and describe what type of science she does?

Dr. ______________________ studies ______________________.

6) Often our first inspiration to be curious and to explore comes from our parents and our teachers. Which explorer's elementary teacher inspired him by having him read *A Half Mile Down*, by William Beebe, a book about the first deep dive? Have you read this book?

Dr. ______________________

Bonus: List other explorers who were inspired by parents and/or teachers?

Dr. ______________________
Dr. ______________________
Dr. ______________________

7) How do you think that exploring the deep sea is similar to exploring outer space? Different?

____
____
____
____
____
____
____

8) Which scientist explorer studies biodiversity and believes that extreme environments (such as those in the deep sea) may give us insight into life on other planets?

Dr. ______________________

Student Handout

9) There is a big world waiting for you to explore it, and the technology to do so gets better every day. Yesterday's discoveries are today's necessities. Which explorer hopes that new compounds from the deep sea will be used in the future to treat diseases?

Dr. ______________________________

10) As we learn more about the vastness of the planet we inhabit, we realize how little we know about the creatures and plants with which we share it. Which scientist studies the relationship between food supply and egg production in deep water invertebrates?

Dr. ______________________________

11) Another group of creatures that shares the Earth with us are beautiful single-celled, shelled protozoans. Name these creatures and the explorer who studies them:

The creatures are known as ______________________________
They are studied by Dr. ______________________________

12) On the back of this data sheet, document your time of exploration on the Deep Sea Explorer Web Quest by drawing something that represents your favorite part of the site. Label your drawing and tell why this part of the site was interesting to you.

Congratulations, Explorers!
You have successfully navigated the Deep Sea Explorer Web Quest!

Part I Cooperative Explorers Web Quest Data Sheet

Teacher Answer Key

The answers are specific to the Deep East 2001 expedition. If the students used the entire OE web site or CD, many more answers are possible!

1) Write that link here:
www.oceanexplorer.noaa.gov/explorations/deepeast01/background/explorers explorers.html

2) List three places in the deep sea where science explorers have done their recent research:
a) George's Bank Canyon
b) Hudson River Canyon
c) Blake Ridge

3) There are many individuals studying the deep sea. List at least five here and describe their field of research.
Answers may vary, some answers include:
Dr. Les Watling, Dr. Scott C. France, Mr. Andrew Shepard
Dr. Peter Auster, Ms. Caren Menard, Dr. Mary Scranton
Dr. Kevin Eckelbarger, Mr. Karl Stanford, Dr. Peter Rona
Dr. Barbara Hecker, Dr. Fred Grassle, Dr. Ellen K. Pikitch
Ms. Diana Payne, Dr. Michael Bothner
Ms. Holly Donovan, Ms. Tanya Podchaski, Ms. Rebecca Cerroni
Dr. Michael DeLuca, Dr. Cindy Lee Van Dover, Dr. Joan Bernhard
Dr. Carolyn Ruppel, Dr. Barun Sen Gupta, Ms. Paula Keener-Chavis

4) Describe what your day might be like if you were a marine chemist: If I were a marine chemist, I would. . . .
Answers will vary-students will probably take information from the interviews of the marine chemists listed above for the descriptions of their imaginary day as a marine chemist.

5) In some ways, deep-sea explorers of modern times are similar to historic explorers. They are brave, curious people who are at the cutting edge of their field of interest. They are very unique individuals. One major difference is that women are an important part of ocean science research in modern times. For example, one of the scientists shown in your Web Quest is the only woman certified to pilot the deep sea submersible known as the *Alvin*. Find her name and describe what type of science she does?
Dr. Cindy Lee Van Dover studies Marine Chemistry

6) Often our first inspiration to be curious and to explore comes from our parents and our teachers. Which explorer's elementary teacher inspired him by making him read *A Half Mile Down*, by William Beebe, a book about the first deep dive? Have you read this book?
Dr. Peter Rona I have/have not read *A Half Mile Down*

Teacher Answer Key

Bonus: List other explorers who were inspired by parents and/or teachers. Some are:
Dr. Fred Grassle
Dr. Mary Scranton
Dr. Joan Bernhard

7) How do you think that exploring the deep sea is similar to exploring outer space? Answers will vary. Some include:
Humans would need special equipment to survive and explore there.
Humans know very little about both places.
Humans get very excited about the prospect of finding life in both places.

8) Which explorer studies biodiversity and believes that extreme environments (such as those in the deep sea) may give us insight into life on other planets?
Dr. Joan Bernhard

9) There is a big world waiting for you to explore it, and the technology to do so gets better every day. Yesterday's discoveries are today's necessities. Which explorer hopes that new compounds from the deep sea will be used in the future to treat diseases?
Dr. Fred Grassle

10) As we learn more about the vastness of the planet we inhabit, we realize how little we know about the creatures and plants that share it with us. Which scientist studies the relationship between food supply and egg production in deep-water invertebrates?
Dr. Kevin Eckelbarger

11) Another group of creatures that shares the Earth with us are beautiful single celled, shelled protozoans. Name these creatures and the explorer who studies them.
The creatures are known as Foraminifera.
They are studied by Dr. Barun Sen Gupta.

12) On the back of this data sheet, document your time of exploration on the Deep Sea Explorer Web Quest by drawing something that represents your favorite part of the site. Label your drawing and tell why this part of the site was interesting to you.
Enjoy your students' drawings and celebrate the diversity of their interests.

Congratulations, Explorers!
You have successfully navigated the Deep Sea Explorer Web Quest!

Student Handout

Part II: Individual Explorers Reflections Sheet

1) Reflect and write about differences and similarities between explorers of the past and modern day explorers. What types of hardships do both have in common?

Some Similarities: ____

____

____

____

Some Differences: ____

____

____

____

2) Name some places that have been explored in modern times.

____

____

____

____

3) Name places that were explored during the early history of humans.

____

____

____

____

4) Describe a place that you have explored. What was unique about it that you think another visitor to that site would not have noticed?

____

____

____

____

5) Name and describe a place that you would like to explore. What do you think you would find there? Why?

____

____

____

____

Student Handout

6) Why is it important to document your explorations? What is your favorite way to remember your own adventures?

7) On the space provided, list a few of your science and exploration role models (alive or historic) and why they inspire you. On a sheet of notebook paper or on the computer, compose a letter to one of your science and exploration role models. Write something you would want them to know about you and why you consider them an inspiration.

Fresh and Salt

Appendix A

Sources for Fresh and Salt Activities

Fresh and Salt

Appendix A

Sources for Fresh and Salt Activities

ES-EAGLS: Earth Systems Education Activities for Great Lakes Schools

This five-volume series of books from the Ohio State University contains 67 activities relating directly to important Great Lakes issues. Activities tie in to a variety of subject areas, including science, math and social studies. Each volume centers around an important Great Lakes topic; *Life in the Great Lakes, Great Lakes Climate & Water Movement, Great Lakes Environmental Issues, Great Lakes Shipping, and Land & Water Interactions in the Great Lakes.* Instructions for ordering can be found at: www.ag.ohiostate.edu/~earthsys/order_2.html.

Great Lakes in My World

This collection of 80 activities for grades K-8 gives students a meaningful way to learn science, history, and culture through study of the Great Lakes. These interdisciplinary, inquiry-based activities attempt to provide a sense of place, and build from the students' own experiential frames of references. Understanding and appreciating their own Great Lake helps develop an ongoing ethic of care and responsible decision making. *Great Lakes in My World* encourages service learning with a positive focus and a problem-solving approach. For more information, visit the Alliance for the Great Lakes at www.greatlakes.org.

NASA Aquarius Education and Public Outreach

A goal of NASA Aquarius is demonstrating how improved understanding of salinity-driven circulation – and its influence on climate and the water cycle–can benefit student learning. Sea surface salinity is key to learning about the water cycle because 86 percent of global evaporation and 78 per cent of global precipitation occur over the oceans. Our *Salinity Patterns & the Water Cycle* resources are aligned with the National Science Education Standards for Physical Science (grades K-12). For more information, visit NASA Aquarius Education at www.Aquarius.nasa.gov.

Office of Education and Outreach at the University Corporation for Atmospheric Research:

This teacher's guide was produced by the National Center for Atmospheric Research as a companion to the Climate Discovery exhibit at our Boulder, Colorado laboratory. Each unit contains lessons appropriate for grades 5-9 on a variety of earth system science topics that facilitate student learning about our planet's climate system. For more information, visit UCAR at www.eo.ucar.edu/.

The Bridge

The Bridge is a growing collection of the best marine education resources available on line. It provides educators with a convenient source of accurate and useful information on global, national, and regional marine science topics, and gives researchers a contact point for educational outreach.

The Bridge is supported by the National Sea Grant Office, the National Oceanographic Partnership Program, and the National Marine Educators Association. For more information visit the Bridge at htttp://web.vims.edu/bridge/?svr=www.

Will Steger Foundation

As eyewitness to the reality of global warming, and as an explorer taking on daunting challenges, the Will Steger Foundation inspires people to embrace the transition to a low-carbon economy: exploring the path forward and leading the way through exciting education, citizen engagement and international cooperation. Supported by robust educational and public policy initiatives, we are making a tangible impact on public awareness concerning the threat of global climate change. To advance state and federal policy that address solutions to global warming, we are mobilizing the public and elected officials through the compelling narrative and credibility of the eyewitness account. For more information visit the Will Steger Foundation at Globalwarming101.com.

NOAA Ocean Exploration Program

The NOAA Ocean Exploration program strives to engage broad audiences to enhance America's environmental literacy through the excitement of ocean discovery. Increasing this literacy requires high-quality, effective collaborations between ocean explorers and America's teachers. NOAA regularly forms such collaborations to reach out in new ways to the public to improve the literacy of learners with respect to ocean issues. For more information visit the NOAA Ocean Exploration Program at www. Oceanexplorer.noaa.gov.

Monterey Bay Aquarium Research Institute

Recognizing the need to educate the public about the value of research and help them understand scientific methodology, this Monterey Bay Aquarium Research Institute (MBARI) and Monterey Bay Aquarium (MBA) collaboration allows us to test new ideas for public outreach and education. One of MBARI's joint projects with MBA, Education and Research: Testing Hypotheses (EARTH), lays new groundwork, providing teachers with means for integrating real-time data with existing educational standards and tested curriculum in an interactive and engaging way. EARTH uses near-real-time data from ocean observatories to design and test outreach with the internet as an interface to scientists, teachers, students, and the public. Several workshops were held at MBARI in 2002-2005 bringing educators, scientists, and engineers together to develop effective educational practices for access and use of near-real-time data in preparation for the future deployment of benthic observatories. For more information visit MBARI at www.mbari.org/earth.

Smithsonian Education for Education and Museum Studies

The mission of the Smithsonian Center for Education and Museum Studies is to increase the Smithsonian Institution's impact as a national educational organization. The center has created a long-term alliance with state education officials that has become the basis for several collaborative teacher training and resource development projects in a wide range of subjects. The center also manages pan-institutional functions such as internships, heritage month celebrations, school tour programming, and the collection and analysis of data on Smithsonian education programs. For more information visit Smithsonian Education at www.smithsonianeducation.org.

Fresh and Salt

Appendix B

Alignment to State and National Standards

Appendix B

Alignment to State and National Standards

Alignment to National Science Standards

<u>Ocean and Great Lakes Literacy Principle 1</u>

Density: Sea Water Mixing and Sinking

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

Going with the Flow

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

<u>Ocean and Great Lakes Literacy Principle 2</u>

Diatom Ooze

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

9-12.3: Students should develop an understanding of the cell, biological evolution, interdependence and behavior of organisms, and the molecular basis of heredity

What Causes the Shoreline to Erode?

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

What Causes the Shoreline to Erode?

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

9-12.6: Students should develop an understanding of personal and community health, population growth, natural resources, natural and human induced hazards, and technology

Ocean and Great Lakes Literacy Principle 3

Implications of Warming in the Artic

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

5-8.7: Students should develop an understanding of the history and nature of science

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

9-12.6: Students should develop an understanding of personal and community health, population growth, natural resources, natural and human induced hazards, and technology

How is Coastal Temperature Influenced by the Great Lakes and the Ocean?

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.4 Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

Ocean and Great Lakes Literacy Principle 4

BATS and Hot Dogs

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.3: Students should develop understanding of reproduction and heredity, regulation and behavior, ecosystems, diversity and adaptations of organisms, and the structure of living systems

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.5: Students should develop understandings about science and technology

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

9-12.3: Students should develop an understanding of the cell, biological evolution, interdependence and behavior of organisms, and the molecular basis of heredity

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

Being Productive in the Arctic Ocean

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.2: Students should develop an understanding of the structure of atoms, properties of matters, chemical reactions, motions and forces, and conservation of energy

9-12.3: Students should develop an understanding of the cell, biological evolution, interdependence and behavior of organisms, and the molecular basis of heredity

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

Ocean and Great Lakes Literacy Principle 5

Tangled Web

Grades 5-8

5-8. 1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.3: Students should develop understanding of reproduction and heredity, regulation and behavior, ecosystems, diversity and adaptations of organisms, and the structure of living systems

Sea Connections

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.3: Students should develop understanding of reproduction and heredity, regulation and behavior, ecosystems, diversity and adaptations of organisms, and the structure of living systems

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

Ocean and Great Lakes Literacy Principle 6

Pollution Solution

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.2: Students should develop an understanding of properties, motions and forces, and the transfer of energy

5-8.3: Students should develop understanding of reproduction and heredity, regulation and behavior, ecosystems, diversity and adaptations of organisms, and the structure of living systems

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

Downeaster Alexa: A Fishery Story

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.3: Students should develop understanding of reproduction and heredity, regulation and behavior, ecosystems, diversity and adaptations of organisms, and the structure of living systems

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

Grades 9-12

9-12.1: Students should develop abilities necessary to understand and do scientific inquiry

9-12.3: Students should develop an understanding of the cell, biological evolution, interdependence and behavior of organisms, and the molecular basis of heredity

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

9-12.6: Students should develop an understanding of personal and community health, population growth, natural resources, natural and human induced hazards, and technology

Ocean and Great Lakes Literacy Principle 7

I, Robot, Can Do That!

Grades 5-8

5-8.1: Students should develop abilities necessary to understand and do scientific inquiry

5-8.5: Students should develop understandings about science and technology

5-8.6: Students should develop an understanding of personal health, natural hazards, risks and benefits, technology in society, and populations

5-8.7: Students should develop understanding of the history and nature of science

Ocean Exploration

Grades 5-8

5-8.4: Students should develop an understanding of the earth system, its history, and earth in the solar system

5-8.7: Students should develop understanding of the history and nature of science

Grades 9-12

9-12.4: Students should develop an understanding of energy in the earth system, geochemical cycles, and the origin and evolution of the universe

9-12.7: Students should develop understanding of the history and nature of science

Alignment to National Geography Standards

<u>Ocean and Great Lakes Literacy Principle 1</u>

Density: Sea Water Mixing and Sinking

Grades 5-8

7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

Grades 9-12

4B. Describe and interpret physical processes that shape places.

7A. Dexcribe how physical processes affect different regions of the U.S. and the world.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

Going with the Flow

Grades 5-8

7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

<u>Ocean and Great Lakes Literacy Principle 2</u>

Ooze Clues

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose

4B. Describe and interpret physical processes that shape places.

7A. Describe how physical processes affect different regions of the U.S. and the world.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

What Causes the Shoreline to Erode?

Grades 5-8

1D. Use geographic tools and technologies to pose and answer questions about spatial patterns on Earth, over time.

2A. Identify the locations of certain physical features and events on maps and answer related geographic questions.

3A. Analyze and explain distributions of physical and human phenomena with respect to spatial patterns.

4A. Analyze the physical characteristics of places (using maps, graphs, tables, and other tools)

7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

What Causes the Shoreline to Erode?

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose

4B. Describe and interpret physical processes that shape places.

7A. Describe how physical processes affect different regions of the U.S. and the world.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

15A. Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

<u>Ocean and Great Lakes Literacy Principle 3</u>

Implications of Warming in the Arctic

Grades 5-8

1D. Use geographic tools and technologies to pose and answer questions about spatial patterns on Earth, over time.

2A. Identify the locations of certain physical features and events on maps and answer related geographic questions.

3A. Analyze and explain distributions of physical and human phenomena with respect to spatial patterns.

4A. Analyze the physical characteristics of places (using maps, graphs, tables, and other tools)

7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose.

4B. Describe and interpret physical processes that shape places.

7A. Describe how physical processes affect different regions of the U.S. and the world.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

15A. Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

How is Coastal Temperature Influenced by the Great Lakes and the Ocean? (Two Activities)

What Happens to Heat Energy Reaching Water and Land?

How Do the Ocean and the Great Lakes Affect Temperature?

Grades 5-8

1D. Use geographic tools and technologies to pose and answer questions about spatial patterns on Earth, over time.

2A. Identify the locations of certain physical features and events on maps and answer related geographic questions.

3A. Analyze and explain distributions of physical and human phenomena with respect to spatial patterns.

Sea Connections

4A. Analyze the physical characteristics of places (using maps, graphs, tables, and other tools)

7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

Ocean and Great Lakes Literacy Principle 4

Bats and Hot Dogs

Grades 5-8

3A. Analyze and explain distributions of physical and human phenomena with respect to spatial patterns.

4A. Analyze the physical characteristics of places (using maps, graphs, tables, and other tools)
7A. Use physical processes to explain patterns in the physical environment.

7B. Analyze physical patterns in terms of the processes that created them.

Grades 9-12

4B. Describe and interpret physical processes that shape places.

7A. Describe how physical processes affect different regions of the U.S. and the world.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

14B. Explain the global impacts of human changes in the physical environment.

15A. Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

Being Productive in the Arctic Ocean

Grades 9-12

7D. Describe the ways in which Earth's physical processes (systems) are dynamic and interactive.

8D. Evaluate ecosystems in terms of their biodiversity and productivity.

Ocean and Great Lakes Literacy Principle 5

Tangled Web

Grades 5-8

8B. Explain the functions and dynamics of ecosystems.

8C.Explain how physical processes influence ecosystems.

8D. Explain how human processes contribute to changes in ecosystems.

14A. Analyze the environmental consequences of humans changing the atmosphere, biosphere, lithosphere, and hydrosphere.

14B. Identify and explain the ways in which human-induced changes in the environment in one place can cause changes in other places.

Sea Connections

Grades 5-8

8C.Explain how physical processes influence ecosystems.

8D. Explain how human processes contribute to changes in ecosystems.

14A. Analyze the environmental consequences of humans changing the atmosphere, biosphere, lithosphere, and hydrosphere.

14B. Identify and explain the ways in which human-induced changes in the environment in one place can cause changes in other places.

Sea Connections

16B. Describe the consequences of the use of resources in the contemporary world.

16C. Evaluate different viewpoints regarding resource use.

18A. Analyze the interaction between physical and human systems to understand possible causes and effects of current conditions on Earth and to speculate on future conditions.

18B. Integrate multiple points of view to analyze and evaluate contemporary geographic issues.

Ocean and Great Lakes Literacy Principle 6

Pollution Solution

Grades 5-8

8C.Explain how physical processes influence ecosystems, including how specific populations within ecosystems respond to environmental stress.

8D. Explain how human processes contribute to changes in ecosystems.

14A. Analyze the environmental consequences of humans changing the atmosphere, biosphere, lithosphere, and hydrosphere.

14B. Identify and explain the ways in which human-induced changes in the environment in one place can cause changes in other places.

16B. Describe the consequences of the use of resources in the contemporary world.

16C. Evaluate different viewpoints regarding resource use.

18A. Analyze the interaction between physical and human systems to understand possible causes and effects of current conditions on Earth and to speculate on future conditions.

18B. Integrate multiple points of view to analyze and evaluate contemporary geographic issues.

18 C. Demonstrate an understanding of the spatial organization of human activities and physical systems and be able to make informed decisions.

Downeaster Alexa: A Fishery Story

Grades 5-8

1D. Use geographic tools and technologies to pose and answer questions about spatial distributions and patterns on Earth.

2A. Identify the locations of certain physical features and events on maps and answer related geographic questions.

3A. analyze and explain distributions of physical phenomena with respect to spatial patterns, arrangements, and associations.

3C. Explain the different ways in which places are connected and how these connections demonstrate interdependence and accessibility.

4B. Analyze the physical characteristics of places using maps, graphs, and tables to make inferences about causes and effects of changes over time.

8C.Explain how physical processes influence ecosystems, including how specific populations within ecosystems respond to environmental stress.

8D. Explain how human processes contribute to changes in ecosystems.

14A. Analyze the environmental consequences of humans changing the atmosphere, biosphere, lithosphere, and hydrosphere.

16B. Describe the consequences of the use of resources in the contemporary world.

16C. Evaluate different viewpoints regarding resource use.

18A. Analyze the interaction between physical and human systems to understand possible causes and effects of current conditions on Earth and to speculate on future conditions.

18B. Integrate multiple points of view to analyze and evaluate contemporary geographic issues.

18 C. Demonstrate an understanding of the spatial organization of human activities and physical systems and be able to make informed decisions.

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose.

3A. Apply concepts of spatial interaction to account for patterns of movement in space.

4B. Describe and interpret physical processes that shape places.

4C. Explain how social, cultural, and economic processes shape the features of places.

5C. Identify human and physical changes in regions and explain the factors that contribute to those changes.

5F. Use regions to analyze geographic issues and answer geographic questions.

6C. Analyze the ways in which people's changing views of places and regions reflect cultural change.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

14A. Evaluate the ways in which technology has expanded the human capability to modify the phy6sical environment.

14B. Explain the global impacts of human changes in the physical environment.

14C. Develop possible solutions to scenarios of environmental change induced by human modification of the physical environment.

15A. Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

16E. Evaluate policies and programs related to the use of resources on different spatial scales.

18A. Develop policies that are designed to guide the use and management of Earth's resources and that reflect multiple points of view.

18C. Analyze a variety of contemporary issues in terms of Earth's physical and human systems.

Ocean and Great Lakes Literacy Principle 7

I, Robot, Can Do That

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose.

4B. Describe and interpret physical processes that shape places.

4C. Explain how social, cultural, and economic processes shape the features of places.

7B. Explain Earth's physical processes, patterns, and cycles using concepts of physical geography.

7D. Describe the ways in which Earth's physical processes are dynamic and interactive.

10C. Explain how cultural features often define regions.

15A. Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

16B. Explain the relationship between resources and the exploration of different regions of the world.

18D. Use geography knowledge and skills to analyze problems and make decisions within a spatial context.

Calling All Explorers

Grades 5-8

2D.Analyze ways in which people's mental maps reflect an individual's attitudes toward places.

3C. Explain the different ways in which places are connected and how these connections demonstrate interdependence and accessibility.

5D. Explain how regions are connected.

6A. Evaluate the characteristics of places and regions from a variety of points of view.

6B. Explain how technology affects the ways in which cultural groups perceive and use places and regions. Explain how technology affects the ways in which cultural groups perceive and use places and regions.

8D. Explain how human processes contribute to changes in ecosystems.

14A. Analyze the environmental consequences of humans changing the atmosphere, biosphere, lithosphere, and hydrosphere.

16C. Evaluate different viewpoints regarding resource use.

18B. Integrate multiple points of view to analyze and evaluate contemporary geographic issues.

Grades 9-12

1C. Evaluate the applications of geographic tools and supporting technologies to serve a particular purpose.

2B. Identify the ways in which mental maps influence human decisions about location and public policy.

2C. Compare mental maps of individuals to identify common factors that affect the development of spatial understanding and preferences.

6A. Explain why places and regions are important to individual human identity, as exemplified by how point of view influences a person's perception of a place.

8C. Apply the concept of ecosystems to understand and solve problems regardsing environmental issues.

16B. Explain the relationship between resources and the exploration of different regions of the world.

18D. Use geography knowledge and skills to analyze problems and make decisions within a spatial context.

Template for Links to State Standards

Name of State: Illinois

	Instructional Mode	Grade Level	Standards
Principle 1: The Earth has one big ocean with many features.			
Density: Sea Water Mixing and Sinking	Experiment	6-9	State Goal 11 A. 3a, 3b, 3c, 3f, 3g
Going with the Flow	Experiment/Data	5	State Goal 11 A. 2a, 2b, 2c, 2e
Principle 2: The ocean and life in the ocean shape the features of the Earth.			
Ooze Clues--Diatom Ooze	Data Interpretation	9	State Goal 11 A. 4a,4d, 4f State Goal 13A. 4c
What Causes the Shoreline to Erode	Investigation	6-12	State Goal 11 A. 4a, 4b, 4c, 4d, 11 B. 4b, 4e Stste Gosl 13 B. 4d
Principle 3: The ocean is a major influence on weather climate.			
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8	State Goal 11 A. 4a, 4d, 4f State Goal 12 E. 3b
Implications of Warming in the Arctic	Cooperative learning groups	6-12	State Goal 11 A. 4a, 4b, 4c, 4d, 4e, 4f, 4g
Principle 4: The ocean makes Earth habitable.			
Bats and Hot Dogs	Real-time Data Interpretation	6-9	State Goal 11 B. 3a State Goal 12 F. 3a, 3b
Being Productive in the Arctic Ocean	Experiment	9-12	State Goal 11 A. 4a, 4c, 4d State Goal 12 B. 4a
Principle 5: The ocean supports a great diversity of life and ecosystems.			
Tangled Web	Simulation	5-8	State Goal (gr 4-5) 11 A. 2c, 12 B. 2a, 13 B 2f (gr 6-8) 11 A. 3c, 12 B. 3a, 13 B. 3f
Sea Connections	Food Web Card Game	6-8	State Goal 11 A. 3f State Goal 12 B. 3a State Goal 12 B. 3b
Principle 6: The ocean and humans are inextricably interconnected.			
Pollution Solution	Experiment/Role-play	6-8	State Goal 11 A. 3a, 3b, 3c, 3f, 3g 11 B. 3b, 3d SG 12 B. 3a, SG 13 B. 3a, 3d
Downeaster Alexa: A fishery story	Data Interpretation	6-9	State Goal 11 A. 3a, 3f, 3g State Goal 13 B. 3a, 3d
Principle 7: The ocean is largely unexplored.			
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8	State Goal 11 A. 3a B. 3a, 3b State Goal 13 B. 3a, 3c
Calling All Explorers	Web-quest NOAA	5-9	State Goal 11 A. 3a, 3g State Goal 13 B. 3c, 3d

Template for Links to State Standards

Name of State: Indiana

	Instructional Mode	Grade Level	Standards							
Principle 1: The Earth has one big ocean with many features.										
			5	**6**	**7**	**8**	**B**	**ES**	**CP**	**C**
Density: Sea Water Mixing and Sinking	Experiment	6-10		6.2, 6.3, 6.5, 6.7	7.1, 7.2, 7.3, 7.4, 7.5, 7.7	8.1.3, 8.1.4, 8.2.2, 8.2.3, 8.2.8, 8.3.7, 8.3.10,8.3.14, 8.4.8, 8.5.1, 8.5.2, 8.5.3, 8.5.4, 8.5.5	B 1.40, B 1.41, B 1.43, B 1.44, B 1.45	ES1.13, ES1.13, ES1.15, ES1.17 ,ES1.20, ES1.21	CP 1.4, CP 1.5, CP 1.11, CP 1.16, CP 1.17	C1.1, C1.2, C1.26, C1.35, C1.38
Going with the Flow	Experiment/Data	5	.1 .2 .3 .5 .6							
Principle 2: The ocean and life in the ocean shape the features of the Earth.										
Ooze Clues--Diatom Ooze	Data Interpretation	9					1.37,1.42 1.43, 1.44 1.46	1.12		
What Causes the Shoreline to Erode	Investigation	6-10		6.2, 6.3, 6.4, 6.5, 6.7	7.1, 7.2, 7.3, 7.4, 7.5, 7.7	8.1.4, 8.2.1, 8.2.2, 8.2.3, 8.2.8, 8.5.1,8.5.2, 8.7.7	B.1.37, B.1.39, B.1.40, B.1.43,B.1.44, B.1.45		CP1.15,CP1.20 ,CP1.24,CP1.2 5,CP1.26	
Principle 3: The ocean is a major influence on weather climate.										
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8		6.3 6.7 7.2 7.3 7.4 7.5 7.6 7.7	7.2 7.3 7.4 7.5 7.6 7.7	2.1 2.2 2.3 2.4 2.7 2.8 3.10 3.14 3.15 4.5 7.3 7.7				
Implications of Warming in the Arctic	Cooperative learning groups	6-10		.3 .7	.1 .4 .6 .7	1.8 2.1 2.3 2.7 2.8 3.10 4.8	1.41 1.43 1.44	1.13 1.14 1.17 1.20 1.21 1.29	1.15 1.17 1.18	
Principle 4: The ocean makes Earth habitable.										
Bats and Hot Dogs	Real-time Data Interpretation	6-9		6.1 6.2 6.3 6.7	7.1 7.2 7.3 7.7	1.3 1.4 1.8 2.2 2.4 2.5 2.7 2.8 2.9 2.10 5.4 5.6 7.3	1.37 1.39 1.42 1.43 1.45	1.20 1.21		
Being Productive in the Arctic Ocean	Experiment	9-10					1.6 1.37 1.39 1.40 1.42 1.44 1.45 1.46	1.11 1.12 1.20	1.17	1.41 1.44
Principle 5: The ocean supports a great diversity of life and ecosystems.										
Tangled Web	Simulation	5-8	.1 .2 .4 .6	.3 .4	.1 .3 .4 .7	1.3 2.7 4.8 7.1				
Sea Connections	Food Web Card Game	6-8		6.3 6.4 6.7	7.1 7.3 7.4 7.7	2.7 4.4 4.5 4.6 7.7				
Principle 6: The ocean and humans are inextricably interconnected.										
Pollution Solution	Experiment/Role-play	6-8		6.2 6.3 6.4 6.5 6.6 6.7	7.1 7.2 7.3 7.5 7.6 7.7	1.6 1.7 1.8 2.2 2.3 2.4 2.6 2.7 3.3 3.4 3.6 3.7 5.1 5.7 5.8				
Downeaster Alexa: A fishery story	Data Interpretation	6-9		.3 .5 .6 .7	.1 .2 .3 .5 .6 .7	2.1 2.2 2.3 2.4 2.7 2.8 2.10 3.7 5.1 5.3 5.8 7.4	1.16 1.41 1.43 1.47			
Principle 7: The ocean is largely unexplored.										
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8			.1 .2 .3 .5 .6 .7	1.1 1.6 1.7 1.8 2.3 2.7 3.2 3.14 4.6 7.1				
Calling All Explorers	Web-quest NOAA	5-9	.1 .2 .4	.1 .6	.1 .3 .6 .7	1.1 1.2 1.4 2.4 2.7 2.8 2.9 2.10 7.1 7.2 Standard 6		1.6 1.8		

Template for Links to State Standards

Name of State: Michigan

	Instructional Mode	Grade Level	Standards								
Principle 1: The Earth has one big ocean with many features.											
Density: Sea Water Mixing and Sinking	Experiment	6-9	S.IP.06.13	S.IP.06.14	S.IP.06.16	S.IA.06.11	S.IP.07.13	S.IP.07.14	S.IP.07.16	S.IA.07.11	P.PM.07.24
			E4.2d								
Going with the Flow	Experiment/Data	5	S.IP.05.13	S.IP.05.11	P.FM.05.21	P.F.05.22	P.FM.05.41	P.FM.05.42			
Principle 2: The ocean and life in the ocean shape the features of the Earth.											
Ooze Clues--Diatom Ooze	Data Interpretation	9	B1.1D	B1.1E	B1.1g						
What Causes the Shoreline to Erode	Investigation	6-12	S.IP.06.13	S.IP.06.15	S.IP.07.13	S.IP.07.15	E.SE.06.12				
Principle 3: The ocean is a major influence on weather climate.											
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8	S.IP.06.13	S.IP.06.15	S.IP.06.16	S.IA.06.11	S.IP.07.13	S.IP.07.15	S.IP.07.16	S.IA.07.11	E.ES.07.73
			E1.1g	E4.2B							
Implications of Warming in the Arctic	Cooperative learning groups	6-12	E1.2D	E4.2A	E4.2B						
Principle 4: The ocean makes Earth habitable.											
Bats and Hot Dogs	Real-time Data Interpretation	6-9	S.IP.06.15	S.IP.06.16	S.IA.06.11	L.EC.06.41	S.IP.07.15	S.IP.07.16	S.IA.07.11		
Being Productive in the Arctic Ocean	Experiment	9-12	B1.1B	B1.1D	B1.1E	B1.1g	B3.3b	B3.5e			
Principle 5: The ocean supports a great diversity of life and ecosystems.											
Tangled Web	Simulation	5-8	S.RS.05.15	S.RS.06.15	S.RS.07.15	B3.3A					
Sea Connections	Food Web Card Game	6-8	L.OI.06.51	L.EC.06.11	L.EC.06.41	B3.1A	B3.3A	B3.4C			
Principle 6: The ocean and humans are inextricably interconnected.											
Pollution Solution	Experiment/Role-play	6-8	S.RS.06.16	S.RS.06.17	L.EC.06.41	S.RS.07.16	S.RS.07.17	E.ES.07.42	E1.2B	E2.4B	
			S.IP.06.11	S.IP.06.15	S.IP.06.16	S.IA.06.11	S.IA.06.12	S.IA.06.13	S.IA.06.15	S.RS.06.11	L.EC.06.41
Downeaster Alexa: A fishery story	Data Interpretation	6-9	S.IP.07.16	S.IA.07.11	S.IA.07.12	S.IA.07.13	S.IA.07.15	S.RS.07.11	B.1.2C	L3.p4A	B3.4C
Principle 7: The ocean is largely unexplored.											
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8	S.RS.07.16	P.CM.07.21	E3.3A						
Calling All Explorers	Web-quest NOAA	5-9	S.RS.05.16	S.RS.06.16	S.RS.07.16	L.EV.05.12	B.1.2E				

Template for Links to State Standards

Name of State: Minnesota

	Instructional Mode	Grade Level	Standards										
Principle 1: The Earth has one big ocean with many features.													
Density: Sea Water Mixing and Sinking	Experiment	6-9	6.1.3.4.1	8.1.1.2.1	8.1.3.4.1	8.1.3.4.2	8.2.1.1.1	8.2.1.2.1	9.1.3.4.2	9.1.3.4.3	9.3.2.2.1		
Going with the Flow	Experiment/Data	5	5.1.1.1.3	5.1.1.2.2	6.2.3.2.1								
Principle 2: The ocean and life in the ocean shape the features of the Earth.													
Ooze Clues--Diatom Ooze	Data Interpretation	9	9.1.3.1.1	9.1.3.1.2									
What Causes the Shoreline to Erode	Investigation	6-12	7.1.1.2.3	8.1.1.2.1	8.1.3.4.1	8.1.3.4.2	8.3.1.2.1	9.3.4.1.1					
Principle 3: The ocean is a major influence on weather climate.													
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8	6.1.3.1.1	6.1.3.4.1	6.2.3.2.3	7.1.1.2.3	8.1.1.2.1	8.1.3.4.1	8.1.3.4.2	8.3.2.1.2	8.3.2.1.3	8.3.2.2.3	
Implications of Warming in the Arctic	Cooperative learning groups	6-12	8.1.1.2.1	8.3.2.1.2	8.3.2.1.3	8.3.2.2.1	8.3.2.3.1	9.1.3.1.1	9.1.3.1.2	9.1.3.1.3	9.3.2.2.1		
Principle 4: The ocean makes Earth habitable.													
Bats and Hot Dogs	Real-time Data Interpretation	6-9	6.1.3.1.1	7.1.1.2.3	7.1.3.4.1	7.1.3.4.2	7.4.2.1.3	7.4.2.2.1	7.4.2.2.2	8.1.3.4.2	9.1.3.1.1	9.1.3.1.2	9.1.3.4.3
Being Productive in the Arctic Ocean	Experiment	9-12	9.1.1.1.2	9.1.3.1.1	9.1.3.1.2								
Principle 5: The ocean supports a great diversity of life and ecosystems.													
Tangled Web	Simulation	5-8	5.4.2.1.1	5.4.2.1.2	5.4.4.1.1	7.1.1.2.3	7.4.2.1.1	7.4.2.2.1	7.4.2.2.2	7.4.2.2.3	7.4.4.1.2		
Sea Connections	Food Web Card Game	6-8	7.4.2.1.1	7.4.2.1.2	7.4.2.2.1	7.4.2.2.2	7.4.2.2.3	7.4.4.1.2					
Principle 6: The ocean and humans are inextricably interconnected.													
Pollution Solution	Experiment/Role-play	6-8	6.1.3.4.1	6.2.1.2.1	7.1.1.2.3	7.1.1.2.4	7.4.4.1.2	8.1.1.1.1	8.1.1.2.1	8.1.3.3.1	8.2.1.1.1	8.3.4.1.2	
Downeaster Alexa: A fishery story	Data Interpretation	6-9	7.1.3.4.1	7.1.3.4.2	7.4.2.1.3	7.4.4.1.2	8.1.1.2.1	8.3.4.1.2	9.1.3.1.1	9.3.4.1.2	9.4.4.1.2		
Principle 7: The ocean is largely unexplored.													
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8	7.1.1.2.3	7.1.1.2.4	8.1.1.2.1	8.1.3.3.1	8.1.3.3.2	8.3.1.2.1					
Calling All Explorers	Web-quest NOAA	5-9	8.1.3.2.1	8.1.3.3.2	8.1.3.3.3	9.1.1.1.2	9.1.1.1.6	9.4.4.1.3					

Template for Links to State Standards

Name of State: New York

	Instructional Mode	Grade Level	1.1	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2	7.1	7.2
Principle 1: The Earth has one big ocean with many features.																									
Density: Sea Water Mixing and Sinking	Experiment	6-9		x		x														x					
Going with the Flow	Experiment/Data	5		x		x																			
Principle 2: The ocean and life in the ocean shape the features of the Earth.																									
Ooze Clues--Diatom Ooze	Data Interpretation	9		x	x	x																			
What Causes the Shoreline to Erode	Investigation	6-12		x	x																				
Principle 3: The ocean is a major influence on weather climate.																									
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8		x	x	x																			
Implications of Warming in the Arctic	Cooperative learning groups	6-12		x	x																				
Principle 4: The ocean makes Earth habitable.																									
Bats and Hot Dogs	Real-time Data Interpretation	6-9		x	x															x	x	x	x	x	x
Being Productive in the Arctic Ocean	Experiment	9-12																		x	x	x	x	x	x
Principle 5: The ocean supports a great diversity of life and ecosystems.																									
Tangled Web	Simulation	5-8																				x	x		
Sea Connections	Food Web Card Game	6-8																				x	x	x	x
Principle 6: The ocean and humans are inextricably interconnected.																									
Pollution Solution	Experiment/Role-play	6-8																						x	x
Downeaster Alexa: A fishery story	Data Interpretation	6-9																						x	x
Principle 7: The ocean is largely unexplored.																									
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8																							
Calling All Explorers	Web-quest NOAA	5-9																							

Template for Links to State Standards

Name of State: Ohio

Activity	Instructional Mode	Grades	Earth & Space Sciences	Life Sciences	Physical Sciences	Science and Technology	Scientific Inquiry	Scientific Ways of Knowing
Principle 1: The Earth has one big ocean with many features								
Density: Sea Water Mixing and Sinking	Experiment	6-9	9B-4,		6A-1, 6A-4, 9C-9		6A-2, 7A-1, 7B-7, 8B-3, 9A-3, 9A-6	9A-3
Going With the Flow	Experiment/Data	5	5C-3, 5A-6					5B-2
Principle 2: The ocean and life in the ocean shape the features of the Earth.								
Ooze Clues - Diatom Ooze	Data Interpretation	9	9B-4				9A-3, 9A-5, 9A-6	9B-5
What Causes the Shoreline to Erode	Investigation	6-12	7C-3, 7C-4, 6D-1, 6D-2, 8E-11, 8E-13, 9B-4, 10B-2, 10D-5, 11B-2, 11B-3, 11B-4, 11B-6, 12B-5, 11B-13	7C-6, 7D-5, 10F-17, 11B-5, 11D-12, 11F-9	6A-4, 8B-2, 6C-6, 7D-3, 8D-4, 9C-9, 9G-19, 9G-20, 12A-2, 11C-3, 12D-3	7A-2, 8A-2, 6B-5, 7B-4, 8B-3, 9A-2, 9A-3, 9B-1,11A-1, 11A-2,	7B-7,8B-3, 9A-3, 10A-2,	10A-2, 10A-3, 9C-2, D-9, 11A-1, 11A-2, 11A-3, 12A-3, 12A-4, 12A-5, 11C-9, 11C-10, 12C-9, 12C-11
Principle 3: The ocean is a major influence on weather climate.								
How is Coastal Temperature Influenced by the GL and ocean?	Lab/Graphing	6-8	7C-6, 7C-7, 7C-8		6A-4		7B-7, 8B-3	
Implication of Warming in the Arctic	Cooperative Learning Groups	6-12	7C-1, 7C-2, 7C-3, 7C-8, 9B-4, 10B-1, 10B-2, 10C-4, 10D-6, 11B-3, 11B-4, 11B-5, 11B-6, 12B-511C-11, 11C-13	7C-3, 7C-6, 7D-5, 10D-9, 10D-11, 10F-15, 10F-17, 10G-18, 11D-12, 11F-9,	6A-1, 6A-4, 6C-8, 9C-9, 9F-17	6A-2, 7A-1, 7A-2, 9A-2, 9B-1, 10B-1, 10B-2,11A-1, 11A-4, 11A-5, 11A-6, 12A-4	7A-3, 7B-5, 9A-3, 9A-5, 9A-6, 10A-2, 10A-4, 10A-5	8A-1, 10A-1, 10A-3, 9B-5, 9B-6, 9B-7, 11A-1, 11A-2, 12A-1, 11C-9, 11C-10, 12C-9
Principle 4: The ocean makes the Earth habitable.								
Bats and Hot Dogs	Real time data Interpretation	6-9	7C-2, 9B-4	6C-8, 7C-3, 7C-6, 7D-5,8D-5	6A- 1, 6A-4, 9C-9, 9D-21	9A-2	7A-1, 7A-2, 7A-3, 6B-3, 7B-5, 7B-7, 8B-3, 8B-4, 9A-3, 9A-5, 9A-6	6A-2, 8A-1, 7C-3, 9A-1, 9B-5, 9B-7, 9C-2, 9D-8
Being Productive in the Arctic Ocean	Experiment	9-12		10D-9, 10D-10, 10D-11,10F-15, 10F-16, 10F-17, 10G-18, 12A-3, 12A-4, 11D-12, 12E-9, 11F-9, 11F-11	9F-15, 9G-18,	9A-2,10B-2, 12A-4	9A-1, 9A-3, 9A-5, 9A-6, 10A-4, 10A-5, 11A-1, 11A-512A-1	9A-1, 10A-1, 10A-2, 10A-3, 9B-6, 9B-7, 11A-2, 12A-1, 12A-4, 11C-9,
Principle 5: The ocean supports a greaat diversity of life and ecosystems.								
Tangled Web	Simulation	5-8	5C-6,	5B-1, 5B-2, 5B-3, 5C-4, 5C-5, 5C-6, 7C-3, 7C-7, 7D-4		6A-2, 7A-2	7A-2, 8B-3	8B-2, 6C-3
Sea Connections	Food Web Card Game	6-8	7C-1, 8E-12, 8E-13	6C-8, C-3, 7C-7		6A-2, 7A-2	6A-1, 7A-3, 8B-3	
Principle 6: The ocean and humans are inextricably interconnected.								
Pollution Solution	Experiment/Role Play	6-8	8A-1, 7C-2, 7C-4, 7C-6, 8E-8, 7C-3, 7C-6, 7D-5, 8D-5	6C-8, 7C-3, 7C-6, 7D-5	6A-2, 7A-1, 8B-1, 8B-2, 8D-4,	6A-1, 6A-2, 7A-2, 7A-3, 8A-2, 6B-5, 7B-4, 8B-3, 8B-4	6A-1, 6A-2, 7A-1, 7A-4, 8A-1,	6C-3, 7C-3
Downeaster Alexa: A fishery Story	Data Interpretation	6-9	7C-1, 7C-2, 7E-13, 9B-4,	6B-4, 7B-8, 6C-8, 7C-3, 7C-6, 8D-5		6A-1, 7A-2, 8A-2, 9A-2, 9A-3, 9B-1	7A-3, 8A-2, 7B-5, 7B-7, 8B-3, 9A-1, 9A-3, 9A-5, 9A-6	6A-1, 6A-2, 8A-1, 7B-1, 7B-2, 8B-2, 6C-3, 7C-3, 9A-1, 9A-3, 9B-5, 9B-6, 9C-2, 9D-9
Principle 7: The ocean is largely unexplored.								
I, Robot, Can Do That!	Technology Investigation/ Decision-Making	7-8		7C-2, 7C-6,		7A-3, 8A-1, 8A-2, 8B-4	7A-4, 8A-1	7C-3
Calling All Explorers	Web-quest NOAA	5-9				5A-1, 6A-1, 8A-1	5B-2, 5C-5, 6A-1	5A-1, 5B-4, 5C-5, 5D-6, 6A-2, 6C-3, 6C-5, 7C-3, 9A-1, 9B-7, 9C-2, 9D-8, 9D-9

Template for Links to State Standards

Name of State: Pennsylvania

	Instructional Mode	Grade Level	Standards
Principle 1: The Earth has one big ocean with many features.			
Density: Sea Water Mixing and Sinking	Experiment	6-9	**3.2.7B** Apply process knowledge to make and interpret observations; **3.2.7C** Identify and use elements of scientific inquiry to solve problems; **3.4.7A** Describe concepts about the structure and properties of matter; **3.5.7D** Explain the behavior and impact of the earth's water systems;
Going with the Flow	Experiment/Data	5	**3.1.7B** Describe the use of models as an application of scientific or technological concepts; **3.2.7A** Explain and apply scientific and technological knowledge; **3.2.7B** Apply process knowledge to make and interpret observations; **3.4.7C** Identify and explain the principles of force and motion
Principle 2: The ocean and life in the ocean shape the features of the Earth.			
Ooze Clues--Diatom Ooze	Data Interpretation	9	
What Causes the Shoreline to Erode	Investigation	6-12	
Principle 3: The ocean is a major influence on weather climate.			
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8	**3.1.7B** Describe the use of models as an application of scientific or technological concepts; **3.2.7B** Apply process knowledge to make and interpret observations; **3.2.7C** Identify and use the elements of scientific inquiry to solve problems; **3.4.7B** Relate energy sources and transfers to heat and temperature; **3.5.7C** Describe basic elements of meteorology;
Implications of Warming in the Arctic	Cooperative learning groups	6-12	
Principle 4: The ocean makes Earth habitable.			
Bats and Hot Dogs	Real Time Data Interpretation	6-9	
Being Productive in the Arctic Ocean	Experiment	9-12	
Principle 5: The ocean supports a great diversity of life and ecosystems.			
Tangled Web	Simulation	5-8	**4.6.7A** Explain the flows of energy and matter from organism to organism within an ecosystem;
Sea Connections	Food Web Card Game	6-8	**3.3.7A** Describe the similarities and differences that characterize diverse living things; **4.6.7A** Explain the flows of energy and matter from organism to organism within an ecosystem; **4.6.7C** Explain how ecosystems change over time; **4.7.7A** Describe the diversity of plants and animals in ecosystems; **4.7.7B** Explain how species of living organisms adapt to their environment; **4.7.7C** Explain natural or human actions in relation to the loss of species; **4.8.7B** Explain how people use natural resources; **4.8.7C** Explain how human activities may affect local, regional and national environments; **4.8.7D** Explain the importance of maintaining the natural resources at the local, state and national levels
Principle 6: The ocean and humans are inextricably interconnected.			
Pollution Solution	Experiment/Role-play	6-8	**3.1.7B** Describe the use of models as an application of scientific or technological concepts; **3.2.7C** Identify and use the elements of scientific inquiry to solve problems; **3.2.7D** Know and use the technological design process to solve problems; **4.2.7A** Know that raw materials come from natural resources; **4.3.7B** Describe how human actions affect the health of the environment
Downeaster Alexa: A fishery story	Data Interpretation	6-9	**3.1.7B** Describe the use of models as an application of scientific or technological concepts; **3.8.7A** Explain how sciences and technologies are limited in their effects and influences on society; **3.8.7B** Explain how human ingenuity and technological resources satisfy specific human needs and improve the quality of life; **3.8.7C** Identify the pros and cons of applying technological and scientific solutions to address problems and the effect upon society; **4.8.7**B Explain how people use natural resources; **4.8.7C** Explain how human activities may affect local, regional and national environments; **4.8.7D** Explain the importance of maintaining the natural resources at the local, regional and national levels; **4.9.7A** Explain the role of environmental laws and regulations
Principle 7: The ocean is largely unexplored.			
I, Robot, Can Do That!	Technology Investigation / Decision-Making	7-8	
Calling All Explorers	Web-quest NOAA	5-9	

Template for Links to State Standards

Name of State: Wisconsin

	Instructional Mode	Grade Level	Standards					
Principle 1: The Earth has one big ocean with many features.								
Density: Sea Water Mixing and Sinking	Experiment	6-9	Sci C.8.2	Sci C.8.6	Sci D.8.1	Sci E.8.1	Sci E.8.3	Mth A.8.1
			Mth D.8.3					
Going with the Flow	Experiment/Data	5	Sci A.8.6	Sci C.8.2	Sci C.8.3	Sci C.8.6	Sci D.8.5	Sci D.8.9
Principle 2: The ocean and life in the ocean shape the features of the Earth.								
Ooze Clues--Diatom Ooze	Data Interpretation	9	Sci A.8.6	Sci E.8.1	Sci E.12.2	Sci F.8.8	Soc A.8.1	Sci E.8.3
What Causes the Shoreline to Erode	Investigation	6-12	Sci A.8.6	Sci C.8.3	Sci C.8.6	Sci E.8.1	Sci E.8.3	
Principle 3: The ocean is a major influence on weather climate.								
How is Coastal Temperature Influenced by the GL and the Ocean?	Lab/Graphing	6-8	Sci C.8.2	Sci C.8.3	Sci D.8.7	Sci D.8.8	Sci E.8.1	Sci E.8.3
			Soc A.8.1	Lit A.8.3				
Implications of Warming in the Arctic	Cooperative learning groups	6-12	Sci A.8.6	Sci D.8.8	Sci E.8.1	Sci E.8.2	Sci E.8.3	Sci E.12.2
			Sci G.8.3	Lit d.12.1	Eng b.12.1			
Principle 4: The ocean makes Earth habitable.								
Bats and Hot Dogs	Real-time Data Interpretation	6-9	Sci A.8.3	Sci A.8.6	Sci C.8.2	Sci C.8.4	Sci C.8.6	Sci C.8.8
			Sci C.12.5	Sci F.8.8	Sci F.8.9			
			Sci F.12.8	Lit A.12.3				
Being Productive in the Arctic Ocean	Experiment	9-12	Sci C.12.5	Sci C.12.6	Sci E.12.2	Sci F.12.10	Lit D.12.1	Eng B.12.1
			Env B.12.4	Env B.12.6				
Principle 5: The ocean supports a great diversity of life and ecosystems.								
Tangled Web	Simulation	5-8	Sci C.8.2	Sci C.8.6	Sci F.8.8	Sci F.8.9	Eng B.8.1	Env B.8.5
			Env B.8.6	Env B.8.8				
Sea Connections	Food Web Card Game	6-8	Sci C.8.6	Sci F.8.8	Sci G.8.3	Env B.8.5	Env B.8.8	Env B.8.10
			Env B.8.15	Env B.8.16				
Principle 6: The ocean and humans are inextricably interconnected.								
Pollution Solution	Experiment/Role-play	6-8	Sci C.8.2	Sci C.8.6	Sci C.8.10	Sci G.8.2	Eng C.8.1	Eng C.8.2
			Eng C.8.3	Env A.8.2	Env A.8.4	Env B.8.18	Env B.8.22	
Downeaster Alexa: A fishery story	Data Interpretation	6-9	Sci A.8.3	Sci A.8.6	Sci A.12.5	Sci C.8.2	Sci C.8.6	Sci C.8.8
			Sci F.8.8	Sci F.12.8	Sci G.8.3			
			Env A.8.4	Env B.8.12	Env B.8.16	Env B.8.23	Env B.12.5	Env B.12.6
			Env B.12.12					
Principle 7: The ocean is largely unexplored.								
I, Robot, Can Do That!	Technology Investigation and Decision-Making	7-8	Sci E.8.2	Sci G.8.2	Soc B.8.8			
Calling All Explorers	Web-quest NOAA	5-9	Sci B.8.1	Sci C.8.2	Sci G.8.1	Soc A.8.8	Eng B.8.1	Eng E.8.1

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