Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

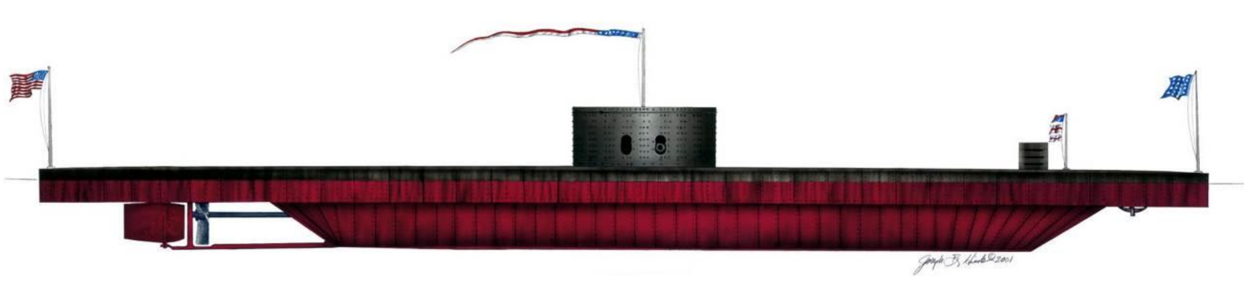
MONITOR NATIONAL MARINE SANCTUARY

Education

Educational Product	
Educators	Grades 6-12

Shipwreck of the Deep

An Educator Guide with Activities in Science, Technology, Engineering and Math



Acknowledgement

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Cover Photo: USS *Monitor*, NOAA
Inside Cover Photo: USS *Monitor* drawing, Courtesy Joe Hines

NATIONAL MARINE SANCTUARIES
MONITOR

NEWPORT NEWS PUBLIC SCHOOLS

Monitor National Marine Sanctuary
Shipwreck of the Deep

An Educator Guide with Activities in Science, Technology, Engineering and Math

Table of Contents

For additional information about **Shipwrecks of the Deep**, contact Shannon Ricles at 757-591-7328 or Shannon.Ricles@noaa.gov.

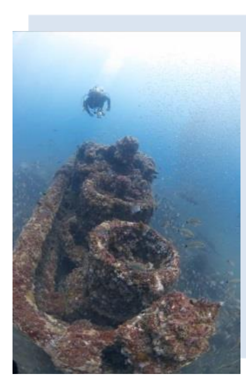
Shipwrecks of the Deep was made possible by the generous support provided by the National Marine Sanctuary Foundation; Newport News Public Schools, Newport News, Va.; and Crittenden Middle School, Newport News, Va.

Writers and Teacher Advisors: Shannon Ricles, Amanda Carmean and Rodney Culverhouse.

Graphic Designer: Shannon Ricles and Matt McIntosh

There are 14 marine protected areas in U.S. waters known as the National Marine Sanctuary System. For more information visit http://sanctuaries.noaa.gov

Divers swims over the *Dixie Arrow* located off the North Carolina coast. Photo: NOAA



NEED FOR STEM EDUCATION

In today's fast-paced ever changing world, science education is more important than ever. Our world is extremely complex, and science knowledge is critical to making sense of it all. If future generations are to make informed decisions, it is imperative that they be science literate. Science education helps students to develop into more responsible citizens who build a strong economy, contribute to a healthier environment and who are better problem-solvers, innovators and researchers.

Children are naturally inquisitive with hundreds of 'why' and 'how' questions. Science education satisfies that curiosity, while providing them with valuable skills and career options for their future. It also gives children a greater appreciation of their world and its inhabitants, along with a healthy dose of skepticism. Understanding how science fits into our lives, helps children to have a greater foundation for success in life. Using real-world problems and unique hands-on activities, excites and motivates children even more to learn science.

The Monitor National Marine Sanctuary, in collaboration with Newport News Public Schools in Newport News, Va., is excited to offer educators this course, *Shipwreck of the Deep*, to enhance and enrich the teaching of science, technology, engineering, and math (STEM), as well as social studies and geography. The course is designed to peak students' natural curiosity and to excite them to learn STEM, using problem based learning (PBL), while engaging in real-world problems focusing around the excitement of shipwrecks and the deep ocean.

PROGRAM OVERVIEW

The curriculum is divided into three parts and is based on a story line where the students are maritime archaeologists, engineers and researchers. As maritime archeologists, they are looking for an unknown shipwreck. As they begin their search, the students learn about NOAA's Maritime Heritage Program, the role of a maritime archeologist, the technology of side scan sonar, how to plot map coordinates and how to identify a ship's parts. Students also explore the shipwreck as maritime archaeologists and become engineers designing and building their own underwater remotely operated vehicle (ROV) for further exploration.

To document the shipwreck, students learn to map it and how to create a photomosaic. Once the shipwreck is documented, students work to identify the shipwreck using log books, primary source documents, first-hand testimony and more. In the second section, as the students continue to discover and explore their shipwreck, they are faced with the challenge of how best to preserve and protect this cultural resource. In the research, they learn that shipwrecks act as artificial reefs and are important habitats for marine life. To determine if their shipwreck might be better left as a reef if left *in situ*, the students build and deploy a buoy with water quality sensors, learn about oysters and the role they play in the health of the bay and ocean.

In the third section of the curriculum, students explore the idea of raising all, part, or none of the shipwreck to conserve and protect its history. To better understand the complexity and cost of the conservation process, students study metals science and chemistry, build a boat, and visit with maritime conservationists working to conserve the USS *Monitor*'s artifacts.

As a culminating activity for the course, the students engage in Socratic seminars debating the best course of action to take for their newly discovered shipwreck. At the end of the course, they give their final presentation with their rationale for their proposal.
.
We hope that you find this course an excellent way to excite and motivate your students in the learning of STEM. Each section has accompanying hands-on activities to explore the various STEM concepts making students become critical thinkers and better problem solvers. However, if a full semester course is not feasible for your class, these activities can be used individually. Please feel free to contact us if you have any questions, and we welcome your feedback.

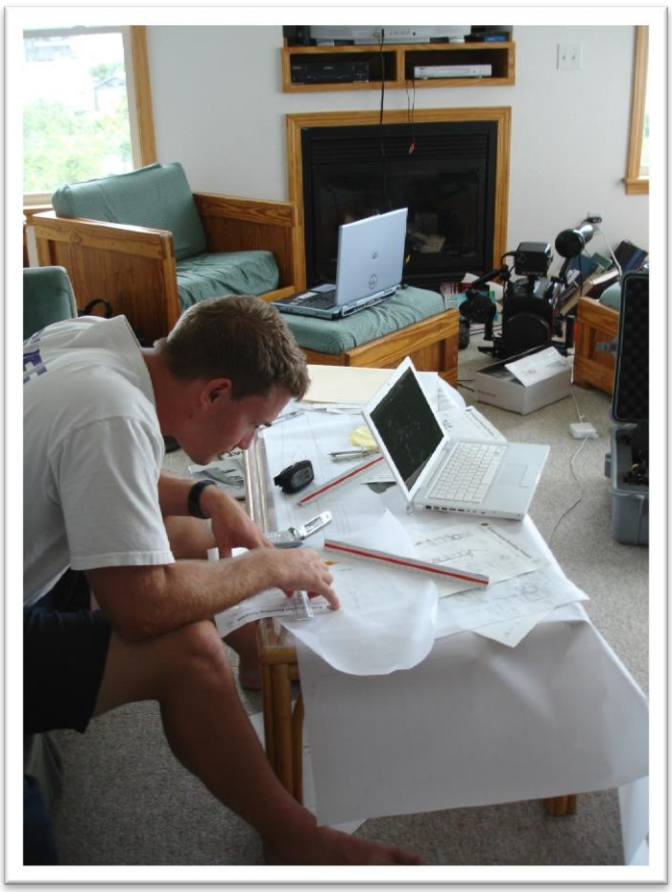
Photomosaic of U-*85*, a German U-boat located off the North Carolina Coast. Photo Courtesy NOAA.

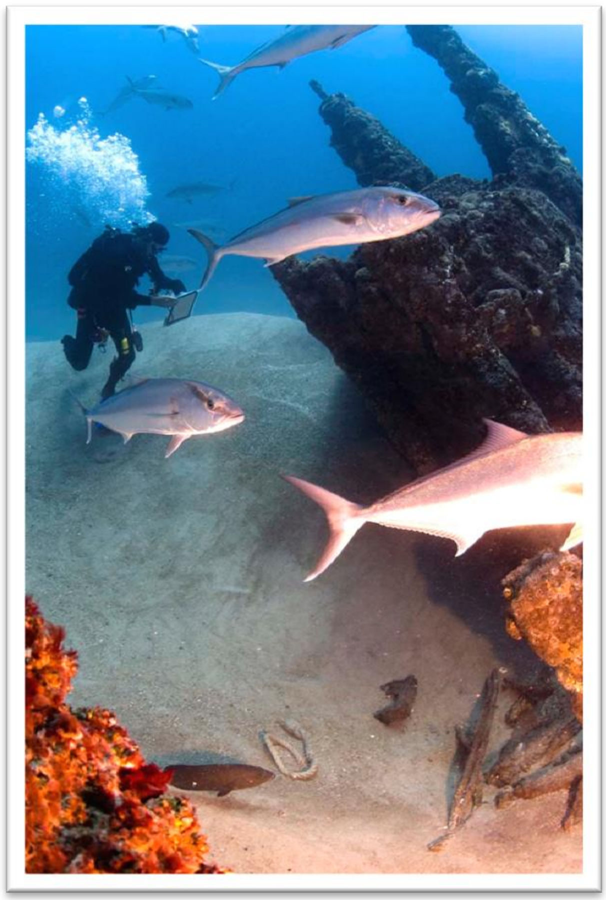
Education Standards

National Science Standards	• Science: NS. 5-8.A Science as Inquiry – Understanding about scientific inquiry • Science: NS 5-8.B Physical Science – Properties and changes of properties of matter • Science: NS 5-8 C Life Science – Structure and function in living systems; Reproduction and Heredity; Regulation and Behavior; Populations and Ecosystems • Science: NS. 5-8.4 Earth and Space Science – Structure of the earth system • Science: NS5-8 E Science and Technology – Abilities of technological design; Understanding about science and technology • Science: NS 5-8 F Science in Personal and Social Perspectives – Populations, resources, and environments; Science and technology in society; • Science: NS 5-8 G History and Nature of Science – Science as a human endeavor; Nature of Science; History of Science • Science: NS 9-12A Science as Inquiry – Understanding about scientific inquire • Science: NS 9-12 B Physical Science – Structure and properties of matter; Chemical reactions; Motion and Forces • Science: NS 9-12 C Life Science – The interdependence of organisms; Matter, energy, and organization in living systems; The behavior of organisms Science: NS 9-12 E Science and Technology – Abilities of technological design; Understanding about science and technology • Science: NS 9-12 F Science in Personal and Social Perspectives – Natural resources; Environmental quality; Natural and human-induced hazards. • Science: NS 9-12 G History and Nature of Science – Science as a human endeavor; Nature of scientific knowledge; Historical perspectives
Next Generation Science Standards	• TO COME
National Mathematics Standards	• Math: NCTM 6-8 Numbers and Operations – Understand numbers, ways of representing numbers, relationships among numbers, and number systems • Math: NCTM 6-8 Numbers and Operations – Compute fluently and make reasonable estimates • Math: NCTM 6-8 Algebra – Understand patterns, relations, and functions; Analyze change in various contexts • Math: NCTM 6-8 Geometry – Specify locations and describe spatial relationships using coordinate geometry and other representational systems • Math: NCTM 6-8 Measurement Standard – Understand measurable attributes of objects and the units, systems, and process of measurement • Math: NCTM 6-8 Data Analysis and Probability – Formulate questions that can b addressed with data and collect, organize, and display relevant data to answer them; develop and evaluate inference and predictions that are based on data; • Math: NCTM 6-8 Process Standards – Problem solving; Connections; Representation • Math: NCTM 9-12 Geometry – Specify locations and describe spatial relationships using coordinate geometry and other representational systems • Math: NCTM 9-12 Measurement Standard – Understand measurable attributes of objects and the units, systems, and process of measurement • Math: NCTM 9-12 Process Standards – Problem solving; Connections; Representation

Education Standards Continued

Ocean Literacy Principles http://oceanliteracy.wp2.coexploration.org/	• OL: 1 – The Earth has one big ocean with many features (a, e, and g) • OL: 5 – The ocean supports a great diversity of life and ecosystems (d, e, f, g, and i) • OL: 6 – The ocean and humans are inextricably interconnected (a, b, c, e, and g) • OL 7 – The ocean is largely unexplored (a, b, c, d, e, and f)
National Geography Standards	• NG: 1 – How to use maps and other geographical representations, geospatial technologies, and spatial thinking to understand and communicate ideas • NG: 4 – The physical and human characteristics of places • NG: 8 – The characteristics and spatial distribution of ecosystems and biomes on Earth's surface • NG: 17 – How to apply geography to interpret the past
Common Core	• **TO COME**





To learn about our past so as to better understand our future, maritime archaeologists document and survey shipwrecks both on land and underwater. Photo: NOAA, Monitor National Marine Sanctuary

Shipwreck of the Deep
Part I

Overview

As the story begins, a group of maritime archaeologists are planning an expedition to search for a shipwreck whose exact location is unknown. The ship they are looking for is a German U-boat that sank off the North Carolina coast in 1942 during World War II's Battle of the Atlantic. Maritime archaeologists know the general area where the ship sank, but the area is very large and searching in the open ocean poses many challenges. They turn to NOAA's Maritime Heritage Program and the Monitor National Marine Sanctuary for guidance and help.

In collaboration, the team of maritime archeologists and researchers begin an expedition on NOAA's 81 foot vessel, SRVx *Sand Tiger*, in search of the lost German U-boat. They team with other researchers and use side scan sonar to take images of the ocean floor over a defined general area. Once the images are captured, they analyze them looking for any anomalies that might indicate a shipwreck. Several sites of interest are noted, so the scientists return to those sites to take a closer look. One of the sites is a shipwreck!

The maritime archaeologists can tell by its sonar image that it is not a German U-boat, but they are intrigued to explore it and to discover which ship they have found. They are at the end of the expedition with only a few days left and the threat of stormy weather is on the horizon. The wreck is deep, and only two of the maritime archaeologists are qualified tech divers and can dive at that depth. They don't have time to go back to port to gather more equipment and other qualified divers, so to help save time, the researchers decide to use the equipment on the ship to design and build a remotely operated vehicle (ROV) with a camera. An ROV can stay underwater continuously and take hundreds of images helping the team study the shipwreck. While the two NOAA tech divers work underwater to map the shipwreck, other researches build and use the ROV to capture hundreds of images, which will later be stitched together to create a photomosaic of the shipwreck.

While documenting and mapping the newly discovered shipwreck, maritime archaeologists discover the ship's log book lying among the wreckage. It appears to be opened to the last entries made by the ship's captain. They know that this information might hold clues to the identification of the shipwreck, so they carefully take photographs of it, but leave it *in situ* (to leave in its original place). Meanwhile, the engineering team is busy collecting images of the wreck site from the ROV camera to give to the maritime archaeologists. The research team works diligently to investigate all possible ships that could have sunk in that specific area. Together, they will combine their information to determine what shipwreck they have discovered. Also, an unusual twist occurs on one of the last dives when the maritime archaeologists discover human remains.

Part I: Suggested Course Outline:

A. Course Introduction (1 hour)
   1) Introduction to the National Oceanic and Atmospheric Administration (NOAA), Office of National Marine Sanctuaries (ONMS), Maritime Heritage Program (MHP) and Monitor National Marine Sanctuary (MNMS)
   2) Overview of the course and course objectives
   3) Introduce the problem: A team of maritime archaeologists and researchers working with NOAA and MNMS are searching for a World War II German U-boat that supposedly sank off the North Carolina coast in 1942. They do not find the U-boat, but they discover an unknown shipwreck.
   4) Students are challenged with the task to identify and explore the shipwreck in order to decide what to do with it. Questions students will answer are: Should a few parts of the ship be brought up and conserved? Should the entire ship be raised for conservation? Should nothing be done and the ship left as an artificial reef? Or should it be left *in situ*, but protected as a national marine sanctuary.

B. Where's the Boat? (2 hours)
   1) Students learn how maritime archeologists and researchers use side scan sonar to find shipwrecks.
   2) Side scan sonar simulation activity
   3) Identifying parts of a ship activity

C. Introduction to Remotely Operated Vehicles (ROV) (2 hours)
   1) Introduction to ROV unit
   2) Activities: *It's All About Air*; Buoyancy; and Newton's Laws of Motion

D. Engineering Design Process and Build Out (5 hours)
   1) Introduce engineering and design
   2) Students design ROV
   3) Students manufacture pieces and complete building motors. Note: The control switch, wiring, and motors are completed by teachers.
   4) Students build ROV

E. Iterative Process and Competition (2 hours)
   1) Test ROV design and make design changes if needed
   2) Practice controlling ROV
   3) ROV Competition

F. Mapping a Shipwreck (1 hour)
   1) Use mock-shipwreck activity to simulate mapping a shipwreck.

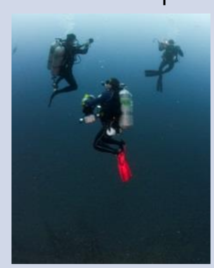
G. What Do the Pieces Tell Us? (3-4 hours)
   1) Learn about different types of ships and their most distinguishing parts
   2) Simulate "stitching" together a photomosaic.
   3) Use photomosaic of newly discovered shipwreck and its most identifiable parts to help identify the ship.
   4) Optional—Field Trip to an aquatic center or local pool to learn to snorkel.

H. Reading the Record (2 hours)
   1) Read "primary" source documents to learn about four different shipwrecks
   2) Use ships' logs to chart the last known location for each ship.
   3) Use all the pieces to identify the unknown shipwreck.

I. Sleuthing through 1908 (1 hour)
   1) Human remains are found. Understand the ethical issues and use clues to learn help identify the remains.

Careers

- ROV pilot
- ROV technician
- SCUBA diver
- dive instructor
- maritime archaeologist
- research scientist
- environmental engineer
- geological oceanographer
- laboratory technician
- submersible pilot



Objectives

Students will:

- Learn about our nation's National Marine Sanctuary System and NOAA;
- Understand how side scan sonar works and is used to locate shipwrecks;
- Identify the various parts of a ship;
- Learn the science principles necessary to construct an ROV, such as Newton's Laws of Motion, buoyancy, and properties of air;
- Understand the engineering design process and that it is an iterative process;
- Design and build an ROV for competition; and
- Describe how ROVs are used in marine science and underwater archaeology.
- Model how maritime archaeologists map shipwrecks;
- Identify and differentiate the parts of a ship;
- Construct a photomosaic of a shipwreck and interpret the image; and
- Dramatize and evaluate the complicated process of identifying unknowns.

Vocabulary

air pressure---measure of the force of air pressing down on a surface

artifact—any object made by humans, typically an item of cultural or historical interest

base line—a line serving as a basis for measurement, calculation or location; a measured line through a survey area from which triangulations are made

bow—forward part of the hull of a ship or boat; the point that is most forward when the vessel is underway

buoyancy—the upward force, caused by fluid pressure, that keeps things afloat

coordinate—a group of numbers used to indicate the position of a point, line, or plane

density— a property of matter that is defined as the ratio of an object's mass to its volume

engineer—person who is trained in or follows a branch of engineering as a profession

engineering—the science or profession of developing and using nature's power and resources in ways that are useful to people

fault tree—a graphical representation of the chain of events in the engineering design process that is used by engineers to analyze their designs from a top-down approach to avoid problems or find solutions

forensics—the use of science and technology to investigate and establish facts in criminal or civil courts of laws

in situ—to leave in its original place

iteration—a process in which a serious of operations is repeated a number of times with the aim of a desired result

photomosaic—a large-scale detailed picture or map built by combining photographs of small areas

ROV—remotely operated vehicle which is a tethered robot that operates underwater and is controlled from a boat or ship by an operator

side scan sonar—a type of sonar system that is used to efficiently create an image of large areas of the sea floor

site plan—an accurate scaled depiction of a shipwreck showing the relationship of artifacts to other artifacts

SCUBA—Self-contained underwater breathing apparatus: a portable apparatus containing compressed air and used for breathing under water

stern—the rear or aft-most part of a ship; opposite the bow

water pressure—measure of the force of water pressing on its surroundings

Suggested Implementation strategy

1. Review the suggested course outline on p. 7 for a recommended implementation strategy for the course.
2. Review the various activities included in this guide and determine which activities are best for your students.
3. Review additional web and book resources for appropriate supplemental material.
4. Once ready to begin the course, give the students an overview of the course and introduce students to NOAA and NOAA's Office of National Marine Sanctuaries, Maritime Heritage Program, and Monitor National Marine Sanctuary.

Resources

Web Resources:

NOAA's Office of National Marine Sanctuaries
Discover the marine life and extraordinary habitats that make up your nation's marine sanctuaries and learn about the continuing efforts to conserve these ocean and coastal treasures.
http://sanctuaries.noaa.gov/

Monitor National Marine Sanctuary
ROV in a bucket! Use easy to follow directions and simple materials to design and construct your own ROV.
http://monitor.noaa.gov/publications/education/rov_manual.pdf

NOAA National Ocean Service
Learn about side scan sonar and how scientists use it to map the ocean floor.
http://oceanservice.noaa.gov/education/seafloor-mapping/how_sidescansonar.html

NOAA Ocean Explorer
Discover how NOAA uses ROVs and learn more about the various NOAA ROVs currently in use. Read how ROV Hercules was built just for scientific research and can travel to depths of 4,000 meters!
http://oceanexplorer.noaa.gov/technology/subs/subs.html

Exploring WWII: Battle of the Atlantic Expeditions
For six years, maritime archaeologists with NOAA and other partners have documented and surveyed the various shipwrecks off the North Carolina coast associated with WWII's Battle of the Atlantic. Visit this site to learn see the remains of German U-boats that plied America's waters and the ships they sank. Experience these underwater treasures firsthand through the divers' blogs and beautiful images.
http://sanctuaries.noaa.gov/missions/battleoftheatlantic/archives.html

Thunder Bay National Marine Sanctuary
With over 200 shipwrecks in the Thunder Bay NMS, maritime archaeologists are continuously documenting the sites for future study. Visit Thunder Bay's education site to download photomosaic images, site plans, and lesson plan to delve deeper into the underwater world of shipwrecks. Lesson Plan:
http://thunderbay.noaa.gov/pdfs/piecetogetherteacher.pdf

US EPA: BOLDkids!: Science Onboard
Watch a video and read more about side scan sonar.
http://www.epa.gov/boldkids/scienceonboard.html

NOAA's National Marine Sanctuaries: Photomosaic Gallery
Here you will find examples of photomosaics created for the various shipwrecks located in some of the national marine sanctuaries.
http://sanctuaries.noaa.gov/missions/2006fknms/photomosaicgallery.html

Immersion Learning: Mapping Shipwrecks
Online interactive activity where you choose any one of five shipwrecks and then try your hand at pieces together its photomosaics.
http://www.immersionlearning.org/index.php?option=com_wrapper&Itemid=215

LSU FACES Lab
Learn how LSU FACES Laboratory helps law enforcement personnel in the methods and techniques used in physical and forensic anthropology.
http://www.lsu.edu/faceslab/

Marine Advanced Technology Education (MATE)
A national partnership of educational institutions and organizations working to improve marine technical education in the U.S. The MATE Center and its partners have developed several curriculum modules and programs including: An introduction to Aquaculture, career scenarios (problems) for the classroom, technology rich lab exercises, a new A.S. degree program, high school pathways, and a careers course. Some of these materials are available on-line.
http://www.marinetech.org/home.php

Woods Hole Oceanographic Institution—Though ROVs have been used extensively by the oil and gas industry for several decades, *Jason/Medea* was the first ROV system to be adopted and extensively used by ocean researchers. Visit this site to learn how scientists and researchers use *Jason/Medea* to conduct underwater expeditions.
http://www.whoi.edu/page.do?pid=8423

Monterey Bay Aquarium Research Institute—Learn how the aquarium uses ROVs and AUVs for research.
http://www.mbari.org/dmo/vessels_vehicles/rov.html

NASA for Kids: Intro to Engineering
Watch this video to learn about engineering and who exactly is an engineer.
http://blip.tv/nasa-goddard-tv/nasa-nasa-for-kids-intro-to-engineering-4722805

NASA SCI Files®: *The Case of the Radical Ride*
Join the tree house detectives in this 60-min video as they learn about the engineering design process.
An educator guide is also available for download.
http://www.knowitall.org/nasa/scifiles/index2.html

Book Resources

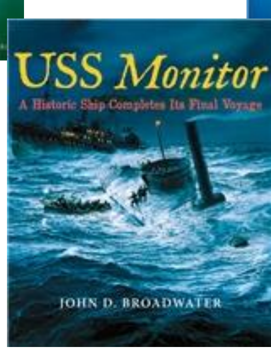
Adams, Simon: *Titanic (DK Eyewitness Books).* DK Children, 2009, ISBN-13: 978-0756650360.

Armstrong, Jennifer. *Shipwreck at the Bottom of the World: The Extraordinary True Story of Shackleton and the Endurance*. Crown Books for Young Readers, September12, 2000. ISBN-10: 0375810498.

Baker, Beth. *Sylvia Earl (Just the Facts Biographies)*. Lerner Publications, January 15, 2006. ISBN-10: 0822534223.

Ballard, Robert D. *Finding the Titanic Level 4*. Cartwheel, November1, 1993. ISBN-10: 0590472305.

Ballard, Robert D., Rick Archbold, and Ken Marschall. *Ghost Liners: Exploring the World's Greatest Lost Ships*. Little, Brown Young Readers, September 1, 1998. ISBN 10: 0316080209.



Broadwater, John D. *USS* Monitor*: A Historic Ship Completes Its Final Voyage*. Texas A&M University Press, February 14, 2012. ISBN10: 1603444734.

Cerullo, Mary M.: *Shipwrecks: Exploring Sunken Cities Beneath the Sea.* Dutton Juvenile, 2009, ISBN-13: 978-0525479680.

Cramer, Deborah. *Smithsonian Ocean: Our Water, Our World*. Smithsonian, October 7, 2008. ISBN 10: 0061343838.

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Gibbons, Gail. *Exploring the Deep, Dark Sea*. Little, Brown Young Readers, April 1, 2002. ISBN 10: 0316755494.
Jefferis, David. *Super Subs: Exploring the Deep Seat (Megatech)*. Crabtree Publishing Company, September1997. ISBN-10: 0778700631.

MacQuitty, Miranda. *Ocean (DK Eyewitness Books)*. DK Children, June 30, 2008. ISBN 10: 0756637767.
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Rose, Paul; Anne Laking, and Phillippe Cousteau. *Oceans: Exploring the Hidden Depths of the Underwater World*. University of California Press, April 15, 2009. ISBN 10: 0520260287

Smith, K.C.: *Exploring for Shipwrecks (Watts Library).* Franklin Watts, 2000, ISBN-13: 978-0531164716.

Walker, Sally M. *Shipwreck Search: Discovery of the H. L. Hunley (On my Own Science)*. First Avenue Editions, November 30, 2006. ISBN 10: 0822564491.

Wall, Julia: *Mapping Shipwrecks with Coordinate Planes (Real World Math: Level 5).* Capston Press, 2011, ISBN-13 978-1429666176.

Activities and Worksheets

Maritime archaeologists and videographers dive on North Carolina's WWII shipwrecks. Photo: NOAA

NOAA Who?

The National Oceanic and Atmospheric Administration (NOAA) is an agency that enriches life through science. NOAA's research goes from the surface of the Sun to the depths of the ocean floor as they work to keep citizens informed of the changing environment around them. From daily weather forecasts, severe storm warning and climate monitoring to fisheries management, coastal restoration and supporting marine commerce, NOAA's products and services support economic vitality. NOAA's dedicated scientists use cutting-edge research and high-tech instrumentation to provide citizens, planners, emergency managers and other decision makers with reliable information they need when they need it.

NOAA's roots date back to 1807, when the Nation's first scientific agency, the Survey of the Coast, was established. Since then, NOAA has evolved in every state and has emerged as an international leader on scientific and environmental matters. There are six line offices within NOAA: National Environmental Satellite, Data, and Information Service; National Marine Fisheries Service; National Ocean Service; National Weather Service; Office of Oceanic and Atmospheric Research; and Office of Program Planning and Integration.

Within the National Ocean Service (NOS), the **Office of National Marine Sanctuaries** serves as the trustee for a network of 14 marine protected areas encompassing more than 170,000 square miles of marine and Great Lakes waters from Washington State to the Florida Keys, and from Lake Huron to American Samoa. The network includes a system of 13 national marine sanctuaries and the Papahānaumokuākea Marine National Monument.

Monitor National Marine Sanctuary

As our nation's first national marine sanctuary, Monitor National Marine Sanctuary (MNMS) was established to preserve and protect our nation's first Civil War ironclad, USS *Monitor*. The *Monitor* and her brave crew helped to turn the tide of the Civil War and forever changed naval warfare when it fought the Confederate ironclad, CSS *Virginia*. As the two ships fought in the Battle of Hamptons Roads on March 9, 1862, the battle marked the first time that iron met iron and the age of the wooden ships came to an end. The *Monitor*'s rotating gun turret was also a new invention and it gave warships more maneuverability during battle.

On December 31, 1862, just 11 months after it launched from Greenpoint, Brooklyn, N.Y., the *Monitor* encountered a storm off Cape Hatteras, N.C., and sank. Sixteen brave men made the ultimate sacrifice when the ship sank that night. The *Monitor*'s exact location remained unknown until 1973, when John Newton and his team from the Duke University Marine Lab, using side scan sonar, identified an unknown shipwreck that they thought to be the *Monitor*. They confirmed its identity in 1974. North Carolina petitioned Congress to protect this national treasure and on January 30, 1975, the *Monitor* became our nation's first national marine sanctuary.

In 2002, NOAA, in collaboration with the US Navy, raised the iconic gun turret from the ocean floor. As Navy divers were excavating the turret, they found the remains of a *Monitor* sailor. Once the turret was on the barge's deck and on its way to The Mariners' Museum, a second set of remains was found. For the 150th anniversary of the USS *Monitor*, Louisiana State University's FACES Lab volunteered their services to recreate the faces of the two sailors in hopes of identifying possible descendants. With no descendants matching the sailors' DNA, the Secretary of the Navy authorized their interment at Arlington National Cemetery on March 8, 2013.

Today the recovered pieces of the USS *Monitor* are being conserved at The Mariners' Museum in Newport News, Va. This national treasure continues to share its history through the recovered artifacts as they reveal what life was like in 1862.

NOAA Who? Web search Activity

Purpose: To explore the many missions of the National Oceanic and Atmospheric Administration

Searching for NOAA

Using *NOAA Who?* and the websites below, answer the following questions to learn more about NOAA, National Marine Sanctuaries and the Monitor National Marine Sanctuary.

NOAA: http://www.noaa.gov/
Office of National Marine Sanctuaries (ONMS): http://sanctuaries.noaa.gov
Monitor National Marine Sanctuary (MNMS): http://monitor.noaa.gov

1. NOAA is part of the Department of ________________________.
2. List one of NOAA's missions.
3. How many line offices are there in NOAA? Name one.
4. Which line office is the sole official voice of the U.S. government for issuing warnings during life-threatening weather situations?
5. How many types of satellites does NOAA operate for the United States?
6. What line office supports the Office of National Marine Sanctuaries?
7. How many marine protected areas does the Office of National Marine Sanctuaries serve?
8. On the ONMS website, in the side bar click on "Visiting Sanctuaries." Click on any of the sanctuaries listed on the map and explain what that sanctuary protects.
9. List the four social medias that ONMS uses to inform people about the sanctuaries.
10. On the ONMS website, click on "Expeditions." Under "2011," click on "Battle of the Atlantic." Who wrote the blog for June 24? What type of camera did he use to document the shipwrecks?
11. What sanctuary led the Battle of the Atlantic expedition?
12. On the MNMS website, click on "About Your Sanctuary." What act gave authority to establish the Monitor National Marine Sanctuary?
13. Under "About Your Sanctuary," click on "History of the *Monitor*." Who designed the USS *Monitor*?
14. On that same page, what did Paymaster William Keeler write to his wife about the *Monitor*'s sinking?
15. In the side bar, click on "Advisory Council." What is the role of the Sanctuary Advisory Council?

Shipwreck Dilemma

Purpose: To become aware of the various ethical issues surrounding shipwrecks.

A shipwreck is what is left of a sunken ship. Shipwrecks are a unique and non-renewable resource, and they can be found in the very deep ocean or even right on a beach. Along the United States' eastern coast, there are hundreds, if not thousands, of shipwrecks with some dating back to the 16th century and the early exploration of North America.

There are hundreds of reasons why a ship might have sunk. Some ships sank due to tropical storms, such as hurricanes. Others sank in times of war by torpedoes or other weapons. Many sank due to poor navigation and shifts in the dynamic coast. Today, some ships are sunk on purpose as an artificial reef to offer a new environment to marine life.

No matter how they sank, shipwrecks offer scuba divers an amazing underwater experience and each one is a small glimpse into a time capsule of its day. Maritime archaeologists, who document and survey shipwrecks, search for historic shipwrecks trying to learn about our past in order to better understand the present and future.

It is estimated that there are over three million shipwrecks at the bottom of the world's ocean. Of these, many are famous shipwrecks, such as the *Titanic*, USS *Arizona* and *Queen Anne's Revenge*. However, there are many that are not so famous, such as small fishing boats. The final resting place of many ships is unknown, and over time the shipwrecks may be reclaimed by the harsh environment of the sea with on one ever finding them.

Occasionally, a new shipwreck is found and it is quite an exciting discovery. But if you find a sunken shipwreck, what should you do? Should it be raised for everyone to enjoy? Should it be left *in situ* for divers to enjoy and maritime archaeologists to study? There is no one answer as there are many factors to consider. What would be gained by raising the shipwreck? What is the condition of the shipwreck? Is the shipwreck historically significant? Is it a threat to the environment or commerce? If a shipwreck or any of its pieces are brought to the surface, all the artifacts must be kept together as a collection and properly conserved, which is a very expensive process. Is there someone or an organization willing to fund the conservation and display of the artifacts?

Shipwrecks are exciting, and they offer beauty for scuba divers and tell the story of our nation's maritime heritage. However, if you are lucky enough to find a new shipwreck, be sure to consider all factors before deciding to raise it or bring up any of its artifacts. Make sure that your reasons are sound and ethical.

Photomosaic of U.S. Navy's YP-*389*. The shipwreck was discovered by a NOAA-led research mission in 2009. The ship sunk off Cape Hatteras, N.C. by a German U-boat during World War II. Courtesy NOAA.

Searching the Deep

Materials—Per Group
prepared shoebox
masking tape
5 different colored pencils
ruler
graph paper
wooden dowel (3 mm diameter by 30 cm length)

Teacher Prep Materials
clay or plaster-of-Paris per box
Ping-Pong balls or other objects
sharp nail 3-4 mm diameter

Teacher Prep
1. For each student group, prepare one shoebox by lining the bottom of the box unevenly with mounds of clay or plaster-of-Paris.
2. Add objects to the clay or wet plaster, such as Ping-Pong balls, toy boats, etc. Objects should be secure, and each box should have areas of different reliefs. Allow plaster to harden.
3. In the lid of the shoebox, use a nail to punch five rows of holes 3-4 mm in diameter and spaced 2 cm apart.
4. Temporarily fasten the lids to the shoebox with masking tape.
5. Make copies of the activity and sonar image.

Note: An alternative is to use a small plastic tub, spray paint it, and drill holes in the lid.

Purpose: To learn how side-scan sonar works; how it is used in locating shipwrecks; and to make inferences about the topography of an unknown and invisible landscape

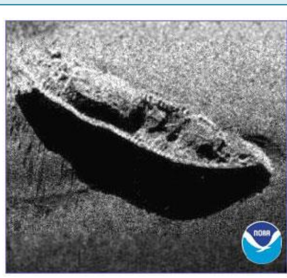
Background

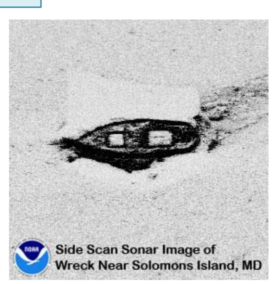
Sonar is short for "sound navigation ranging." Sonar uses sound waves to locate underwater objects by measuring the time it takes for a transmitted sound wave to be reflected back to its source. The sound wave is transmitted through a transducer, which is comparable to a speaker in a radio. Side scan uses a transducer housed in a hollow container called a towfish that is towed through the water 10 to 20 feet above the bottom. The transducer emits sound waves to either side of the towfish and measures the time it takes for the waves to be reflected back to the towfish. These measurements are processed into an image that resembles an aerial photograph. They can be viewed in real-time on a computer monitor aboard the towing vessel. A differentially corrected global positioning system (DGPS) is used to guide the towing vessel along predetermined search paths, as well as to identify points of interest on the side-scan image. This allows searchers to return to any point on the image for further investigation. Side-ascan sonar does not depend upon light and can be used under conditions that would make searching by divers dangerous or impossible. Because it typically covers a swath of 60 to 120 feet at about 2 miles per hour, it is a very efficient way to search large areas. For these reasons, side-scan sonar has been used increasingly over the last few years to search for drowning victims.

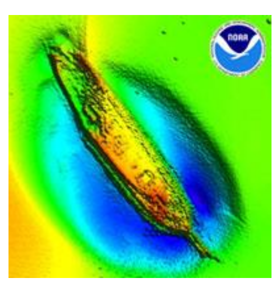
The Expedition

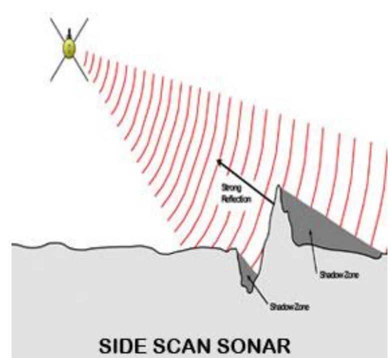
A group of scientists, researchers, and maritime archaeologists, led by NOAA's Monitor National Marine Sanctuary, are conducting an expedition onboard NOAA's 81 ft. Scientific Research Vessel *R-81* (SRVx) to search for a German U-boat. The U-boat sank off the North Carolina coast during a battle in 1942, and it has never been found. The expedition team uses side scan sonar to explore a large ocean area near Cape Hatteras, N.C. The sonar images show several anomalies that are areas of interest. Just before the end of the expedition, the team goes back to one area to take a closer look.

Your team's mission is to conduct the side scan sonar imaging of the area of interest and to interpret the image. Follow the directions for the activity *Sonar Simulation.*









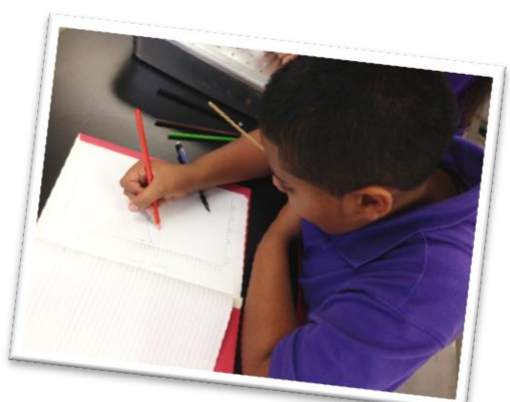
Searching the Deep—Continued

Sonar Simulation

Setting the Stage

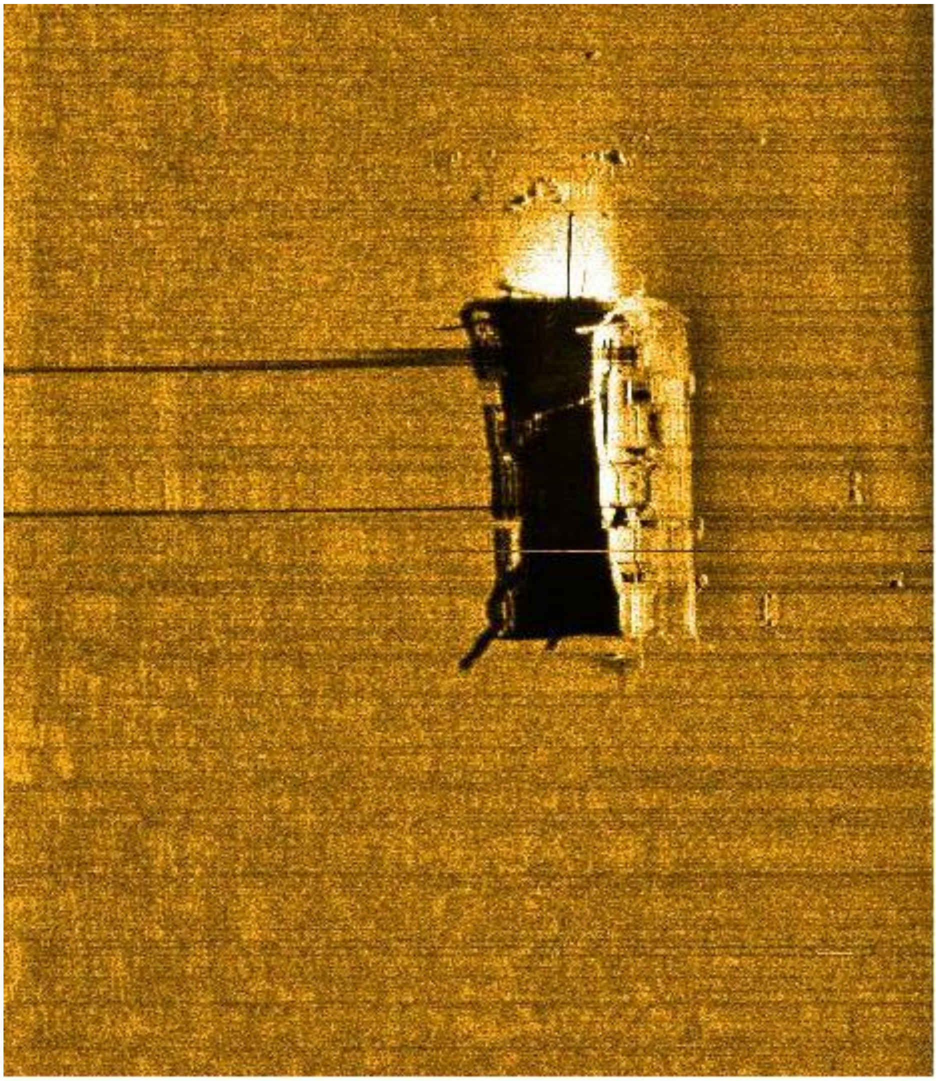
In this activity, you will map an unexplored landscape and simulate a centuries-old method used by mariners. In days of old, mariners lowered a lead weight attached to a measured line into the water until the weight touched the bottom (or some object resting on the bottom). Today, a conventional sonar system would provide a continuous record of depth directly beneath a ship. This type of sonar improves resolution along the search path, but there are still gaps between the paths that are much greater than the area actually imaged. Side-scan sonar fills in these gaps and gives an almost continuous picture of the search area. When mapping ocean floor topography and identifying objects, such as shipwrecks, it is important to have a high resolution of an image for more accurate identification.

1. Assign a different color to each of the five rows of holes on your shoebox.
2. Select one row (doesn't matter which one), and insert the wooden dowel into the first hole in the row.
3. Measure the depth from the surface (lid) by marking it with your finger, pulling the dowel out, and measuring the distance with your ruler. Record this measurement on your graph paper in the appropriate color. **Note:** *The x-axis should correspond to the numbers of holes in each row. For example, the first hole should correspond to number 1 on the x-axis, the second hole to number 2 and so on. The y-axis of your graph should correspond to the depth measurements.*
4. Repeat steps 2-3 until you have measured the depth through all holes in the first row.
5. Connect the dots on your graph with the appropriate color.
6. Based on these measurements from the first row, predict what the topography is like inside the shoebox. Record your predictions in your science journal.
7. Repeat steps 2-6 for the second row of holes using a different color. Is your data for the second row the same? What does this new information reveal?
8. In your science journal, record any changes in your prediction.
9. Continuing measuring and recording for the other three rows of holes.
10. Label your graph with a title, label the x-axis and label the y-axis.
11. Analyze your graph. Write in your science journal any predictions you have about your mystery landscape.
12. Present your graph and report the conclusion you made describing the mystery landscape.
13. After each group has reported their conclusions, open your box and compare the actual topography with your prediction.
14. Write in your science journal how your investigation could be improved.
15. Discuss as a class the methods that were used to map the topography and how the ocean floor is mapped today with sonar.
16. Look at the sonar image of the unknown shipwreck and record any identifiable parts.



Searching the Deep—Continued

Side Scan Sonar Image of Unknown Shipwreck



1) Label any recognizable parts of the shipwreck.

2) Describe the seafloor surrounding the shipwreck.

I Can Name that Part in One Try

Parts of a Ship

There are many parts to a ship, and ships have changed through time. Centuries ago, the age of wooden ships and sails ruled the sea. Soon steam powered ships came into power and wood changed into metal. Today, many ships, especially military ships, are even nuclear powered. However, no matter what century a ship sailed, there are certain parts of the ship that have remained constant. See how many parts of the ship pictured below you can match with the following definitions.

_____**amidships**—the middle of the ship, either lengthwise or widthwise, or both

_____**anchor**—a large hook attached to the ship which is cast overboard and digs into the sea bed to keep the ship from moving

_____**bow**—the front of the vessel

_____**deck**—floors on a ship. Each level is called a deck.

_____**fore and aft**—from the bow to the stern. Fore is towards the front and aft is towards the back.

_____**hull**—the main body of the boat. It may have more than one level.

_____**keel**—the timber or metal at the very bottom of the hull that runs from the bow to the stern, often called the ship's backbone

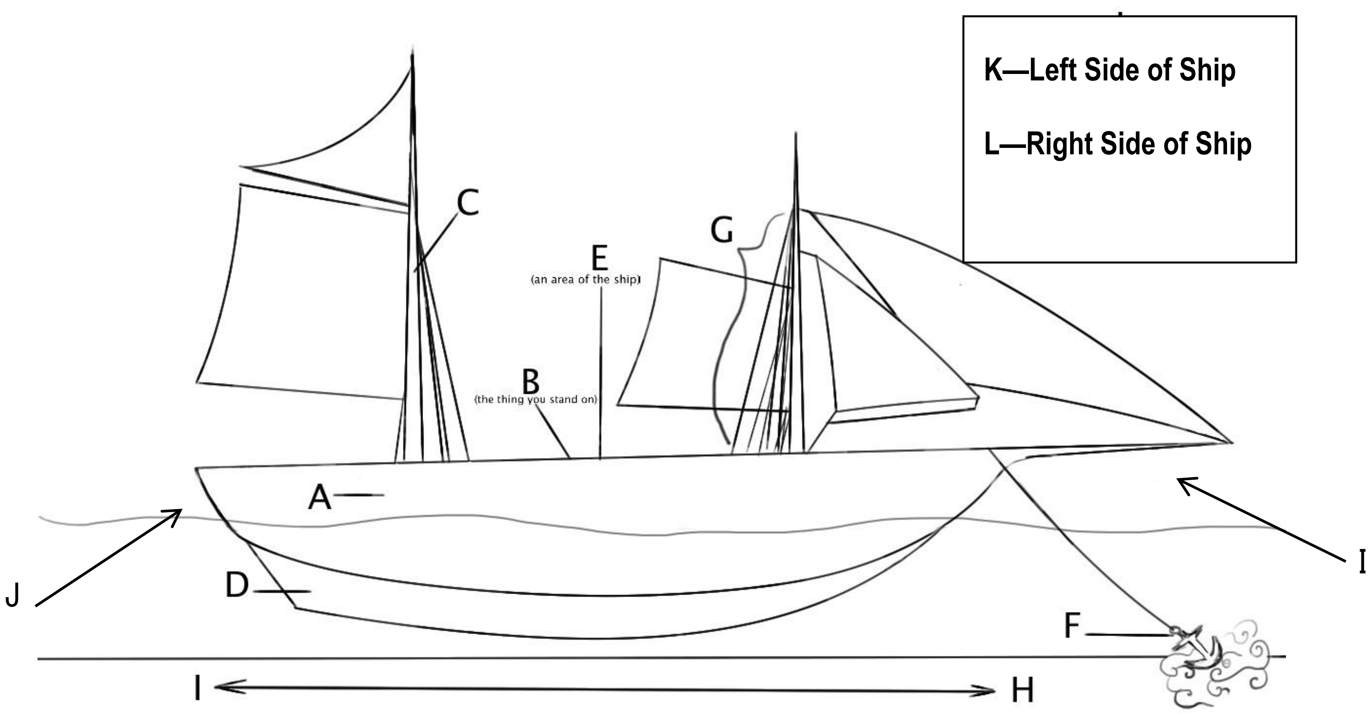
_____**line**—sailor's word for rope

_____**mast**—the tall vertical pole on a boat which supports the spars and sails

_____**port**—when facing the bow, the left side of the ship

_____**starboard**—when facing the bow, the right side of the ship

_____**stern**—the back of a vessel



Drawing Courtesy Samantha Hahn

What Floats Your Boat?

Materials—Per Student

- 50-60 g of modeling clay (non-hardening)
- paper towels
- 30 cm x 30 cm piece of wax paper
- masking tape
- **Optional:** Various items to create the parts of a ship (i.e. toothpicks for mast, tissue for sails; twine for rope; washer for anchor, etc.)

Per Class

- 100+ large washers (1.5")
- 6 small tubs of water about 15 cm deep

Teacher Prep

Cut a roll of wax paper into about 30 cm lengths—one for each student. Students will tape this to their work area for easy cleanup. Measure the modeling clay for each student. Fill each small tub 3/4th full of water. Tubs will be for testing the boats. Distribute washers between the six stations.

Prior to the activity, ask students to predict if modeling clay will sink or float. Take a half-stick of modeling clay, about 50-60 g, and drop it into a beaker of water. Have students explain what happened and why.

Extensions: Use other building materials, such as aluminum foil, cardboard, paper, etc.

Note: To introduce this activity, you can use engineering activities on pages 24 – 26 to discuss the engineering design process.

Purpose: To use the engineering design process to create a boat from modeling clay that will float

Background:

For centuries, people have built ships. Ships are built from wood, metal, fiberglass, and many other types of materials. One thing they all have in common is successful ships float! But how do those really large ships weighing thousands of tons stay afloat? It's all about their size and shape.

Objectives:

In this activity, you are a boat builder and your task is to design a boat from the materials you are given that will hold the largest payload (washers) as possible, and float for at least 10 seconds.

Procedure:

1. Gather your materials: wax paper, masking tape, paper towel, clay.
2. Using masking tape, secure the wax paper to your work area.
3. To soften the clay, roll and squeeze it, making it more malleable.
4. Think about how to build the boat and draw your design below.
5. Build your boat based on your design.
6. When finished, take the boat to one of the testing tubs and see if it floats.
7. If it floats, begin to add washers one at a time until the boat sinks.
8. Analyze your results and determine how to improve your boat design.
9. Repeat steps 4-8, making a total of three boats.
10. As a class, share boat designs and determine which boat held the largest payload.

Boat 1 | **Boat 2** | **Boat 3**

Discussion Questions

1. Observe all the boats built by the class. What boat design worked best? Why?
2. How did you redesign your boat differently from first to third? Explain your design changes.
3. Explain how you used the scientific method to design your boat. Was it systematic?
4. Hypothesize why a boat floats.

What's an ROV?

Hercules is specifically designed as a scientific tool. Photo: NOAA

ROPOS can explore up to 5,000 meters. Photo: NOAA

Purpose: To learn how ROVs are used in the marine industry and by NOAA.

Background

Remotely operated vehicles (ROVs) are unoccupied robots operated underwater by a person on a ship or boat. They are easy to maneuver through the water and are linked to the ship by a group of cables that carry electrical signals back and forth between the operator and the ROV. Most ROVs have a camera and lights. Additional equipment is often added to the ROV to increase its capabilities. For example, additional equipment might include sonars, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration, and temperature.

ROVs were first developed for industrial purposes, such as inspections of pipelines and testing the structure of offshore platforms. However, today ROVs are used for many applications, many of them scientific. They have proven extremely valuable in ocean exploration. They are also used for educational programs at aquaria and to link to scientific expeditions live via the Internet.

ROV History

In the 1950s, the Royal Navy used a remotely operated submersible to recover practice torpedoes. In the 1960s, the US Navy funded research to develop what was then named a "Cable-Controlled Underwater Recovery Vehicle (CURV). CURV gave the Navy the ability to perform deep-sea rescue operations and recover objects from the ocean floor. ROVs became essential in the 1980s when much of the new offshore development exceeded the reach of human divers. Submersible ROVs have been used to locate many historic shipwrecks, including the RMS *Titanic*, *Bismarck*, USS *Yorktown*, and SS *Central America*. However, there is a lot of work that remains to be done!

More than half of the Earth's ocean is deeper than 3000 meters, which is the depth that most ROVs can currently work. That leaves a lot of ocean to be explored. ROVs are mostly used by the oil and gas industry, but they are also used for science research, military applications, and marine salvage operations of downed planes and sunken ships. As technology improves, the ROV will perhaps one day in the near future be capable of exploring the deepest depths of the ocean.

ROV Construction

Conventional larger work class ROVs are built with a large flotation pack on top of an aluminum chassis, to provide the necessary buoyancy. A special type of foam is often used for the flotation. A tool sled may be fitted at the bottom of the system and can hold a variety of sensors for conducting tests. The ROV not only needs to be buoyant, but it also must be stable. In order to make the ROV stable, the lighter components are placed on the top of the structure while the heavy components go on the bottom. This creates a large separation between the center of buoyancy and the center of gravity making the ROV stable and stiff so it can work underwater. Electrical cables may be run inside oil-filled tubing so as to protect them from corrosion in seawater. There are usually thrusters in all three axes to provide full control. Cameras, lights, and manipulators are on the front of the ROV or occasionally in the rear to help in maneuvering. Smaller ROVs can have very different designs, each geared towards its specific task.

Science of ROVs

Science ROVs take many shapes and sizes and are used extensively by the science community to study the ocean. A number of deep sea animals and plants, such as the jellyfish Bumpy and the eel-like halosaurs, have been discovered or studied in their natural environment through the use of ROVs. Because good video footage is a core component of most deep-sea scientific research, science ROVs are often equipped with high-output lightning systems and broadcast quality cameras. Depending on the research being conducted, a science ROV will be equipped with various sampling devices and sensors. Many of the devices are one-of-a-kind, state-of-the-art components designed to work in the extreme environment of the deep ocean.

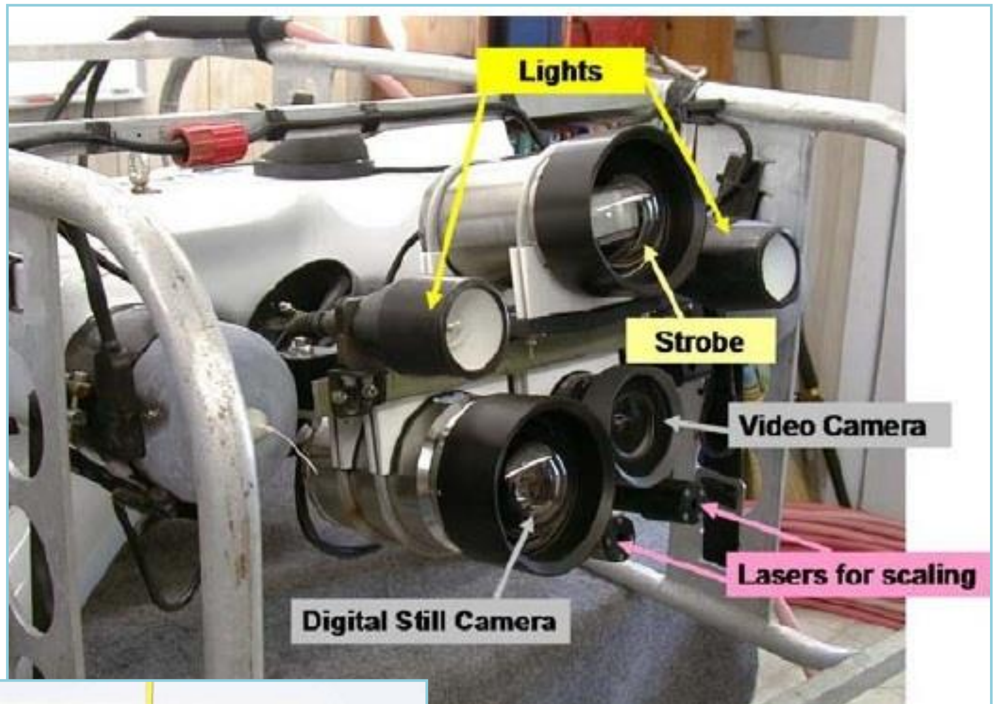
What's an ROV? Continued

Careers

- ROV pilot
- ROV technician
- diver
- dive instructor
- maritime archaeologist
- research scientist
- environmental
- engineer
- fishery biologist
- geological
- oceanographer
- laboratory technician
- lifeguard
- submersible pilot

ROV Components

There are many ROV components. Some of the basic ones are thrusters, motors, tether, power source, monitor and radio controlled transmitters.



ROVs are often equipped with various types of tools, such as still and video cameras, lasers, lights, mechanical arms, collection jars and more.

What's an ROV? Continued

NOAA Ocean Explorer

Over the last few decades, engineers have developed submersible technologies capable of meeting the many challenges that the deep sea imposes upon explorers. Visit NOAA's Ocean Explorer website to learn more about the submersibles used by scientists in ocean exploration http://oceanexplorer.noaa.gov/technology/subs/subs.html .

For each submersible, write a short description and explain its primary purpose. Then answer the questions below.

***Alvin*:**

***Deepworker*:**

***Hercules ROV*:**

***Jason ROV*:**

***ROPOS*:**

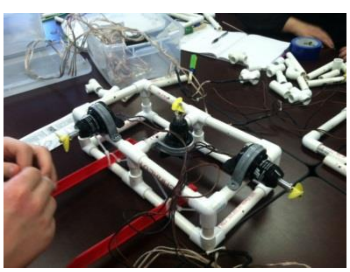
Questions:

1. What is the main difference between an ROV and a submersible?
2. Name three inactive submersibles.
3. Who built the *Autonomous Benthic Explorer*? Why was its career cut short?
4. What was *Hercules* primarily designed to study and recover?
5. What does the *Deepwater*'s life-support system include?
6. How many people does it take to operate *Jason* once it is in the water? List and describe their jobs.
7. How many dives does *Alvin* make each year? How deep is a typical dive and how long does it last?
8. What was the major consideration for engineers who designed the *ROPOS*?
9. On the *Mirs I* and *II*, what primary data are collected?
10. *Pisces IV* and *V* are each equipped with a pinger receiver system. What does this enable them to do?

Envisioning an Engineer—Teacher Information

Engineering is fun and exciting, but did you know that most people don't have a clue what an engineer does? Almost everything in society is linked to engineering. If it weren't for engineers, we would not have cars, computers, televisions and the many other conveniences that we take for granted each day.

To help students better understand what an engineer is and what he/she does, use the following activities and watch the suggested videos. Once students have an understanding of engineering, introduce the engineering process and get ready to build your own ROVs!



Engineering an ROV Suggested Implementation Strategy

1. For a curriculum guide with additional information and activities to prepare students for building a remotely operated vehicle (ROV), visit http://monitor.noaa.gov/education Also for step-by-step instructions on how to build ROVs using PVC pipe and bilge motors, visit http://monitor.noaa.gov/publications/education/rov_manual.pdf
2. Before beginning the engineering process, introduce students to remotely operated vehicles (ROV). Assess their prior knowledge of what ROVs are, how they are used, and any other information they might know about ROVs. Make a list of all prior knowledge and save for use at the end of the unit, and add any new information they learned and correct any prior misconceptions.
3. Explain to the students that they will work in teams to design (engineer) their own ROV. Have students define an "engineer" and discuss the engineering process. Complete activities (pp.22-24) to help students understand engineering.
4. To introduce the engineering design process, have students conduct the activity ***Help! I Could Use a Hand!*** (pp.25-26).
5. Explain to the students that before they begin to engineer their ROV, they need to understand a few basic principles. Review Newton's Laws of Motion and buoyancy. **NOTE:** Activities for these concepts can be found in ROV curriculum guide listed in step 1.
6. To begin the ROV design phase, break students into groups of 2-4. Give each team a copy of ***Working Under Pressure*** (pp. 28-30).
7. Show students the various materials available for ROV construction. Review the criteria for design, the competition rules, Newton's Laws of Motion and any other parameters you want to impose.
8. Remind students that they must work as a team to design their ROV. Their design must be drawn on the sheet provided with all parts labeled. Once they have an approved design, then they may collect the materials (parts) needed.

Envisioning an Engineer

Engineering is fun and exciting, but did you know that most people don't have a clue what an engineer does? Almost everything in society is linked to engineering. If it weren't for engineers, we would not have cars, computers, televisions and the many other conveniences that we take for granted each day.

So just what is an engineer? An engineer is someone who is creative and thinks of new ways to solve problems by using math, science and technology. Many people think that an engineer is a scientist, but even though they may use science, engineers are not usually scientists. Theodore Von Karman, an aerospace engineer, put it nicely when he said, "Scientists discover the world that exists; engineers create the world that never was." There are many different types of engineers, such as electrical, mechanical, civil, chemical, aerospace, biomedical, agricultural, computer and many more. There is an engineer for almost every area that might be interesting to you!

When engineers have ideas, they usually follow a few simple steps to help them as they search for the solution. Use the checklist below to help you as you design your solution to the challenge.

- Keep a design log. Engineers keep a log to record their work and ideas.
- Use your imagination. Think wild and crazy thoughts. Remember that no idea is too silly. Everyone laughed at the Wright brothers and said that man would never fly. Good thing they didn't get discouraged!
- Plan and design your idea. Careful design is important. This is the time to brainstorm for ideas and evaluate them.
- Research. Conduct research to verify that your design is based on sound science and math principles.
- Draw your design. Make a detailed drawing of your idea so others will understand how your design works.
- Make a model of your design.
- Test your design. Test your model to see if it works as planned.
- Evaluate your test results. Use data collected from testing to determine whether your design performs as it was meant to perform.
- Redesign. If your design did not work as planned, do more research, redesign it and test it again. **This procedure is called an iterative process**.
- Patent your design. Engineers often have unique designs that others might want, so they apply for a patent from the U.S. Patent Office to protect their ideas from being claimed by others.

Watch MIT Video describing an engineer: *What is an Engineer?* (3 min and 27 sec)
http://video.mit.edu/watch/what-is-an-engineer-3788/

In your own words describe an engineer. What skills does it take to be an engineer? How do engineers look at the world?

Thinking Out of the Box

Scientists, designers, engineers, and many others have to be creative in their thinking as they develop new ideas and designs. You have to cast off the old way of doing things and try to free your mind for innovative ideas. So clear out the old ideas and get ready for the new.

Your mission for this lesson is to help NOAA design a new remotely operated vehicle (ROV) for the future. The field is wide open for your design and materials are not an obstacle. You decide what the ROV should look like, how it should maneuver, how long it should stay submersed, and its uses.

First, you will want to brainstorm some ideas, and once you get an idea for your ROV's design, draw your design on the grid below. Share your ideas and drawing with the class. If possible, make a model of your ROV and present your design to the class.

Scale: 1 square = _________

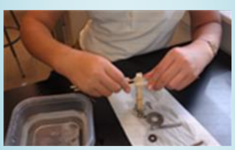
Help! We Could Use a Hand!

Suggested Materials:

For Arm:
- skewers
- straws
- small craft sticks
- large craft sticks
- pipe cleaners
- tape
- clay
- clothespins
- other misc. items

Tools:
- various washers, nuts, and bolts

Other:
- plastic container
- water



Teacher Prep:
- Place various "tools" in a plastic shoe box
- Cover with 10 cm of water
- Make available various materials to build ROV arm
- Suggested time to build is 15 min.

Problem:
NOAA was working off the coast of Virginia. Suddenly, a storm came up. The boat was tossed around by huge waves. It began to take on water and the pump quit working. Luckily, just as the boat was about to sink, the US Coast Guard came and rescued the crew. However, many valuable tools were lost. NOAA needed those tools. So once the storm was over, NOAA sent a group of divers to where the boat sank. When the divers went down, they noticed that the boat had slid down much too deep for them to dive. Fortunately, they brought an ROV with them. But the ROV does not have any way to pick up the tools.

You are an engineer. You and your team must design and build an arm for the ROV that is able to capture all the lost tools. The arm must also be able to pick up several different types of tools because you only have enough time to make one arm. And you need to hurry … …another storm is brewing!

Objective: To build an arm for an ROV that is able to pick up a variety of objects off the ocean floor

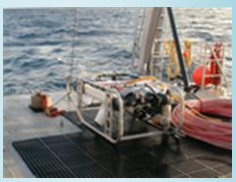
Procedure:
1. As a team, look at the "tools" that need to be recovered.
2. Review the materials available to build an arm.
3. As a team, decide how best to design an arm that can be attached to the ROV to pick up the tools.
4. As a team, draw a design of your arm. Be sure to label all parts.
5. Select the correct materials and build your arm.
6. Retrieve the tools. **YOU HAVE 15 MINUTES!**

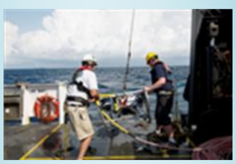
Design Your Arm Below:

Help! We Could Use a Hand! Continued

An ROV was used onboard the NOAA Ship *Nancy Foster* to identify an unknown shipwreck. By using the ROV's lights and cameras, the maritime archaeologists identified it as a WWII, US Navy ship, YP-*389*. A German U-boat sank the YP in 1942.

http://sanctuaries.noaa.gov/missions/battleoftheatlantic2/welcome.html





Photomosaic of YP-*389* created from images taken by ROV

Discussion:

1. Explain your design. Tell why you chose this design.

2. Explain your choice of materials. Why did you choose those items to build your arm?

3. Did your arm pick up all the "tools" on the ocean floor? Why or why not?

4. What could you do to make your arm better for the next rescue mission?

Engineering an ROV

Building a remotely operated vehicle (ROV) is exciting for students and engages them in the engineering design process. There are many options for building an ROV in the classroom. Below are a few of the options; however, they are not the only options available.

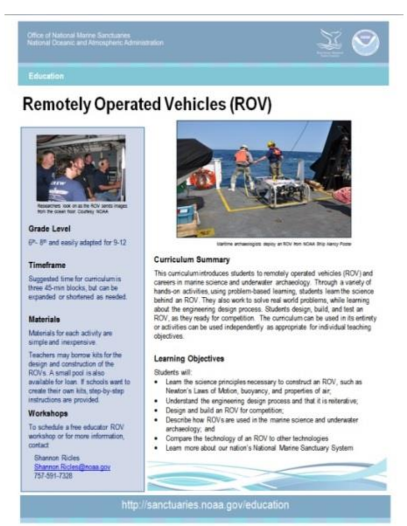
SeaPerch is an innovative underwater robotics program that equips teachers and students with the resources they need to build an underwater Remotely Operated Vehicle (ROV) in an in-school or out-of-school setting. Students build the ROV from a kit comprised of low-cost, easily accessible parts, following a curriculum that teaches basic engineering and science concepts with a marine engineering theme. Kits can be purchased through the SeaPerch website ($169 with battery) and teachers may apply for a grant to purchase up to 10 kits and a tool kit ($245). Kits need to be replaced each year. http://www.seaperch.org

ROV in a Bucket is an inexpensive alternative. The step-by-step manual has a detailed parts list of items that can be bought at most hardware and hobby stores. It also gives instructions on how to build and wire all the components. These kits can be used year after year with your classes giving hundreds of students the opportunity to engage in engineering. The ROV kits can be built by students or adults depending on resources available. The motors and controllers can either be built by an adult or your students. Once built, the kits need minimal upkeep. The cost per kit is about $115. http://monitor.noaa.gov/publications/education/rov_manual.pdf

Marine Advanced Technology Education (MATE) ROV program aims to teach science, technology, engineering and math and prepare students for technical careers. MATE also hosts regional and national competitions and each year has a different theme and ROV obstacle course. An ROV textbook is also available for purchase. ROV kits can be purchased from about $130, but there is a loaner program for a small fee. http://www.marinetech.org/rov-competition-2/

Science of ROVs Curriculum
No matter which ROV program you decide to use, be sure to check out the Monitor National Marine Sanctuary's ROV Curriculum. This curriculum introduces students to remotely operated vehicles (ROV) and careers in marine science and underwater archaeology. Through a variety of hands-on activities, using problem-based learning, students learn the science behind an ROV. They also work to solve real world problems, while learning about the engineering design process. Students design, build, and test an ROV, as they ready for competition. The curriculum can be used in its entirety or activities can be used independently as appropriate for individual teaching objectives.
http://monitor.noaa.gov/education/teachers.html

ROV in a Bucket. Photo Courtesy NOAA



Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Education

Remotely Operated Vehicles (ROV)

Researchers look on as the ROV sends images from the ocean floor. Courtesy: NOAA

Grade Level
6th - 8th and easily adapted for 9-12

Timeframe
Suggested time for curriculum is three 45-min blocks, but can be expanded or shortened as needed.

Materials
Materials for each activity are simple and inexpensive.

Teachers may borrow kits for the design and construction of the ROVs. A small pool is also available for loan. If schools want to create their own kits, step-by-step instructions are provided.

Workshops
To schedule a free educator ROV workshop or for more information, contact

Shannon Ricles
Shannon.Ricles@noaa.gov
757-591-7328

Maritime archaeologists deploy an ROV from NOAA Ship Nancy Foster

Curriculum Summary
This curriculum introduces students to remotely operated vehicles (ROV) and careers in marine science and underwater archaeology. Through a variety of hands-on activities, using problem-based learning, students learn the science behind an ROV. They also work to solve real world problems, while learning about the engineering design process. Students design, build, and test an ROV, as they ready for competition. The curriculum can be used in its entirety or activities can be used independently as appropriate for individual teaching objectives.

Learning Objectives
Students will:
- Learn the science principles necessary to construct an ROV, such as Newton's Laws of Motion, buoyancy, and properties of air;
- Understand the engineering design process and that it is reiterative;
- Design and build an ROV for competition;
- Describe how ROVs are used in the marine science and underwater archaeology; and
- Compare the technology of an ROV to other technologies
- Learn more about our nation's National Marine Sanctuary System

http://sanctuaries.noaa.gov/education

Free ROV curriculum is available online.

It's All about Air –Teaching Suggestions

Note: The following teaching suggestions (pp. 30-36) are from the Monitor National Marine Sanctuary's ROV Curriculum Guide. Activities and additional information can be found in the guide at http://monitor.noaa.gov

Before Building

Before beginning the designing and building process, teachers may want to review and/or assess students' knowledge of several key ideas and concepts, such as the properties of air, air pressure, buoyancy, water pressure and diving. Having a better understanding of these concepts enables students to design and build an ROV more accurately and successfully. Understanding of the properties of air also helps students to recognize the need for ROVs and submersibles in research. The guidance listed in this section can be adapted for various age levels and should be used as appropriate for ages and abilities of the students.

Facts and Properties of Air Demonstrations

- Facts about air—Air is colorless, odorless (unless something is added to air), has no taste, and takes the shape of the container. Most abundant gas in our atmosphere is nitrogen—78% nitrogen, 21% oxygen, and 1% trace gases with argon being 0.9% of the trace gases. Carbon dioxide is 0.03%.
- Air takes up space—To demonstrate, use a tornado tube connecting two 2-liter bottles with one bottle filled with colored water. Carefully, turn the bottle upside down so that the water is on the top and it DOES NOT pour into the bottom half. Although gravity is pulling the water down and water is heavier than air, the water does not go through the opening. This is because the air in the bottom half prevents it from flowing. However, if there is a disturbance (shaking), then there is a transfer of air and water to opposite bottles. Shake bottle and have students observe the bubbles (air).
- Air has mass—Use a triple-beam balance to find the mass of a deflated balloon. Blow air into the balloon until partially filled. Find the mass the balloon now filled with air and note the increase in mass.
- Air exerts pressure—
    - **Pushy Air**—Place water in a clear plastic cup. Place a piece of cardstock (index card) over the cup and make sure that it has a good seal. Turn the cup upside down and remove your hand from the cardstock. The cardstock continues to stay in place, because air is exerting pressure upward on the cardstock.
    - **Can Crushing**—place a few milliliters of water in an aluminum soda can. Using tongs set the can on a hot plate (use fire retardant matt), or hold it above a Bunsen burner until steam escapes through the opening. Quickly, flip the can upside down into a shallow pan of water making sure that there is a good seal between the can and the surface of the water. The can will implode immediately. Can Crushing Explanation: Air exerts 14.7 psi in all directions (equal to about three 5 lb. bags of sugar). We don't feel it because our body is exerting 14.7 psi in every direction inside our body. When the air in the can heated, the air molecules began to move excitedly and farther away from each other. Once you flip the can into the water and seal it, the few air molecules inside the can quickly condense and fall to bottom, creating a vacuum inside the can. With no air inside the can to exert pressure outward, the can crushes.
    - **Egg in the Bottle**—Light a large kitchen match and drop into glass milk jar (old fashioned type). While it continues to burn, quickly place a peeled hardboiled egg on the rim of the jar. In a few seconds, the egg will be pushed into the jar by air pressure. Burning match uses all the oxygen creating a vacuum, thus no air inside the jar is exerting pressure back up. To get the egg out of the jar, position egg over opening and blow into jar with lips sealed on rim.

Fluids—Air and Water

Air and water are both fluids and have similar properties. They take up space, have mass, take the shape of the container and exert pressure. To demonstrate air is a fluid, fill an aquarium with water. Take two clear plastic cups and turn one cup upside down and submerse so that the air remains inside the cup. Repeat with second cup and then tip the second cup to the side to release the air. Let students observe the bubbles. Hold the two cups (one with air and one with water) close to each other and pour the air into the cup with water. The air in the cup is a bubble and when you pour it into the other cup, the bubble rises and is trapped by the other cup before it can escape to the top and burst. It displaces the water in the other cup.

Putting On the Pressure –Teaching Suggestions

SCUBA Facts:

Pressure increases by one atmosphere for every 33 ft. of water

Diving on air alone, divers can dive to depths of about 100 ft.

Mixed gas, compressed air, and rebreathers allow divers to reach deeper depths, but divers need special training

The deeper the depth, the shorter the bottom time

Water Pressure

To help students understand why ROVs and submersibles are important for exploring and researching our ocean, they should understand the limitations of a human body under extreme pressure in water. The following activities and explanation may help students to understand.

- Demonstrate a column of water by stacking several books on top of each other. Explain that each book has a mass. As you stack more books onto the first book, you increase the total mass of the books. With the additional books, the bottom book now has more mass pressing down on it. The same is similar as you go deep into the ocean. The deeper you go, the more water you have pressing down on an object.
- Just like air, water has mass. For every cubic foot of water you add on top of another, the greater the mass of the water. The pressure exerted from a column of air from the upper reaches of the atmosphere to the surface of the land/water is known as one atmosphere of pressure. For every 33 feet you go below the surface of the water, pressure increases by one atmosphere.
- The greater the depth, the greater the pressure—Using a 2-liter bottle, puncture one hole near the top of the bottle and a second hole near the bottom of the bottle. Place masking or duct tape over the holes. Fill the bottle with water and hold it over a sink or basin and remove the tape from both holes. Observe the streams of water. The one at the top does not arch out as far as the one at the bottom. This is because the one at the bottom is under more pressure, which creates more force to expel the water.

Water Pressure and Divers

How deep can a diver go in the ocean?

- As a diver enters the water, the pressure on exerted on her body is determined by the mass (weight) of the atmosphere. At the surface, air pressure is 14.7 psi. For a comparable pressure under the ocean, you only have to go 10 meters or 33 feet. Water is about 1000 times denser than air. Therefore, the pressures at a depth of only 33 feet is equal to two times normal atmospheric pressure—combine the weight of the air on top of the water and the weight of the water above the diver.
- For every 33 feet a diver submerges, one more atmosphere of pressure pushes down.
- As a balloon floats upward high into the sky, air pressure decreases (there is less air in the upper atmosphere), so the air inside the balloon becomes less compressed (it expands out making the balloon enlarge). Therefore, the same amount of air takes up more volume than at sea level. However, the deeper you go in the ocean the greater the pressure, because the more water (increased mass) you have pressing on you. In the water, the air inside a balloon would become more compressed taking up less volume, and the balloon would become smaller. If you took a Styrofoam cup to the bottom of the ocean, it would shrink to a very small size!
- A diver's lungs are filled with air and at the surface they are normal. But at 33 feet, there is twice the amount of air in the lungs, because the air in the lungs compressed with the pressure, thus allowing the diver to breathe in more air. Divers have to keep their lungs filled or their lungs will collapse, and they would die. At 99 feet, a diver's lungs hold about 4 times the amount of air as they do on the surface.
- To demonstrate how pressure acts upon objects (and divers' lungs), you can use a vacuum pump and marshmallows or Peeps. As you create a vacuum in the bell jar, the Peep will expand to fill the jar. As you allow air back into the bell jar, the Peep will decrease in size. You can also use the activity ***Dive, Dive, Dive*** (p. 13).

Buoyancy –Teaching Suggestions

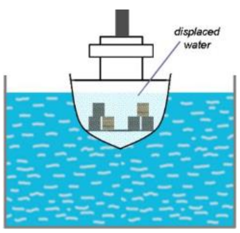
Density

Density is a property of matter that is defined as the ratio of an object's mass to its volume. Mass is the amount of matter contained in an object and is commonly measured in grams (g). Volume is the amount of space taken up by a quantity of matter and is commonly expressed in cubic centimeters (cm^3) or in milliliters (ml) 1 cm^3 = 1 ml. Therefore, common units used to express density are grams per milliliters (g/ml) and grams per cubic centimeter (g/cm^3).

To demonstrate the role of density, fill a clear large tub or small aquarium two-thirds full of water. Ask students to predict if objects will sink or float. Drop objects of various densities into the water and discuss. Ask students to hypothesize about objects that are equal in volume, such as a can of soda. Drop various sodas (regular and diet) into the tank and observe. Although they are equal in volume (same ml), regular sodas sink, while diet sodas float. Regular soda has about 16 teaspoons (40 grams) of sugar, while diet has aspartame or some other sugar substitute. It takes less sugar substitute than sugar to sweeten a soda. Therefore, diet sodas have less mass.

Buoyancy

Any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of a fluid displaced by the object.



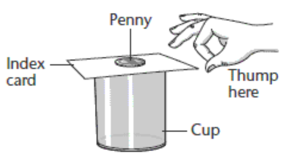
- Fill a clear tub about half full with water. Mark the water level. Add a heavy object, and watch the water level rise as the object is added. Mark the new level for the water.
- Explain Archimedes' Principle—an object in a fluid experiences an upward force equal to the weight of the fluid displaced by the object. Given that various fluids have differing densities, this upward or buoyed force changes accordingly. If an object is less dense than the fluid it is in, then it will float. If it is denser than the fluid, it will sink. This concept explains why some objects float on water, while others sink. Wood floats on water because it is less dense and a piece of steel sinks because it is denser.
- But how can a large steel ship float? Archimedes' Principle explains this phenomenon. The water that the ship floats in has a constant upward force equal to the weight of the fluid displaced by the object. So if a boat weighs 1,000 pounds, it will sink into the water until it displaces 1,000 pounds of water. However, the boat must displace the 1,000 pounds of water before the boat is completely submerged! It is fairly easy to design the shape of a boat so that the weight is displaced before the boat sinks, because a good portion of the interior of any boat is air. And the average density of a boat is very light compared to the average density of water. View demonstration of Archimedes' Principle at YouTube http://www.youtube.com/watch?v=xniW3_afO-0
- The weight of a displaced fluid can be found mathematically. This fluid displaced has a weight of W=mg. The mass can be expressed in terms of the density and its volume m=pV, hence W=pVg.
- We call things that float, positively buoyant and things that sink, negatively buoyant. Objects that neither float nor sink are neutrally buoyant. To simulate the feeling of weightlessness in space, astronauts practice space walking in a huge pool where they become neutrally buoyant.

Submarines can both float on top of the water and sink to the bottom. To help students understand how submersibles sink and then float, use the activity *Dive, Dive, Dive* (p. 13) This activity can also be used to demonstrate how air is compressed in a diver's lungs. Explanation: There is a small space of air at the top of the dropper. When you squeeze the bottle, the added pressure compresses the air in the dropper. As the air compresses, there is more room for water to flow into the dropper. With more water in the dropper, it is now heavier and sinks (negatively buoyant).

Newton's in the Driver's Seat –Teaching Suggestions

How does an ROV move?

ROV's have motors with thrusters that help propel them through the water. In building an ROV, it is important that students understand Newton's Three Laws of Motion (***Newton Lays Down the Law***, p. 24).



- 1st: An object will stay in motion or at rest, until acted upon by an outside force. (Also known as the Law of Inertia.)
  - Demonstrate the Law of Inertia by using a chair with several books piled in the chair. Quickly push the chair along the floor and then suddenly stop. The books will fall off the chair because they continue to go forward since there is not an outside force acting upon them. Wearing a seatbelt is another good example.
  - Another activity to demonstrate the Law of Inertia is to place an index card on top a plastic cup so that it completely covers the cup. Place a penny in the middle of the index card. Have students use their index finger to quickly flick the card away from the cup. The penny will fall directly into the cup.
  - The ROV will just sit in the water until a force, such as your motor, acts upon the ROV to move it.

- 2nd: Force equals mass times acceleration F=ma. It takes more force to move a heavier object the same distance as a lighter object.
  - If the ROV is really large, then it might be really heavy and need a larger force, which means a bigger motor. So students should carefully consider the size of the motor to be used when designing and building the ROV.
  - Demonstrate by having a student pick up a light object versus a heavy object. Ask which one took more force to lift.

- 3rd: For every action there is an equal and opposite reaction.
  - The ROV will need to move forward, backward, and sideways. There are only three motors, so think about Newton's Third Law before placing them.
  - If you want to move your ROV forward, which way will your motor need to push the water?
  - Use a Newton's Cradle to demonstrate the 3rd Law of Motion.

After Reviewing

After reviewing and/or learning about air pressure, buoyancy and water pressure, discuss submarines, submersibles, ROVs, and AUV's.

ROV AND AUV

- Distribute ROV information and photographs. Explain that to go deep into the ocean, scientists can use a submarine, but they are very expensive and more dangerous for humans. A less expensive alternative is to use ROVs or Autonomous Underwater Vehicles (AUV). The main difference between the two is that an ROV is tethered to the ship by a cable and controlled by humans, where the AUV is not tethered and it is controled by a computer.
- ROVs allow people to work at deep depths or in hazardous environments, while the operator is safely on the surface. ROVs can also be used to lift or recover heavy items.
- Downside to using an ROV is a loss of the human senses—you cannot touch or smell, and you can only "see" through video monitor.
- ROV Arms—Discuss how ROVs pick up objects and other special features found on many ROVs (see p. 7).

Page from MNMS's ROV Curriculum Guide at http://monitor.noaa.gov

Working Under Pressure

Materials:

- PVC pipe and fittings
- multiple sets of small motors with controller
- zip ties
- duct tape
- crabs
- noodles
- swimming pool
- auto or marine
- batteries (2+)

Teacher/Adult Prep:

- See detailed instructions for creating ROV kits at http://monitor.noaa.gov/publications/education/rov_manual.pdf
- Suggested time for building an ROV is 2 hours for 5th-8th, less for older students.
- Suggested time for testing, redesigning, and competition in the pool is about 2 hours.

Purpose: To work as a team to design, build and test an ROV to compete in a competition

Problem:
Oh no! The bay has been invaded by small baby crabs! They are in danger of getting eaten by the large monster crabs. You must capture as many of the babies as you can and get them back to the protected area of the bay as quickly as possible!

Objective:
Design and build an ROV with the ability to successfully capture the baby crabs, maneuver to the protected area (corner of the pool), and deposit the baby crabs into the designated area.

Point Criteria:

- Touch any crab = 1 point (given only once)
- Pick up large crab = 3 points
- Pick up small crab = 4 points
- Deposit crab in corner = 3 points

Things to Think About!

- Need to balance buoyancy with ability to pick up crab.
- The ROV can be any size, but think about the size of your motors and how much force it will take to move the ROV.
- Need to be able to pick up the crabs, carry to corner, and deposit.
- In what directions are you going to need to move? Will you need to go up, down, sideways? Keep this in mind as you place the motors. Remember Newton's Third Law of Motion!
- How are you going to attach motors, buoyancy sleeves, etc.?

Procedure:

1. With your team discuss the mission objective.
2. Observe the crabs.
3. Review the materials available to build your ROV.
4. In your team, discuss how to engineer and design your ROV.
5. Draw your design onto graph paper, and be sure to label all the parts.
6. As you draw your design, make a list of supplies you will need.
7. Show your design to one of the ROV Specialists (teacher).
8. Return to the team to discuss any necessary changes.
9. Gather the ROV supplies.
10. Build your ROV.
11. At the pool, test your ROV design and make any changes needed.

Working Under Pressure Continued

Designing is an iterative process. Iterative means that first you design something, build it, test it, and then you analyze the data from the tests. From the data, the design is modified over and over again until it is correct. To begin the iterative process for your ROV, carefully design and draw it. Remember to draw in detail and label it clearly, neatly, and correctly so that others can follow it. Write a detailed description of your ROV.

To view a short clip on engineering, designing and the iterative process http://www.youtube.com/watch?v=6PJTlzY0Aak&list=UUyf-z0ENg77xiAy1COGN-2w&index=35&feature=plpp_video2w&index=35&feature=plpp_video

Page from MNMS's ROV Curriculum Guide at http://monitor.noaa.gov

Working Under Pressure Continued

Points Awarded:

Team 1:

Team 2:

Team 3:

Team 4:

Team 5:

Team 6:

NOTES:

POOL TIME!!!

At the pool—

- Each team will have five minutes to test their ROV in the water and to make any adjustments needed.
- Competition Time: Each team will have five minutes to pick up as many crabs as possible and return them to their corner, as instructed.

Oh no…the baby crabs are in danger!

Here comes the big monster crabs!

Conclusion:

1. How well did your ROV perform?

2. What would you do differently next time?

3. Why is it important to design the ROV before building it?

4. Describe how scientists and researchers might use an ROV underwater.

Mock Shipwreck: Mapping the Past

Materials:

Mock shipwreck outline

Per Group:
- tape
- 30 ft. measuring tape
- shorter measuring tape
- clipboard
- log sheets
- dive slate

Teacher Prep:

Use diagram on p.38 or create your own shipwreck outline on canvas, pavement or other large surface (approximately 20 ft.) using tape, chalk, marker or other medium.

Use 30 ft. tape measure to transect the wreck in half. This is called the baseline.

Copy Log Sheets on pages 40 – 51 (12 quadrants); evenly divide students into the quadrants

Optional: Place 3-dimensional objects on template to represent key artifacts.

NOTE: This is a modified shortened version, for full activity visit http://monitor.noaa.gov/education/teachers.html

Purpose: To construct a scale model of a mock shipwreck by measuring and plotting points for individual quadrants and assembling to create a site plan

Background

The wrecks of sunken ships litter the bottom of the ocean floor. Many of these shipwrecks are historically significant, such as the German U-boats off North Carolina's coast, a national treasure, such as the USS *Monitor*, or simply a fishing boat. However, each wreck offers a unique story and a glimpse back in time. It is the job of maritime archaeologists to find and study these links to our past in order to understand our history, preserve our heritage and honor the memory of those who might have died.

Maritime archaeologists carefully measure a wreck underwater and then transfer their measurements onto graph paper to create a site plan. Site plans help archaeologists see how the whole site looks. They can tell exactly where parts of the ship are in relation to other things onboard and around the site. They can also see from site plans how the ship was built.

In this activity, you are maritime archaeologists working to map a newly discovered shipwreck. You will work in pairs on a dive team. Each pair will be responsible for mapping a specific section (quadrant) of the shipwreck. You will have limited time on the bottom of the ocean; therefore, review all your equipment, determine the scale needed for the log sheets, determine which section of the shipwreck you are mapping and coordinate with your dive buddy how you will begin mapping your section (read directions below before beginning).

Activity 1: Sketching Sections of the Wreck

1. Review your log sheet and determine if you are starboard or port. Identify the bow of the shipwreck and then stand on the correct side indicated on your log sheet.
2. Identify the baseline (tape measure) that has been set from bow to stern. Find the baseline noted on your log sheet.
3. Note the scale on the log sheet. If using inches, each square is equal to 2 inches. There are 30 squares or 5 feet on each log sheet. Which section are you mapping? Circle your section: 0-5; 5-10; 10-15; 15-20; 20-25; or 25-30.
4. Determine who will be the measurer and who will be the recorder.
5. When the dive team (class) is ready to dive, stand next to your section and wait for the dive master (teacher) to give you the signal to dive.
6. Once on the bottom, you will measure and record the distance from the baseline to the outer edge of the shipwreck all along your section. Plot these measurements on your log sheet.
7. When finished, go back and measure from baseline and record other features located within your section. Plot the measurements on your log sheet and sketch in any interesting features to the best of your abilities.
8. When finished, return to the surface and connect the points you plotted and finish sketching the outline and any artifacts in your section.

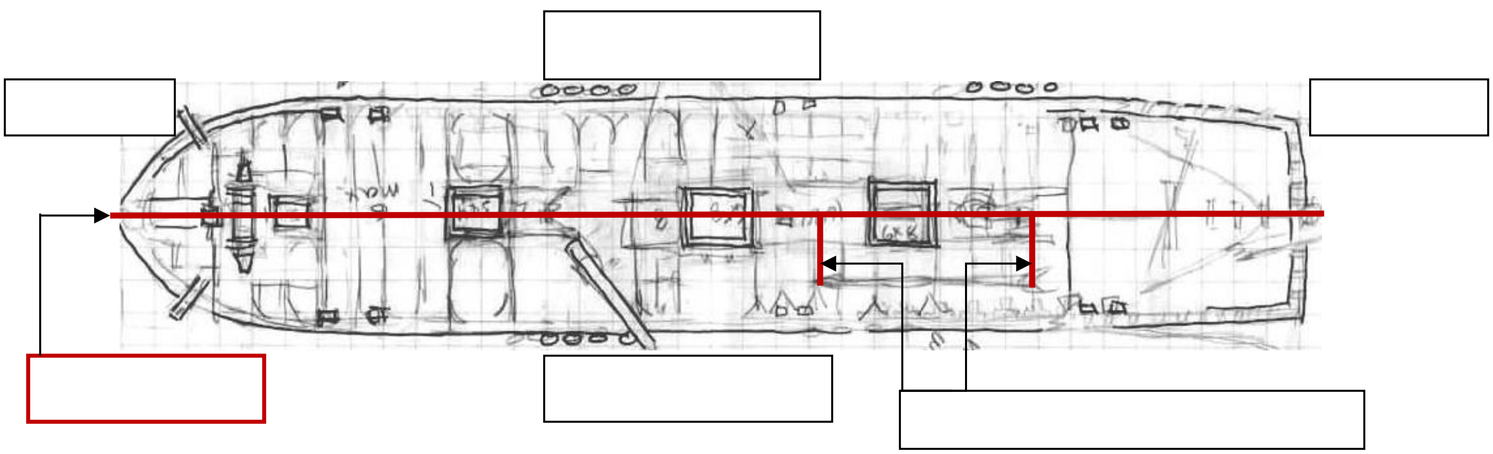
Mock Shipwreck: Mapping the Past Continued

Activity 2: Putting It Together

1. Once all dive teams have completed their sketches, come together to put the pieces together.
2. Line up all the port side log sheets in order lined up on the baseline indicated on your log sheet.
3. Overlap the pages and tape together.
4. Repeat steps 2 and 3 with the starboard side.
5. Compare the final sketch of the shipwreck to the actual wreck site.

Discussion Questions

1. Does the site plan look like the mock shipwreck? Are key structural features and/or artifacts represented?
2. What techniques did you use to measure? Were some methods more efficient than others?
3. In looking at the site plan created, is there any damage noted on the shipwreck? If so, is it from natural erosion? Battle? Storm?
4. Why is a uniform scale (1square = 2 inches) important?
5. Why should the work be split among teams? Consider limited dive time, size of the wreck, weather conditions, etc.
6. What are the key structural features divers should focus on?



Identify the section your group is responsible for: Side: _____________ _____ft → _____ft

Are you the **Measurer** or **Recorder**? (Circle one)

The mock shipwreck has an overall length of ________ft and a width of ________ft.

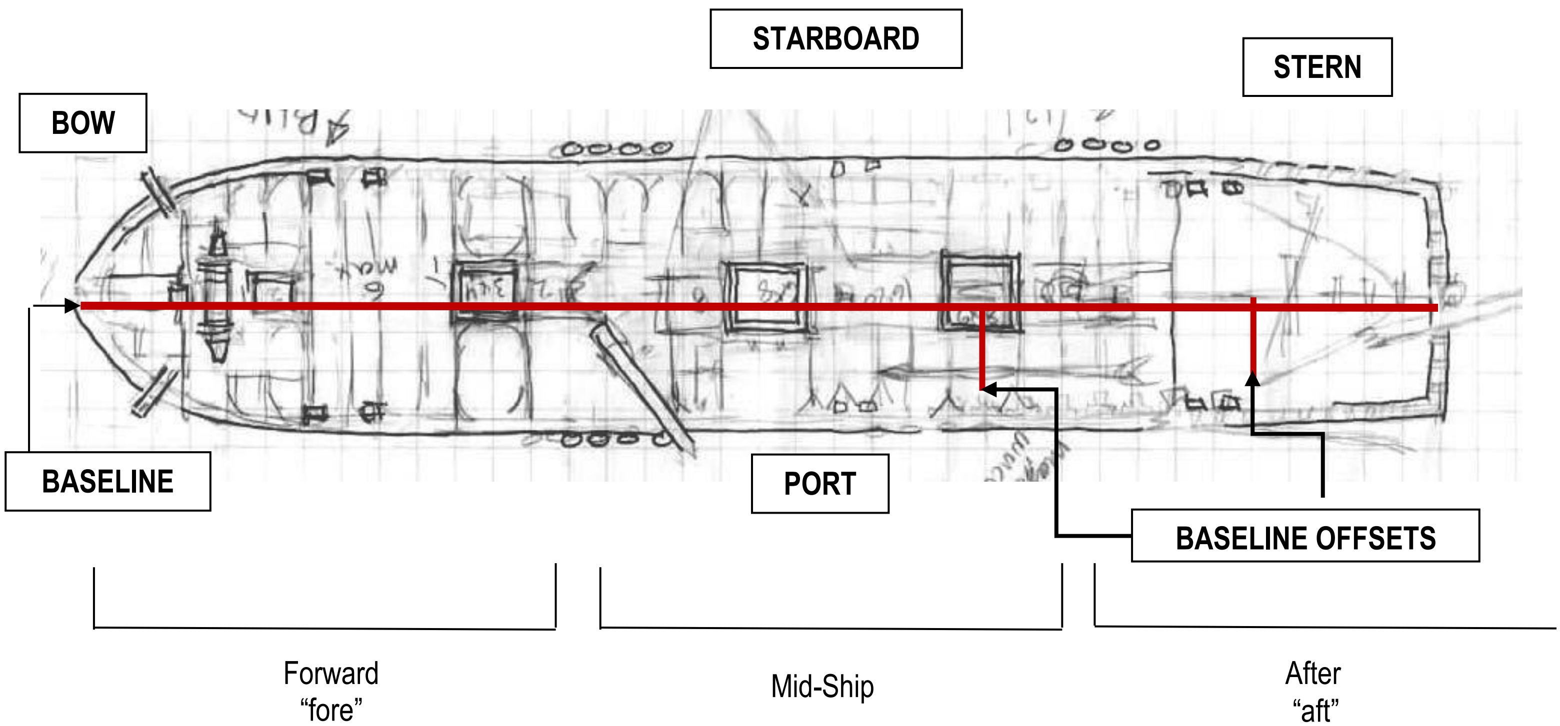
The site plan shipwreck has an overall length ________ft and a width ________ft.

The **scale factor** is _____:______

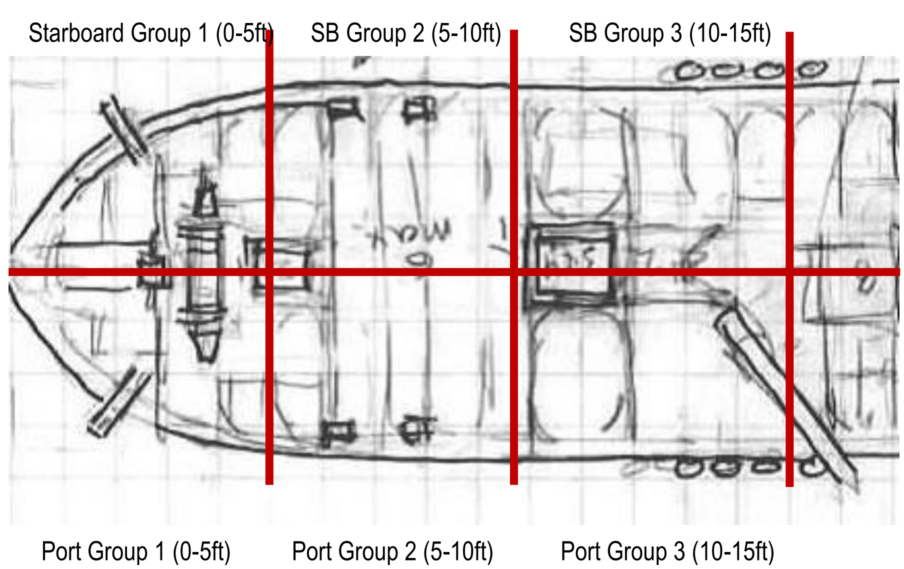
Did you observe any areas that were damaged? If so, what can you infer from your observations?

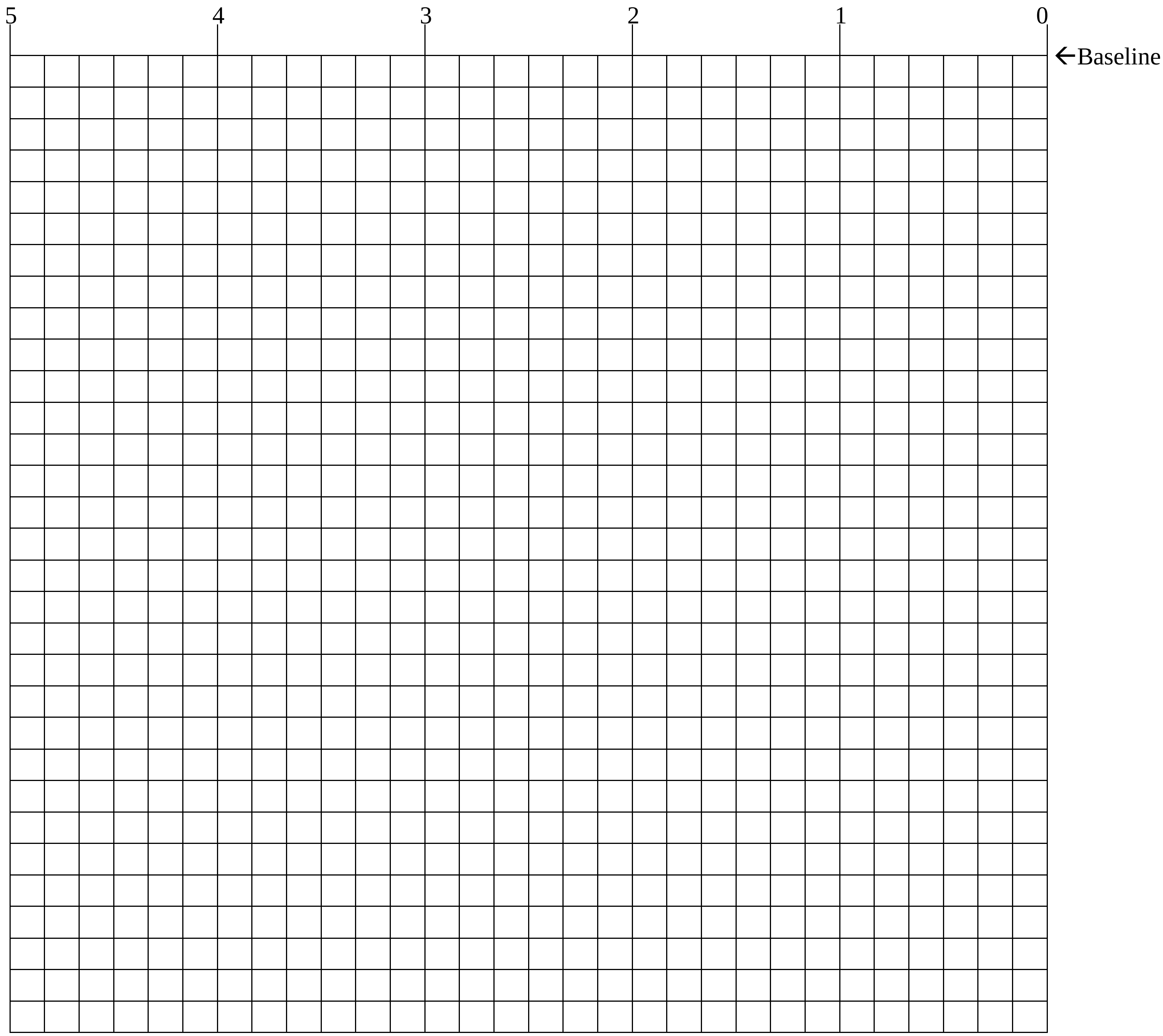
Mock Shipwreck: Mapping the Past TEACHER PAGE

Outline of a shipwreck with vocabulary words:



Sample *Log Sheet* sections based on larger template of mock shipwreck. The number of sections can be modified based on the length of the mock shipwreck and/or number of students participating in the activity (Ex. 30ft ➡ 5ft sections, 24 students)





Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side
0’ to 5’

10 9 8 7 6 5

←Baseline

Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side
5’ to 10’

15 14 13 12 11 10

←Baseline

Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side
10’ to 15’

20 19 18 17 16 15

←Baseline

Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side
15' to 20'

25 24 23 22 21 20

←Baseline

Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side 20' to 25'

30 29 28 27 26 25

←Baseline

Shipwreck Mapping Log Sheet

1 square = 2 inches

Starboard Side
25’ to 30’

0 1 2 3 4 5

Baseline →

Shipwreck Mapping Log Sheet

1 square = 2 inches

Port Side
0’ to 5’

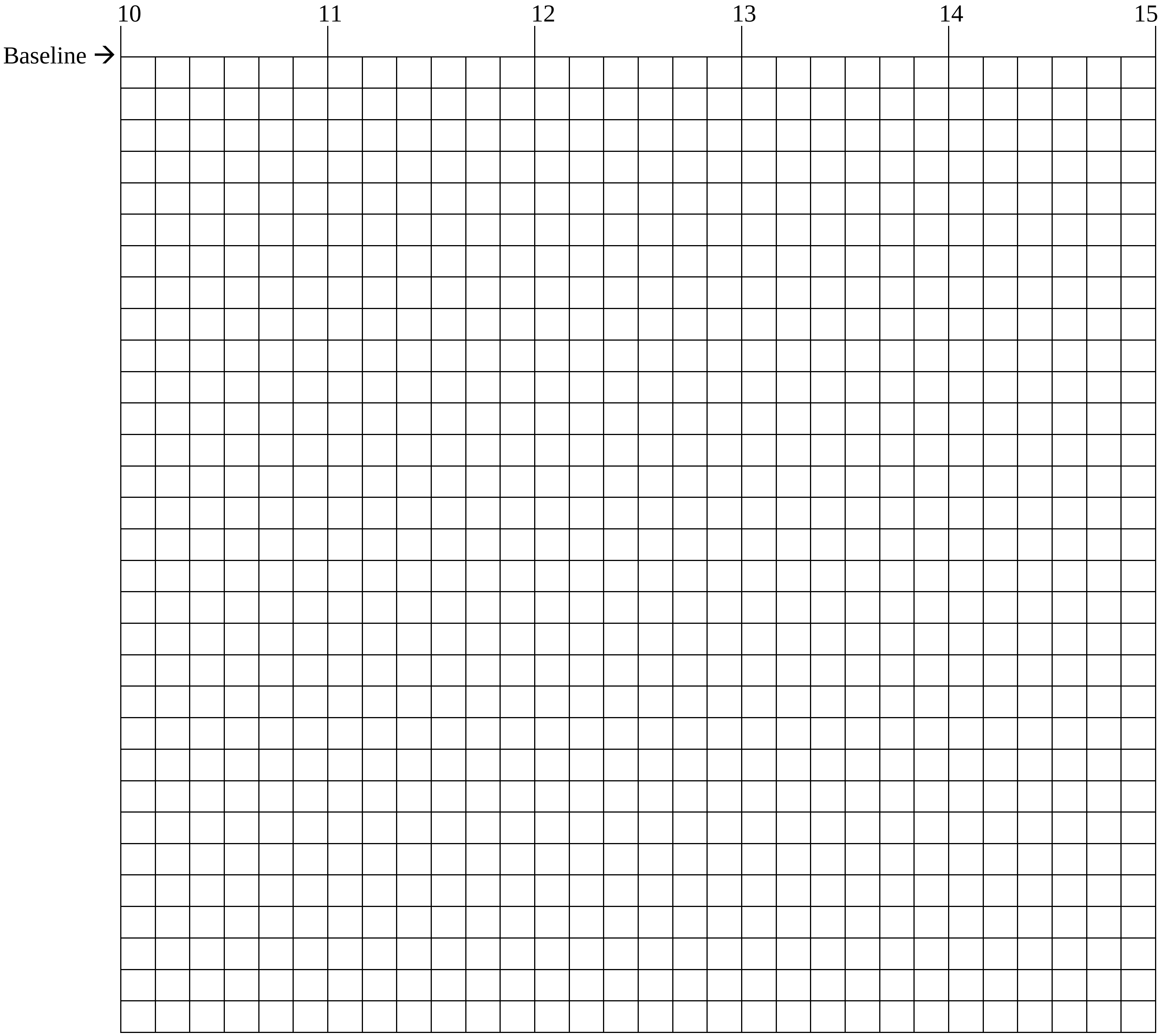
5 6 7 8 9 10

Baseline →

Shipwreck Mapping Log Sheet

1 square = 2 inches

Port Side
5’ to 10’



Shipwreck Mapping Log Sheet

1 square = 2 inches

Port Side
10’ to 15’

15 16 17 18 19 20

Baseline →

Shipwreck Mapping Log Sheet

1 square = 2 inches

Port Side 15’ to 20’

20 21 22 23 24 25

Baseline →

Shipwreck Mapping Log Sheet

1 square = 2 inches

Port Side 20’ to 25’

25 26 27 28 29 30

Baseline →

Shipwreck Mapping Log Sheet

Port Side 25’ to 30’

1 square = 2 inches

Puzzling Pieces

Materials:

Per Pair:
- Bag 1 of puzzle pieces
- Bag 2 of puzzle pieces
- cardstock
- *Parts of a Ship*
- *Dream Gazette*

Teacher Prep:

For each team, copy activity pp. 52-53.

For each team, copy diagrams on pp. 54-56. Cut along the dotted lines into small square pieces. Keep the pieces for each page together and place them in a zip lock bag. You will have four bags. Label bags accordingly: *Ship 1-A* (bow); *Ship 1-B* (stern); *Ship 2-A* (bow); and *Ship 2-B* (stern)

Copy *Parts of a Ship*, p. 57 and *Dream Gazette*, p. 58-59 for each team.

Extension:
Give students the ship pages and have them cut into their own unique puzzle pieces and exchange puzzles with another group.

Have students draw their own shipwrecks and create puzzles.

Purpose: Assemble small piece-like images to create a photomosaic

Background
Another way for maritime archaeologists to look at a shipwreck is through a photomosaic. A photomosaic is a picture that is made up of many smaller pictures of a wreck site. These smaller pictures are all pieced together to create a larger image of the whole shipwreck. This image is not measured, but gives archaeologists a look at the entire shipwreck just as it is underwater. Because visibility (how far you can see in water) can be very poor and wrecks are big, taking many small images of a shipwreck and piecing them together is a great way to see all the details of the whole wreck at once.

In this activity, you will simulate stitching images together to create a photomosaic of a shipwreck. You will then use the photomosaic to help you identify the ship.

Activity 1
1. On a piece of cardstock, match the puzzle pieces in Bag 1.
2. Determine if you have the bow or the stern of a ship.
3. Find a team that has the opposite and see if your two sections fit together to make one complete ship.
4. Look at the complete photomosaic of your shipwreck. Read the Dream Gazette and review Parts of a Ship.
5. Identify your ship.

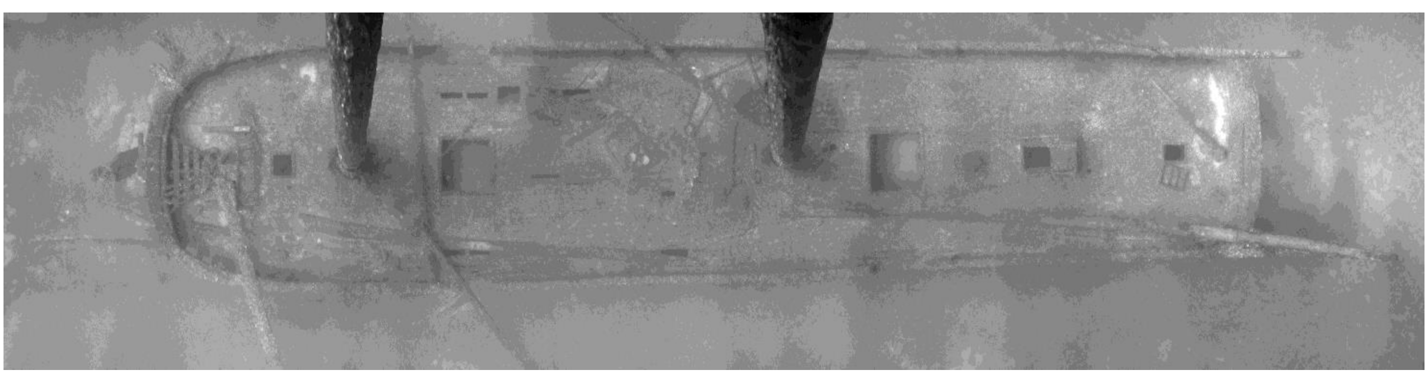
Activity 2
1. On a piece of cardstock, match the puzzle pieces in Bag 2.
2. Determine if you have the bow or stern of a ship.
3. Find a team that has the opposite and see if your two sections fit together to make one complete ship.
4. Compare and contrast this photomosaic to the previous one. How are they different? How are they the same?

Discussion Questions
1. Which photomosaic was easier to create? Why?
2. What are some difficulties that maritime archaeologists have in identifying an unknown shipwreck?
3. How do the parts of a ship help in identification?
4. How would objects (artifacts) found on or near the shipwreck help in identification?

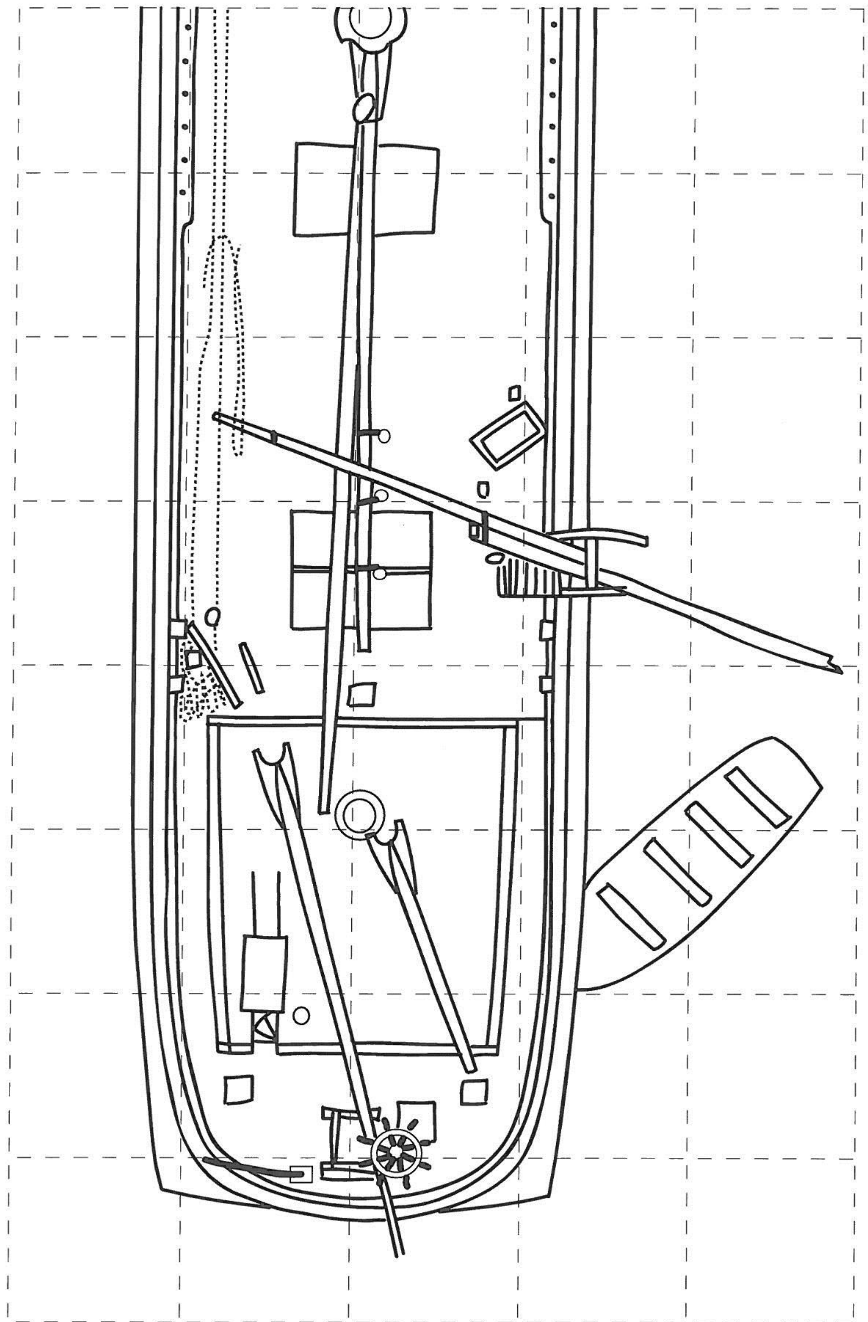
Photomosaic of U-*85*, a German U-boat located off North Carolina's coast. Photo: NOAA

Puzzling Pieces Continued

Activity 3
Maritime archaeologists have completed the photo mosaic of the newly discovered shipwreck. Look at the images below and use *Parts of a Ship* to identify the various structures in the images.

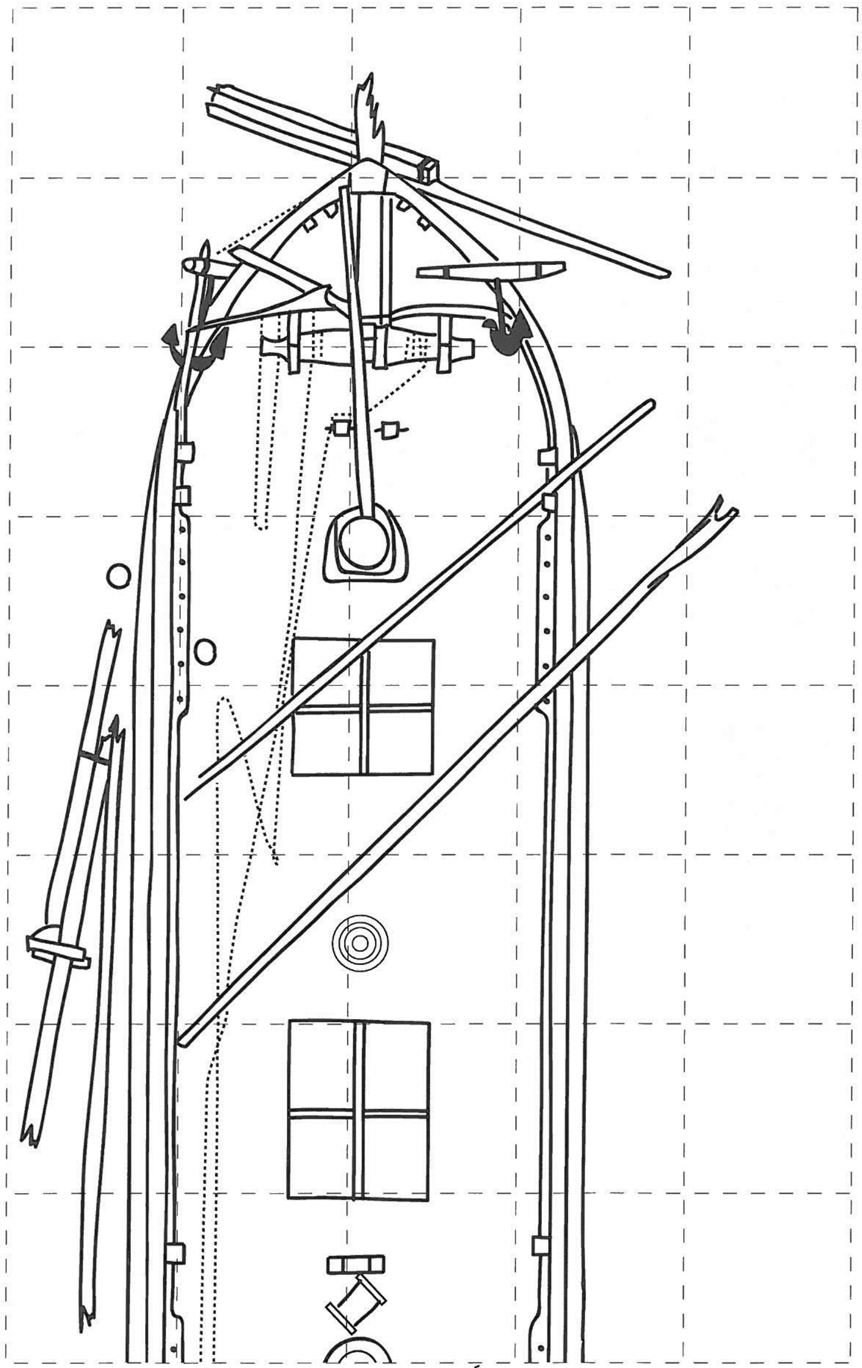


Puzzling Pieces—Continued



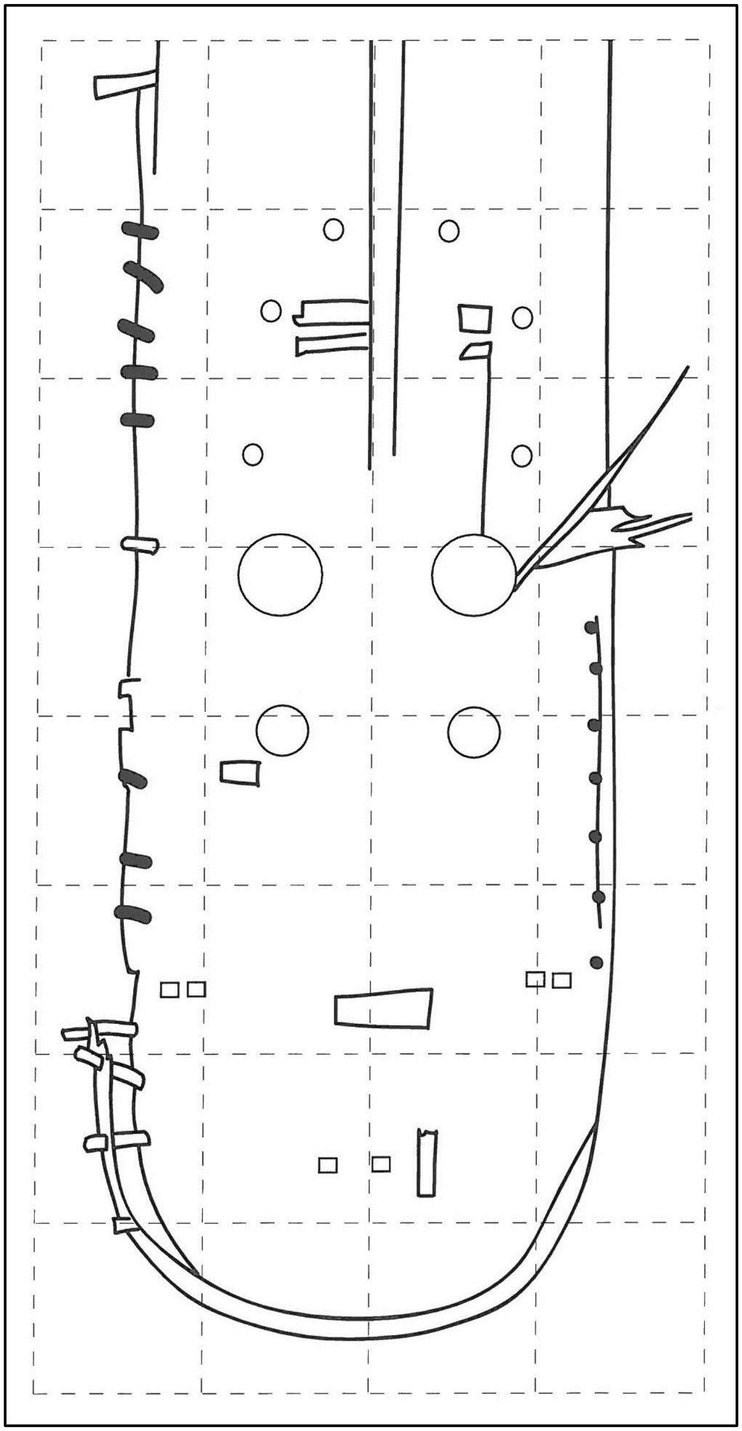
Stern Ship 1

Puzzling Pieces—Continued

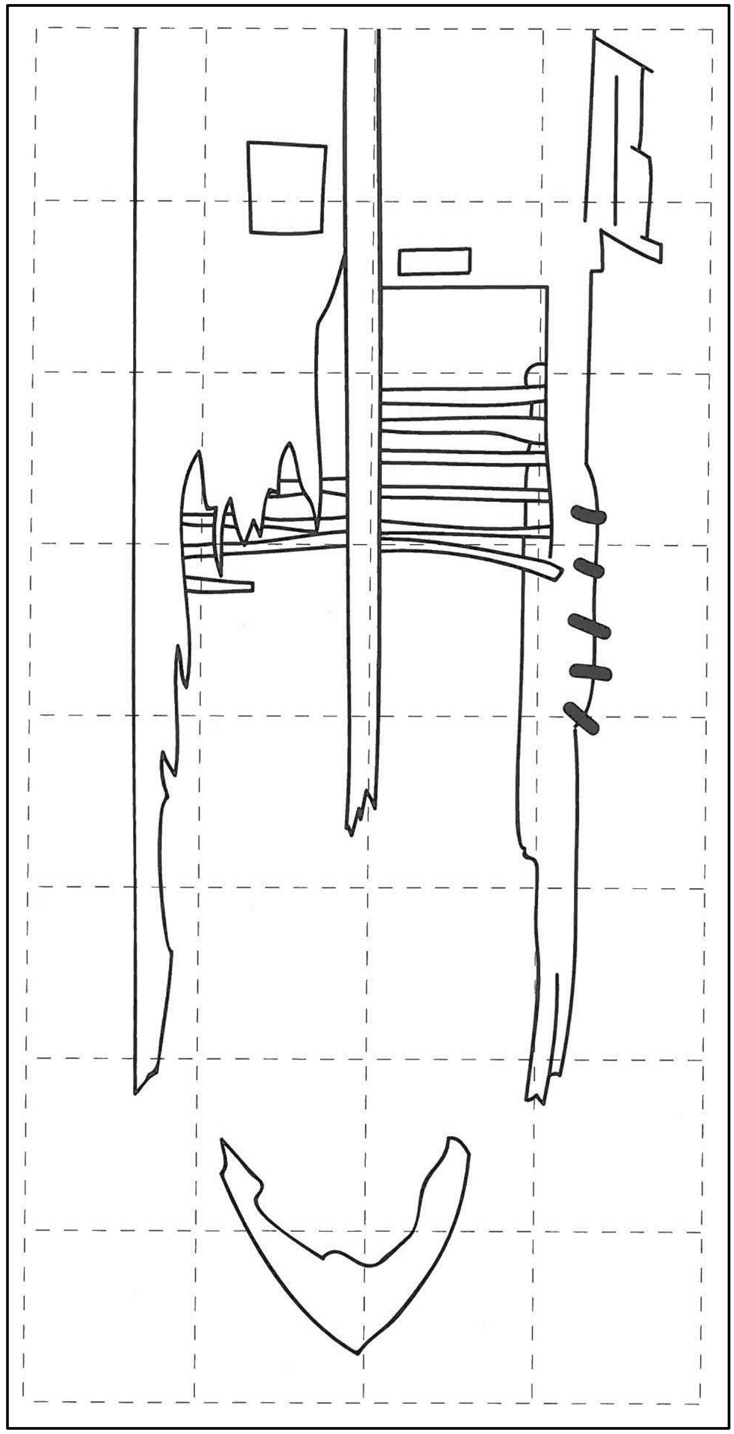


Bow Ship 1

Puzzling Pieces—Continued

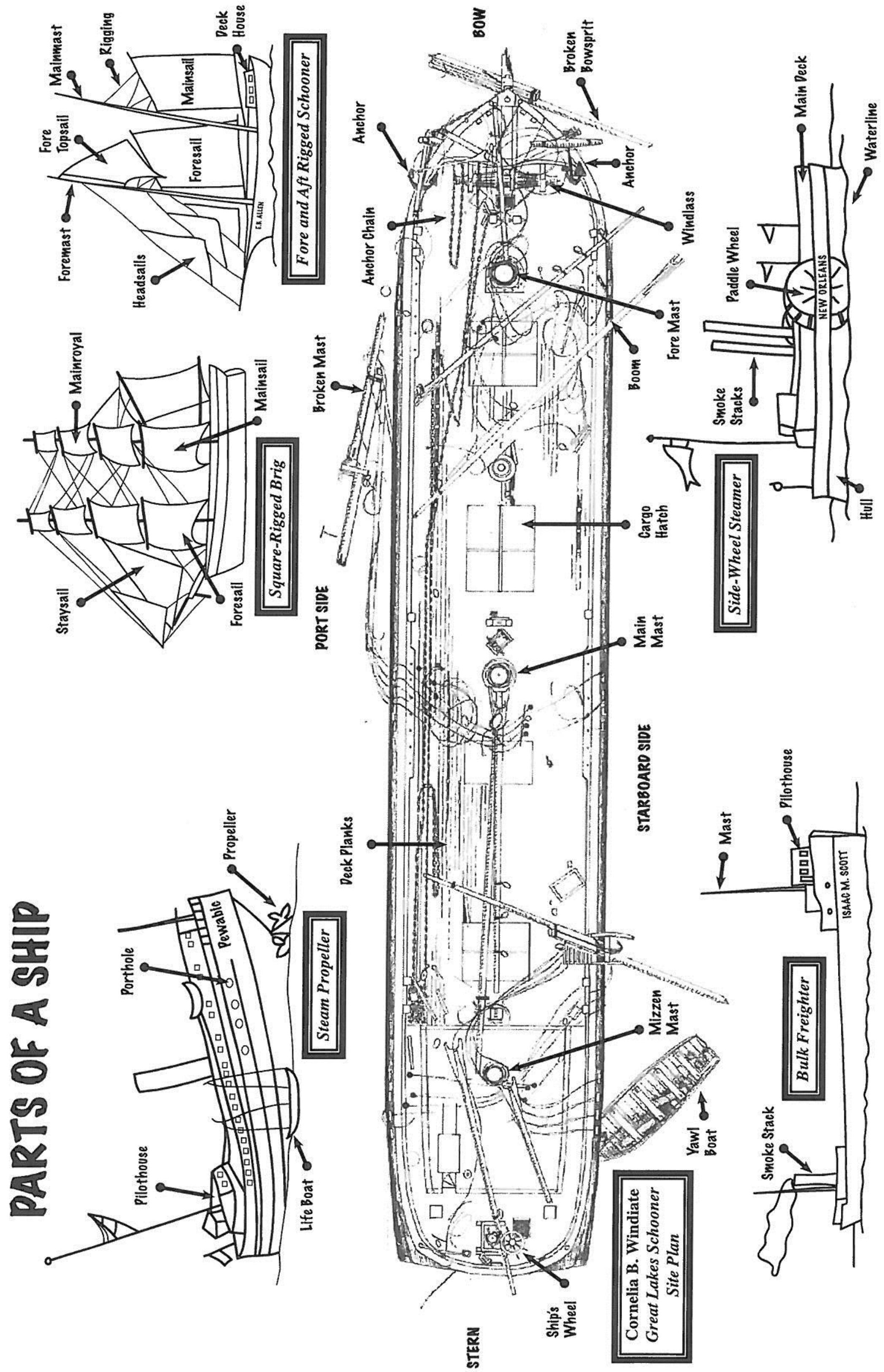


Stern Ship 2



Bow Ship 2

Puzzling Pieces—Continued



Puzzling Pieces—Continued

Divers' Dream Gazette

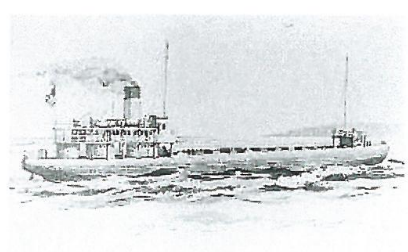
VOLUME 1, ISSUE 1

SEPTEMBER ISSUE

Brass Spike

Brass Spike
Laying about 75' deep, this wooden hulled steam assisted sailing vessel was discovered in 1994. A Brass sexton was found laying in the sand. This vessel has brass spikes (thus the name) in the hull. Off the port side of the stern remains rudder debris, with one large brass gudgeon left. The wreck site contains some of the biggest tautog you will ever see. The treasure of this wreck is waiting to be discovered.

Thomas Wilson



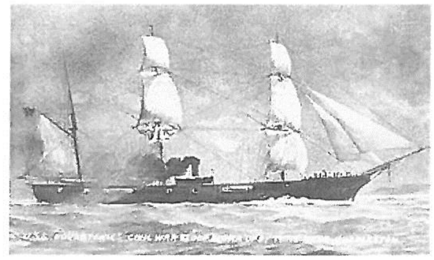
The wreck of the steam propeller Thomas Wilson, lies on the bottom of Lake Superior. The Wilson was a riveted-steel, single propeller steamship. Its hull was of a special form known as a whaleback. Whalebacks were designed by Captain Alexander McDougall to carry bulk cargoes of grain or iron ore economically about the Great Lakes. A pair of Scotch boilers provided steam for the three-cylinder, triple expansion steam engine which drove a single screw propeller.

Puzzling Pieces—Continued

USS *Housatonic*

In 1864, the *Housatonic* was a 1,240 ton vessel with an armament of twelve large cannons, stationed at the entrance of Charleston Harbor roughly five miles off the coast. *Housatonic* was commanded by Charles Pickering and had a crew of 150 men. The *Hunley* began her approach at about 8:45 pm, commanded by First Lieutenant George Dixon and crewed by seven volunteers.

Accounts differ about the initial approach; what is known is that the *Hunley* was spotted just before embedding her torpedo into *Housatonic*'s hull. Official accounts say *Housatonic* was unable to fire a broadside at *Hunley* and hit her with only small arms fire. The *Hunley* attached her explosives to *Housatonic*'s



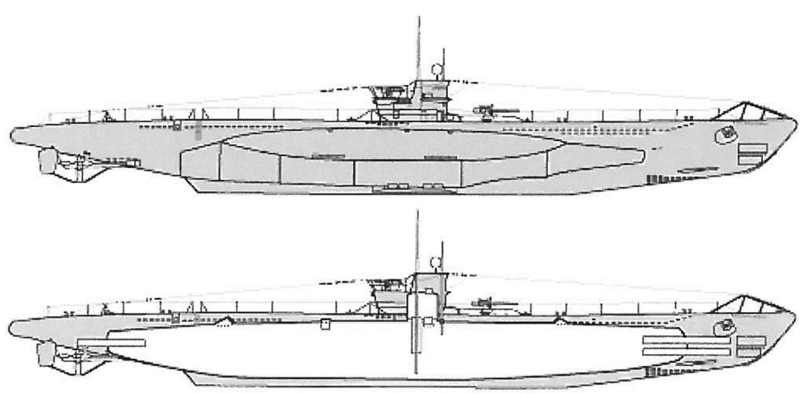
side before reversing and setting a course for home.

A few moments later, the torpedo detonated and sank the wooden schooner.

U-*85*

In the early morning hours of April 14, 1942, U-*85* was hunting allied shipping just a few miles off Nags Head, N.C., when the American four-stack destroyer, USS *Roper* acquired a sonar contact. The *Roper* gave chase and was narrowly missed by a stern torpedo fired by U-*85*. As the USS *Roper* closed the distance, it succeeded in delivering a fatal shot from its 3-inch deck gun, which breached the pressure hull of U-*85* causing it to sink to the bottom.

Visitation and enjoyment of these wrecks are encouraged. Removal of artifacts or alteration of the site is strictly prohibited.



U-BOAT Type VIIB (1940)

Reading the Records

Materials:

Per Pair:
- nautical chart
- ships' logs (4)
- colored pencils

Teacher Prep:

Make copies of the ships' logs and nautical chart for each student.

Old Weather Project
Under the leadership of the University of Oxford's Zooniverse programme, the U.S. National Oceanic and Atmospheric Administration (NOAA), U.S. National Archives, UK Meteorological Office and Naval-History.Net are working with large numbers of online volunteers to transcribe historical weather data and naval events from the logbooks of United States ships in the 19th and 20th centuries. This includes ships of the United States Navy, U.S. Revenue Cutter Service, later the U.S. Coast Guard, and the U.S. Coast and Geodetic Survey. These transcriptions will contribute to climate model projections and will improve our knowledge of past environmental conditions.

http://www.oldweather.org/

Purpose: To examine resource documents, evaluate content and hypothesize, while tracing ships' movements and mapping coordinates. To use imagination to compose a ship's log from another time period.

Background
Ships' logs have been kept since the very beginning of marine navigation. It is the official record book of a ship. Originally, logbooks were kept to record positions and to facilitate the calculation of a course to steer. It would record the distance the ship traveled within a certain amount of time to give the distance traveled from the start position. It would also record the speed the ship traveled.

Today, the ship's log contains many types of information and can be kept electronically or written. It is a record of operational data relating to the ship, such as weather conditions, times of routine events and significant incidents, ports of call, list of crewmembers, maintenance on the vessel, and more. It is filled in at least daily, but sometimes even hourly. The logs can help crews to navigate should radio, radar, or GPS fail. It is also an important part of the investigative process for official inquiries, in much the same way as a "black box" is used on an airplane. They can also be used in legal cases involving maritime disputes.

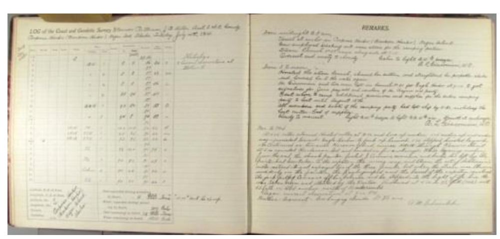
Ships' logs also offer a look at what life might have been like aboard ships of the past. They might also give clues as to what happened to a lost ship. In addition, they are a record of valuable weather data from a time before weather stations. That data can be used to infer climate of that time period and to solve mysteries.

In this activity, you will plot the course of four different ships using the latitude and longitude coordinates given in each ship's log. You will then compare the different routes and use information from an article in a 1908 newspaper, along with the photomosaic and site plan, to determine which ship is most likely the newly discovered shipwreck.

Activity

1. Use a colored pencil to plot the coordinates on the nautical map for Ship 1.
2. Connect the points and color in the key with the appropriate color.
3. Repeat steps 1 and 2 with Ships 2, 3, and 4, using a different color for each ship.
4. Read the 1908 newspaper article and review the photomosaic and site plan for clues to identify shipwreck.
5. The shipwreck is ____.
6. Write a complete log book for the ship. Provide information about the weather, crew. food. conditions. and other items to tell her storv.

Log of Coast and Geodetic Survey Steamer Patterson from 1914. Photo: NOAA



Reading the Records—Continued

Latitude: A geographic coordinate that specifies the north – south position on the Earth's surface. It is an angle which ranges from 0° at the Equator to 90° north or south.

Longitude: A geographic coordinate that specifies the east – west position on the Earth's surface. It is an angular distance east or west from an imaginary line, called the prime meridian, which goes from the North Pole to the South Pole and passes through Greenwich, England.

SHIP #1

Date 1901	Latitude	Longitude
12/3	33N	79W
12/4	33N	78W
12/5	33N	77W
12/6	34N	77W
12/7	34N	76W
12/8	35N	75W
12/9	36N	74W
12/10	37N	74W
12/11	38N	74W
12/12	39N	73W
12/13	40N	71W
12/14	42N	70W

SHIP #2

Date 1908	Latitude	Longitude
9/16	38N	76W
9/17	37N	76W
9/18	37N	75W
9/19	36N	75W
9/20	35N	74W
9/21	34N	73W
9/22	34N	74W

SHIP #3

Date 1908	Latitude	Longitude
9/17	41N	72W
9/18	40N	72W
9/19	39N	73W
9/20	38N	74W
9/21	37N	74W
9/22	36N	75W

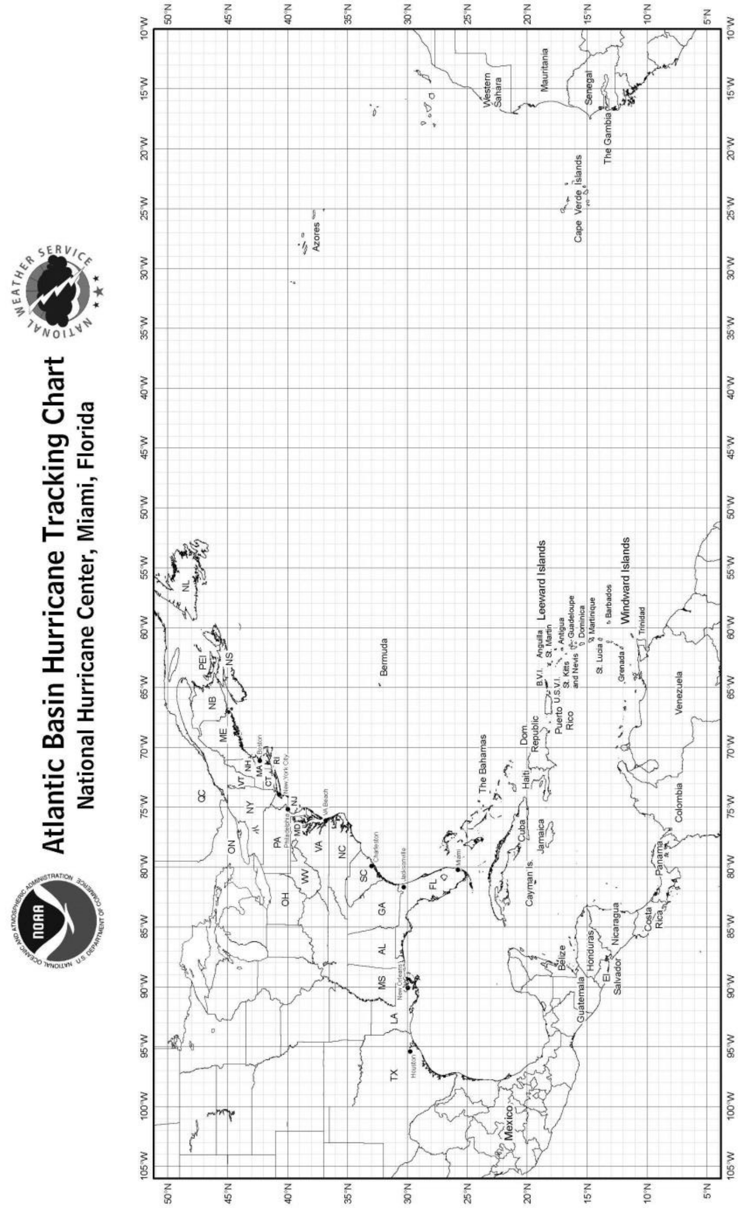
SHIP #4

Date 1914	Latitude	Longitude
8/6	37N	76W
8/7	37N	75W
8/8	37N	74W
8/9	36N	74W
8/10	35N	74W
8/11	34N	74W
8/12	33N	75W

Reading the Records—Continued

Nautical Chart

Plot coordinates for the four ships using a different colored pencil for each.



It is recommended that the map is enlarged for easier plotting of points.

To download a full-size chart visit: http://www.nhc.noaa.gov/pdf/tracking_chart_atlantic.pdf

Reading the Records—Continued

The Sun Gazette
Extra!

Evening Edition **October 8, 1908**

Tragic Day at Sea
By Theodore Bean

It has been reported that two ships, the *Betsy* and the *Bluewater*, and all souls on board, were lost at sea two weeks ago. The unexpected nor'easter on September 22, hit the East Coast with violent 70 mph northeast winds that created waves offshore of up to 20 ft. The waves were powerful enough to toss ships about like twigs.

It is not known exactly what happened to the ships, but neither ship pulled into port at their scheduled time causing alarm. Ships that were heading toward the area where the two ships were last known to be sailing were asked to keep a lookout for any signs of the ships and their crew.

Last week, there were firsthand reports of debris seen in the water from the Captain of the USS *Relief*, a Navy hospital ship. The debris matched descriptions of the cargo being carried by the *Betsy*. A merchant steamer, *Heredia*, also claimed to have seen floating debris that would have come from the *Bluewater*. Although both sightings of debris were far off course from the last known locations of the ships, it is speculated that the debris was carried by ocean currents.

The *Betsy* was a wooden two-mast schooner out of Gloucester, Virginia, carrying bushels of oysters in her cargo hold. She was captained by Sam Plate who hailed from New Jersey. She had a crew of 9 and was heading to Charleston, South Carolina. She was last seen off the North Carolina coast as Captain Plate tried to head further out to sea to avoid the approaching storm. It is tragically reported that his wife and son were also onboard the ship.

The *Bluewater* was a steamship from Mystic Port, Connecticut heading to Jacksonville, Florida. Her captain, Daniel Trygstad, hailed from Newport News, Virginia. The *Bluewater* carried lumber and hardware supplies and had a crew of 10 onboard. She was last seen off Cape Hatteras, North Carolina as she was trying to make port before the storm.

Discussion Questions

1. What important pieces are missing from the ship's log?
2. Why is it essential that a good log record of location is kept during trips at sea?
3. How did the log help you identify the ship?
4. How did the photomosaic help in identification?
5. What else would have been helpful to know in order to make a more accurate identification?

Sleuthing Through 1908

Materials:
Per Group:
- 12 bags with artifacts and letters
- list of missing people

Per Class:
- tub or small swimming poos filled with sand

Sailors of the USS *Monitor*
When the turret of the Civil War ironclad, USS *Monitor,* was recovered in 2002, two sets of human remains were discovered inside. In anticipation of human remains being found and due to the fact that the *Monitor* was a U.S. Navy vessel, the Joint POW/MIA Accounting Command (JPAC) was onboard.

With the help of Navy divers, maritime archaeologists, and JPAC, the remains of the two sailors were recovered and sent to JPAC for investigation. Personal artifacts recovered with the remains were sent to The Mariners' Museum for conservation.

On March 8, 2013, the sailors were laid to rest at Arlington National Cemetery with full military honors.

To learn more about the sailors, JPAC, the forensics, the recreation of their faces, and the burial, visit http://monitor.noaa.gov/150th
+


Casts of the USS *Monitor* sailors' skulls
Photo: *Monitor* Collection, NOAA

Cornelia B. Windiate. Photo: NOAA

Purpose: To collect clues, analyze and compare them and use source documents to draw conclusions

Background

In this activity, students read a story of a fictional ship, the *Betsy*, which sank in September 1908. In the story, 12 people perished with the ship, including the Captain's wife and son. Then the story jumps to 2013, when the shipwreck was found, along with human remains. Because the remains were not military, they were left *in situ*, but extensive documentation was done. A report was made to the company that had the legal rights to the ship, and later the next year, the company raised parts of the ship that included the remains. Forensic anthropologists conducted an investigation on the remains and attempted to identify them against records and DNA samples. Artifacts recovered also helped to identify the unknown.

Teacher Prep

The teacher will create 12 bags (one will be used with the tub of sand). Inside each small bag, place "artifacts" that help to identify the owners of each bag. Suggested "artifacts" are listed on the *Artifact Sheet* (p. 65), but you may substitute other items that might be more readily available. Just be sure to have the stories of each person match the items you place in the bag (e.g.—if the story says that a sailor had a wife and two children, then the photograph should be of a woman and two children). Search the Internet for images that match information. Write letters from sweethearts. (See *Sample Letters* p. 66.)

To model how to use artifacts to help identify unknowns, fill a large tub or small swimming pool about halfway with sand. Make sure sand is dry and not damp. In the sand, hide the suggested "artifacts" for, William Stuarts, whose remains have been discovered. Also in the sand, conceal some seashells and other ocean related items you might have on hand. To spark a conversation on marine debris, you may also want to put some marine debris, such as a soda can, into the sand. Ask the students if they had soda cans in 1908, and if not, then how did the can get there?

For each group of students, print story sheet, *The Demise of Betsy: A Fictional Story* (p. 69) and the activity sheet with the *List of Crew and Passengers* (p. 67). Go through the artifacts in the tub one-by-one, and have students review the story and the list of those onboard. Come to a consensus with the group as to the identity of the remains. Have students continue working independently with their group going through the artifacts in their bag to determine who once owned the bag.

***NOTE: For realism, wear gloves as you handle the "artifacts."**

Sleuthing Through 1908—Teacher Page Continued

Extension:

- Set up each bag as a station and have students rotate through each station to determine who belongs to each bag.
- Discuss the USS *Monitor* and the two sets of remains discovered in 2002 inside the turret as it was excavated. Visit the 150th website http://monitor.noaa.gov/150th to learn more about the 16 sailors that died, the genealogy research conducted, the unveiling of the face for the two sailors recovered, and more. Have students debate what should happen to the remains if no living relatives are found. Should they be buried? If so, where?

Artifact Sheet

To offer clues for identification, use these suggested items or items that might be more readily available. Be sure to make the items in the bags correlate with the information given about each person. Add additional general items to the bag, such as clothing, shaving kit, and other items as available. Number each bag 1-12.

NOTE: Paper and other biodegradable items would not survive totally intact. However, depending upon the environment, parts of the item could still be readable. Therefore, make any paper items torn and hard to read.

To model the process, use items related to William Stuarts or other person of your choice.

William Stuarts, 35, England • William and Mary stationary • Mathematical puzzle • Letters from his single mother • English flag • Tools	Charlie Huntsman, 41, Delaware • Picture of an oyster boat, man and son • Book • Delaware papers
Henry Plate, 8, Virginia • Baseball • Train • Fishing hook	Kenneth "Kenny", 56, Virginia • Spoon • Can of food • Picture of the ocean tucked in a book
Sam Plate, 37, New Jersey • Naval memorabilia • Picture of wife and boy and girl • Captain's hat	Masters Lessing, 51, Maryland • Tools • Oil can • Letter from aunt
Elizabeth Plate, 30, Virginia • Bonnet from daughter • Knitting needles • Picture of family (mom, dad, son, and daughter) • Women's perfume bottle	Jon Schmidt, 27, Virginia • Picture of wife and two young children • Letter from wife • Drawing from children • Oil rag
Robert Bunchman, 44, Virginia • Letter from wife Lucelle • Journal with letters from Lucelle and all the 6 children • Picture of husband, wife, and 6 children	Carl Patch, 20, Virginia • Letter from his mother • Handkerchief
Harvey Wisenger, 40, Virginia • Letter of disappointment from his father • Chesapeake Bay memorabilia • Expensive facets for clothing	Mitchel Patch, 23, Virginia • School books • Mathematical scribbles • Letter from his mother

Sleuthing Through 1908—Teacher Page Continued

Sample Letters for Bags

For Harvey Wisenger

Dear Son,

Things in the county are well. Continuing to serve the people and protect the innocent. I am near retirement age now, and it is not too late for you to come back home. I can pull some strings and get you into my seat when I am gone. Please reconsider… Come home…

Your Honor

For William Stuarts

My Dearest Son,

You are missed dearly. The fish crop is increasing year after year. I hope you're doing well and the fish count west is doing just as good. Tell me, my son, are the waters the same? I imagine you with your fancy schooling over there, teaching all the crew new things. You make me so proud my love! Come visit.

Love Always,

Mom

For Jon Schmidt

My Love,

You are missed every day. I show pictures to the young ins every day to remind them of their precious father. Little Sissy is now saying Paw when she sees your picture. It makes me cry. The landlord came by again last week my love. He wants his payment this week. What are we going to do my love? Junior's medicine is running us dry. Be safe my sweet angel.

Your Loving Wife,

Sara

Sleuthing Through 1908—Student Page

Directions

1. Read *The Demise of* Betsy: *A Fictional Story* (p. 68), and review the list of crew and passengers below for details of each person.
2. Observe the artifacts that are recovered from the wreck (teacher recovers them).
3. As a class, come to a consensus as to whose artifacts were recovered.
4. Open your bag of artifacts and with your team carefully observe each object. Use the story and list of crew and passengers to determine whose artifacts are in your bag.

List of Crew and Passengers

Captain: Sam Plate (37), New Jersey, 5'11"- 170lbs
Sam grew up in Cape May County, NJ. He joined the Navy at 18, which brought him to Virginia a few years later. He left the Navy after 10 years of service and became a sea captain. After many years of success, he started a seafood shipping business with a partner. Sam is married to Elizabeth and has a son named Henry. His daughter Betsy, who passed away, is the ship's namesake.

Captain's Wife: Elizabeth Plate (30), Virginia, 5'4"- 110lbs
Elizabeth grew up in Gloucester County, Virginia. Her father was an oysterman. She lived on the water her whole life. When Elizabeth was 18, she went to school to become a teacher. While in school, she met a sailor by the name of Sam, two years later they were married. They had two children; Betsy and Henry. Betsy passed away at a young age of 4. Elizabeth copes with her loss by knitting blankets and hats for the children at the local hospital.

Captain's Son: Henry Plate (8), Virginia, 5'2"- 100lbs
Henry grew up in Gloucester County, Virginia with his mother, father and little sister. Henry loved all the things most typical boys loved; fishing, trains and baseball. After his little sister's accident, Henry had to leave all his friends behind to do deliveries with his father on his cargo ship. Henry enjoyed being on his father's ship, but didn't want to leave school and have his mother home school him on the ship.

1st Mate: Robert Bunchman (44), Virginia, 5'11"- 200lbs
Robert was born in Gwynn's Island, Virginia. He was the oldest of eight boys. All of the boys were trained to work the waters by their father and grandfather. Robert has a wife, Lucelle and six children. Lucelle is very supportive of Robert's career, even though it takes him away from the family for months at a time. Lucille gives Robert a journal before every trip. In the journal, Lucille has written a message for everyday that he will be gone, and Lucille ensures the kids write at least one letter as well.

2nd Mate: Harvey Wisenger (40), Virginia, 5'8"- 160lbs
Harvey was born and raised in York County, Virginia. He came from an affluent family. His father was the county's judge. For all of Harvey's life he knew he had to be near the water. He spent his childhood days splashing in the mouth of the Chesapeake Bay, and in older years, hanging around the docks doing any odd job he could find, just to get time on the boats. After much disagreement of the future with his father, Harvey moved to Gloucester County and found his way on *Betsy*. For the first time in his life, Harvey feels like he has found family with Sam, Elizabeth and Henry.

3rd Mate: Charlie Huntsman (41), Delaware, 5'10"- 210lbs
Charlie was born and raised in Bowers Beach, Delaware. Bowers Beach sits on the Delaware River. Charlie's father worked on an oyster boat all his life and taught Charlie everything he knew. From the start, Charlie was a loner and just worked hard to stay close to the water. After a shortage in oysters, Charlie found himself moving south on the coast looking for work… when he stumbled upon a small cargo ship in need of a 3rd mate, *Betsy*.

Sleuthing Through 1908—Continued

Engineer: William Stuarts (35), England, 6'0"- 195lbs
William was born and raised in Falmouth, England. It is located on the tip of the English Chanel. William came to America to attend the College of William and Mary in 1902. William had always been extremely bright and was always tinkering with mathematical puzzles. It was no surprise to his single mother that he was going to leave her and travel west to the U.S. He always had a vision of the open water and escaping the small fishing town of Falmouth. After graduation, William found himself missing home… so he took a job with Captain Sam, and an iron clad relationship was built.

Cook: Kenneth "Kenny" (56), Virginia, 5'9"- 155lbs
Kenny was born and raised in Gloucester County, Virginia. He joined the Navy right out of school and found his niche as the ship's cook. Thirty eight years in the kitchen on a ship…and he couldn't imagine the day he would have to sit on dry land. His place was in the galley, where he could bring smiles and comfort to the captain and crew. The galley was more than a kitchen to him, it was a place for the crew to escape and find comfort if they were homesick, injured, or if they needed a quiet moment. Kenny spent so much time on the water; he didn't have much of a life on land.

Oiler: Masters Lessing (51), Maryland, 5'10"- 170lbs
Masters was born in Dorchester, Maryland. When he was a young teenager, his parents passed away in a boating accident. Masters was sent to live with his aunt and twelve younger cousins in Gloucester County. Masters took on the role of big brother and "man of the house." When Masters turned 16, a neighbor took him out on his boat and taught him the basics of boating. Masters followed the neighbor around for an entire year, absorbing as much boating knowledge as he could.

Wiper: Jon Schmidt (27), Virginia, 5'7"- 155lbs
Jon was the newest member to the crew. Masters found Jon meandering through the docks and asking about odd and end type of jobs. Jon was young and willing to learn. He had a wife and two young children at home; Rosie and Junior. Bills were piling up and Jon needed a job. Masters started teaching Jon about the mechanics of the cargo ship and took him on as his apprentice.

Able-bodied Seaman: Carl Patch (20), Virginia
6'2"- 235lbs
Carl Patch and his brother took on a job with Captain Sam three years prior. Carl is large in stature and does the heavy lifting on the boat. He helps with loading and unloading of the oyster barrels. The Patch boys look after Captain Sam as if he was their father. Captain Sam took Carl and Mitchel under his wing after their father ran out on their mother. Captain Sam pays the boys enough for their hard work to keep their mother's house running.

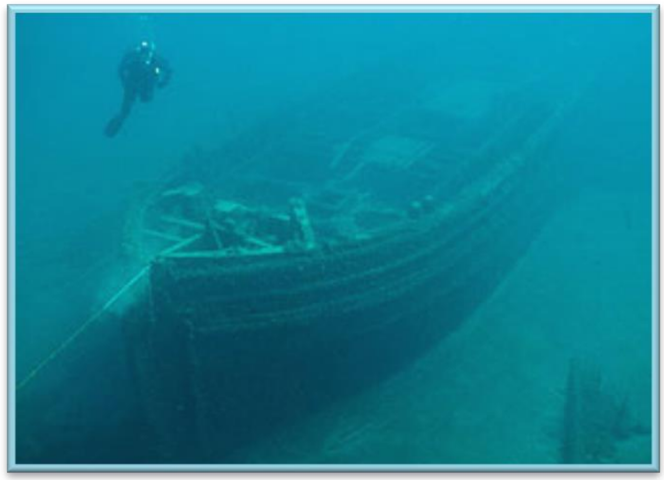
Able-bodied Seaman: Mitchel Patch (23), Virginia, 5'10"-190lbs
Mitchel and his brother, Carl, took on a job with Captain Sam three years prior. Mitchel is smaller than his younger brother, but is very intelligent. He is quick thinking and is very efficient. When Captain Sam gives the boys a task, Mitchel leads his brother in the best way to get it done. Mitchel is the brains and Carl is the brawn. Mitchel plans to go to college after he earns enough money to take care of his mother for a few more years. The crew would tease him because before every delivery he would bring a book bag full of old school books. When there was down time on the ship, Mitchel's nose was in the books.

Bag number ______
Belongs to: ____

USS *Monitor* crew. Photo: Library of Congress

Sleuthing Through 1908--Continued

E. B. Allen. Photo: NOAA



The Demise of *Betsy*: A Fictional Story

September 16, 1908 - Carl and Mitchel were finishing loading the last of the oyster barrels into *Betsy*. Captain Sam was standing on the bridge watching proudly as his boat was getting ready to move south. This would be the first delivery since the death of his daughter Betsy. Since the accident two months ago, Sam decided that for now on he would bring his family with him on deliveries. He was not going to have his family more than a mile apart ever again. His son, Henry, enjoyed sitting on the deck watching the water, hoping to catch site of fish jumping or playing catch with one of the crew…and his wife would sit and knit while looking out at the open sea.

After about 9 hours into their travels, second mate Harvey came up to the bridge to tell Robert and the Captain that the air pressure was dropping and wind gusts were shifting the weight below deck. Captain Sam saw the worry on Harvey's face. He too had been noticing a change in the seas. The Captain told Harvey to get the crew ready for an upcoming storm and to get Jon, Carl and Mitchel to tie down the supply. They were going to try and loop around the storm, but it looked like high seas were inevitable. Captain Sam left Robert at the helm and went to find Elizabeth and Henry to tell them to stay in their quarters until morning because it was going to be a rough night.

The last entry in the ships log was at 3:57 am--

> 100mph gusts of wind; there is no controlling the wheel; lost contact with the mainland at 0200; air pressure is 910 millabars; air temperature 76^{o}F; in route to Charleston, SC… 12 souls onboard

The ship sank off the North Carolina coast during a violent nor'easter and all souls onboard perished.

In 2013, while searching for a World War II German U-boat, divers with NOAA's Office of National Marine Sanctuaries' Maritime Heritage Program located an unknown shipwreck. Side-scan sonar indicated that it was not a U-boat, but the maritime archaeologists were not sure of the ship's identity. Therefore, NOAA divers began the process of mapping the shipwreck, while other scientists took video and photo images of the wreck site to create a photomosaic. While mapping the shipwreck, archaeologists found the remains of the ship's log book and documented it with video and photos. It appeared to be turned to the last entries recorded and dated in September 1908.

Research was conducted by looking at archived ship records from September 1908 and from reading primary source documents, such as newspapers. All data supported that the ship was a cargo ship from the late 1800's to early 1900's and it was assumed to be the *Betsy.*

On the last dive, maritime archaeologists were surprised when they found human remains. Video and photographs were taken of the remains and the artifacts lying nearby. A report was made and given to the company who had legal rights the *Betsy*. The following year, the company decided to recover the part of the ship that contained remains.

NOTE: ***Recovery of civilian human remains from a civilian shipwreck is highly unlikely. NOAA's Maritime Heritage Program does not support the recovery of human remains unless there is a significant and/or historical reason for doing so. The issue is extremely complex and many factors would need to be considered, such as whether the ship is in state or federal waters, was the vessel abandoned by the owners, and many more. This activity is merely to give students an idea of what can be learned from remains and any artifacts associated with them.***

Ethically Speaking

Shipwrecks can be found in deep water, near shore and sometimes even on the beach. The idea of finding a shipwreck is exciting and mysterious as shipwrecks are vessels of untold stories that connect us to the ocean and our maritime past. Unlocking the secrets a shipwreck holds may be difficult, which fuels our imagination and curiosity to learn more.

Shipwrecks may be intriguing for many different reasons. To scuba divers, they are part of an underwater world of wonder offering divers a firsthand look at the past. To marine biologists and fishermen, they are an oasis of life teaming with so much variety it can be overwhelming. Military vessels sunk during World War I and II, along with colonial ships and vessels sunk during the Civil War provide historians an opportunity to learn so much more than what books can tell.

The presence of shipwrecks also provides economic support to coastal communities through maritime tourism. For example, they offer charter dive boat operators amazing sites for scuba divers to visit and are excellent places for fishing charters to take people to fish. Shipwrecks along the beach also offer those who don't dive or fish an opportunity to experience a wreck from shore. As all these people visit the community, they stay in hotels, eat in restaurants, visit local museums, and buy souvenirs or groceries from local stores, to name only a few. These visitors can provide a large source of income to communities.

When a new ship is discovered, it is quite exciting. Most people want to protect shipwrecks for archaeological or historical purposes, but also to ensure that its remains can be seen by many people for generations to come. In very rare instances, a diver that is perhaps not aware of the importance of leaving a shipwreck *in situ* might take a piece of a ship or an artifact home. Never intending to do any harm, they just may not realize that a shipwreck is a finite resource and cannot be replenished. Hurricanes, storms, currents, and water all take a huge toll on a shipwreck, and if all divers took a piece of it back with them each time they dove, over time, there would not be much of a shipwreck left. Therefore, it is important to educate divers "to take only pictures and leave only bubbles," so that future generations will have an opportunity to experience and explore these resources as well.

There are rules and regulations in place that provide protection to shipwrecks. For example, some shipwrecks are protected by the Sunken Military Craft Act of 2004. This act protects all military vessels (foreign and domestic) and their associated contents. While visitation and enjoyment of these cultural resources is encouraged, the removal of artifacts is strictly prohibited. Also, some shipwrecks may belong to a foreign government, such as the German U-boats off the North Carolina coast. Just as we would want citizens in foreign countries to respect and preserve our military vessels off their shores, we want to show that same level of respect. Another consideration is that many of the military vessels had loss of life, so they are also considered war graves.

Visit the Naval History and Heritage Command to learn more about the Sunken Military Craft Act.
http://www.history.navy.mil/branches/org12-12a.htm

Shipwreck of the Deep
Part II

Overview

As the story continues…

The maritime archaeologists continue to assess the shipwreck. Meanwhile, marine biologists begin to document and survey the marine life living on the wreck. Fish are identified and counted, and water quality is monitored. Soon there is talk about the shipwreck becoming a possible location for a major habitat and oyster restoration project.

Part II: Suggested Course Outline:

A. Artificial Reefs (0.5 hour)

B. Oyster Introduction (1 hour)
 1) Overview of oysters as filter feeders and their value to the health of the bay
 2) Introduction to spat and spat measuring process (ongoing process)
 3) Overview of oyster restoration project

C. Watersheds (1-2 hours)
 1) Watershed overview
 2) Human and natural effects on watersheds
 3) Point and nonpoint sources
 4) Land use and pollution
 5) Measuring in parts per million and billion

D. Water Quality Testing (5 hours)
 1) Dissolved Oxygen
 2) Temperature
 3) Measuring pH levels
 4) Chemical Waste
 5) Nitrates
 6) Eutrophication
 7) Salinity
 8) Turbidity

E. Build a Buoy (7 hours)
 1) Introduction to data buoys
 2) Build a Basic Observation Buoy
 3) Attach data sensors
 4) Prepare to deploy buoy with review of sensor data and water quality testing

F. What does the Water Tell Us?
 1) Field trip: Deploy buoy in a secure location (1-5 hours)
 2) Field trip: Retrieve buoy (1-5 hours)
 3) Clean buoy and analyze data (1 hour)
 4) Determine if water quality is sufficient for an artificial reef

G. Oysters—Continued
 1) Oysters filter feeders cleaning the bay
 2) Other marine life associated with an oyster reef
 3) Continue measuring spat as needed

Careers

- ecologist
- ecoinformatics specialist
- ecotoxicologist
- environmental educator
- environmental lawyer
- forensic anthropologist
- marine biologist
- marine engineer
- oceanographer
- oyster farmer

NOAA habitat conservation project. Courtesy NOAA.

Objectives

Students will:

- Recognize the impact of human activity and natural causes on watersheds;
- Describe how oysters aid in the health of the bay;
- Collect data on growing oyster spat;
- Learn how to use water quality sensors to collect data and interpret the data;
- Recognize the importance of data buoys;
- Construct a data buoy, deploy it and collect and analyze data; and
- Assess water quality for the viability of an artificial reef.

Implementation strategy

1. Review the suggested course outline for Part II on p. 71 for a recommended implementation strategy for the course.
2. Review the various activities included in this guide and determine which activities are best for your students.
3. Review additional web and book resources for appropriate supplemental material.
4. Once ready to begin Part II, give students an overview of the storyline as it continues.

Vocabulary

buoy---a float moored in water to mark a location, warn of danger, or to collect data

dissolved oxygen—refers to microscopic bubbles of gaseous oxygen that are mixed in water and available to aquatic organisms for respiration

filter feeder—animals that feed by straining suspended matter and food particles from water, typically by passing the water over a specialized filtering structure

forensics—the use of science and technology to investigate and establish facts in criminal or civil courts of laws

nitrates—a salt or ester of nitric acid (NO_3); a compound that contains nitrogen and water and comes from decomposing organic materials

oyster—any of a number of bivalve mollusks with rough irregular shells; several kinds are eaten and may be farmed for food or pearls.

pH—a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline.

pollution—the presence in or introduction into the environment of a substance or thing that has harmful or poisonous effects

salinity—the saltiness or dissolved salt content of a body of water

spat—the life cycle of the oyster begins with a free-swimming larval stage that eventually attaches to a hard substrate forming an oyster spat. The spat commences a growth period that is classified into sub-adult and adult phases.

turbidity—the cloudiness or haziness of a fluid caused by individual particles that are generally invisible to the naked eye, similar to smoke in air; a key test of water quality

watershed—an area or ridge of land that separates waters flowing to different rivers, basins or seas

Web Resources:

NOAA Chesapeake Bay Office: Oyster Reefs
Visit this site for information on oysters range and life history, ecosystem roles, restoration oyster mapping, and more.
http://chesapeakebay.noaa.gov/oysters/oyster-reefs

NOAA National Data Buoy Center
View maps of data buoys around the world and access real-time data.
http://www.ndbc.noaa.gov/

NOAA Chesapeake Bay Interpretive Buoy System
Learn how data provided support the use and management of a healthy Chesapeake Bay.
http://chesapeakebay.noaa.gov/cbibs

Bridge: Watersheds
An activity that helps students define a watershed and explain the importance of riparian buffers, while examining types of land use and more.
http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive0203.html

Sea Grant—Maryland: Oysters
This site contains a wealth of information and videos, along with interactive lessons plan about oysters.
http://www.mdsg.umd.edu/topics/oysters/oysters

Oysters in the Classroom
Use this online program to learn about the external and internal anatomy of the eastern oyster.
http://ww2.mdsg.umd.edu/interactive_lessons/oysters/anatlab/index.htm

Watershed Game
Interactive game features two skill levels that teach about water quality, watersheds, and management of this important resource.
http://www.bellmuseum.umn.edu/games/watershed/

Environmental Protection Agency
Learn the issues, test your knowledge and explore classroom activities that help your students understand water quality concerns.
http://www.epa.gov/

The Water Project
Comprehensive teacher guide with activities, worksheets, research ideas, and more for students in elementary through high school.
http://thewaterproject.org/

The National Park Service: Water Quality
Play an online game to learn how rangers can tell the cleanliness of a river or pond just by studying the creatures that live in the water.
http://www.nps.gov/webrangers/activities/waterquality/

Virginia Department of Environmental Quality
Learn what it takes to become an oyster gardener.
http://www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/Oysters/Gardening.aspx

Books:

Allen, Elaine Ann: *Olly the Oyster Cleans the Bay*. Tidewater Publishers, 2008, ISBN-13: 978-0870336034.

Chambers, Jennifer: *Watershed Adventures of a Water Bottle*. Tate Publishing, 2013, ISBN-13: 978-1625103918.

Cherry, Lynne: *A River Ran Wild: An Environmental History*. HMH Books for Young Readers, 2002, ISBN-13: 978-0152163723.

Kaye, Catheryn Berger, M.A, and Philippe Cousteau: *Going Blue: A Teen Guide to Saving our Oceans, Lakes, Rivers, & Wetlands*. Free Spirit Publishing, 2010, ISBN-13: 978-1575423487.

Tate, Suzanne: *Pearlie Oyster: A Tale of an Amazing Oyster*. Nags Head Art, Inc., 1989, ISBN-13: 978-0961634476.

Activities and Worksheets

Oyster restoration at Jockey's Ridge, N.C. Photos: NOAA

Wrecks as Reefs

Purpose: To identify the importance of oyster reefs to our water quality and to recognize the significance of shipwrecks in creating underwater artificial reefs

Background

In tropical waters around the world, snorkelers and divers can view an amazing variety of beautiful marine organisms that live on coral reefs. Coral reefs occur only where there is a suitable hard substrate, such as limestone rock out-croppings, where sponges and corals can attach themselves to live and colonize. North of the Florida Keys, most of the eastern coast of the United States is covered with several feet of sand, which does not allow for the formation of a reef community. While there are low-profile areas known as 'hard-bottom' or 'live-bottom' habitats in this area, they lack the coral diversity, density, and reef development of the tropical coral reefs.

The generally flat, sandy bottom does not provide adequate shelter for many marine organisms and as a result is not a great place to catch fish or scuba dive. However, when a reef emerges off the seafloor, providing habitat for a wide variety of sea creatures, more opportunities arise which can have a positive economic effect on tourism within a coastal community. Therefore, many communities and states have implemented a program to create artificial reefs on an otherwise sandy bottom. These manmade structures provide a quantity of stable and durable substrate for habitat and can be created from concrete or even a decommissioned ship.

Off the coast of North Carolina, nature has made sure that there are lots of artificial reefs! The area near Cape Hatteras is known as the *Graveyard of the Atlantic* due to the large number of ships that have sank there. The dangerous mix of severe weather, shallow waters, and strong currents held this area earn its nickname. As each ship sank to the bottom of the ocean floor, it immediately began attracting marine life. Submerged shipwrecks are the most common form of artificial reef; and today, hundreds of shipwrecks are scattered in the waters of North Carolina, making it a popular recreational area for beachgoers, fishermen, and divers alike.

One organism that can be found on the near-shore reefs is an oyster. An oyster is a bivalve mollusk that has a rough irregular shell. While oysters are often eaten by people, they are also very important to the health of our ocean and bays. As filter feeders, they consume phytoplankton and improve water quality while they filter their food from the water. The Chesapeake Bay was once known for its abundance of oysters. However, over time, oysters have declined in the bay mostly due to decades of overharvest, habitat destruction, coastal development, and pollution. Today, diseases are adding to the devastation of the remaining oyster populations in the bay and its tributaries. The decline in oyster population has resulted in poor water quality in the bay which has had negative effects on other organisms, such as blue crabs and fish.

Increasing the local oyster population is one of the most effective ways to enhance water quality. To help restore the oysters in the bay and ocean, many organizations have begun oyster gardens. In an oyster garden, young seed oysters, called spat, are grown in mesh bags in a floatation device until they reach about 3 to 8 cm. Once they are the correct size, they are placed on conservation reefs where they can reproduce and repopulate the bay with oysters.

Activity

1. What are some other factors that add to decreased water quality in the bay other than fewer oysters?
2. Go to NOAA's Chesapeake Bay Office's web site http://chesapeakebay.noaa.gov/oysters/oyster-reefs.
3. In your science journal, answer the following
   a. Briefly describe where oysters are found in the United States.
   b. When do oysters usually spawn and under what conditions?
   c. How quickly were oysters estimated to have been able to filter all the water in the bay?
   d. Using the diagrams at the bottom of the page, summarize the benefits and stressor of oysters.
   f. List one interesting fact that you did not know about oysters.

Don't Spit on My Spat—Oysters

Life Cycle of an Oyster

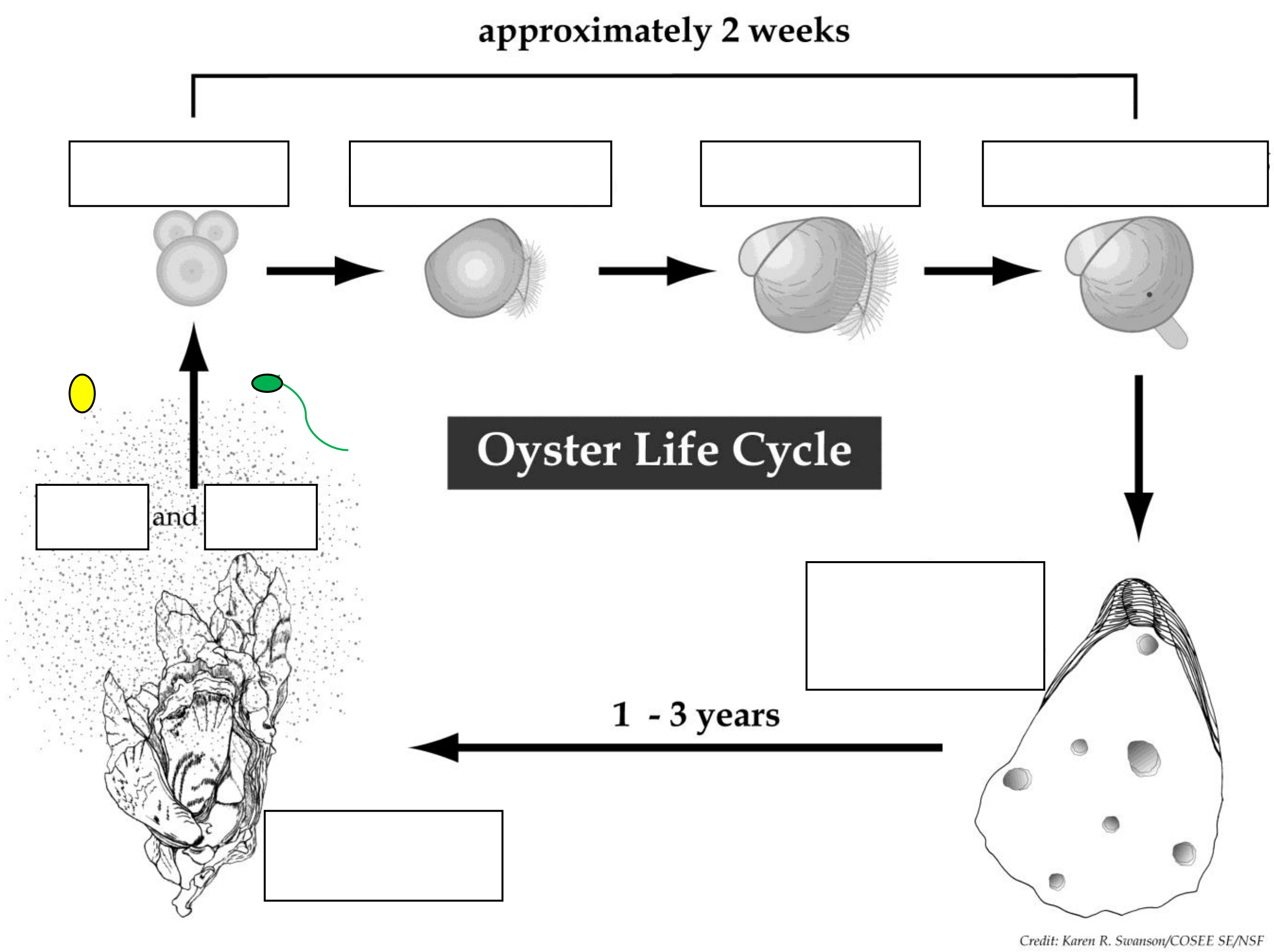
Oysters begin life as eggs that float like a cloud of dust in the water, where they are fertilized by male *spermatozoa*. The fertilized embryos multiply into many cells, becoming a trochophore larva that swim through the water by waving tiny hairs called cilia. Next, two shells (bi-valves) and the velum grow during the d-hinge veliger stage. In the veliger stage, a hinge, known as the umbo, develops on the straight side of the d-hinge. After about two weeks, free swimming larvae grow a foot called a pseudopod that it uses to feel around for a suitable place to attach. This is called the pediveliger stage.

Oyster larvae prefer oyster shells or similar material, called cultch. Cultch is fossilized shell, coral, or other similar materials produced by living organisms. It is generally a by-product of sand mining and can be placed on at the bottom of a bay or estuary to enhance oyster habitat or to create a new oyster reef.

Once a larva settles, it becomes spat and will spend the rest of its life in its newfound home. After a couple of months, the spat grows to about the size of a quarter and becomes a juvenile. During the juvenile stage, the oyster continues to grow until it reaches adulthood. As an adult, the oyster is then able to reproduce and start the cycle of life once again.

Use the word bank to complete the diagram below:

trochophore larva, egg, pediveliger stage, spat, sperm, adult male and female oysters, D-hinge veliger stage, Veliger with umbo



How Does Your Garden Grow?—Oyster Restoration

Oyster Gardens

To begin an oyster garden, use this complete "how-to" guide—Oyster Gardening for Restoration & Education. http://www.mdsg.umd.edu/sites/default/files/files/Oyster-Gardening-Guide-1.pdf

More Information

Visit these sites for information on oysters, restoration, lesson plans and more.

Video of a 2012 Oyster Reef Restoration project in Florida (5:48) https://www.youtube.com/watch?v=4QsGqNZNUOw&feature=youtu.be

Sea Grant video explaining oyster gardening in the Chesapeake Bay http://www.mdsg.umd.edu/topics/oyster-gardening/oyster-gardening

Sea Grant BRIDGE: Oyster Gardens http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive0501.html

MAMEA's CHESSIE: Lesson plans for K-12 http://web.vims.edu/chessie/lessons.html#k12

Oyster Gardens

Along America's coastlines, a new type of gardening is gaining in popularity. There is no soil or shovels required! However, some unique equipment is necessary and salty water is essential.

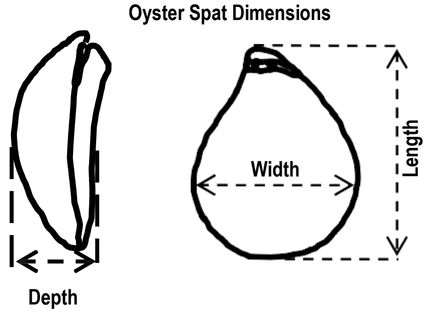
Oysters are sessile (stationary) and cannot move if their environment is no longer suitable for them to grow and reproduce. When runoff from the land is filled with toxins or when dissolved oxygen levels are too low, oysters begin to die. Oysters are also affected by diseases, Dermo and MSX, and from overharvesting by humans. All of these factors cause a decrease in oyster populations. Because oysters are filter feeders, they play a critical role in the ecosystem by improving water quality. As their numbers decrease, so does our water quality.

To help increase oyster populations, oyster gardening has evolved. Today, biologists, students, teachers, and adults are getting involved to raise hatchery-produced oyster seed to a size that allows them to be transplanted safely onto reefs for restoration. This allows oysters to be spawned earlier than in the natural environment, and it gives young oysters a head start in growth before they might be exposed to diseases. Researchers are also testing new strains of oysters that will be more resistant to disease and changes in water quality.

To begin an oyster garden, a location must be selected. Salinity, water quality, amount of sunlight, and tides and currents are a few considerations in choosing a location. Since the oysters will grow near the surface of the water, a dock facility or other area that is easy to reach works well. Depending upon the location, spat is either placed in a Taylor Float or oyster cage.

Sometimes oysters grow rapidly, reaching 25 mm in two or three months, but growth is variable and depends on many factors. Therefore, once the garden has been "seeded," it is important to monitor such factors as salinity, temperature, and other water quality measurements. Data collected about your oyster garden will provide valuable information for scientists and future oyster restoration projects. By growing and monitoring an oyster garden, you will be helping to improve water quality, providing homes for other marine life, and securing the future of oysters.

Oyster Spat Dimensions



Periodically, collect 50 random spat and measure the length, width, and depth. Record your measurements.

DATA	Date	Date	Date	Date
Spat Dimensions				
Water Temp				
Air Temp				
Salinity				
Dissolved Oxygen				
Nitrogen				
pH				
Tides				

Create a chart with the data measurements you want to collect and determine the intervals between collections.

Discussion Questions

1. Why have oysters declined over the centuries?
2. Explain in detail how an oyster garden helps restore the oyster population.
3. Research the Kingdom, Phylum, Class, Order and Family of an oyster.

Where's the Water Shed?

Materials

- Internet
- science journal
- state map
- 4 different colored markers

Teacher Prep
Print a copy of your state map (with rivers) for each student. Printable maps can be found at http://www.nationalatlas.gov/printable/reference.html

Stream Flow
Each small stream can have thousands of liters of water flow through it each day, and each stream is only one part of a river system. Just as a tree is a system of stems, twigs, branches and a trunk, a river system also has many parts. Water runs off the ground into small streams. The small streams merge to form a larger body of water called a river. The areas drained by these bodies of water are watersheds. Areas of higher elevation separate watersheds from each other.

Purpose: To identify and define the local water shed. To discover how pollutants enter the ocean.

Courtesy EPA

Background

A watershed is an area of land where all the water, that is under it or drains off of it, drains to the same location. Watersheds come in all shapes and sizes. They may be large, such as the Mississippi River drainage basin, or small, such as the 40 acres that drain into a farm pond. Watersheds cross county, state and national boundaries. In the continental U.S., there are 2,110 watersheds. If you include Hawaii, Alaska and Puerto Rico, there are 2,267 watersheds. Watersheds are vital to everyone as they provide water for drinking, recreation, irrigation, as well as for industrial activities. They also provide food and water to plants and animals. Watersheds also drain into our ocean and can affect its health. Because watersheds are so important, it is essential to protect them.

The Environmental Protection Agency's (EPA) mission is to protect human health and the environment including our watersheds. One way to achieve this mission is through educating people about the environment. Protecting the environment is everyone's responsibility and starts with understanding the issues. In this activity, you will learn about your watershed, where the water comes from, and where it goes.

Activity 1

1. Visit EPA's *Surf Your Watershed* website: http://cfpub.epa.gov/surf/locate/index.cfm
2. Enter your zip code or search by state to find your watershed.
3. Takes some time to explore the different information given for your watershed.
4. In your science journal, list three things you learn about your watershed.

Activity 2

1. Locate your city or town on the map and put a box around it.
2. Find the river on the map closest to your city and use a colored marker to trace the flow of the river from its origin. If your river's origin is outside your state, use the closest state boundary.
3. Use a different color marker to highlight any small creeks or streams that feed into the river.
4. Color any lakes by using a third color. Can you tell which way the water flows?
5. With a fourth colored marker, broadly circle the area around your markings, but do not cross any other streams. The area inside the circle is the watershed for your local area.

Extension

While exploring *Surf Your Watershed* website, click on real-time stream flow data. Create a chart and record the date and time, stream stage in feet, and the stream flow in feet per second. Check and record data for several days. Create a graph depicting your data.

Where's the Water Shed?—Continued

Materials for Watershed Model

- plastic tub
- clay
- plastic houses or other objects to simulate a town
- red drink mix
- green drink mix
- cocoa
- soy sauce
- small containers for mixes and soy sauce and spoons
- spray bottle with water

Teacher Prep
In a plastic tub, use clay to form hills and valleys with streams, lake, and rivers to make a watershed model for each group or one for the class as a demo. Small tubs can be used for students to make their own models. Add houses or other objects to simulate a town.

If doing the activity in groups, put a small amount of each drink mix and soy sauce in containers for each group.

NOTE: This activity can also be done by using crumpled paper instead of clay.

Activity 3

1. Use the water bottle to spray a small amount of "rain" on the watershed.
2. Observe how the water flows from points A, B, C, and D.
3. On Diagram 1, record the direction of the water flow.
4. Look at the model and determine where pesticides, fertilizers, sediment and gas/oil would be most likely found.
5. Use different colored pencils representing the pollutants and shade in each area.
6. To simulate pollution on your model, follow the chart below and add a small amount of each of the pollutants to the area as indicated.
7. On Diagram 2, indicate where you placed each type of pollution. Label each.
8. Using your observations in step 2, predict where the different pollutions will flow. Record your predictions in your science journal.
9. Use the water bottle to spray a small amount of "rain' on the watershed.
10. Observe the water flow.
11. On Diagram 2, use colored pencils to draw arrow(s) indicating which direction the rain runoff flowed.

Diagram 1

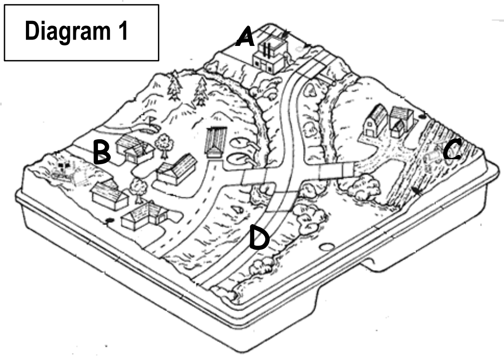
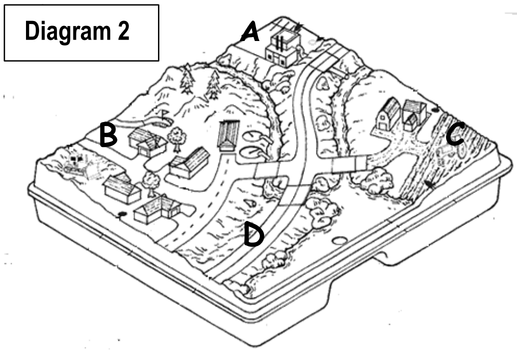


Diagram 2



Pollutants
Area A: pesticides ……… red mix
Area C: fertilizers.……..green mix
Area D: sediment ……..…..cocoa
Area B: gas and oil … soy sauces

Discussion

1. Which direction did the water flow? Why?
2. Where did most of the water flow?
3. How are watersheds defined? How could a watershed change over time?
4. What happened to the water when you added pollutants? Was it clear or dirty?
5. How are pollutants harmful to watersheds?
6. What effects do people and animals have on a watershed?

Making the Point

Purpose: To distinguish between nonpoint and point source pollutants and to understand how they affect the environment.

Background

As rainwater and snowmelt flows over and through the ground, into streams and down rivers, various pollutants are dissolved in and/or carried by the water. These **nonpoint source pollutants** typically have no single source, but rather accumulate over a large area. Examples of nonpoint source pollutants are pesticides, fertilizers, sediment, animal waste, gasoline from spills, and oil (e.g. from car leaks). These pollutants cause most of our water quality problems as they flow into rivers, lakes, bays, wetlands, groundwater and the ocean.

Point sources pollutants come from a single source, such as chemical waste entering a stream or pipe. Several decades ago, factories and poorly operated sewage treatment plants were the major source of pollutants in our waters. We could “point” to the source of the problem. Today, we see little point source pollution, because federal laws, such as the Clean Water Act, were passed making it illegal for companies to pollute our creeks and rivers.

Activity

In the chart below there is a list of land use activities that could contribute to nonpoint pollution. Identify the type of pollutants associated with each land use activity. You can use the types of pollutants more than once.

Types of Pollutants

- **sediment**—loose dirt that can get caught in runoff
- **fertilizers**—chemical or natural fertilizers used to help plants grow faster and bigger, but can overload water bodies with nutrients.
- **pesticides**—toxic chemicals that are used to kill pests, such as insects
- **E-coli bacteria—**bacteria that comes from the intestines of warm blooded animals, typically found in waste products.
- **petroleum products**—toxic chemical compounds such as gasoline, motor oil and anti-freeze
- **organic debris**—sticks, leaves and other natural litter that can get caught in runoff
- **pathogens**—disease-causing organisms (bacteria, viruses, etc.)

Land Use Activity	Type of Pollutant	Type of Pollutant	Type of Pollutant
Eroding Stream Bank 			X
Farming 			
Garden and Lawns 			
Ranching and Pets 			
Recreation/Parks 			
Septic Tanks and Sewers 			X
Roads and Streets 			

Pollution Perils

Materials

- 3-6 different colored candies
- small, plastic bags
- graph paper
- colored pencils
- copies of *Land Use Table*

Teacher Prep

Students may complete this activity individually or in a small group. Divide the candy so that each student/group has about 30 pieces of 3-6 different colored candy and place them in a small, plastic bag. Copy and cut apart enough pollutant strips for each bag. Place one strip inside each bag.

Purpose: To differentiate between types of land uses and the pollutants associated with each

Background

Pollutants accumulate in watersheds as a result of various practices and natural events. If we can determine the type of pollutant, then we cannot only classify the source of the pollutant, but also take the preventive measures to stop any further contamination.

Activity

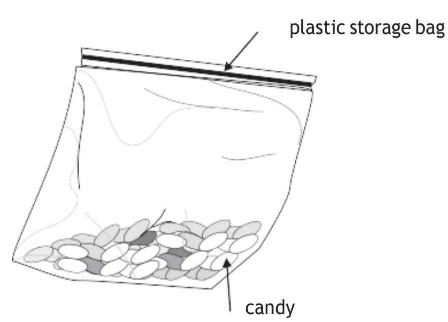
1. Each bag of candy represents a watershed. Open your bag and separate the candies by color.
2. The candies represent different kinds of pollutants associated with various land uses that may be found in a watershed.
3. Using the list of pollutants in the bag, assign a pollutant to each color of candy. If you have more colors than pollutants, make the extra colors “harmless” bacteria.
4. In your science journal, create a key indicating what each color represents.
5. Use graph paper to create a graph of the pollutants found in your watershed.
6. Title your graph and add the pollutant color key.
7. Use the *Land Use Table* to determine what activities are occurring in your watershed based on the pollutants that were found there.
8. Classify the watershed as agriculture, construction or forestry, urban, mining, or wastewater.

Discussion

1. How are watersheds different from one another?
2. What can a scientist learn from studying the kinds of pollutants found in a watershed?
3. How might these pollutants change an ecosystem?

Extension

1. Contact your state geological survey office or local zoning office to obtain a land use map for your area. Determine how the land in your area is primarily used. What kinds of pollutants might be a problem?
2. Visit the U.S. Geological Survey’s (USGS) website at http://www.usgs.gov to learn more about land use and your environment.



Pollution Perils—Continued

Pollutant Strips

sediments, nitrates, ammonia, phosphate, pesticides, bacteria	sediment, pesticides, ash	bacteria, nitrates, phosphates, chlorine, organic waste
sediment, heavy metals, acid, nutrients	oil, gas, antifreeze, nutrients, pesticides, paint	

Land Use Table

Land Use	Activities	Pollution Problems
Agriculture	cultivation, pest control, fertilization, animal waste management, weed control	sediments, nitrates, ammonia, phosphate, pesticides, bacteria
Construction and Forestry	land clearing, grading, timber harvesting, road construction, fire control, week control	sediment, pesticides, ash
Wastewater Disposal	septic systems, laundry, personal hygiene, dishwashing, restaurant waste	bacteria, nitrates, phosphates, chlorine, organic waste
Mining and Industry	dirt, gravel, mineral excavation, chemical cooling, waste products, manufacturing	sediments, heavy metals, acid, nutrients
Urban Storm Runoff	automobile maintenance, lawn and garden care, painting, rain runoff from blacktop	oil, gas, antifreeze, nutrients, pesticides, paint

Millions or Billions

Materials per Group

- 9 test tubes
- dropper or pipette
- food coloring
- clean water
- science journal

Teacher Prep
Create a set of materials for each group.

Purpose: To understand why water quality is tested and to demonstrate how small quantities of pollutants may not be visible, but still may be harmful

Background
Water quality standards are determined by the government. They are important because they help to protect our nation's water supply ensuring the health of the people. By having standards, scientists can identify any potential water quality problems early and prevent possible problems. There are many ways that water quality can be affected. For example, it can be affected by 1) improperly treated wastewater discharge, 2) runoff or discharges from active or abandoned mines, 3) an abundant amount of sediment, fertilizer, and chemicals from agricultural areas, and 4) erosion of stream banks caused by improper grazing practices.

Scientists measure the quality of water in many different ways. They collect water samples using boats, they wade into streams, drop buckets over bridges, and more. Once they collect the water, there are certain factors that they measure to determine the water quality. Some factors they measure are **temperature**, **dissolved oxygen** (DO), **pH**, **nutrients** (nitrate), **salinity** and **turbidity**.

Concentrations of chemical and other contaminants are frequently expressed in units of **parts per million (ppm)** or **parts per billion (ppb)**. It is important to measure these small quantities because some chemicals that contain nitrates can be dangerous to pregnant women even in quantities as small as ten parts per million.

Procedure
1. Label test tubes 1, 2, 3, 4, etc.
2. Place ten drops of food coloring into test tube 1. Note: Food dye, as it comes from the bottle, is already a dilution of one part in ten (1:10).
3. Place one drop of food coloring in test tube 2.
4. Add 9 drops of clean water to test tube 2 and stir the solution. Rinse the medicine dropper.
5. Use the medicine dropper to transfer one drop of the solution in test tube 2 to test tube 3. Add nine drops of clean water and stir the solution. Again rinse the dropper with clean water.
6. Transfer one drop of the solution in test tube 3 to test tube 4. Add 9 drops of water and stir. Rinse the dropper with clean water.
7. Continue the above process until all nine containers contain successively more dilute solutions.

Data:
Check the box if you can detect any color in the liquid.

Test Tube	1	2	3	4	5	6	7	8	9
Color									

Millions or Billions—Continued

Questions

1. The food coloring in container # 1 is a food coloring solution which is one part colorant per ten parts liquid. What is the concentration in each successive dilution?

Test Tube	1	2	3	4	5	6	7	8	9
Concentration	1/10	1/	1/	1/	1/	1/	1/	1/	1/

2. What is the concentration of the solution when the diluted solution first appeared colorless?

____

3. Do you think there is any of the colored solution present in the diluted solution even though it is colorless? Why or why not?

____

____

4. What would remain in the containers if all the water were removed?

____

____

Essay:
Knowing what you have learned about parts per million and the harmful effect of nitrates to the environment, humans and livestock, why is it important to monitor our water for pollution? In your science journal write a short essay (3-4 complete sentences) explaining the importance.

Look at the analogies below and in the boxes below, create your own for parts per millions.

If you had ten thousand dollars,

then one penny is one part per million.

If you had 7,900 gallons of milk,

then one ounce of milk is one part per millions.

Testing, Testing 1, 2, 3

Testing Water Quality

Some factors that scientists measure to determine water quality are **dissolved oxygen** (DO), **temperature**, **pH**, **nutrients** (nitrate), **salinity** and **turbidity**. Below is an explanation for each and why it is an important measure of water quality. To learn more about each, visit the USGS web site listed at the end of each paragraph. Then use the activities pp. 86-100 to learn more about each factor.

Dissolved oxygen (DO) is the concentration of molecular oxygen (O_2) dissolved in water. Aquatic animals need oxygen to breathe and live, but they cannot use the oxygen in a water molecule (H_2O) because it is bonded too strongly to the hydrogen atoms. Healthy waters generally have high levels of DO. Most of the molecular oxygen enters the water from mixing with the atmosphere. Wind and waves help that process. Other factors that can affect the amount of DO in water include temperature, number of plant and algae growing to produce oxygen, pollution in the water (chemicals, fertilizer and manure) and even the composition of the stream bottom. Water that moves faster or over a gravel or rocky bottom, stirs up the water more creating bubbles that add oxygen to the water. http://water.usgs.gov/edu/dissolvedoxygen.html.

Temperature can affect the chemistry of the water because chemical reactions generally increase at high temperatures. Higher temperatures can dissolve more minerals from the rocks making the water have a higher electrical conductivity. This affects the amount of dissolved oxygen in the water. Warm water holds less dissolved oxygen than cool water and it may not contain enough oxygen for aquatic life to survive. Some chemicals are also more toxic to aquatic life at higher temperatures. http://water.usgs.gov/edu/temperature.html.

pH is a measure of how acidic or basic water is. pH ranges from 0 (very acidic) to 14 (very basic). Seven is neutral, and most water ranges from 6.5 to 8.5. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Chemicals in the water affect the pH making it an important indicator of water that is changing chemically. Changes in pH can affect the health and life of organisms. High acidity can be deadly to fish and other aquatic organisms. The dumping of chemical waste by individuals, industries, or communities into the water hurts water quality. Another factor that affects the pH of water is the amount of acid rain that falls in a watershed. Acid rain is caused when air pollution combines with water vapor. When it rains, these air pollutants fall to the Earth and runoff into streams, rivers, and lakes. http://water.usgs.gov/edu/ph.html.

Nutrients, such as **nitrogen** and phosphorus are used in agriculture and are essential for plant and animal growth. Nitrogen is found naturally in the atmosphere (78%), and some nitrate enters the water from air that carries nitrogen-containing compounds derived from automobiles and other sources. An overabundance of nitrogen in our water can cause problems. Nitrate, nitrite, and ammonium are forms of nitrogen. Nitrate can get directly into the water as the result of runoff of fertilizers, wastewater, and animal manure. Excess nitrogen can harm water quality by causing a rapid growth of aquatic plants and algae. These organisms can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters. Too much nitrogen in drinking water can also be harmful to young infants and livestock. http://water.usgs.gov/edu/nitrogen.html.

Salinity is the amount of dissolved salt in water. Salinity is measured by the number of grams of salt dissolved in 1000 grams of water and is expressed as parts per thousands (ppt). Ocean water averages 35 grams of dissolved salt per 1000 grams water, a salinity of 35 ppt. Freshwater ranges from 0-5 ppt, while estuaries range from 5-30 ppt. Salty water is not just found in the ocean. In New Mexico, approximately 75% of groundwater is too salty for most uses without treatment. The water in that area may have been leftover from ancient times or some of the salinity may come from highly soluble minerals that dissolve as rainwater trickles down into the ground. http://water.usgs.gov/edu/saline.html.

Turbidity is the measure of how clear a liquid is and it is an expression of the amount of light that is scattered by materials in the water when a light shines through the water. Materials that cause water to be turbid include clay, silt, algae, organic matter, plankton and other microscopic organisms. Turbidity makes water cloudy or opaque. High concentrations of particles in the water affect light penetration and habitat quality and can cause lakes to fill faster. It can also represent a health concern. Turbidity can provide food and shelter for pathogens which can cause waterborne disease outbreaks. http://water.usgs.gov/edu/turbidity.html.

To DO or Not to DO: Measuring Dissolved Oxygen

Materials per Group

- plastic water bottle with cap
- beaker
- 500 ml hot water
- 500 ml room temperature water
- 500 ml cold water
- dissolved oxygen probe
- science journal

For other great DO lessons, download ***Eyes on Dissolved Oxygen*** at http://mddnr.chesapeakebay.net/eyesonthebay/lesson_plans/do_lesson_plan.pdf

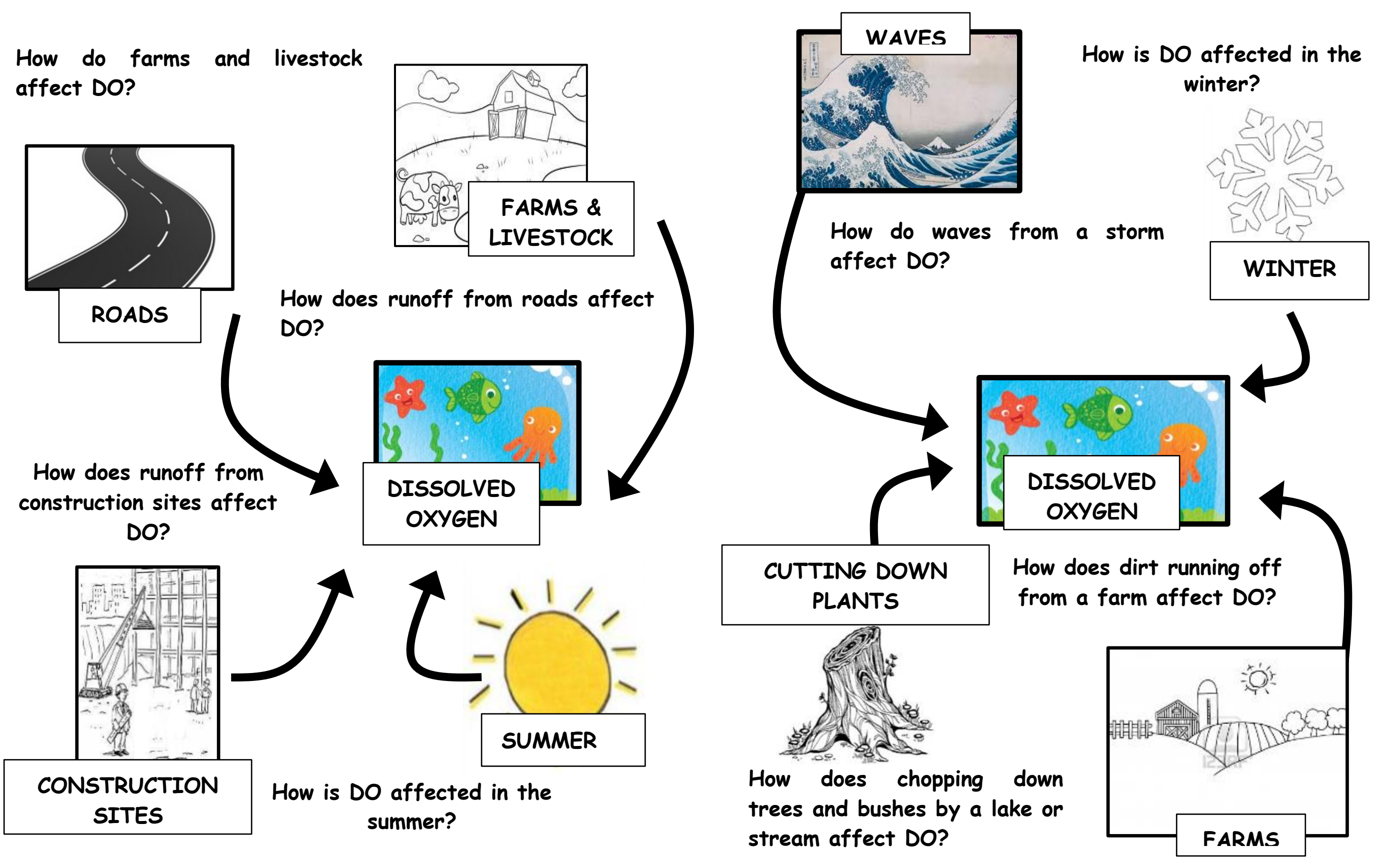
Purpose: To measure the amount of dissolved oxygen (DO) in water

Testing for Dissolved Oxygen

1. Pour about 500ml of hot water into a plastic water bottle. Screw on cap and shake for 30 seconds.
2. Pour the shaken water into a beaker and measure the amount of dissolved oxygen.
3. Repeat for the room temperature water and cold water.
4. In your science journal, interpret the results and answer the questions below.

Water	DO Reading	Interpretation
Hot		
Room Temp		
Cold		

Dissolved Oxygen Level	Interpretation
0 – 2 mg/L or ppm	not enough oxygen to support life
2 – 4 mg/L or ppm	only a few fish and aquatic insects can survive
4 – 7 mg/L or ppm	good for many aquatic animals, low for cold water fish
7 – 11 mg/L or ppm	very good for most stream fish



Too Hot to Handle: Measuring Temperature

Purpose: To understand how changes in temperature affect an aquatic environment.

Background
Fluctuation in air temperature occurs naturally each day as the Sun rises and sets. Air temperature also changes with the seasons. These changes affect the temperature of a body of water. Most aquatic organisms can adapt to minor changes in temperature within a certain range, but severe and/or sudden changes may cause major problems for the organisms that live in the water. Sometimes droughts and high temperatures for prolonged periods will increase a body of water's temperature, but sometimes humans can cause changes.

Thermal pollution occurs when humans cause a change in the temperature of a body of water. Stormwater runoff flowing over warm surfaces, such as streets and parking lots, is the most common nonpoint source of thermal pollution. Another cause is soil erosion because it can cause the water to become cloudy, and cloudy water better absorbs the Sun's rays resulting in a temperature rise. Sometimes thermal pollution may even be caused by the removal of trees and other vegetation that would normally shade the body of water.

Thermal pollution can result in significant changes in the aquatic environment. Drastic temperature changes outside the normal range can kill aquatic life. As temperatures rise, cold water species, such as trout, die and may be replaced with warm-water species, such as carp. Thermal pollution may also make fish more vulnerable to toxic compounds, parasites, and disease. If the temperature of a water body reaches extreme heat or cold, very few organisms will survive.

There are also numerous indirect effects on aquatic life caused by thermal pollution. For example, thermal pollution results in lowered levels of dissolved oxygen because cooler water can hold more oxygen than warmer water. Low dissolved oxygen levels will cause oxygen-sensitive species to die. Water temperature also affects chemical processes, such as the solubility of compounds, rates of chemical reactions, density inversions and mixing, and water currents.

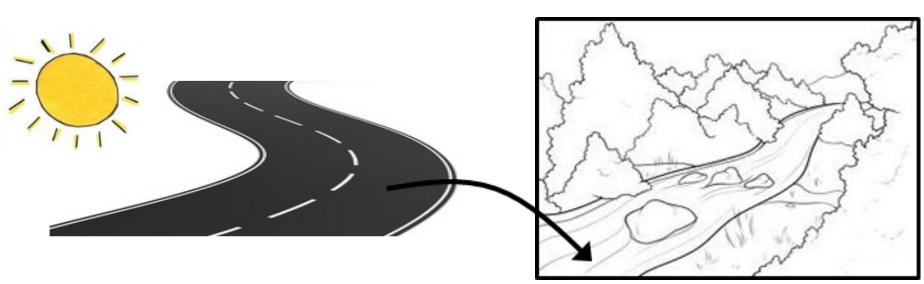
Although temperature may be one of the easiest measurements to take, it is probably one of the most important variables to measure.

Questions:

1. What is thermal pollution?

2. What are some causes of thermal pollution?

3. Why is temperature one of the most important variables when measuring water quality?



Layer upon Layer: Temperature Inversions

Materials per Group or Student

- 3 test tubes
- test tube rack
- straw
- 3 different temperatures of clean water in small containers
- science journal

Teacher Prep

- food coloring

Depending upon the availability of supplies, this activity may be done individually or in small groups.

Prepare three different temperatures of water (room, warm, and ice cold). Add a different color of food coloring to each. For example: warm water—red; ice water—blue; room temperature—yellow. For each group, pour a small amount of each of the colored water into its own small container.

Purpose: To illustrate the stratification of water due to varying temperatures

Background

Temperature fluctuations depend upon the body of water. In shallow waters, the water temperature is much more susceptible to changes. The water heats quicker during the day and cools faster at night. Shallow water has a very small capacity to store heat over time. Larger bodies of water, such as the ocean and lakes do not fluctuate as much as the volume of water is large.

During the summer, the water temperature in lakes can vary between the surface and subsurface waters. This difference results in thermal stratification of deeper water, and can lead to density differences. Cold water is heavier than warm water. As the water warms in the summer, the warmer water remains on top and it receives sunlight and usually enough oxygen to support aquatic plants and animals. The colder, denser water remains on the bottom, and may lose much of its oxygen because it does not have contact with the air nor is there light to support plant life to produce oxygen.

In the fall, as sunlight diminishes, the water temperature on the surface begins to decrease causing an increase in the water's density and weight. Once the surface water becomes heavier than the warmer water below it, it begins to sink and destratification occurs. Winds may help the mixing process and bring nutrients up from the bottom into the surface water. The excess nutrients may cause an algae bloom.

Procedure

1. For this experiment, you will use water of three different temperatures. You will have three tries at making a test tube with three separate colored layers.
2. Practice using a straw to pick up water. Place the straw in a container of water and then place your finger over the end of the straw. Remove the straw from the container and place it in the test tube. Release your finger, and the water will empty into the test tube. Once you can transfer water successfully, you may go to next step.
3. Using water from each of the containers, layer the water in the first test tube.
4. Repeat with test tubes two and three or until you have successfully created three separate color layers. You must keep all attempts at layering.
5. In your science journal, list in order of water density by color from most to least and. illustrate.

Taking pH to a Higher Level: Measuring pH

Materials per Group or Student

- 4 different solutions of varying pH
- 4 small containers
- pH test strips with scale or pH meter with probe
- paper towels
- science journal

Teacher Prep

Prepare 4 small containers with 4 different solutions, such as lemon juice, dish soap, cola, orange juice, vinegar, water, etc. There should be at least one base and one acid for each group/student.

Note: if you do not have pH strips or a meter, you can use red and blue litmus paper for students to determine if solution is an acid or base.

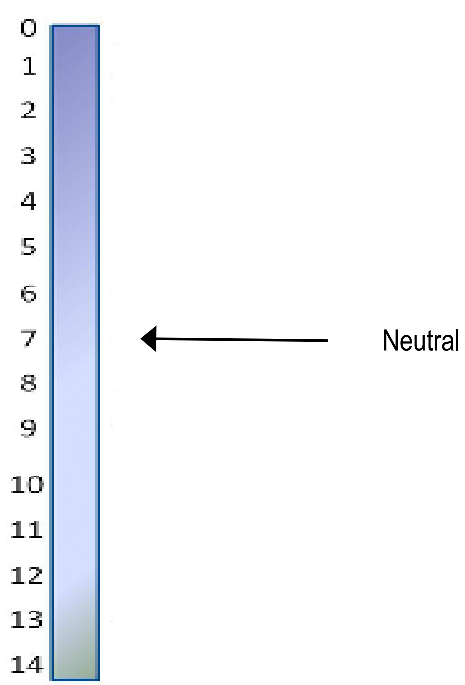
Purpose: To practice measuring pH and to differentiate between acids and bases

Background

pH is a measure of a solution's acidity or alkalinity (basic). It is measured on a scale ranging from 0 to 14 with seven being neutral. A pH less than seven indicates acid and greater than seven indicates a base. pH is reported in "logarithmic units" where each number represents a 10-fold change. For example, water with a pH of five is ten times more acidic than water having a pH of six. The pH determines the solubility and biological availability of chemicals, such as nutrients like phosphorus, nitrogen, and carbon, and heavy metals like lead, copper, and cadmium. Aquatic life is affected by a change in pH. Normal rainfall has a pH of about 5.6, which is slightly acidic, due to carbon dioxide gas from the atmosphere.

Procedure:

1. Observe each of the four liquids. Record your observations in your science journal.
2. Take one pH strip and dip into the first liquid. Hold the strip flat and compare the color of the end of the strip to the pH scale. Record in the approximate pH on the scale below by drawing an arrow on the scale to where the pH corresponds and label the arrow with the solution number. (If using a pH meter with probe, follow your instructor's direction for proper use.)
3. Repeat with the other three liquids.
4. Which liquids were acidic? Which were basic? Record in the box below.
5. Based on your observations and pH measurements, hypothesize what each liquid contains? Record in the box.



Solution 1: Acid or Base?

____

Solution 2: Acid or Base?

____

Solution 3: Acid or Base?

____

Solution 4: Acid or Base?

____

There's Chemicals in My Waste: Nonpoint Source Pollution

Purpose: To recognize how chemicals enter the water and how they affect the water's pH

Directions: Fill in the blanks using the word bank below each paragraph and complete the crossword puzzle.

Chemical Waste

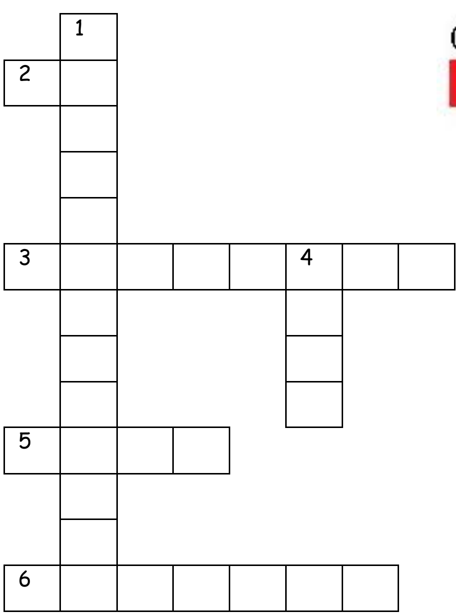
The dumping of ________________ into the water by individuals, industries, and communities hurts water quality. Remember - something as "harmless" as shampoo rinse water is actually a chemical that can affect water. Another factor that hurts water quality is the amount of ________________ that falls in the watershed. Acid rain is caused when air pollution combines with water vapor. When it rains, these air pollutants fall to Earth and ________________ into streams, rivers, and lakes. These pollutants are primarily from automobiles and coal-fired power plant emissions. A way to measure these chemicals in water is to determine the ________________. Normal pH in water is anywhere from 6 – 9. If the value for pH is higher or lower than normal, plants and animals in the water begin to suffer.

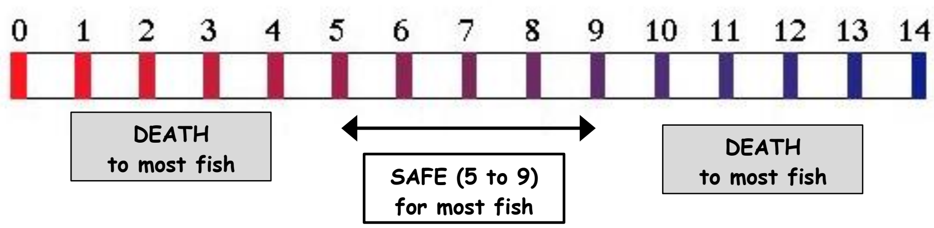
(WORD BANK: acid rain, chemical waste, pH, run off)

Testing for Chemical Waste - pH

Changes in ____________ values in aquatic locations  have an effect on the organisms  living at that location. Since the majority of aquatic life has adapted to living in certain pH levels, change may cause these organisms to ____________.The pH scale is a range of numbers from ____________. **pH** means the **potential of Hydrogen**. To determine if a solution is an acid or base, the amount of hydrogen ions present is measured. A pH level registering from 0 to 6 is a(n) ____________, with **pH of 0 being a very strong acid**. A pH level registering from 8 to 14 is a (n) ____________, with **pH of 14 being a very strong base**. A pH of 7 is considered ____________.

(WORD BANK: 0 to 14, acid, base, die, neutral)





Cross word Puzzle

ACROSS
2. Potential of hydrogen
3. Air pollution combined with water vapor
5. A solution with a pH level between 8 to 14
6. A solution with a pH level of 7

DOWN
1. pH is one way to measure the amount of ________ ________ in the water.
4. A solution with a pH level between 0 to 6

No, No Nitrates

Purpose: To summarize how nitrates affect our environment and health

Background

Although nitrogen is abundant naturally in the environment, it is also introduced through sewage and fertilizers. Chemical fertilizers or animal manure is commonly applied to crops to add nutrients. Unless specialized structures are built on farms, heavy rains can generate runoff containing these materials into nearby streams and lakes. Some nitrate enters the water from the atmosphere, which carries nitrogen-containing compounds derived from automobiles and other sources. More than 3 million tons of nitrogen is deposited each year in the United States. Some of the nitrogen occurs naturally from chemical reactions or from the combustion of fossil fuels, such as coal and gasoline.

Nitrates can get into water directly as a result of runoff of fertilizers containing nitrate. Photo: USGS

Why You Should Care about Nitrates

Measuring the levels of nitrate in our water is important not only for humans and animals, but also the environment. Nitrates are undetectable in water without testing because they are colorless, odorless, and tasteless.

Nitrate is a form of nitrogen that plants can easily use. When we over-fertilize our waters with nitrates we can cause excessive plant growth. These plants can clog canals and streams, and when they die and decay, can use up too much oxygen causing fish to die. Concentrations greater than 4 parts per million can lead to these environmental impacts.

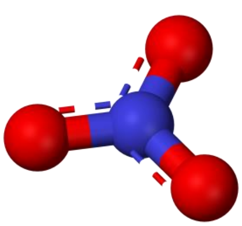
Sugar Creek, Indiana, has been modified to favor rapid removal of water from farm lands. High nitrogen levels in streams can be the result. Photo: USGS

High concentrations of nitrates in drinking water can cause methemoglobinemia (blue baby syndrome) in infants. Concentrations greater than 10 parts per million can be harmful to young babies, and should be avoided by nursing mothers.

High nitrate levels can be harmful to ruminant animals (cows) as well. Concentrations over 100 parts per million are toxic to these animals.

"Get the Gist" Summary

Write a sentence or two of no more than 20 words that captures the "gist" of what you read. Use the 20 word-size blanks below.



Nitrate Molecule

_____________ _____________ _____________ _____________ _____________

_____________ _____________ _____________ _____________ _____________

_____________ _____________ _____________ _____________ _____________

_____________ _____________ _____________ _____________ _____________

Visit the United State Geological Survey at http://water.usgs.gov/edu/nitrogen.html to learn more about areas at high risk of nitrate contamination to shallow ground water.

No, No Nitrates Continued

Materials per Group or Student

- Nitrate test kit
- water samples—about a half cup each
- clean containers to collect and store water

Teacher Prep

Collect or have students collect water samples from their environment. Use as many samples as appropriate, but at least three. Use clean containers with lids for each water sample. Label with date and location collected. Possible sources for water samples are local streams and lakes, ponds or farmland, stormwater puddles in the street, etc.

Discuss the concept and importance of replication—testing a number of samples from the same location or repeating the tests a number of times to ensure precision.

Extension: Fill beakers with tap water and use nitrogen pellets (fertilizer) to vary amount of nitrates. Test and note how many pellets it took to increase level.

Purpose: To compare and contrast the amount of nitrates in various water samples from different locations

Procedure:

1. Collect three different water samples from your teacher.
2. Record in the chart below, the date the water sample was taken and the location.
3. Take the lid off the container and observe the water sample. Record your observations.
4. Follow the instructions on the nitrate test kit to conduct a test(s) on each sample.
5. Record your results in the chart below.
6. Share each group's results and create a class chart with all data.

Date Collected	Source/Location	Nitrate (ppm)	Observations

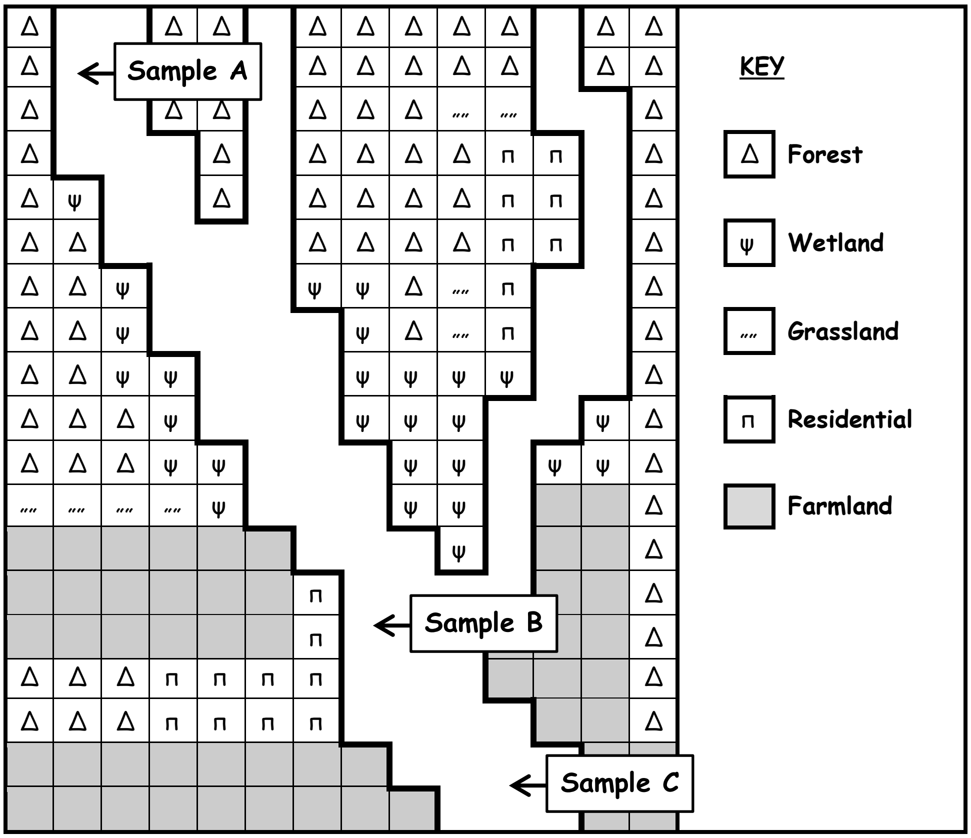
Discussion Questions

1. Were there any samples with over 50 mg/L (ppm) nitrate content? Why might the level be high?
2. Why do you think samples may have measured differntly? What are some of the difficiculties in obtaining an accurate test?
3. Explain why replication is important in measuring the levels.
4. Woud the results be different if you tested the same water in six months? A year? Why or why not?
5. Would the various levels of nitrate affect human health? Why or why not?

Nigh Nitrates

Purpose: To interpret data map and explain nitrate concentrations

The map shows a section of a river. Three water samples were taken and tested for nitrates. The results are in the chart below. Use the interpretation chart to interpret the results of the nitrate levels indicated on the map. Answer the discussion questions.



Nitrate Level (ppm)	Interpretation
0 – 4	Safe for humans and livestock. Concentrations of more than 4 ppm could cause environmental problems.
10 – 20	Generally safe for adults and livestock. Not safe for infants.
21 – 40	Short-term use acceptable for adults and all livestock.
41 – 100	Risky for adults and young livestock
Over 100	Should not be used.

Water Sample	Nitrate Level (ppm)	Interpretation
A	**2**	
B	**7**	
C	**21**	

Discussion Questions:

1. What are some possible reasons why the nitrate levels in **Sample C** are greater than the other samples?
2. When would nitrate levels be the highest – before or after a rain storm? Why?
3. Manure is a type of fertilizer that contains a high amount of nitrates. Many cities have a law that do allow animals, such as a dog, to defecate (poop) in any part of public property without the owner immediately cleaning up the waste. Why do cities have this type of law?
4. Wetlands reduce the amount of harmful substances that enter a stream, river, pond, or lake by acting as a strainer to filter out the bad stuff. Imagine two farms next to a lake. On one of the farms, there are wetlands next to the lake. On the other farm, there is not. Which farm do you think is going to release more harmful substances into the lake? Why?

You Won a Trophy? : Eutrophication

Purpose: To illustrate the eutrophication process

Background
When lakes and ponds receive too much fertilizer (nutrients), the body of water undergoes a process that slowly kills all aquatic life. That process is called **eutrophication**.

Draw a six frame cartoon that shows the process of eutrophication. The steps of the process are outlined below:

1. During a rainstorm, fertilizer from a field runs off into a nearby lake.
2. The nitrates and nitrites in the fertilizer cause the algae to grow uncontrollably on the top of the lake.
3. The growing algae on the top of the lake block the sunlight to the underwater plants on the bottom of the lake killing the plants.
4. Over time the growing algae on the top of the lake die and sink to the bottom of the lake.
5. Bacteria (decomposers) in the water eat the dead plants and dead algae and use all the dissolved oxygen in the lake.
6. As the dissolved oxygen disappears, all fish and aquatic wildlife die. When the water has no dissolved oxygen, it is called a "dead zone".

Sealz, Salz, Saldus, Sal, & More NaCl: Salinity

Materials per Group or Student

Activity 1
- ocean water
- pie pan
- metric ruler
- balance
- science journal

Activity 2
- graduated cylinder (or clear jar)
- table salt
- paper cup
- spoon or stir stick
- balance
- water

Activity 3
- graduated cylinder (or clear jar)
- table salt
- spoon or stir stick
- pen cap
- modeling clay
- metric ruler
- water

Teacher Prep

Activity 1: Collect ocean water or simulate your own by using 480 mL of water and 10 mL of salt. Stir until completely dissolved.

Activity 3: To save time, you may prepare the pen caps ahead of time for the students.

Extension: Have students layer liquids of different densities: oil, syrup, water, etc.

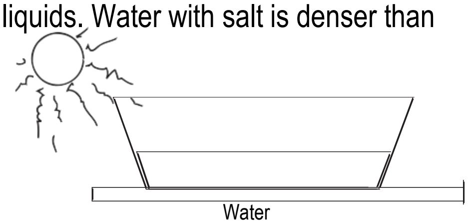
Purpose: To recognize that water contains vary amounts of salt and salinity is measured in parts per thousand (ppt)

Background

The ocean covers over 70% of the Earth's surface. The ocean is one large body of water divided into five major bodies based on ocean current flow: the Atlantic, Pacific, Indian, Arctic and Southern Oceans. Ocean water is approximately 96% pure water and 4% dissolved elements. The two most abundant dissolved elements in ocean water are sodium (Na) and chlorine (Cl). Sodium plus chlorine form sodium chloride (NaCl), or common salt. Rivers wash minerals from the land. River runoff carries salt into lakes, ponds, bays, estuaries, and eventually into the ocean. Volcanic activity on land and in the ocean also contributes to the salinity of water.

If you have ever gone swimming in the ocean, you know that the water is salty. The term salinity describes the amount of dissolved salt in water. Salinity is expressed in parts per thousand (ppt). The salinity of the ocean can vary from 33 to 37 ppt, although the average salinity is 35 ppt. In other words, for every 1000 parts of ocean water, 35 of them (3.5%) are salt. Concentrations of salt may vary because of depth, temperature, location, and many other factors. Tropical and some polar waters tend to have higher salinity levels. Waters close to freshwater rivers tend to have lower salinity levels. Surface water salinity varies greatly due to evaporation, precipitation, and runoff from the land. Deeper water does not vary as much.

One way that scientists can measure salinity, is by measuring how well electricity travels through the water. This property of water is called conductivity and water that has dissolved salt in it will conduct electricity better than water with no salt. Another tool used to measure salinity is a hand-held refractometer, which measures the change of direction or bending of the light as it passes from air to water. The more salt in the water, the slower the light moves. A hydrometer is used to measure the specific gravity (relative density) of liquids. Water with salt is denser than water without salt.



Activity 1

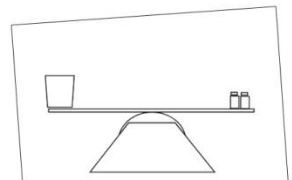
1. Pour 480 mL of ocean water into a shallow pie pan.
2. Place the pan in a warm, dry place.
3. Observe the water in the pan and record your observations in your science journal.
4. Use a metric ruler to measure the depth of the water and record it.
5. Allow the water to sit for several days. Observe and measure the water at the same time each day and record.
6. Once all the water evaporates, collect any residue left in the pan and observe. Record your observations.
7. Use a balance to measure the amount of salt and other minerals left in the pan. Determine the ratio of salt/minerals to original amount of water and find percentage.
8. How does this compare to the average of 4%?

Sealz, Salz, Saldus, Sal, & More NaCl: Salinity Continued

Activity 2

Note: *A gram of water at 4° C is equal to 1 mL. To simplify this exercise, 1 gram of water is equal to 1 mL. However, when 35 mL of salt is added to the water, it is will not increase the volume to 1,000 mL because the sodium and chloride ions occupy space between the water molecules. Oceanographers use grams to determine the mass (weight) of ocean water, so for every 1,000 grams of ocean water, on average, 35 grams would be salt.*

1. Using a balance, find the mass of the paper cup.
2. To find the total amount of salt needed, add the mass of the paper cup to 35 g and record. ____________
3. Place the cup on the balance and add salt until you reach the total mass required.
4. To find the total amount of water needed, subtract 35 from 1,000 and record. __________
5. Using 1 g = 1 ml, add the correct number of mL (of water) to the graduated cylinder.
6. Pour the measured salt into the graduated cylinder with the water.
7. Using a spoon, gently stir until well mixed. No salt should remain on the bottom.
8. Using the spoon, taste the saltwater mixture and record your observations.
9. Keep the graduated cylinder with salt water for Activity 3.

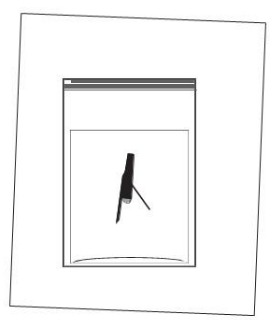

Balance

Activity 3

Note: *A hydrometer is used to measure the specific gravity (relative density) of liquids. Water with salt is denser than water without salt. Objects are more buoyant in salt water than in fresh and if the water is very salty, such as in the Dead Sea, even people can easily float.*

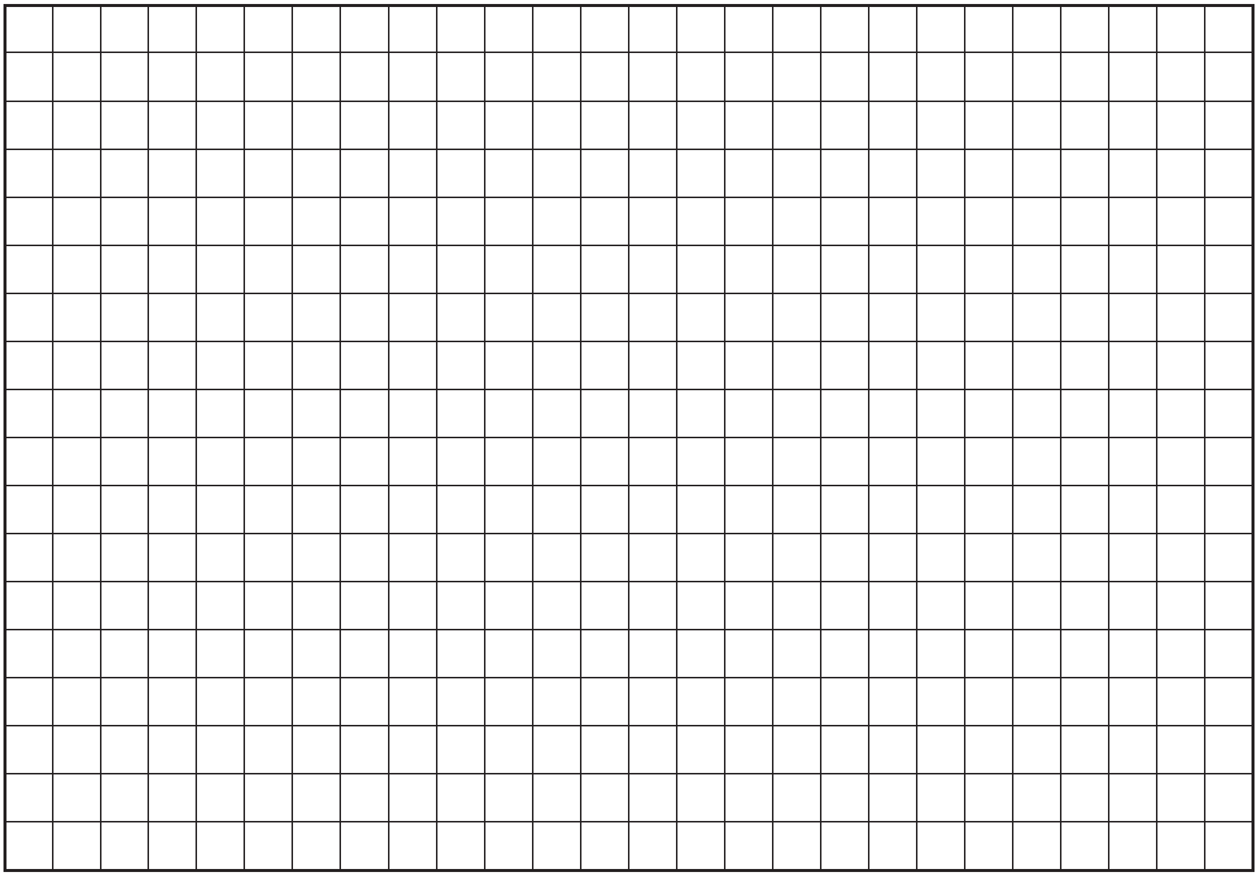
10. Fill a graduated cylinder with tap water to the same level as the salt water graduated cylinder from Activity 2.
11. Place a small amount of modeling clay into a pen cap. Place the pen cap into the water and observe. The cap should float about halfway in the cylinder. If not, either add or subtract clay as needed until it floats correctly.
12. Once the cap floats correctly, use a metric ruler to measure the depth at which the cap is floating. Record the depth. __________
13. Remove the cap from the water and place it in the graduated cylinder from Activity 2 with 35 mL of salt. Observe the depth of the cap, measure and record. _________
14. Add 15 mL of salt to the salt water from Activity 2 and repeat observations and measurement. Record. _______
15. Repeat step 13, continuing to add 15 mL of salt at a time until you have 80 mL of salt added to the water. Record the measurements ____
16. Use the *Ocean Salt Chart* to display your data of recorded measurements. Be sure to label the x and y axes. The chart should include measurements for the tap water (control), 35 mL, 50 mL, 65 mL, and 80 mL.
17. Share data with class and create a class chart from all data.
18. Answer **Discussion Questions.**

Use a pen cap and clay to make a hydrometer.



Sealz, Salz, Saldus, Sal, & More NaCl: Salinity Continued

Ocean Salt Chart



Discussion Questions

1. What happened when all the water evaporated from the pie pan? Was there anything left in the pie pan? Why or why not?
2. What does ppt mean? What is the average salinity of ocean water?
3. Is saltwater heavier than freshwater? Explain.
4. Why doesn't all ocean water have the same salinity level?
5. What happened to the depth of the pen cap as more salt was added to the water? Why?

Extension

Conduct research to find the salinity of the Great Salt Lake in Utah, the Dead Sea between Israel and Jordan, the Caspian Sea in Asia, and the Aral Sea in Asia. Determine whether the salinity of each body of water is higher or lower than the average ocean salinity (35 ppt). Hypothesize and explain why or why not. Discuss how the salinity levels might affect aquatic life. Conduct research to learn what types of plants and animals live in each environment.

Salinity in the Chesapeake Bay

Materials per Group

Activity
- 4 beakers (50 mL) with different water samples
- cotton swabs
- refractometer
- science journal

Teacher Prep

Activity: For each group, create 4 beakers of water with different salinities. Label each beaker sample A, B, C, and D.

Purpose: To understand the importance of estuaries and how salinity affects aquatic life

The Chesapeake Bay is an **estuary**. An estuary is a partially enclosed body of water where salt water from the ocean mixes with fresh water from creeks, streams and rivers. Estuaries are places of constant environmental change.

Although estuaries contain fewer resident animal species than ocean or freshwater ecosystems, estuaries serve as nurseries for many organisms. About 85% of fish and shellfish that are sold in world commercial markets spend all or part of their lives in estuaries. Plants in estuaries serve as the basis for all food chains, and provide shelter for young animals.

In the Chesapeake Bay, the **salinity**, or the amount of dissolved salt in water, is very important. If you have ever been to the ocean, you know that ocean is very salty! But if you have been swimming in a lake, pond, or river, you might know that "fresh" water has a lot less salt. The amount of salt in water determines what kinds of plants and animals can live there.

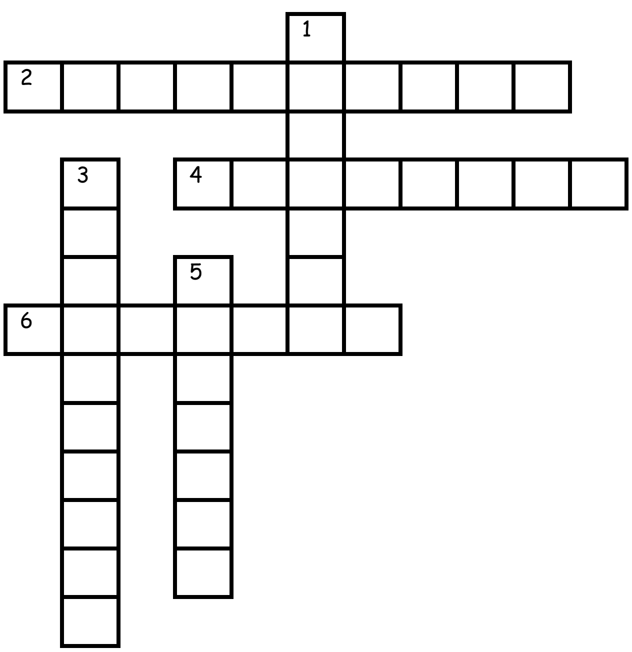
Name an animal that lives in salt water ________________________________

Name an animal that lives in "fresh" water _____________________________

Salinity is measured by the number of grams of salt dissolved in 1000 grams of water and is expressed as parts per thousands (ppt). Ocean water averages 35 grams of dissolved salt per 1000 grams water, a salinity of 35 ppt. Freshwater ranges from 0 – 5 ppt, while estuaries range from 5 – 30 ppt.

Explain why estuaries are important. ____

____



ACROSS

2. Plants in an estuary serve as the basis for all ___ ___.

4. Dissolved salt in water

6. A body of water where salt and fresh water mixes.

DOWN

1. Estuaries provide _____ for young animals.

3. This type of water has a salinity of 0-5 ppt.

5. Estuaries serve as a _____ for many organisms.

Salinity in the Chesapeake Bay Continued

A TASTE OF THE BAY

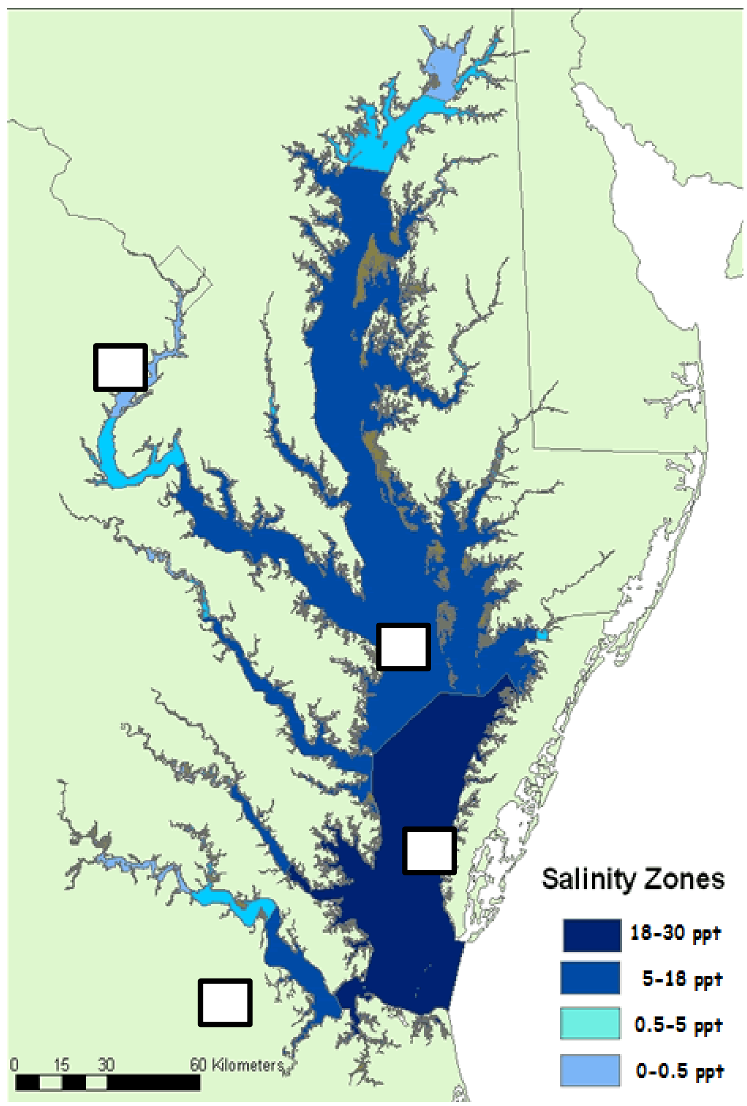
Procedure:

1. On your table, you will find four 50 mL beakers full of water. These are different water samples. Each beaker has a different salinity, but the salinity is not marked, so you do not know which is which!
2. Dip a cotton swab into each small beaker. Taste the water.
3. After you have tasted the water, make a guess as to which salinity level corresponds with the water in the beaker. Record your guess.
4. Use the refractometer to find the actual salinity and record.
5. Now that you have identified the salinity levels, look at the map of the Chesapeake Bay on the next page. There are four location marked on the map where water samples were collected. On the map, identify each of the four locations as A, B, C, or D.

Salinity Levels

0 ppt
5 ppt
15 ppt
30 ppt

	Guess	Actual
Water Sample A	_______ ppt	_______ ppt
Water Sample B	_______ ppt	_______ ppt
Water Sample C	_______ ppt	_______ ppt
Water Sample D	_______ ppt	_______ ppt



Turbo Testing: Turbidity

Materials per Group

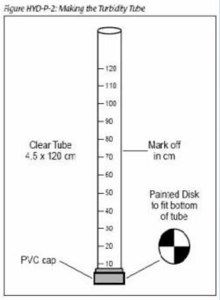
Activity
- 3 beakers of water
- turbidity tube
- loose soil in dish
- spoon
- science journal

Teacher Prep

For each group, fill a beaker with water, and place small amount of loose soil in a dish.

Turbidity Tube: To make your own Secchi disk tube, visit http://www.teachengineering.org/collection/cub_/activities/cub_waterqtnew/cub_waterqtnew_lesson01_activity1_howtomake_tube_jly_tedl.pdf

Figure HYD-P-2: Making the Turbidity Tube



Secchi Disk: For directions on how to make a Secchi Disk visit http://serc.carleton.edu/microbelife/research_methods/environ_sampling/turbidity.html

Purpose: To demonstrate a scientific method of measuring turbidity using a Sechhi Disk Tube. To analyze the results and relate turbidity to the ability of light to penetrate water. To describe the relationship between turbidity and the ability of aquatic life to survive. To understand the cause and effect relationships between human activities on land and the health of a body of water.

Background

Turbidity is a measure of water clarity, which is how far light passes through the water. Suspended materials in water can decrease light's penetration. Suspended materials include soil particles (silt, clay, and sand), algae, plankton, microbes, and other substances. They are some of the most damaging pollutants of waterways and bodies of water, such as the Chesapeake Bay. The content and concentration of suspended materials, can affect the color of the water.

Sediment fills streams, harbors and reservoirs. When suspended in the water, sediment prevents sunlight from reaching underwater plants. High turbidity also increases water temperatures and in turn, reduces the concentration of dissolved oxygen. Suspended sediment can clog the gills of fish and make it harder for fish to find food. As sediment settles to the bottom, it can smother the organisms living on the bottom. It can also cover the rocks on the bottom of the waterways, where many aquatic creatures lay their eggs.

There are many sources that cause high turbidity including soil erosion, waste discharge, urban runoff, eroding stream banks, excessive algal growth, and large numbers of bottom feeders that stir up the bottom sediments. Turbidity can be useful as an indicator of the effects of runoff from construction, agriculture practices, logging activity, discharges and others. Turbidity often increases sharply during a rainfall, especially in developed watersheds where there are a lot of impervious (water-resistant) surfaces. Turbidity can also rise sharply during dry weather if earth disturbing activities occur in or near a stream without controls put in place.

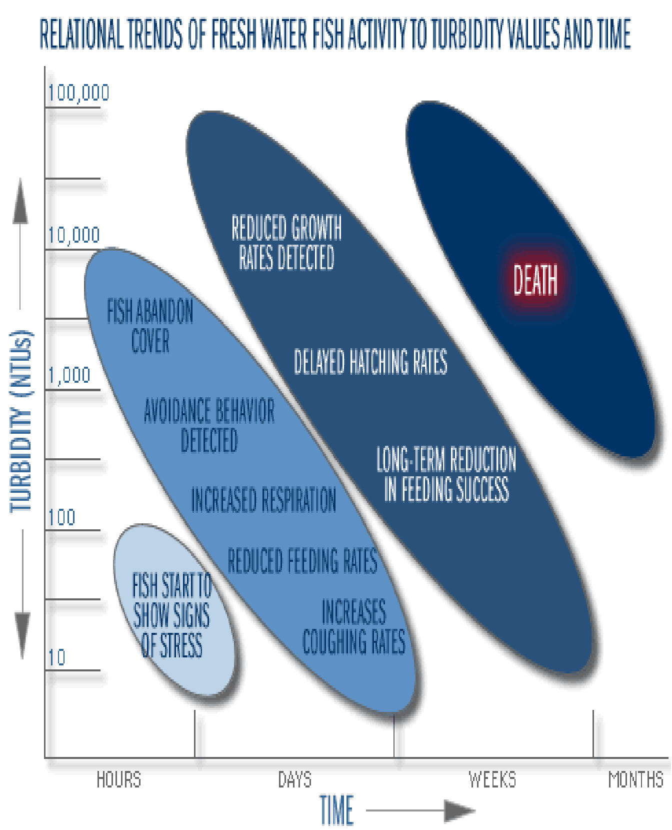
Turbidity is not a measurement of the amount of suspended solids present or the rate of sedimentation of a stream since it measures only the amount of light that is scattered by the suspended particles. Generally, turbidity is measured by using a turbidity meter. It measures the intensity of light scattered in nephelometric turbidity units or NTUs. A clear mountain stream might have the turbidity of around 1 NTU, whereas the Mississippi River might measure 10 NTUs during dry weather.

Another way to measure turbidity is by using a Secchi disk. The disk is about 20 cm in diameter with alternating black and white quadrants. It is lowered into the water until it can no longer be seen from the surface. The point at which the disk disappears is a function of the lake's turbidity. A turbidity tube (T-tube) is a plastic tube with a small-scale Secchi disk pattern at its base. Water samples are poured into the tub until the bottom disk cannot be seen.

Turbo Testing: Turbidity Continued

Procedure

1. Vigorously stir or swirl the water sample in the container until it is homogenous. Introduce as little air as possible.
2. Place your head 10 to 20 centimeters directly over the turbidity tube so that you can see the Secchi disk while the water is being poured into the tube.
3. Slowly pour water into the tube. Try not to form bubbles as you pour. If bubbles do form, stop pouring and allow any bubbles to rise and for the surface of the water to become still.
4. Keep adding water slowly until the pattern on the disk becomes hard to see and then stop.
5. Observe the Secchi disk closely and continue to add water very slowly. Stop pouring as soon as the pattern on the disk can no longer be seen.
6. Measure the depth of the water and record in the chart below. **Note:** If your turbidity tube is not marked with measurements, use a metric ruler.
7. Carefully, pour the water back into the beaker and label it “Sample A”
8. Using a different beaker, add five spoonful’s of soil to the water in the beaker
9. Repeat steps 1-7, but label this beaker “Sample B.”
10. Using the third beaker, add ten spoonful’s of soil to the water in the beaker.
11. Repeat steps 1-7 again, but label this beaker “Sample C.”
12. Use the graph below on the left to interpret the effects of each beaker’s turbidity (if it remained the same) on aquatic life over a few hours, days, weeks, and months. Record in your science journal.
13. Leave the beakers undisturbed. Observe them in an hour and record your observations in your science journal.
14. Continue to observe and record your observations at the same time each day for two weeks.



Water Sample	Turbidity (centimeters)	Turbidity (NTU)
A (0 Scoop)		
B (5 Scoops)		
C (10 Scoops)		

Turbidity (centimeters)	Turbidity (NTU)
2.5	500
3.7	300
5.1	200
8.3	100
13.5	50
19	30
25	20
41.5	10
63	5

Discussion Questions

1. What are five harmful effects of sediment?
2. How might you be able to tell if a body of water is healthy or unhealthy?
3. What can people do to protect the health of water?
4. How will the water in beakers B and C look in an hour? In a day? In a week?
5. Do sediments “settle” in a body of water? Explain.

May the Force Always Buoy You: Data Buoys

Materials per Group
- Four 6” PVC pipe with 1.5” diameter
- Four 90° elbows 1.5” diameter
- 8 3-way connectors 1/2” in diameter
- 12 PVC pipe 6” in length and ½ “ in diameter
- 1 plastic disc (Frisbee™) with 8 ½” holes drilled at the edge
- 12 zip ties

Per Class
- ~120 golf balls
- 3 small 2’ x 3’ tubs of water

Teacher Note

For this activity, the class works in small groups to build a buoy. Materials and directions for creating a class set of buoy building kits can be found at http://secoora.org/sites/default/files/webfm/classroom/documents/BuildABuoyManuscript.pdf

Elementary version can be found at http://marex.uga.edu/uploads/documents/eBOBGuide_11_20.pdf

To learn more about Ocean Observing Systems (OOS) and for lesson plans using real-time data visit Virginia Institute of Marine Science at http://www2.vims.edu/bridge/search/bridge1oos_menu.cfm?q=oos

Purpose: To understand how data buoys are used to collect water quality data and to build a buoy.

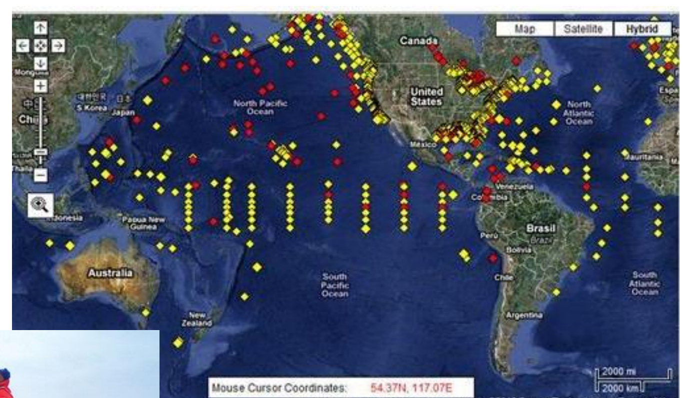
Background

Today, technology has increased our ability to collect data from the air, land, waterways, and ocean. One technology used to collect data from bodies of water is a buoy. Buoys can drift or be moored. They can be on the surface, below the surface or stationary. Buoys can transmit data automatically in a controlled way communicating in real-time via satellites or their data can be stored until it is retrieved.

Drifting buoys are generally attached to some form of anchor. They are easy to deploy and relatively inexpensive to operate. They reliably measure the atmosphere and water surface conditions for up to 18 months. Drifting buoys have a long history of use in oceanography, principally for the measurement of currents.

Moored buoys are anchored at fixed locations and regularly collect data from many different atmospheric and oceanographic sensors. Moored buoys are usually deployed to serve national forecasting and maritime safety needs or to observe regional climate patterns. They are normally expensive and relatively large ranging in size from a few meters high and wide to over 12 meters.

Measurements from mooring buoys include surface data, such as sea state; wind speed; air, sea, and surface temperature; salinity; air pressure; and more. They can sometimes measure subsurface temperatures down to a depth of 500 meters or more. Moored buoys collect so much data, that some data can be stored on-board and then processed at a later date when the buoy is retrieved or serviced.



NOAA has over 350 data buoys and receives data from hundreds of other stations from around the world. For more information http://www.ndbc.noaa.gov/

May the Force Always Buoy You: Data Buoys—Continued

Problem

A group of NOAA researchers are on an uninhabited island off the coast of American Samoa. In one of the small lakes on the island, they noticed that the water is an unusual color and the color changes during the day. They want to collect water quality data over the two weeks that they are on the island to try to determine what is happing in the lake. However, they did not bring a buoy with them, but they have a lot of PVC pipe and PVC connectors on their ship that can be used to build a buoy. You and your team are the engineers in the group, and NOAA has tasked you to design and build a buoy that will hold 50 lbs. of scientific sensors. You are limited to equipment you have onboard the ship, and the researchers have asked you to build it quickly so they can collect as much as data as possible before they leave.

Note: *For this activity, golf balls will represent the scientific equipment with each golf ball simulating 1 lb.*

Objective:

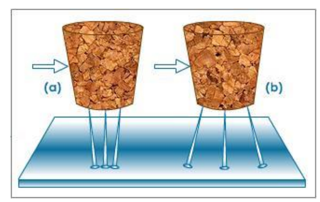
To design and build a buoy, using only the materials given, which will hold 50 or more golf balls and remain floating.

Things to Think About!

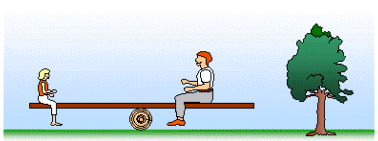
Stability—the buoy must be stable, which means it has a foundation that prevents it from falling or giving away. A wide base helps to make an object more stable.

The tower is unstable and could easily fall. Why?

Which of the two corks is the most stable? Why?



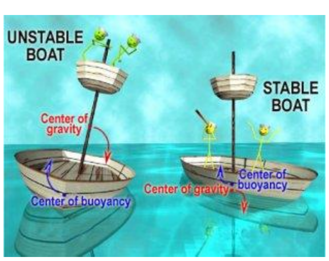
Center of Gravity—that point in a body or system around which it's mass or weight is evenly distributed or balanced through which the force of gravity acts.



Find the center of gravity for a ruler or pencil. Explain.

Traffic cones are designed to be very stable. Explain what features makes them stable.

Center of Buoyancy—the center of gravity of the volume of water displaced by a hull.



Look at the picture of the two boats, and explain why one boat is stable and the other is not.

May the Force Always Buoy You: Data Buoys

Procedure:

1. With your team discuss the mission objective.
2. Discuss center of gravity and buoyancy and how they relate to making your buoy more stable.
3. Observe the materials that are available to build the buoy.
4. In your team, discuss how to engineer and design the buoy.
5. Draw your design below or in your science journal.
6. Show your design to a Buoy Specialist (teacher).
7. Return to the team and discuss any necessary changes if needed.
8. When you have determined a final design, make a list of supplies needed.
9. Gather the buoy supplies.
10. Build your buoy.
11. In the tub provided, test your buoy for stability. If needed, make any necessary design changes and retest.
12. Once your buoy is stable in the water, begin to carefully add the payload (golf balls) counting as you go.
13. Once the buoy starts to become unstable or sinks below the surface, stop adding golf balls.
14. Remove and subtract golf balls, if needed, to reestablish stability and/or to bring the lower part of the buoy above the surface of the water. Record the number of golf balls. ____________________
15. If the buoy did not hold 50 golf balls, then discuss in your team how to make the buoy more stable.
16. Make any design changes and retest following steps 11-14. Record number of golf balls. ______________
17. Keep repeating until the buoy can hold 50 golf balls or more. This is an ***iterative*** process of testing, redesigning, testing, redesigning, etc.

Design Your Buoy Below:

Photos: NOAA

Discussion Questions

1. Where was the center of gravity on your buoy?
2. What changes did you make to make your buoy more stable and why?
3. What would you do differently next time?

Bob, Bob, Bobbing Along: Data Buoys—Teacher Page

Building an Observation Buoy

A great way to engage students in field work is to build an observation buoy and test waters in your surrounding area. The buoy is a simple floating platform made from PVC, peg board, and other easily obtained items, and it has a variety of environmental sensors attached. The buoy can be placed in a body of water and moored to the bottom or it can be placed dock-side by a pier or quiet shoreline. Data sensors of your choice are attached and data are retrieved regularly over a specified period of time as determined by you and/or the class. This is a great class project, but can also be done after school with a science or oceanography club.

Before you decide if building an observation buoy is something you want to do, there are a few items to take under consideration. Depending upon how you build the buoy, supplies and sensors can run anywhere from a few hundred dollars to $1500. However, costs can be drastically reduced, if you or your school already has educational grade sensors. Some local hardware stores are also willing to provide PVC and supplies as a gift or at a reduced cost. If funds are available, each group of students can build the buoy each class/year. However, if funds are limited, then the buoy can be built once and used over-and-over again.

Another consideration is where you will place the buoy. The area needs to be somewhat secure, so no one can take the buoy or the sensors. Depending upon where it is placed, you may also need to acquire a permit or permission. Most localities should not have a problem, since this is an educational project, but it always is better to ask than to return and not have a buoy!

If your school offers a technology education or shop class, this is the perfect project to work on together. Your students can design and engineer the buoy and the technology education class can cut the PVC pipe and peg board and do any other work needed.

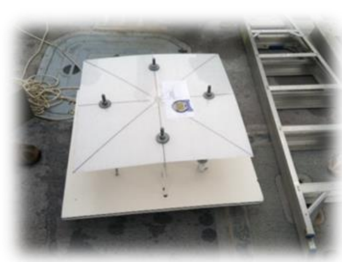
Below is a list of a few web resources that can help you to get started building your own observation buoy. Download a manual from SECOORA that gives step-by-step instructions to building a buoy.

Southeast Coastal Ocean Observing Regional Association (SECOORA)
This site provides great information on the different types of observing technologies, the ocean, waves, hurricanes, boats and buoys. **It also includes a manual for building a Basic Observation Buoy (BOB).** This is the manual that we use as a foundation for building, but it can easily be modified.
http://secoora.org/classroom/BOB_educational_water_quality

Students Monitoring Coastal and Inland Waters with the BOB
An article that gives the history of the BOB program and how it has been implemented.
http://www.mbari.org/earth/2012/resources/Adams-etal-final-2.pdf

Integrated Ocean Observing System (IOOS)
A vital tool for tracking, predicting, managing, and adapting to changes in our ocean, coastal and Great Lakes environment. Check out the education section.
http://www.mbari.org/earth/2012/resources/Adams-etal-final-2.pdf

NOAA Sea Grant's The Bridge
A wealth of resources for ocean observing systems.
http://www2.vims.edu/bridge/search/bridge1oos_menu.cfm?q=oos



Top to Bottom: Deploying buoy from NOAA's SRVx *Sand Tiger*; waiting to see if anchor holds it in place; success; retrieving the buoy 3 days later; buoy is missing a few parts due to rough weather. Photos: NOAA

What does the Water Tell Us?: Analyzing the Data

Materials per Group
- water quality test kit
- 3-5 clean beaker
- 3-5 water samples
- masking tape
- science journal

Per Class
- ~ gallon each of 3-5 water samples

Teacher Prep
If you live near an estuary, bay or ocean, collect water samples from 3-5 different areas. Collect enough water to divide between the groups. If you don't have access to salt water, you can create your own and vary the water's quality in each sample. Label each sample A, B, C, and so on. Label one sample from the shipwreck *Betsy*.

Extension:
Use this interactive USGS map to look at real-time data and archived data to determine water quality in local rivers and streams. http://waterwatch.usgs.gov/wqwatch/

Coastal Restoration Project. Photo: NOAA

Purpose: To explore the water quality of various marine areas and determine if optimum for an oyster garden

Background
According to NOAA's Chesapeake Bay Office, oysters are usually found on hard bottom areas and natural oyster bars are often located on the edges of channels. Specific habitat tolerances for oysters in the bay are

- Depth: 2-26 feet (0.6-8.0 meters) in the Chesapeake Bay, except oysters near the mouth of the Bay (and farther south, and rarely north) may be intertidal. Winter mortality limits intertidal oysters (exposed out of the water at low tide) to the southern, warmer parts of their range, generally south of Maryland, except oysters may be intertidal in locations farther north that are not subject to ice scour.
- Salinity: varies by life stage. Larvae need 10-27.5 practical salinity units (psu), adults can tolerate 5-40 psu, but optimum range is 14-28 psu. Adults have little growth below 5-10 psu.
- Temperature: optimum for larvae is 68-90.5o F (20-32.5oC), for adults 68-86oF (20-30oC); adults can tolerate 35.6-96.8oF (2-36oC) and up to 120.2oF (49oC) for short periods. Larvae can grow in water as cold as 63.5oF (17.5oC).
- pH: larvae are the most sensitive; tolerable range is 6.75-8.75.
- Dissolved oxygen: >20% saturation, which corresponds to 2.3 milligrams/liter at 50oF (10oC) and 1.5 mg/l at 86oF (30oC). Hypoxia for most marine life is considered <30% dissolved oxygen saturation, so oysters are more tolerant of low dissolved oxygen than are many Bay animals. Sub-tidal oysters can close their shells and use anaerobic respiration for several hours if the water has low dissolved oxygen, just as intertidal oysters close their shells at low tide.

Procedure
1. Label each beaker "A," "B," "C," and so on.
2. From water sample "A," pour 300 ml of water into your beaker labeled "A."
3. Repeat step 2 with the remaining water samples.
4. Test the water quality of each sample and record your findings in your science journal.
5. Create a data chart or graph comparing the water quality data collected for each sample. Using the relative information from above, analyze and determine which sample is the most ideal for an oyster restoration project.

Discussion Questions
1. Which water sample had the most ideal conditions to start an oyster garden? Justify your answer.
2. Where do you think each sample was collected and why? Estuary? Ocean? Bay?
3. Turbidity was not measured, but how would it affect the ability of an oyster garden to thrive? Explain.
4. What is the deepest water depth that oysters survive? Would depth affect turbidity? Explain.
5. Comparing your data, is *Betsy* an ideal location for an oyster restoration project? Why or why not?

Ready, Set, Filter—Oysters as Filter Feeders

Materials

- 2 tanks with pumps filled with high turbid river or bay water
- live clams in one tank
- live oysters in other tank
- turbidity tube or sensor
- 6 mason jars
- 6 bags filled with 6 cotton balls
- 6 bags filled with sand
- 6 bags filled with gravel
- 6 bags filled with rocks
- 6 coffee filters
- 6 sheets of paper towels
- 6 napkins
- 6 rubber bands
- 6 sponges
- stop watch
- 50 mL beaker
- masking tape
- marker

Teacher Prep
Set up each tank with water and pumps. Have students observe as you place clams in one tank and oysters in the other. Remind students that clams and oysters are filter feeders and discuss how they might filter the water. Divide class into six groups.

Purpose: To gain an understanding of how mollusks are natural filters for our waterways. To compare and contrast the amount of filtration between a clam and oyster.

Background

Oysters are filter feeders. They eat by pumping water over their gills through the beating cilia. Plankton, algae, and other small particles of food get trapped in the mucus of the gills. Then the oyster is able to consume and digest the food. After the oyster removes the food particles from the water, it expels the filtered/clean water through the external valves.

Clams are also bottom dwelling mollusks that feed on phytoplankton. Water is drawn in through a siphon to gills. The water is moved by the tiny cilia hairs. The food gets caught in the mucus on the gills. The food is then digested and the filtered water is expelled through the second siphon.

Procedure

1. As a class discuss how oysters and clams feed and filter the water.
2. In your science journal, write a hypothesis for which mollusk will filter the water the most (better) in 40 minutes.
3. In your group, you are to engineer a filtration system. You may purchase supplies from the ***Filter Store Supply List.*** Your budget is **$50** and you will have **10 minutes** to design and build. You may **NOT** test your filtration system. The group's design will be judged on the following criteria:
    a. fastest construction
    b. fastest filter
    c. cheapest filter
    d. clearest filter
    e. filter that produces the most water
4. Points are awarded for each criterion as follows: 10 points for 1st place, 8 points for 2nd place, 6 points for 3rd and 4th place, 4 points for 5th place, and 2 points for 6th place. All points will be added after each filter test and the group with the most points wins the competition.
5. Once the group's filter is complete, let the teacher know and she/he will keep track of who finished first, second, etc. **Points awarded.**
6. Next, the teacher will test each filter by filing a 50 mL beaker full of high turbid water and slowly pouring it into a mason jar through the filter-system. The teacher or time-keeper will time and record the time it takes to filter the water.
7. The teacher or record keeper will label the jar with the group's name and time. **Points awarded.**
8. The jars will then be lined up from the fullest to the least full. **Points awarded.**
9. The jars will then be lined up in order from clearest to least clear. **Points awarded.**
10. Teacher will **award points** for the cheapest to the most expensive.
11. A final total of all points earned by each group is tallied and the group with the most points wins!

Ready, Set, Filter—Oysters as Filter Feeders Continued

Filter Store Supply List

Mason jar	FREE!
Cotton Balls (6)	$20
Sand	$15
Gravel	$15
Rocks	$15
Coffee Filter	$40
Paper Towel	$20
Napkin	$10
Rubber Band	$ 5
Sponge	$40

Items purchased:

Total Cost: ____________________

Group Name: ____________________

Points Earned

Fastest Construction	
Fastest Filter	
Fullest Jar	
Clearest jar	
Cheapest to Build	
TOTAL POINTS	

Placed ____________________

Discussion Questions

1. Which mollusk filtered the water more (better) within the 40 minute time span?
2. What are the differences between the two filtering systems for the clams and oysters?
3. What are some benefits for having a high population of clams and oysters in the bays, rivers, and ocean?
4. What would be the costs and benefits for creating a man-made oyster reef on *Betsy*?
5. Are there any negative effects to the natural preservation of *Betsy* if oysters, clams, and other underwater species use it as a reef?

It's an Underwater Zoo Out There!: Life on an Oyster Bed

Materials

- oysters (2 per group)
- oyster cage placed in estuary by rope
- taxonomic key (1 per student)
- clothes pins
- small clear cups
- species cards
- 6 plastic tubs (1 per group)
- small tank dip net
- **Optional if doing in classroom:** large tub and aeration pump

Teacher Note: This activity is for oyster reefs near Virginia's coast, but can be adapted for your local area.

Teacher Prep
Two weeks or more prior to the activity, locate an easily accessible dock in an estuary where you can place an oyster cage. Fill the oyster cage with a minimum of two oysters per group. Tie the oyster cage to the dock and carefully place it in the water. Wait two weeks. On day of activity, fill each tub with two oysters, a variety of other organisms that are in cage and enough water to allow any fish to swim.

This activity can be done dockside as a field trip. If students are unable to go to the dock, then place the oyster cage in a large tub filled with estuary water and an aeration pump to take it to classroom.

Make copies of key and specie cards.

Purpose: To use a taxonomic key to identify different marine species that live on oyster reefs in Virginia and to create an underwater zoo.

Background
Oyster reefs form a complex ecosystem. They provide large surface areas for the attachment of other sessile organisms, such as barnacles, tunicates, mussels, sea anemones, and tube worms. Many of these organisms, like oysters, are filter feeders and contribute to the overall filtration capacity of the reef. Oysters also serve as food for other reef inhabitants, such as crabs and fish. Small crustaceans, called amphipods, are abundant on most oyster reefs and are favorite prey items for some fish. In addition to providing habitat for prey items, oyster reef crevices and empty shells provide habitat and protection for a variety of animals. Some fish (e.g., gobies, blennies, skilletfish, and oyster toadfish) deposit their eggs inside the empty oyster valves, where they are less likely to be eaten by predators.

Using a Taxonomic Key
A taxonomic key, sometimes called a dichotomous key, is one method of classifying and identifying objects. Using a series of paired statements, a taxonomic key looks at the similarities and difference between objects. Each paired statement describes contrasting characteristics that are physical and observable. The researcher chooses one statement out of the pair that is true of the object they are trying to identify. The statement chosen may then ask you to go onto another pair of statements or it may give the name of the object.

Procedure:
1. In each plastic tub, there are two oysters and a variety of other marine organisms. Observe the marine life and record your observations being sure to note the different varieties of life and how many of each. You may carefully handle the marine organisms, but DO NOT pull apart the oysters or break anything off of the oyster cluster.
2. Once you have recorded your observations, work as a group to place each specimen in a separate clear cup.
3. In your group, use the taxonomic key to correctly identify each species.
4. Verify with your teacher that your identification is correct. If so, then find the correct species card and pin it onto the cup using a clothespin.
5. Once finished, place your cups in a line with the other groups' cups and take a walk through your underwater zoo!
6. When the zoo closes, give your cups to your teacher, so he/she can return the organisms to the oyster cage or tub.

Discussion Questions
1. What organisms did your group find?
2. When you walked through the underwater zoo, which organisms were the most abundant?
3. Were there species that you could not identify? Why?

Extension:
1. Conduct research and write an essay on the loss of oysters in your community or the Chesapeake Bay.
2. Create a poster that explains the benefits of oyster and what stressors in their ecosystem affect them?

It's an Underwater Zoo Out There!: Life on an Oyster Bed

Common Reef Dwelling Organisms of Virginia
Dichotomous Key
Adapted from Oyster Reef Keepers of Virginia

1	Is the organism attached to the oyster shell or the float or is it unattached and able to move freely? If it is attached, go to 2. If it is unattached, go to 20.
2	Does the organism look like seaweed or does it look like something else? If it looks like seaweed, go to 26. If it looks like something else, go to 3.
3	If you touch the organism, is it hard or soft? If soft, go to 4. If hard, go to 15.
4	Is the organism spherical, like a grape? If yes, go to 54. If no, go to 6.
5	Are the tubes approximately the width of spaghetti and hollow inside, or are they bigger, similar to the size of a drinking straw? If they are the width of spaghetti, go to 8. If they are drinking-straw sized or larger, you have found the tube of a **TUBE-BUILDER AMPHIPOD**.
6	Is the organism bright red/reddish-orange or is it another color? If it is bright red/orange, you have **REDBEARD SPONGE**. If it is another color, go to 7.
7	Does the organism appear to have built little tubes on the oyster shell? If yes, go to 5. If no, go to 10.
8	Are the tubes brown and muddy or are they yellowish-brown and sandy? You may need to touch the tubes to answer this question. If they are muddy and brown, go to 9. If they are yellowish-brown and sandy, you have a **SANDBUILDER WORM** tube.
9	Gently push on one of the tubes. If it is fragile, soft and disintegrates easily, you have a **MUD WHIP WORM** tube. If it is "leathery" and slightly more durable, you have a FAN WORM tube. Place the shell in water to see if the worm's head emerges from any of the openings.
10	Does the organism look like a small mound of jelly in a roughly circular shape? If yes, go to 11. If no, go to 12.
11	If the organism is dark green with yellow lines on it, you have a **GREEN-STRIPED ANEMONE.** If the organism is white or pinkish, you have a **WHITE ANEMONE**. Put this shell in water to see the sea anemone's tentacles emerge. It is beautiful.
12	Does the organism form a coating on the oyster shell? If yes, go to 13. If no, you probably have a bryozoan colony called **DEAD MAN'S FINGERS**.
13	Does the organism form in colonies that look like little yellow stars or flowers? If yes, you have a **GOLDEN STAR TUNICATE**. If no, go to 14.
14	Is the organism yellow or brown? If yellow, go to 52. If brown, go to 53.
15	Does the organism look like a tube? If yes, go to 16, if no go to 17.
16	You have a **LIMY TUBE WORM** tube and there may be a limy tube worm inside. Place the shell in brackish water to see if a feathery worm pokes its head out of the tube.
17	Does the organism look like a thin layer of mesh coating the oyster shell? If yes, go to 18. If no, go to 19.
18	You have a bryzoan colony called **LACEY CRUST BRYOZOAN**. Put it in brackish water under a dissecting scope to see if you can see the little organisms living in the bryozoan colony.

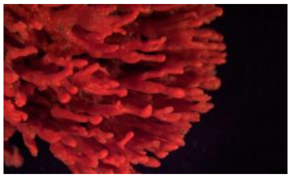
Common Reef Dwelling Organisms of Virginia
Dichotomous Key
Page 2

19	Does the organism have a hole in the top of it? If yes, you have a BAY BARNACLE. (Put it in brackish water and watch it feed.) If no, go to 32.
20	Is the organism a fish? If yes, go to 21, if no go to 39.
21	If you look directly into the fish's face, is it round, like this 0, or oblong, like this 0 or O? If it is round, go to 22. If it is oblong, go to 23.
22	The fish you have is a NAKED GOBY.
23	Is the fish's face flat, like this or narrow, like this ? If narrow, go to 24. If flat, go to 25.
24	Does the fish have tentacles over its eyes that look like bushy eyebrows? If yes, it is a FEATHER BLENNY. If no, it is a STRIPPED BLENNY.
25	Does the fish have a suction cup on the underside of its head? If yes, it is a SKILLETFISH. If no, it is an OYSTERTOAD. Be careful of the oystertoad's teeth!
26	Does the organism look flat and thin like lettuce or is it branchier? If it is lettuce-like, go to 27. If it is branchy, go to 28.
27	If the organism is green, it is a green seaweed called SEA LETTUCE. If it is brown or red, it is a red seaweed called LAVER.
28	Is the organism very fine (similar to or finer than hair) or is it slightly thicker? If very fine, go to 29. If slightly thicker, go to 33.
29	Is the hair-like organism green or brown? If green, go to 30. If brown, go to 31.
30	The organism is a green seaweed called GREEN TUFTED SEAWEED.
31	If you rub the organism between your fingers, does it feel mushy or coarse, like hay? If it feels mushy, you have algae called BROWN FUZZ. If it feels like hay, you have a HYDROID. Put your hydroid in brackish water under a dissecting scope to see if you can see the hydroid organisms moving.
32	Is the organism dark-brown to black, or is it another color? If it is dark-brown to black, you have a HOOKED MUSSEL. If the organism is another color, go to 36.
33	Is the organism green? If yes, go to 34. If no, go to 35.
34	The organism is a green seaweed called HOLLOW-TUBED SEAWEED.
35	Hold the organism up to the light and look to see if there are little red bands all over the branches? If yes, you have a brown seaweed called BANDED SEAWEED. If no, the organism is called RED WEED.
36	Does the organism have little brown or purple lines on it? If it does have lines, go to 37. If it doesn't have lines, go to 38.
37	If the organism is shaped like a tear-drop, you have a SLIPPER SHELL gastropod. If the organism is round, you have a baby EASTERN OYSTER called a "SPAT."
38	You have a JINGLE SHELL bivalve.
39	Does the organism look like a snail? If yes, go to 40. If no, go to 43.

Common Reef Dwelling Organisms of Virginia
Dichotomous Key
Page 3

40	If you follow the spiral of the snail's shell with your finger, is it smooth or bumpy? If smooth, go to 41. If bumpy, go to 42.
41	If it is white, you have an **ODOSTOME** snail. If it is brown, you have a **MUD SNAIL**.
42	Hold the snail shell upright, with the tip of the spirals pointing upward, and the opening on the bottom facing toward you. Is the snail thicker on the top half or on the bottom half? If it is thicker on the top, you have a **THICK-LIPPED OYSTER DRILL**. If thicker on the bottom, you have an **ATLANTIC OYSTER DRILL**.
43	Is the organism soft or does it have a shell or a hard body? (Note: even small organisms like insects have hard bodies) If it has a shell or a hard body, go to 44. If it is soft, go to 48.
44	Does the organism have at least one big claw? If yes, go to 45. If no, go to 47.
45	Does the organism look like a crab? If yes, go to 46. If no, you have a **SNAPPING SHRIMP**.
46	Does the body (carapice) of the crab feel smooth or bumpy? If it feels smooth, go to 56. If it feels bumpy, you have a **SPIDER CRAB**, also called a decorator crab. Place this crab in water with redbeard sponge, dead man's fingers or macro algae and watch it camouflage itself.
47	Does the organism have long, thread-like antennae that are roughly the length of the organism's body? If yes, you have a **GRASS SHRIMP**. If no, go to 55.
48	Is the organism long and thin? If yes, go to 49. If no, go to 50.
49	Does the organism look like it has tiny legs (called parapodia)? If yes, you have a **CLAMWORM** (Look at this worm closely and you'll be able to see blood pulsing down its back). If no, you have a **CAPITELLID THREAD WORM**.
50	Is the organism spherical, like a grape? If yes, go to 54. If no, go to 51.
51	If the organism is larger than 1/3" in size, you have an **OYSTER FLATWORM**. If the organism is smaller than 1/3" in size, you likely have a **LIMPET NUDIBRANCH**, although it could be a young **OYSTER FLATWORM** too.
52	Does the organism appear to be growing up through of the oyster's shell? If so, you will probably see little yellow circles emerging in numerous spots on the surface of the shell. If the organism does appear to be boring in the oyster's shell, you have a **BORING SPONGE**. If not, you have a **SUN SPONGE**.
53	Run your finger over the brown soft coating. If you feel little spines, you have a hydroid called **SNAIL FUR**. If you do not feel little spines, you have a bryozoan called **CUSHION MOSS**.
54	You have a tunicate called a **SEA SQUIRT**.
55	Put the organism on your finger to watch it move. Does it move around like an inchworm, or does it circle about on its side and look like the letter *"C"?* If it moves like an inchworm, you have a **SKELETON SHRIMP**, which sometimes are called the acrobats of the bay. If it looks like the letter *"c"* and it circles about on its side, you have an **AMPHIPOD** species, called a **SCUD**.
56	Look at the hind-most appendages on your crab. If the last segment of this appendage (furthest from the crab's body) is rounded, you have a **BLUE CRAB**. If it is pointy, you have a **MUD CRAB**.

SPECIE CARDS


REDBEARD SPONGE


WHITE ANEMONE


GOLDEN STAR TUNICATE


LACEY CRUST BRYOZOAN


BAY BARNACLE


NAKED GOBY


FEATHER BLENNY


STRIPPED BLENNY


SKILLETFISH


OYSTERTOAD


SEA LETTUCE


LAVER (RED SEAWEED)


GREEN TUFTED SEAWEED


BROWN FUZZ ALGAE

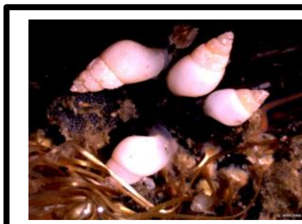

HYDROID


HOOKED MUSSEL


RED WEED


EASTERN OYSTER SPAT


JINGLE SHELL


ODOSTOME SNAIL

SPECIF CARDS

MUD SNAIL

THICK-LIPPED OYSTER DRILL

ATLANTIC OYSTER DRILL

SNAPPING SHIRMP

SPIDER CRA B

GRASS SHRIMP

CLAMWORM

CAPITELLID THREADWORM

OYSTER FLATWORM

LIMPET NUDIBRANCH

BORING SPONGE (RED)

SUN SPONGE

SNAIL FUR

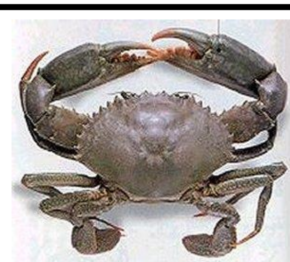
CUSHION MOSS (WHITE)

SEA SQUIRT

SKELETON SHRIMP

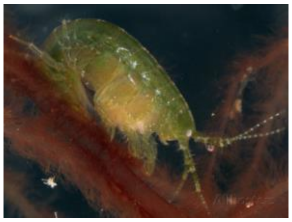
SCUD (AMPHIPOD)

BLUE CRAB



MUD CRAB

MUD SNAIL

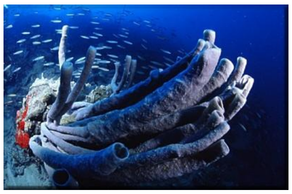


TUBE-BUILDER AMPHIPOD

SANDBUILDER WORM

MUD WHIP WORM

STRIPED ANEMONE



DEAD MAN'S FINGERS

LIMEY TUBE WORM

HALLOW TUBED SEAWEED

BANDED SEAWEED (RED)

DISCLAIMER: The images have not yet been verified by a marine biologist.

SHIPWRECK OF THE DEEP
PART III

OVERVIEW

As the story continues…

Now that the water quality of *Betsy* has been assessed, and the researchers have determined if the waters surrounding the shipwreck are ideal or not for a possible habit or oyster restoration project, it is time to learn more about the ship's construction. They know it is made from metal, but what kind? Is it of sufficient strength to stay intact if parts of the ship are raised? What effect has the ocean had on the metal? With so many questions, the researchers collaborate with metals scientists at NASA to learn more. They also contact The Mariners' Museum where over 200 tons of metal is being conserved from the USS *Monitor*, a Civil War ironclad that sank in 1862 off the coast of Cape Hatteras, N.C. They work in partnership with the conservators at the museum to learn about the conservation process and the costs involved.

Finally, the maritime archaeologists, researchers, marine biologists and other scientists, along with interested citizens come together to debate what to do with the *Betsy*. After the debates, each team determines their recommendation and presents their finding to the group and to NOAA.

PART III: SUGGESTED COURSE OUTLINE:

A. Oysters in the Bay—Continued (10 min)
   1) Conduct another oyster spat measurement lab

B. Chemistry and Conservation of Metals (4 hours)
   1) Field Trip: The Mariners' Museum Batten Conservation Laboratory and USS Monitor Center
   2) To inquire about a virtual field trip visit http://www.marinersmuseum.org/education/distance-learning

C. Metals Science (1 hour)
   1) Guest Speaker: NASA Metals scientist on density of metals and the invention of new metals
   2) To connect virtually with a NASA Scientist on this topic or any other visit http://www.nasa.gov/offices/education/programs/national/dln/special/NASA_DLN_Virtual_Visits.html#.U6C_cfldV8E

D. Build a Boat lab (3 hours)
   1) Build a boat and observe for oxidation
   2) Note: This lab needs to occur over 2-3 days to allow time for oxidation
   3) Cost benefit analysis for the various options: leave shipwreck *in situ*, bring up specific artifacts, raise the entire ship, etc.

E. Socratic Seminar (2 hours)
   1) Students will debate the pros and cons of each option
   2) Note: Invite interested parties to attend the debate and to ask students questions

F. Oyster in the Bay (10 min)
   1) Conduct another oyster spat measurement lab

G. Final Presentations (1-2 hours)
   1) Students will work either as individuals or in teams to present their final decision.
   2) Note. Invite interested parties to attend and/or judge the presentations

Objectives

Students will:

- Continue to conduct oyster spat measurements;
- Identify the properties of metal;
- Recognize that metals corrode in a chemically unstable environment;
- Understand the process of oxidation;
- Calculate the cost of conserving a large tonnage of metal and evaluate the cost benefit;
- Discover that conservation of metals recovered from salt water is a slow process;
- Debate the pros and cons of leaving Betsy *in situ*, raising all of the ship, or raising part(s) of the ship; and
- Evaluate all options and choose an option to defend.

Vocabulary

chemical change—any change that results in the formation of new chemical substances. At the molecular level, chemical change involves making or breaking of bonds between atoms.

conservation—preservation, repair, and prevention of deterioration of archaeological, historical, and cultural sites and artifacts

conservator—a person responsible for the repair and preservation of works of art, building, or other things of cultural or environmental interest

copper—a red-brown metal, the chemical element of atomic number 29

corrosion—a chemical action that causes the breakdown of a material, especially metal

ethics—moral principles that govern a person's or group's behavior

iron—a strong, hard magnetic silvery-gray metal, much used as a material for construction and manufacturing, especially in the form of steel

metal—a solid material that is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity

oxide—a binary compound of oxygen with another element or group

physical change—changes affecting the form of a chemical substance, but not its chemical composition. Physical changes are used to separate mixtures into their component compounds, but cannot usually be used to separate compounds into chemical elements or simpler compounds

pottery—pots, dishes, and other articles made of earthenware or baked clay

restoration—the action of returning something to a former owner, place or condition

rust—a reddish- or yellowish-brown flaky coating of iron oxide that is formed on iron or steel by oxidation, especially in the presence of moisture

Socratic—of or relating to Socrates or his philosophy

solution—a homogeneous mixture composed of only one phase. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent. The solvent does the dissolving.

tarnish—a thin layer of corrosion that forms over copper, brass, silver, aluminum, and other similar metals as their outermost layer undergoes a chemical reaction

Implementation strategy

1. Review the suggested course outline for Part III on p. 115 for a recommended implementation strategy for the course.
2. Review the various activities included in this guide and determine which activities are best for your students.
3. Review additional web and book resources for appropriate supplemental material.
4. Once ready to begin Part III, give students an overview of the storyline as it continues.

Careers

- archaeobotanical researcher
- art conservationist
- artifact illustrator
- attorney for archaeological law
- corrosion resistance engineer
- corrosion technician
- electrician
- historical interpreter
- historical re-enactor
- machinist
- mechanical engineer
- metallurgist
- museum curator
- physicist
- materials scientist
- mining engineer
- mineralogist
- reclamation expert
- research engineer
- casting machine operators
- metal molding tenders

RESOURCES

Web Resources:

Monitor National Marine Sanctuary: Preserving a Legacy—An in depth look at the USS Monitor's history, discovery, recovery of artifacts, and present day conservation efforts. http://monitor.noaa.gov/150th

NOAA's Maritime Heritage Program—Visit the Office of National Marine Sanctuaries to learn how NOAA maritime archaeologists are exploring the ocean. http://sanctuaries.noaa.gov/maritime/welcome.html

The Mariners' Museum—Explore the USS *Monitor* Center and watch live webcams of the turret and other artifacts undergoing conservation and more. http://www.marinersmuseum.org/uss-monitor-center/uss-monitor-center

Nautical Archaeology Society—Visit this site to learn how to arrange an activity session for your school or club. http://www.nauticalarchaeologysociety.org/content/childrens-activities

The Archaeology Channel—Visit this web site to learn what is happening in the world of archaeology around the world. http://www.archaeologychannel.org/

Comic Book Periodic Table—Explore the periodic table of elements in a whole new way. Connect each element to a comic book hero who has the same characteristics as the element. http://www.uky.edu/Projects/Chemcomics/

Chemistry for Kids—Explore the structure of molecules and learn how atoms combine to form compounds. http://www.chem4kids.com/files/atom_intro.html

David's Whizzy Periodic Table—This website provides a multimedia crash course on the chemistry behind all materials, and includes the ever popular and very interactive "David's Whizzy Periodic Table." http://www.colorado.edu/physics/2000/periodic_table/index.html

National Park Service Archeology for Kids—Learn more about archaeologists and how they work. http://www.nps.gov/Archeology/public/kids/index.htm

Young Archaeologists' Club—Dive into this British website to play your favorite games to learn more about ancient cultures. http://www.yac-uk.org/funandgames

The National WWII Museum—Visit this site to learn more about the techniques and guidelines for preserving artifacts. http://www.nationalww2museum.org/give/donate-an-artifact/preservation-of-artifacts.html

Science Kids: Metals for Kids—Check out the cool topic of metals with a range of free games, experiments, and more. http://www.sciencekids.co.nz/metals.html

Great Schools Science Worksheets—Great teacher resource for metals with printable worksheets. http://www.greatschools.org/worksheets/science/?start=18

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Volunteer diver helps NOAA to survey and document the *Caribsea*. Photo: NOAA

Dive slates with site drawings Photo: NOAA

Activities and Worksheets

A Story of a Shipwreck: Maritime Archaeology

Purpose: To understand maritime archaeology and the ethical handling of shipwrecks, so as to evaluate and develop a position on *Betsy*

Background
Shipwrecks are remnants of human history. The suddenness with which a ship often sinks creates an "accidental" time capsule and is the perfect place for archaeologists to study the past and what to expect as time goes by. However, a shipwreck is more than just a collection of objects lying on the seabed. They offer a wealth of information representing human activities and the cultural and social systems of their time. For example, they can tell us what items were considered essential for survival on a ship; give us a look at a cross-section of social classes by the different quarters (living spaces) onboard; tell us how ships were constructed; teach about ship life; help to understand the trade of goods; and through the personal belongings of the crew and passengers, give us glimpses into the lives of the people who sailed on the ship. Sometimes, something as seemingly insignificant as a small stamp or mark on an artifact can even provide valuable, previously unknown information. Therefore, a shipwreck's treasure is not always its cargo, but rather the infinite amount of information that can be learned about our past.

Although legend and lore often provide us with stories of shipwrecks full of treasure, every shipwreck, even those without "treasure," provide archaeologists with a bounty—of information. The position of the wreck, distribution of wreckage and/or other items, rate of deterioration, and much more help archaeologists tell a ship's story. Therefore, it is important to preserve a shipwreck *in situ* (in its original place), so that it can be studied as a whole. Removal of artifacts from a site destroys the archeological context. If artifacts are removed, it should be done by archaeologists who have been trained to keep an accurate record of the artifacts through notes, photographs, site plans, and other documents. Still, no matter how well they collect data, the site will never be intact and whole again once artifacts are removed.

The raising of a shipwreck and the removal of artifacts is often debated. For most shipwrecks, archaeologists agree they should be studied *in situ*. However, a water environment, especially salt water, can have devastating effects on a shipwreck. Salty water, hurricanes, storms, and human activities can all cause a shipwreck to deteriorate quickly over just a few decades. Therefore, in a few instances, when a shipwreck is historically significant, such as the USS *Monitor,* a decision is made to recover some or all of the ship's artifacts.

Any recovery of artifacts must be carefully planned as it is imperative that they be immediately conserved. Without conservation, most artifacts will perish and all historical data lost. Organic material can crumble within a few hours after it dries; iron may last a few days or months, but will eventually fall apart; and glass and pottery will slowly become hard, opaque, or crystalline. Therefore, is it is imperative that all factors be considered before recovering these delicate artifacts. Some factors include the location for conservation and display after artifacts are preserved; the amount of money available to conserve the artifacts; and the reason for the artifacts conservation.

You will also learn about the conservation process for preserving artifacts. As you begin to understand the intricate process involved in conservation, think about *Betsy* and think like an archaeologist to decide how best to conserve the wreck.

Discussion Questions
1. Explain "accidental time capsule."
2. What can artifacts from shipwrecks tell an archaeologist? How?
3. Why is it important to sometimes preserve the shipwreck *in situ*? When might artifacts be recovered?
4. Explain why it is imperative to plan for conservation before recovering artifacts?

Analyzing Artifacts

Materials per Student

- artifact (box)
- science journal

Teacher Prep

Collect a variety of discarded empty containers, such as soda cans, cereal boxes, or frozen food boxes so that each student has at least one. These containers will be artifacts for the student archaeologists.

Extensions

Create a time capsule by collect items that represent your culture. Put the items in a coffee can or other container that is waterproof and can be sealed tightly. Record the date the items were collected. You may wish to bury the container and leave it for someone to find in the future or put the can in a safe place to be opened by a future class.

Purpose: To examine and analyze an “artifact” to interpret and draw inferences about a human culture

Background

An artifact is an object that is made or used by humans. Archaeologists often study cultures that existed before the written word, so they must try to interpret the artifacts that are left by the people who used them. A shipwreck, offers a unique look at the life of the people who sailed on the ship and of the culture when the ship sank. These time capsules hold a wealth of information and even their “trash” can give clues of what life was like onboard. Artifacts that were discarded as trash many years ago are treasures to archaeologists. Archaeologists carefully examine the objects and analyze them to learn their stories. A simple everyday object may actually tell us more than we think about the people who made and used it. The artifact might even tell us what their lives were like, how they thought, what they valued, and how they changed the world in which they lived.

In this activity, you are an archaeologist who is analyzing the artifacts from an archaeological site.

Procedure

1. Select an artifact.
2. Carefully observe the artifact.
3. In your science journal, record your observations providing as many details as possible about the artifact.
4. Answer the following questions about the artifact and write a sentence to explain the culture from which it might have come. For example, a nutritional label on a box might indicate that the culture was concerned about their health.
    a. Is the artifact plain or decorated?
    b. How was it sealed?
    c. Is there any writing on the artifact?
    d. What material is the artifact made of?
    e. Where was the product made?
5. Share and compare your findings and explanations with the other archaeologists in your class.

Discussion

1. Why do archaeologists look at objects that were discarded or thrown away by people?
2. What are some of the things archaeologists can learn about a culture by studying artifacts?

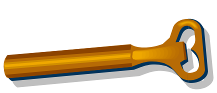
Go, Go, Gadgets

Materials per Group

- artifact (tool)
- science journal

Teacher Prep

Collect several unique kitchen/garden tools or other unusual objects, such as a cherry pitter or garlic press that students may not readily recognize. Provide one for each group. Using a tag, label each item with a number. On an index card, record the number of the artifact, what it actually is, and the purpose of the object. Save the cards until the conclusion of the activity.



Purpose: To make inferences about the uses of unfamiliar tools

Background

Artifacts must be analyzed by the archaeologists who find them. Unless someone has personally used the artifact and can explain its purpose, archaeologists are left to interpret the purpose and use of the artifact based on what they know about the culture and how people might use the same kind of object today. When ancient Egyptian artifacts were first uncovered, the archaeologists had difficulty interpreting the objects and making sense of how they were used. After the discovery and translation of the Rosetta stone, archaeologists were able to interpret Egyptian hieroglyphics (picture writing), which gave them a new and better understanding of Egyptian artifacts.

You are future maritime archaeologists from the twenty-third century who have uncovered some unique artifacts from the twentieth-first century.

Procedure

1. Carefully observe the artifact.
2. In your science journal, draw a picture of the object. Record your observations including as many details as possible.
3. In your group, discuss your observations and using what you know about life in the twentieth-first century; determine a purpose for the object. Come to a consensus on its purpose.
4. In your science journal, explain what the artifact might have been used for and why your group came to that conclusion.
5. As a group, create a short 2-3 min skit that explains to the other archaeologists in your class the artifact and its use without naming it.
6. After all archaeologists have completed their skits, get the card from your teacher that explains what the artifact is and how it was/is actually used.
7. Compare your inferences and conclusions.

Discussion

1. Were you able to identify the purpose of your artifact? Why or why not?
2. Did everyone agree about the purpose of each artifact? Why or why not?
3. How is this activity similar to what happens when an archaeologist recovers an artifact?

Extensions

1. Read excerpts from historical journals. What clues do the authors leave about the cultures in which they lived? How are journals helpful to archaeologists? What might an archaeologist learn from these kinds of records found at a site?
2. Look at a picture of an old painting. What can you learn about the culture from the painting? Conduct research to find out about ancient artworks that have been found on cave walls or rock cliffs.
3. Conduct research to find out about primary and secondary sources of information. How do historians use inferences to help them interpret events from the past?
4. Visit a museum to look at the artifacts from another culture. Before reading the information cards, predict how the object may have been used. Then read about the object in the museum case. Keep track of the number of times you were correct in your predictions.

What's In Your Trash?

Materials per Group

- bag of clean trash
- science journal

Teacher Prep
Collect several bags of clean, safe trash from various locations such as an office, home, or a public place. Make sure that the trash doesn't have any food, cans, glass, or any other objects that might be dangerous and cause injury. There should be one bag of trash for each group.

Purpose: To understand that material remains, such as trash, can be useful in studying the life and habits of past human cultures

Background

Archaeology is the scientific study of past human cultures by analyzing the material remains of objects that were left behind. Much can be learned about a society by the trash it leaves behind. An archaeologist can learn how the people of the society lived, what they ate, and even what games they played. The value that people placed on certain objects can also be determined. Think about it, you wouldn't throw away a diamond necklace, but you wouldn't think twice about discarding an old pair of shoes.

Procedure

1. Carefully go through the bag of trash.
2. In your group determine how to sort the trash. Should all paper products go together, and all plastic, and so on.
3. Once you have the trash sorted, carefully observe each grouping and try to analyze the pile. Are there similar items or extremely different items?
4. After analyzing each pile, take a look at the trash as a whole. Does each pile "connect" to the other pile in some way?
5. Come to a consensus on where your trash came from and be sure to give supporting evidence. Don't overlook even the smallest of clues, for even the type of dirt on the sneaker might hold an answer.
6. Present your trash to the class and explain how you came to your conclusions.
7. Ask the class if they support your findings and why or why not.
8. Have your teacher confirm the origin of your trash.

Discussion

1. Was it difficult to determine the origin of your trash? Why or why not?
2. What would have made your analysis easier? More difficult?
3. When an archaeologist uncovers artifacts, even artifacts from trash, they are not always found whole. Often pieces are missing. Explain how that would make analysis more difficult?

Extension

- Place various pieces of "trash" in a container of salt water and observe or several weeks.
- Bury "clean trash" in an open area or in a large tub and leave it for several weeks or a month. Carefully dig it up to see how it has changed over time.

Conservation Conservators

Background

When planning to recover artifacts from a marine archaeological site, one of the most important items to consider is how to preserve the artifact. For without conservation, most artifacts would perish and all historical information would be lost. For many people, conservation seems like a straightforward and simple process, but it is very complicated. Conservation is also time consuming and expensive, often costing more than the original recovery of the artifact.

Conservation is not just a set of procedures, therefore, only highly trained professional conservators should work to conserve artifacts. They are often the first person to see the actual artifact, and for that reason, they are deeply concerned with the integrity of the artifact and the history it represents. Conservators take on the same responsibilities as an archaeologist, and they also fill the roles of a mender, caretaker and recorder of the artifacts they conserve. They take great care to handle the artifact with respect and ensure that the artifact is conserved correctly. Conservators are also guided by a set of ethical guidelines adopted by the International Institute for Conservation.

When artifacts are recovered from a salt water environment, they must not be allowed to dry. Artifacts absorb salt from the water and over time, these salts become embedded in the artifact, especially in iron objects. The presence of salt can be fatal for the artifact, because as the artifact dries, salt comes out of solution and crystalizes. Salt crystals act as tiny wedges breaking apart the artifact. Therefore, before the artifact can dry, the salt must be removed. The salt removal process varies in length. Other factors that affect the length of time it takes to conserve an artifact are its size and the material from which it is made.

Removing salt from objects can take years or even decades as is the case with the USS *Monitor*'s turret. The process requires that skilled, professional conservators and other support staff are hired. A facility (rent) must be acquired and then there are numerous other costs, such as utilities, supplies, chemicals and so on. Therefore, funding is a key component to making any decision to recover artifacts from a shipwreck site. If decades are required, as with the *Monitor*, then the funding required can be in the millions of dollars.

In your science journal, answer the following questions using information form The Mariners' Museum's web sites listed for each set of questions.

http://www.marinersmuseum.org/uss-monitor-center/conservation-process

1. Where are the USS *Monitor*'s turret, steam engine, condenser, Dahlgren guns and other artifacts being conserved?

2. How many years were these artifacts submerged in the ocean?

3. How many tons of iron artifacts are being conserved at the museum?

4. When the conservation process is completed, where are the artifacts displayed?

5. What is concretion?

http://www.marinersmuseum.org/uss-monitor-center/countering-effects-corrosion

6. What is electrolytic reduction? Explain fully.

7. Why is a negative charge applied to the artifact?

8. When is the solution changed?

9. Why are there bubbles?

10. What happens when objects are finally removed from the tanks?

Top: USS *Monitor*'s turret
Bottom: Conservation of an artifact. Courtesy: The Mariners'

Changing Changes

Materials per Group

- 1 sheet of paper
- 30 mL vinegar in a small cup
- 15 mL baking soda in a plastic snack bag
- 1 cookie
- marble size ball of modeling clay
- ice cube in a small plastic zippered bag
- bag of burned paper prepared by the teacher
- small cups
- stirring sticks

Teacher Prep

Burn several sheets of paper. Let the ash and burned remains cool and then place them into small plastic zippered bags. Prepare one bag for each group. During the activity, burn another sheet of paper as a demonstration for the students to observe.

Purpose: To understand the differences between a physical and chemical change

Background

A physical change is a change in the way something looks or how it is arranged. The material may change in size, shape, or state of matter, but the identity of the material is not changed. Dissolving, freezing, and boiling are all physical changes. When water freezes it is still water. It is a solid instead of a liquid, but it is still H_2O. The material does not change in the freezing process. Tearing a piece of paper changes its shape, but it is still paper.

A chemical change is when materials are chemically combined with other atoms, and a new material is formed with an entirely new set of properties. A flame, the production of a gas, formations of bubbles, an unpleasant burning odor, and rapid releases of energy, such as heat, light, and sound, may all be signals that a chemical change has taken place. When hydrogen burns, water is formed. Hydrogen and water are different substances that don't look or act alike. When metal corrodes, a chemical change takes place. The rust that forms on iron, for example, has different properties than the iron itself.

Procedure

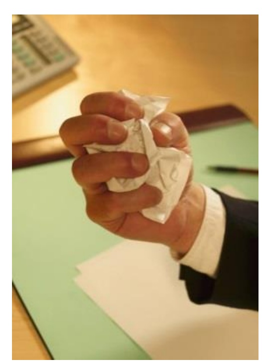
1. Follow the directions in each box on the activity sheet (page 125).
2. Determine whether a physical or chemical change has taken place.
3. Explain your answer in the box stating the reason you chose it.
4. Discuss your answers with your classmates.

Discussion

1. What is a physical change?
2. What is a chemical change?
3. When a material corrodes or rusts, is the change physical or chemical? Why?
4. Make of list of physical changes you have observed at other times. Make a list of chemical changes you have observed.

Extensions

Make a poster that explains the difference between chemical and physical changes. Create a skit or song that clarifies the differences.



Look at these images, what physical changes do you observe? Chemical changes?

Changing Changes—Continued

Changing Changes Activity Sheet

As a group, read and follow the directions in each box in the left column. Individually, mark if the change was a physical or chemical change and write why you chose that type of change. In your group, discuss each person's decision and come to a consensus.

Direction	Physical Change?	Chemical Change?	Rational
Observe as your teacher burns a sheet of paper. Observe the ashes in your bag.			
Add the baking soda to the cup of vinegar. Stir.			
Flatten the ball of clay.			
Crumple a sheet of paper into a ball.			
Hold an ice cube in your hand and observe the changes.			
Crush the cookie.			

After coming to a consensus as a group, write below your final decision for each and a short explanation.

Rusting Away

Materials per Group

- 5 pieces of steel wool (without soap)
- 5 shallow plastic disposable bowls
- 4 small clear jars
- 15 mL baking soda
- 60 mL vinegar
- 15 mL salt
- 180 mL water
- 2 stir sticks
- 2 tongue depressors (or tweezers)
- 5 paper plates
- safety goggles

Teacher Prep
Create a set of materials for each group.

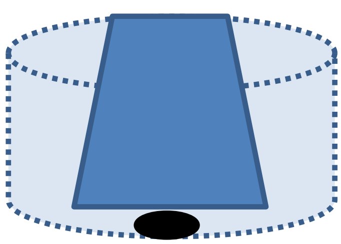
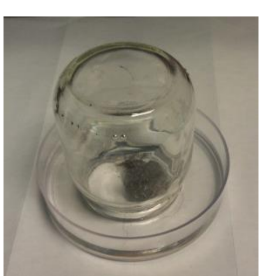


Diagram: Small shallow bowl with solution and steel wool (at bottom) covered with clear jar or cup.



Purpose: To observe the destructive properties of rust, and to predict how rust forms in different environments

Background
Corrosion is a naturally occurring physical and chemical deterioration, or break down, of a material as it reacts with oxygen and other parts of its environment, such as acids, salts, or moisture. Corrosion takes place slowly over a long period of time. Often there are no clues to announce that the reaction is taking place until the corrosion is seen. In the United States, corrosion of metals causes more than five billion dollars of damage each year. Different metals corrode in different ways. When iron is exposed to oxygen for an extended period of time, iron oxide (Fe_2O_3) or rust, is formed on the surface. Because the rust is porous, exposure to oxygen and water in the air continue the corrosion process until the metal is entirely broken down.

When copper is exposed to gases in the air, the product of the corrosion reaction is a green finish that acts much like a coat of paint in preventing the air from further reaching the metal so only the surface of the object corrodes. This green coating is a layer called patina. Corrosion on silver is a dull tarnish that changes the physical appearance of the silver. Tarnish can be removed using another chemical reaction with aluminum foil and baking soda.

Scientists and researchers study ways to reverse the problems of corrosion and to prevent corrosion from happening, and conservators work to find ways stop or slow the corrosion of artifacts.

Procedure

1. Put on your safety goggles.
2. Label each bowl:
   a. Water
   b. Salt
   c. Baking soda
   d. Vinegar
3. Pour the vinegar into the bowl labeled vinegar.
4. Pour 60 mL of water into each of the other three bowls.
5. In the bowl marked “salt,” add the salt to the water and stir until dissolved. Discard stir stick.
6. In the bowl marked “baking soda,” add the baking soda to the water and stir until dissolved. Discard stir stick.
7. Place a piece of steel wool in each bowl.
8. Turn a jar upside down over each piece of steel wool in the bowl to form a sealed environment. See diagram.
9. Label the last bowl, “control.”
10. Put a dry piece of steel wool in the control bowl and leave it uncovered.
11. Place the bowls in a location where they will not be disturbed.
12. Predict what will happen to the steel wool in each of the bowls.
13. Determine which bowl will show the most change. Record your predictions on your Student Observation Chart.
14. Over the next four days, while wearing your safety goggles, observe the steel wool. Record your observations on the Student Observation Chart.
15. Label 5 paper plates, using the same labels as the bowls.

Rusting Away—Continued

16. On day 5 put on your safety goggles and remove the steel wool from each of the bowls and place them on the corresponding paper plate.
17. Using the tongue depressors (or tweezers if available), pull apart each piece of steel wool.
18. Observe what happens and record your observations.
19. Compare the "control" sample to the other samples.

Discussion

1. What happened to the steel wool pieces in each of the bowls?
2. Which bowl showed the most change after four days?
3. Why is it important to protect metal surfaces from corrosion?
4. Using what you have learned from your test results, how does iron react in salt water? Fresh water?

Student Observation Chart

Day	Water	Baking Soda	Vinegar	Salt Water	Control
Prediction					
0					
1					
2					
3					
4					

In your science journal, answer the following questions:

1. Which piece of steel wool rusted the fastest?
2. Which piece rusted the most?
3. What happened when you used the tongue depressors to pull apart the steel wool from the four experimental containers?
4. What happened when you tried to pull apart the control piece of steel wool?
5. Explain what this activity taught you about rust?

Extensions

1. Place one of the rusty pieces of steel wool in a glass of cola for an hour. What happens to the rust? Can the metal that was destroyed be replaced?
2. Visit a car dealership or automotive shop that puts protective coatings on the underside of a car. Interview the technician to find out what the coating is made from and why it is used.
3. Repeat this same experiment using pennies, paper-covered metal twist ties, and brass nails. Make a poster to compare and contrast the results. What does this experiment tell you about the corrosion of different metals in the same environments? Use this information to talk about the kinds of buildings that might be built in different climates or which kinds of metals will need the most protection from corrosion.

Shiny as a New Penny

Materials per Group

- pennies that are not shiny (at least 8 for each group)
- 7 small plastic cups
- graduated cylinder or beaker
- 30 mL water
- 30 mL vinegar
- 15 mL baking soda mixed in 30 mL water
- 30 mL lemon juice
- 30 mL liquid hand soap
- 15 mL salt mixed in 30 mL water
- 30 mL ketchup
- tape
- soft paper towels
- seven litmus strips

Teacher Prep

Review acids and bases and how to use a litmus strip.

Extensions

- Visit the United States Mint web site http://www.usmint.gov to learn more about the metals that are used in coins.
- Visit or contact a museum to find out how they clean and restore their paintings or other artifacts. Prepare a report to share with your class.

Purpose: To predict the most effective way to clean a penny

Background

Scientists are always looking for ways to protect metals and prevent corrosion. Because different metals corrode in different ways, scientists can develop new combinations of metals that will resist corrosion and last longer.

Although many common items are made of metals, the composition of the metals used today may be different than in the past. Pennies are a good example of this difference.

- From 1793 to 1837, pennies were made of pure copper.
- From 1837 to 1857, pennies were made of bronze (95% copper and 5% tin and zinc).
- From 1857 to 1864, the penny was 88% copper and 12% nickel, giving the coin a whitish appearance.
- From 1864 to 1962 (except for the year 1943), the penny was again bronze.
- In 1943, copper was needed for use in World War II, so most of the pennies that were minted, or made, were zinc-coated steel coins.
- In 1962, the small amount of tin that was used in earlier pennies was removed, making the metal composition of the one cent piece 95% copper and 5% zinc.
- From mid-1982 to present day, pennies are made with 97.5% zinc and 2.5% copper.

A penny is shiny when it is first made, but exposure to oxygen and dirt cause it to become dull and turn dark brown. Copper oxide forms and coats the penny, much like tarnish on silver. Copper oxide reacts with mild acids. When dipped in an acidic solution the copper oxide dissolves, leaving a bright shiny penny again.

Archaeologists, museum curators, and art restoration technicians all use a variety of cleaning methods to restore artifacts. Scientists have discovered that oxygen atoms react with organic materials causing them to dissolve. Many common laundry and carpet cleaners today use the power of oxygen to boost their cleaning power. People who do metal restoration must take into consideration the time period that the metal was made because metals were created differently throughout time just like the penny. Knowing the time period helps archeologists to know how best to clean or restore the item.

Procedure

1. Predict which chemicals will clean the pennies, making them shiny again.
2. Write your predictions in your science journal and explain your predictions.
3. Label each cup—water, vinegar, water and baking soda, lemon juice, soap, saltwater, and ketchup.
4. Using a graduated cylinder or beaker, measure and pour the amounts listed for each cup.
5. Place a penny into each cup.
6. Leave the last penny on the table. This penny is your control.
7. Leave the pennies in the cups overnight.
8. Observe the penny the next day and record your observations. What changes did you see?
9. Remove one penny from its solution.
10. Rinse the penny with plain water and dry with a soft paper towel.
11. Observe the penny after it is rinsed and dried. Record your observations.

Shiny as a New Penny—Continued

12. Tape the penny onto the chart in the correct space provided.
13. Repeat with the other pennies, one at a time.
14. Determine which solutions cleaned the pennies best.
15. Test each solution using a litmus paper strip to determine if the solutions were primarily acids or bases.

Discussion

1. What changes did you observe after the pennies had soaked in the solutions overnight?
2. Which solutions were the most effective to clean the pennies?
3. Why do you think rinsing the pennies with water made a difference?
4. Would you achieve the same effect by simply wiping the pennies with a clean paper towel? Why or why not?
5. What conclusions can you draw about the types of substances that would best remove corrosion from a copper surface?

Penny Observation Chart

Solution	Prediction	Results before Rinsing	Results after Rinsing	pH of Solution (Acid or Base)	Penny (Tape in Box)
Water					
Vinegar					
Water and Baking Soda					
Lemon Juice					
Soap					
Salt Water					
Ketchup					

What do the results tell you?

Picking Up the Pieces

Materials per Group

- basket of artifacts
- science journal

Teacher Prep
Purchase or acquire several inexpensive and various shaped ceramic objects from places such as a thrift store or flea market. If possible, have two objects that are similar. Carefully break the objects into many pieces and remove several of the pieces. Divide the class into small groups. Either give each group a basket with most of the pieces for several objects, or for more difficulty, divide the broken pieces among all the groups in class.

Purpose: To understand the difficulty in piecing together artifacts

Background
Once a maritime archaeologist has unearthed the artifacts, recorded their location, and documented each piece, the scientific process of archaeology continues. The artifacts are usually brought back into a lab where they may be washed, counted, weighed, and catalogued. Next, archaeologists carefully sort the artifacts into groups according to their characteristics. Think of the last time you put a puzzle together. Did you first find all the edge pieces? Or did you find all the ones of the same color? Similarly, an archaeologist sorts the artifacts and any pieces. Pottery is an important artifact for archaeologists to find. It doesn't break down as easily as cloth, and it is often the most abundant artifact found. Another helpful characteristic of pottery is that the method and style for making pottery changes over time and in different cultures. Therefore, pottery can be used to determine the age of the site and its relationship to other cultures.

Procedure
1. Carefully, observe the pieces of artifacts in your group's basket.
2. Come to a consensus in your group how to best sort the artifacts and carefully sort them.
3. Once the artifacts are sorted, try to put the pieces together and to determine what type of object the artifact once was.
4. Continue until you either have no more pieces or you can no longer make them fit together.
5. As a class, discuss the difficulty of piecing together the artifacts.
6. If you have only some of the pieces and other groups have the other pieces, send a group member to look at each of the other groups' pieces.
7. If there is a group that has similar pieces as your artifacts, join them and try to put the artifacts together.

Discussion
1. What was the most difficult part about putting the pieces together?
2. In a real archaeological recovery, why might there be missing pieces?
3. Are all artifacts always identified?

Extension
Place three animal cookies in a small baggie and gently break them apart. On a flat surface and a paper towel, spread the cookies apart. Try to put the cookies back together again. Don't eat until you have them together…well almost together at least!

Socratic Seminar

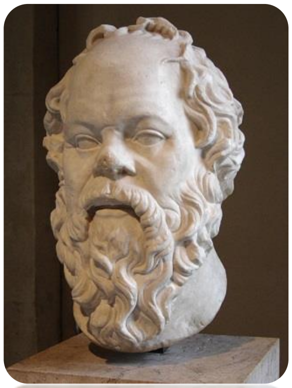
Purpose: To inquire, discuss and justify the course of action that should be taken to best preserve the shipwreck *Betsy*.

Background
Socratic seminars are named for one of the most interesting and influential thinkers of the fifth century, Socrates. Socrates was born around 470 B.C, in Athens, Greece. His *Socratic Method* became the groundwork for Western systems of logic and philosophy. He believed in the power of asking questions and encouraged inquiry and discussion. Although Socrates left no written legacy of his own, we know much about him and his philosophy through the writings of his students, such as Plato and Xenophon.

A Socratic seminar is a formal discussion in which a leader asks open-ended questions. Throughout the discussion, students listen to the answers and comments of others and think critically for themselves in order to offer their own thoughts and responses.

During the discussion some basic rules should be followed:

- Be courteous at all times
- Listen while others are talking
- Support all comments with evidence from the source
- Avoid raising your hand to talk – instead jump in at an appropriate time
- When disagreeing with a previous comment, disagree with the idea rather than attack the person
- Address the group when talking, not the teacher



You are responsible for:
- Asking questions
- Asking for clarification
- Being courteous and respectful
- Pausing and thinking before responding
- give your opinions clearly
- Make judgments hat you can defend with facts and evidence
- Explain how you derived any inferences
- Listening patiently as peers share their ideas
- Listening critically to others' opinions and taking issue with an inaccuracies or illogical reasoning
- Move the seminar forward to new concepts
- Listen to a peer's entire position before responding
- Exhibit mature behavior

Discuss:
The shipwreck *Betsy*, has been discovered, documented, and surveyed. You have met with archaeologists, conservators and others to learn all you can about conservation and the protection of a shipwreck. Now discuss all options available for the best protection and preservation of *Betsy*.

Past, Present, and Future

Final Presentation

You have travelled into *Betsy's* past and dove into her history to learn more about her mission and the people who sailed on her. You explored the ship as she sits today, discovered the rich biological community that now resides, and you surveyed, documented and recorded all details of the wreck site. You discussed the pros and cons of releasing the sites' coordinates to the general dive community and have evaluated the ship's historical significance. You learned the intricacies involved in the conservation process and now have a better understanding of the costs associated with any artifact recovery. Finally, you discussed all this information with your peers, listened to their ideas and after much critical thought, formed new ideas of your own.

It is now time for you to decide what is best for protecting and preserving the newly discovered shipwreck, *Betsy*. You may work as an individual or in a small group of not more than three. You will create a final presentation that outlines your choice of what should be done with *Betsy*. Your presentation must have supporting documentation and you need to be ready to defend your choice.

Presentation Criteria

The form of your final presentation will be determined by your teacher, but might include a PowerPoint presentation, poster, and/or written text. Below is a rubric for how your presentation will be scored.

Category	Scoring Criteria	Max Point Value	Score
Organization (15 points)	Type of presentation is appropriate for the topic and audience	5	
	Information is presented in a logical sequence	5	
	Presentation appropriately cites references	5	
Content (45 points)	Introduction grabs your attention, lays out the problem well, and establishes a framework for the presentation	5	
	Technical terms are used appropriately for the target audience	5	
	Presentation contains accurate information	10	
	Material is relevant to the overall message/purpose	10	
	Material supports the points made and reflects well their relative importance	10	
	There is an obvious conclusion and summarization	5	
Presentation (40 points)	Speaker maintains good eye contact and is appropriately animated	5	
	Speaker uses a clear, audible voice	5	
	Delivery is poised, controlled, and smooth	5	
	Good language skills and pronunciation are used	5	
	Visual aids are well prepared, informative and not distracting	5	
	Length of presentation is within assigned time limits	5	
	Information was well communicated	10	
Score	**Total Points**	**100**	

Note: Invite others to view your final presentations. If there is a museum or other appropriate institution nearby, send them an invitation to be a judge.