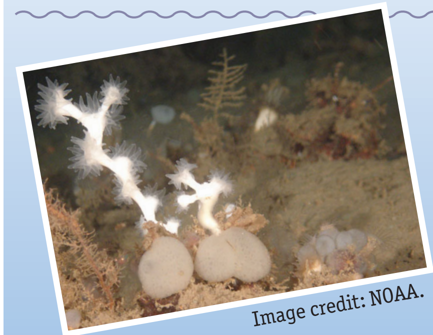
Lophelia II 2009:
Deepwater Coral Expedition: Reefs Rigs, and Wrecks

An Oceanographic Proxy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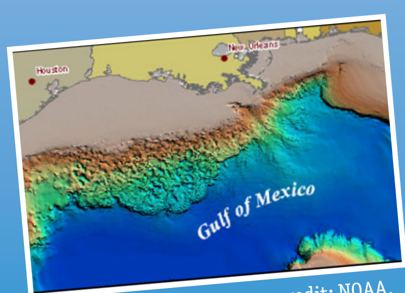

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Image captions on Page 2.

lesson plan

Focus
Conductivity and Salinity in Seawater

Grade Level
9-12 (Physical Science/Earth Science)

Focus Question
How can the salinity of seawater be measured using conductivity?

Learning Objectives
- Students will be able to define salinity and conductivity.
- Students will be able to describe the relationship between salinity and conductivity.
- Students will be able to construct a simple conductivity meter and use it to demonstrate the relationship between conductivity and salinity.
- Students will be able to explain how a conductivity measurement may be used as a proxy for a salinity measurement.

Materials
- Copies of *Salinity and Conductivity Inquiry Guide* and *Conductivity Meter Construction Guide*, one copy for each student group
- Materials for conductivity meters (for one student group)
  - 1 Plastic food storage container with flat sides, about 4 oz capacity
  - 2 Rubber grommets to fit 5/16” hole, with 3/16” center hole
  - 2 Stainless steel bolts, 3/16” diameter, about 3/4” long
  - 2 Stainless steel washers, 3/16” diameter hole
  - 2 Stainless steel nuts to fit bolts
  - 2 Jumper cables (Radio Shack Part Number 278-1156, or equivalent)
  - 1 Ohm meter or multimeter (may be shared by several student groups; (Radio Shack Part Number 22-820, or equivalent; be sure the meter is capable of measuring at least 10 megohms)
- Hand or electric drill
- 5/16” drill bit
- Screwdriver to fit bolts
- Small wrench or pliers to fit nuts

- Sodium chloride (kosher salt is adequate); quantity depends upon number of student groups; see Learning Procedure, Step 1
- 1000 ml graduated cylinder
- Containers for seawater dilutions; quantity depends upon number of student groups; see Learning Procedure, Step 1

[*NOTE: Mention of trademarks or proprietary names does not imply endorsement by NOAA*]

Audio-Visual Materials

None

Teaching Time

One or two 45-minute class periods, plus time for student inquiry

Seating Arrangement

Groups of two to four students

Maximum Number of Students

32

Key Words

Deep-sea coral
Lophelia
Salinity
Conductivity
Proxy
Conductance
Resistance

Background Information

[*NOTE: Explanations and procedures in this lesson, except for the Inquiry Guide, are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.*]

Deepwater coral ecosystems on hard substrates in the Gulf of Mexico are often found in locations where hydrocarbons are seeping through the seafloor. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, and make these locations potential sites for exploratory drilling and possible development of offshore oil wells. Responsibility for managing exploration and development of mineral resources on the Nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found.

Images from Page 1 top to bottom:
Lophelia pertusa colony with polyps extended.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

The ROV from SeaView Systems, Inc., is prepared for launch.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept20/media/rov_prep.html

Multibeam bathymetry allows terrain models to be created for large areas of the seafloor.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept21/media/gomex_multibeam.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

For the past three years, NOAA's Office of Ocean Exploration and Research (OER) has collaborated with MMS on a series of expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. These communities not only indicate the potential presence of hydrocarbons, but are also unique ecosystems whose importance is presently unknown. To protect these ecosystems from negative impacts associated with exploration and extraction of fossil fuels, MMS has developed rules that require the oil and gas industry to avoid any areas where geophysical survey data show that high-density chemosynthetic communities are likely to occur. Similar rules have been adopted to protect archeological sites and historic shipwrecks.

OER-sponsored expeditions in 2006, 2007, and 2008 were focused on discovering seafloor communities near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico; detailed sampling and mapping at selected sites; studying relationships between coral communities on artificial and natural substrates; and gaining a better understanding of processes that control the occurrence and distribution of these communities. The *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks will take place aboard the NOAA Ship *Ronald H. Brown*, and is directed toward exploring deepwater natural and artificial hard bottom habitats in the northern Gulf of Mexico with emphasis on coral communities, as well as archeological studies of selected shipwrecks in the same region.

One of the most fundamental questions for every investigation of ocean ecosystems is, "How salty is the water?" This lesson guides a student inquiry into the method most often used to answer this question.

Learning Procedure

1. To prepare for this lesson:
- Review introductory essays for the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html;
- Review procedures and questions on the *Salinity and Conductivity Inquiry Guide*, and make copies for student groups.
- Collect materials needed for students to construct conductivity meters. Multimeters may be shared by more than one group if necessary. Note that the size of the grommets is not particularly critical, but the diameters of the drill bit and the bolt must match the grommet size. Most hardware stores will have grommets, bolts, washers, and nuts in the specified sizes. It doesn't matter whether you use brass or stainless steel hardware, but bolts, washers, and nuts should all be the same material.
- Make sodium chloride test solutions. Each student group will need about 300 ml of each solution. To make 1 l of each solution, first prepare 3 l of a 2.0 M solution by dissolving 350 g NaCl in 3 l of water (ordinary tap water and table salt are adequate). Next, make a 1.5 M,

1.0 M, and 0.5 M solutions by diluting volumes specified in Table 1 to a final volume of 1.0 l.

Table 1

Volumes of a 2.0 M NaCl Solution Needed to Make 1.0 l of Other Concentrations

To Make this Concentration	Use this Volume of a 2.0 M Solution
1.5 M	750 ml
1.0 M	500 ml
0.5 M	250 ml

- The focus of this inquiry is the relationship between concentration of dissolved salt and conductivity, but this scope may be broadened to include other factors that affect salinity such as ionic mass and temperature. See "Extensions" for suggestions.

2. Briefly introduce the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and describe deepwater coral communities. You may want to show images from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html. Tell students that while deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, very little is known about the ecology of these communities or the basic biology of the corals that produce them. Emphasize that a primary purpose of this expedition is to provide information needed to protect these deepwater coral ecosystems from negative impacts associated with exploration and extraction of fossil fuels. Say that one of the most basic pieces of information needed for the study of marine ecosystems is a measurement of the "saltiness" of the water surrounding the ecosystems being investigated.

   Discuss the concept of salinity. Be sure students understand that while it is common to refer to ocean water as "salty," normal seawater contains many dissolved compounds in addition to sodium chloride (see sidebar at left). Ask students how these dissolved compounds make seawater different from fresh water. Students who have been swimming in the ocean will probably recall that it is easier to float in salt water than in fresh water, and should recognize that this is because dissolved substances increase the density of seawater. Increased density results in a greater buoyant force than in fresh water, according to Archimedes' Principle. Students may also say that the osmotic pressure of seawater is higher than that of fresh water, and may recognize that the ionic composition of seawater is very similar to that of human blood. If students do not mention

Approximate Composition of Normal Seawater (moles)

55.3 % Chlorine
30.8 % Sodium
3.7 % Magnesium
2.6 % Sulfur
1.2 % Calcium
1.1 % Potassium

conductivity, ask whether seawater or fresh water is a better conductor of electricity.

Briefly discuss some ways that students could measure salinity. The most direct method would be to evaporate all of the water from a sample and weigh the remaining substances. This is time-consuming, however, and not really practical for making a large number of measurements in the field. Point out that since dissolved substances change certain properties of water, these changes can provide a way to estimate the quantity of dissolved material, and hence provide an estimate of salinity. This is called measuring with a proxy. There are many other examples of proxy measurements, such as using growth rings to estimate the age of trees.

Density can be measured with a hydrometer and used as a proxy for salinity (temperature of the water sample must be measured at the same time, because density also changes with temperature). Another classic technique is to measure one dissolved substance (chloride) with chemical reactions, and then convert this measurement to an estimate of salinity (which is possible because the major dissolved substances in seawater occur in about the same ratio throughout Earth's ocean). Today, the most common method for measuring salinity uses conductivity as a proxy.

Unfortunately, it is easy to confuse the terms conductance and conductivity. The conductance of a solution is the amount of electric current that flows through the solution at a specified voltage

$$S = I \div E$$

where S is conductance in siemens, I is current in amperes, and E is voltage in volts.

Conductance is the reciprocal of resistance, so one can measure the resistance of a solution and divide the measurement into 1 to find the conductance. The actual value of this measurement will depend upon the ability of the solution to conduct electrons, as well as the temperature of the solution, the surface area of the electrodes used to make the measurement, and the distance between the electrodes. This means that a series of conductance measurements of a single solution could produce different values if different electrodes were used for each measurement. To correct for this, conductance measurements are usually multiplied by a cell constant, which is equal to the space between the electrodes divided by the surface area of the electrodes. The result is known as conductivity. So,

$$k = S \bullet d \div A$$

where k is conductivity, S is conductance in siemens, d is the distance between the electrodes in cm, and A is the surface area of the electrodes in cm^2. The units of k are siemens/cm.
In practice, conductivity meters are calibrated shortly before making measurements. Calibration is done with a solution whose conductivity is known, and adjusting the meter so that it displays the correct conductivity value. Research-grade instruments also include circuits to compensate for temperature so that measured conductivity values correspond to conductivity at 25°C.

The *Salinity and Conductivity Inquiry Guide* does not include a calibration step, since the described activity is concerned with comparing the conductivity of various solutions measured with the same apparatus. If you want different student groups to be able to compare their measurements, arbitrarily select one group as the reference group, and have other groups compare their measurement of the conductivity of a 2.0M NaCl solution to the reference group's measurement. Each group should calculate a conversion factor and multiply their readings by this factor to make the readings equivalent to those of the reference group.

Oceanographers usually measure salinity with an instrument called a CTD, which collects data on conductivity, temperature, and depth. For more information about CTDs, visit http://www.oceanexplorer.noaa.gov/technology/tools/sonde_ctd/sondectd.html.

Tell students that their assignment is to make a simple conductivity meter, and use this instrument to investigate the relationship between conductivity and the concentration of a salt solution.

Provide each student group with a copy of the *Salinity and Conductivity Inquiry Guide* and required materials. Remind students to:

- Take meter readings within three seconds of adding a test solution to the conductivity cell;
- Rinse their conductivity cells after each measurement; and
- Wipe the bolt heads with a paper towel after each measurement.

Now on with the Inquiry!

4. Discuss the results of students' inquiries. Bubbles formed on the bolt heads by electrolysis of water are the source of the greatest potential variability, but this can be minimized by taking resistance readings within three seconds of pouring the test solution into the conductance cell, and by wiping the bolt heads between each reading.

   Be sure students understand that their conductivity meters actually measure resistance, which is the opposite of conductance. This makes intuitive sense, and is reflected in the formal relationship between the two parameters according to Ohm's law:

$$R = E \div I \text{ and } S = I \div E$$

where R is resistance in ohms, E is voltage in volts, I is current in amperes, and S is conductance in siemens. Students convert resistance to conductance by finding the reciprocal of the average resistance; commercial conductivity meters make this conversion automatically. Commercial instruments also use more complex electronics to eliminate the bubble problem.

Students should also realize that this inquiry measures the *relative* conductivity of the solutions being tested; not the absolute conductivity. Absolute conductivity includes the cell constant, so that measurements of the same solution should have the same value regardless of the instrument used for measurement.

Ask students why salinity is an important environmental factor to measure during the *Lophelia* II 2009 Expedition, since this expedition takes place far from land masses and rivers that might affect salinity. In fact, salinity in the water column probably doesn't vary a great deal; but remember that this expedition is concerned with deepwater bottom habitats. Brine pools are small lakes found in various locations on the Gulf of Mexico seafloor. They exist because they contain very salty water which is denser than the surrounding water. Brine pools are the result of a process called salt tectonics, which refers to the movement of large salt deposits that were formed during a time when the Gulf dried out and were later buried by sediment. When these salt deposits come into contact with seawater, they dissolve, and form brines many times saltier than normal seawater. Some brine pools have dense communities of chemosynthetic organisms nearby, but very little is known about these communities. Salinity measurements near the Gulf of Mexico seafloor may provide clues to the location of undiscovered brine pools and lakes.

For more information and images about brine pools see: http://oceanexplorer.noaa.gov/explorations/02mexico/background/brinepool/brinepool.html.

The Bridge Connection

http://www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then "Habitats," then "Deep Sea" for links to resources and activities related to chemosynthetic communities in the deep ocean. See http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive0905.html for another activity related to conductivity.

The "Me" Connection

Have students write a brief essay describing how they use proxies to obtain information about their environment.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics

Assessment

Students' Inquiry Guide reports and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html to find out more about the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks.
2. The conductivity meter can also be used to investigate other factors that affect conductivity of ionic solutions. The effect of ionic mass can be studied by comparing the conductivity of 1.0 M solutions of different salts such as NaCl, KCl, NaBr, and KBr. The effect of temperature can be studied by comparing the conductivity of 2.0 M NaCl s that are heated in a hot water bath, cooled in an ice bath, and measured at room temperature.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(*All of the following Lesson Plans are targeted toward grades 9-12*)

What's the Difference?
(PDF, 300 kb) (from the Lophelia II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf

Focus: Identification of biological communities from survey data (Life Science)

In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

My Wet Robot
(300kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles (Physical Science)

In this activity, students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Cool Corals
(7 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/corals.pdf

Focus: Biology and ecology of Lophelia corals (Life Science)

In this activity, students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

This Old Tubeworm
(10 pages, 484k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus: Growth rate and age of species in cold-seep communities (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

Biochemistry Detectives
(8 pages, 480k) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus: Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

Hot Food
(4 pages, 372k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf

Focus: Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)

In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deepwater coral reef communities.

What Was for Dinner?
(5 pages, 400k) (from the 2003 Life on the Edge Expedition)
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/dinner.pdf

Focus: Use of isotopes to help define trophic relationships (Life Science)

In this activity, students will describe at least three energy-obtaining strategies used by organisms in deep-reef communities and interpret analyses of ^{15}N, ^{13}C, and ^{34}S isotope values.

Chemosynthesis for the Classroom
(9 pages, 276k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Chemo.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

In this activity, students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

C.S.I. on the Deep Reef
(Chemotrophic Species Investigations, That Is)
(11 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20CSI.pdf

Focus: Chemotrophic organisms (Life Science/Chemistry)

In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

This Life Stinks
(9 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

In this activity, students will be able to define the process of chemosynthesis, and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.gomr.mms.gov/index_common.html - Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf (PDF) - *Chemosynthetic Communities in the Gulf of Mexico* teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students.

http://www.coast-nopp.org/ - Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ - Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Structure and properties of matter

Content Standard C: Life Science
- Interdependence of organisms

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying

more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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For More Information

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An Oceanographic Proxy
Salinity and Conductivity Inquiry Guide

Background

Salinity is defined as the content of dissolved salts in seawater. Since seawater contains a variety of salts (magnesium sulfate, magnesium chloride, calcium carbonate, etc.) in addition to sodium chloride, salinity is not directly equivalent to the concentration of sodium chloride in seawater. Historically, salinity was measured in grams of dissolved salts per kilogram of seawater, which is equivalent to parts per thousand (ppt or ‰). Because modern oceanographers almost always use conductivity to measure salinity, they now use practical salinity units (psu) instead of ppt. The salinity of full strength seawater is about 35 psu, while the salinity of fresh water is 0 psu.

Conductance is a measure of a material's ability to pass electrons, and is the opposite of resistance (which is a measure of a meterial's opposition to the flow of electrons). The unit of resistance measurements is the ohm, which is the resistance of an electrical circuit in which a voltage of one volt produces a current of one ampere. Conductance is defined as the reciprocal of resistance and its unit formerly was the mho (ohm spelled backward). Most scientists now use the siemen as the unit of conductance, but it is equivalent to the mho. In water, conductance is related to the concentration of dissolved ions. For this reason, conductance can be used to estimate salinity.

Because the amount of electricity that flows between electrodes in a solution depends upon the distance between the electrodes as well as the surface area of the electrodes, a slightly different measurement called conductivity is used that takes these factors into account. The units of conductivity are siemens per centimeter (S/cm). Since 1S/cm is a very high level of conductivity for most solutions, conductivity is usually expressed in millisiemens per centimeter (mS/cm) or microsiemens per centimeter (μS/cm). One millisiemen is one-thousandth of a siemen, and one microsiemen is one-millionth of a siemen. Conductivity increases with increasing temperature, so measurements are usually reported as specific conductivity, which means the conductivity value that would be obtained at a temperature of 25°C. The specific conductivity of fresh water ranges from 0.001 to about 1.000 mS/cm. The specific conductivity of full strength seawater is about 55 mS/cm.

Inquiry

Your assignment is to make a simple conductivity meter, and use this instrument to investigate the relationship between conductivity and the concentration of a salt solution.

1. Construct your conductivity meter according to directions in the Conductivity Meter Construction Guide.
2. To use your conductivity meter:
   a. Pour about 100 ml of the solution to be tested into the conductivity cell. Be sure the solution completely covers the bolt heads.
   b. Record the resistance reading no more than three seconds after pouring the test solution into the conductivity cell (If you wait, you will notice that the resistance reading continues to rise. This is because bubbles are forming on top

An Oceanographic Proxy
Salinity and Conductivity Inquiry Guide - continued

of the bolt heads due to electrolysis of water, and resistance between the bolt heads increases as the bubbles build up). Be sure to note the units displayed by your meter; these will probably be kilohms (1,000 ohms) or megohms (1,000,000 ohms).

c. After you have recorded the reading, dispose of the test solution as directed by your teacher, then rinse the conductivity cell with tap water and wipe the bolt heads with a paper towel.

d. Repeat the test process three times for each solution then calculate the average resistance.

e. Convert resistance to conductance by dividing resistance in ohms into 1.0. The units of conductance will be siemens. If the numbers are very small, you may want to use millisiemens (1 mS = 0.001 S) or microsiemens (1 µS = 0.000001 S). For example, if the average resistance of a solution is 10,000 ohms (10 kilohms), the conductance is

$$1 \div 10{,}000 = 0.0001 \text{ S} = 0.1 \text{ mS} = 100\ \mu\text{S}$$

3. Measure the conductance of 2.0 M, 1.5 M, 1.0 M, and 0.5 M sodium chloride solutions, and tap water. Measure the least concentrated solution first to minimize possible contamination by salt remaining from previous measurements.
4. Plot the average conductance as a function of solution concentration. What do your data show about the relationship between concentration and conductance?

Conductance Data Sheet

Solution	Resistance			Average Resistance	Average Conductance
	Trial 1	Trial 2	Trial 3		

An Oceanographic Proxy
Conductivity Meter Construction Guide

Materials

1 Plastic food storage container with flat sides, about 4 oz capacity
2 Rubber grommets to fit 5/16” hole, with 3/16” center hole
2 Brass or stainless steel bolts, 3/16” diameter (also called #10 size), about 3/4” long
2 Brass or stainless steel washers, 3/16” diameter hole
2 Brass or stainless steel nuts to fit bolts
2 Jumper cables (Radio Shack Part Number 278-1156, or equivalent)
1 Ohm meter or multimeter (may be shared by several student groups; (Radio Shack Part Number 22-820, or equivalent; be sure the meter is capable of measuring at least 10 megohms)

[*NOTE: Mention of trademarks or proprietary names does not imply endorsement by NOAA*]

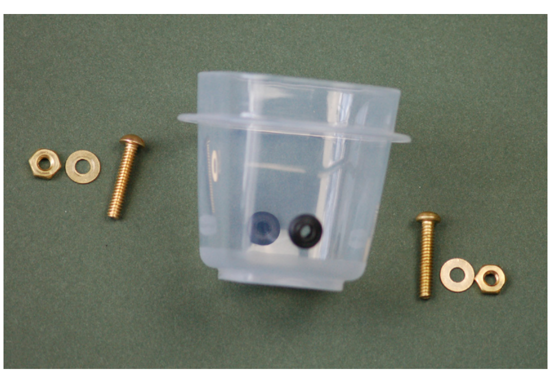
Tools

Hand or electric drill
5/16” drill bit
Screwdriver to fit bolts
Small wrench or pliers to fit nuts

Construction Procedure

1


1. Drill two 5/16” holes on opposite sides of the plastic food storage container, about 3/4” from the bottom of the container.

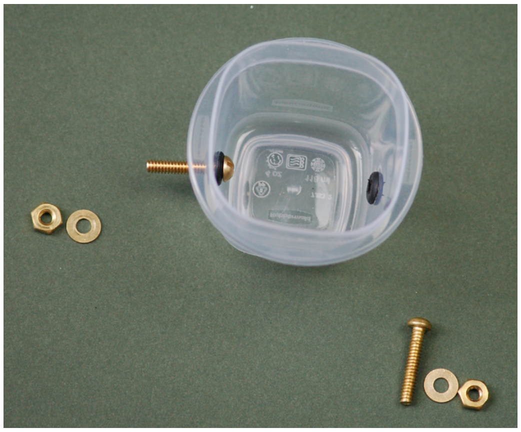
2


2. Install a rubber grommet in each hole.

An Oceanographic Proxy

Conductivity Meter Construction Guide - continued

3a



3. Starting from the inside portion of each grommet, install a stainless steel bolt through the grommet, and place a stainless steel washer and stainless steel nut onto the bolt. Hold the bolt with a screwdriver, and tighten the nut until the rubber grommet is slightly compressed. Do not crush the grommet.

3b

4. Pour water into the plastic container until it is about half full. Check to be sure no water is leaking around the bolt or grommet. If there is a leak, tighten the nut a little more. This assembly is called a conductivity cell.

5

5. Attach one end of a jumper cable to one of the bolts, and the other end to one of the test leads on your ohm meter. Use a second jumper cable and repeat for the other bolt and other test lead. If you are using a multi meter, set the meter to measure resistance (ohms).

6. Your conductivity meter is completed and ready to use!