

## Corrosion to Corals

(updated from the 2008 Deepwater Coral Expedition: Reefs, Rigs, and Wrecks)



### Focus

Galvanic exchange and carbonate precipitation

### Grade Level

7-8 (Physical Science)

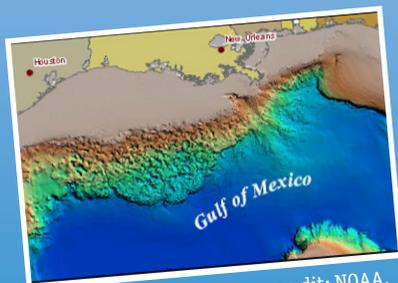
### Focus Question

What can cause electrical currents in deep oceans, and how might these currents affect reef-building corals?



### Learning Objectives

- ⊗ Students will be able to describe galvanic exchange and explain how this process produces electric currents.
- ⊗ Given two dissimilar metals and information on their position in an Electromotive Series, students will be able to predict which of the metals will deteriorate if they are placed in a salt solution.
- ⊗ Students will be able to describe the effect of electric currents on the availability of metal ions, and how this might contribute to the growth of corals on shipwrecks.



### Materials

- ✂ Copies of *Electrochemical Reactions Inquiry Guide*, one copy for each student group

### Supplies for Part I (See Learning Procedure, Step 1):

- ✂ Voltmeter with at least 0.5 volt sensitivity
- ✂ 2 jumper cables (Radio Shack Part Number 278-1156, or equivalent)
- ✂ Plastic cup (approximately 9 oz capacity)
- ✂ 3 oz seawater or artificial seawater
- ✂ Pencil "lead," approximately 3" length (a thick "lead" from a carpenter's pencil is ideal)
- ✂ Metals for testing (e.g., galvanized nail, 3" length of copper wire, aluminum nail, lead fishing weight, brass screw, steel bolt)
- ✂ Small piece of emery paper or sandpaper, 100 grit or finer

### Supplies for Part II (for one student group):

- ✂ 9-volt battery
- ✂ 2 jumper cables (Radio Shack Part Number 278-1156, or equivalent)

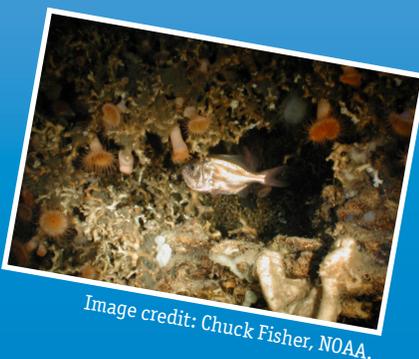


Image captions on Page 2.

- ✂ Plastic cup (approximately 9 oz capacity)
- ✂ 3 oz seawater or artificial seawater
- ✂ 2 pencil “leads,” approximately 3” length (a thick “lead” from a carpenter’s pencil is ideal)

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

### Audio-Visual Materials

 None

### Teaching Time

One 45-minute class periods

### Seating Arrangement

Groups of three to four students

### Maximum Number of Students

32

### Key Words

Deepwater coral  
Electrolytic cell  
Galvanic exchange  
Electrodeposition  
Oxidation  
Reduction  
Electrolyte

### 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](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](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](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](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 archaeological studies of selected shipwrecks in the same region. Expedition scientists will:

- Make collections of *Lophelia*, other corals, and associated organisms from deepwater reefs;
- Collect quantitative digital imagery of characterization of deepwater reef sites and communities;
- Deploy instruments to measure currents and sedimentation in several sites for a period of approximately one year; and
- Conduct archaeological/biological investigations on deep water shipwrecks.

What do shipwrecks have to do with deepwater corals? Some studies of tropical corals have shown higher growth rates in the presence of an electrical field due to the increased abundance of dissolved mineral ions (such as calcium) for calcification. Since the metal components of shipwrecks often produce electric currents, these wrecks might create conditions favorable to higher-than-normal growth rates. This lesson guides a student inquiry into the electrochemical activity of several metals, and how electrical currents might enhance the growth of corals.

### 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 *Electrochemical Reactions*

*Inquiry Guide*, and make copies for student groups. To do Part I as a student activity you will need several voltmeters. Ideally each student group should have their own meter, but it is possible for two groups to share a single meter. If only one voltmeter is available, do Part I as a demonstration and have student groups do Part II individually.

2. Briefly introduce the *Lophelia II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks*, emphasizing that very little is known about deep-water coral communities, but these communities may be important to humans in a variety of ways, including their potential as sources for new drugs to treat human diseases (for more information on this point, see the 2003 Ocean Explorer Deep Sea Medicines expedition, <http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html>).

Explain that the *Lophelia II 2009* expedition includes studies of shipwrecks as well as deep-water coral communities. Ask students what connection shipwrecks might have to deep-water corals. Some students may correctly hypothesize that shipwrecks may provide substrates that are suitable for coral larvae. Unless students mention it, do not comment on electric currents at this point. Tell students that their assignment is to conduct an inquiry that may give them some clues about another potential connection between shipwrecks and corals.

3. Provide each student group with a copy of the *Electrochemical Reactions Inquiry Guide* and materials needed for Part I, or complete Part I as a demonstration. Review the basic concept of oxidation and reduction. Be sure students understand the role of seawater in the experimental procedures, and that while oxygen is often involved in oxidation-reduction reactions, “oxidation” means loss of electrons.
4. Discuss students’ ideas about sources of electrical currents in the deep ocean, and results of Part I. Explain the concept of “galvanic exchange” (or “galvanic coupling” or “galvanic corrosion”). This process results from different metals in electrical contact with each other in seawater. Metals can be classified into an Electromotive Series (Table 1) according to the strength with which they hold on to their electrons. Metals higher in the Series tend to give up their electrons more readily than metals that are lower in the Series.

When iron rusts, iron atoms give up electrons and form positively charged iron ions that react with water and oxygen to form iron oxides. If two metals with different electromotive strengths are electrically connected and submerged in an electrolyte (such as seawater), electrons will flow from the metal higher in the electromotive series, creating an electric current (and also causing the process we know as corrosion). Besides the iron in its hull, a typical shipwreck contains many other metals such as lead, bronze, copper, and brass that are

**Table 1**  
**Electromotive Series of**  
**Some Common Metals**

Lithium
Potassium
Calcium
Sodium
Magnesium
Aluminum
Zinc
Chromium
Iron
Cobalt
Nickel
Lead
Tin
Bronze
Brass
Copper
Mercury
Silver
Platinum
Gold

lower in the electromotive series than iron. As a result, the steel in the ship's hull is degraded as iron within the steel is replaced by other compounds formed through galvanic exchange.

By using the voltmeter, students should have been able to measure an electric current when two dissimilar metals are immersed in seawater. They should also have noticed that different combinations of metals produce different voltages (the magnitude of the voltage depends upon the "half cell potentials" of the metals, but this concept is not normally studied at the target grade level for this lesson). Based on these observations, students should identify shipwrecks as a potential source of electrical currents.

5. Have each student group complete Part II, and lead a discussion of students' observations. Students should identify "something in the seawater" as a likely source of the precipitates observed around one of the electrodes. Tell students that seawater contains many different chemical substances, but most of these are in very small quantities. Students should also notice that the precipitate formed near the electrode that was connected to the negative terminal of the battery, and this may suggest that the materials forming the precipitate might have received electrons from the electrode. From the information presented in Table 2, students might hypothesize that one or more of the elements that exist as positive ions in seawater may be involved in the precipitate. If you tell students that sodium and potassium cannot exist as pure solids in water, they should identify calcium and magnesium as the most likely components of the precipitate.

Explain to students that corals reproduce by means of free-swimming larvae, and that for coral reefs to form there must be a suitable surface on which these larvae may settle. Explain that limestone rocks provide a very good surface for coral larvae, and that two of the main components of limestone are calcium and sometimes magnesium. Remind students that corals also produce limestone skeletons. Ask whether this information combined with their experimental observations suggests why shipwrecks might be good places to look for corals. Students should realize (perhaps with a few more clues) that electrical currents resulting from electrochemical reactions between dissimilar metals on shipwrecks could favor formation of suitable substrate and/or aid corals in producing limestone skeletons.

### The Bridge Connection

<http://www.vims.edu/bridge/> – Click on "Ocean Science" in the navigation menu to the left, then "Ecology," then "Coral" for resources on corals and coral reefs.

**Table 2**

**Some Chemical Components  
of Seawater**

**Component Concentration  
(mol/kg)**

H <sub>2</sub> O	53.6
Cl <sup>-</sup>	0.546
Na <sup>+</sup>	0.469
Mg <sup>2+</sup>	0.0528
SO <sub>4</sub> <sup>2-</sup>	0.0282
Ca <sup>2+</sup>	0.0103
K <sup>+</sup>	0.0102

**The “Me” Connection**

Have students write a short essay on how better understanding of deep-sea coral communities might be personally beneficial.

**Connections to Other Subjects**

English/Language Arts, Life Science, Earth Science

**Assessment**

Student 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. Have students investigate the biography of Wolf Hilbertz, who has written extensively and holds several patents dealing with the use of electrochemically deposited minerals from seawater as building materials.

**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 7-8)*

**Shipwreck Mystery**

(10 pages, 322k) (from AUVfest 2008)  
<http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/shipwreck.pdf>

Focus: Marine Archaeology (Earth Science/Physical Science/Social Science)

In this activity, students will be able to draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; use a grid system to document the location of artifacts recovered from a model shipwreck site; and identify and explain types of evidence and expertise that can help verify the nature and historical content of artifacts recovered from shipwrecks.

**I, Robot, Can Do That!**

(9 pages, 357k) (from the 2005 Lost City Expedition)  
[http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05\\_i\\_robot.pdf](http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf)

Focus: Underwater Robotic Vehicles for Scientific Exploration (Physical Science/Life Science)

In this activity, students will be able to describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

**Sonar Simulation**

(PDF, 308kb)(from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)  
<http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/sonarsim.pdf>

Focus: Side scan sonar (Earth Science/Physical Science)

In this activity, students will describe side-scan sonar, compare and contrast side-scan sonar with other methods used to search for underwater objects, and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

**This Old Ship**

(9 pages, 272 kb) (from the 2006 Phaedra Expedition)  
[http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/old\\_ship.pdf](http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/old_ship.pdf)

Focus: Ancient and Prehistoric Shipwrecks (Earth Science/Social Studies)

In this activity, students will be able to describe at least three types of artifacts that are typically recovered from ancient shipwrecks, explain the types of information that may be obtained from at least three types of artifacts that are typically recovered from ancient shipwrecks, and compare and contrast, in general terms, technological features of Neolithic, Bronze Age, Hellenistic, and Byzantine period ships.

**Mapping the Aegean Seafloor**

(8 pages, 288 kb) (from the 2006 Phaedra Expedition)  
[http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/seafloor\\_mapping.pdf](http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/seafloor_mapping.pdf)

Focus: Bathymetric mapping of deep-sea habitats (Earth Science)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, create a three-dimensional model of landforms from a two-dimensional topographic map, and interpret two- and three-dimensional topographic data.

**Monsters of the Deep**

(6 pages, 464k) (from the Expedition to the Deep Slope 2007)

<http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/monsters.pdf>

Focus: Predator-prey relationships between cold-seep communities and the surrounding deep-sea environment (Life Science)

Students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities; and will be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment. Students will also be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe at least five deep-sea predator organisms.

**One Tough Worm**

(8 pages, 476k) (from the Expedition to the Deep Slope 2007)

<http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/worm.pdf>

Focus: Physiological adaptations to toxic and hypoxic environments (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 describe three physiological adaptations that enhance an organism's ability to extract oxygen from its environment. Students will also be able to describe the problems posed by hydrogen sulfide for aerobic organisms, and explain three strategies for dealing with these problems.

**Let's Go to the Video Tape!**

(11 pages; 327kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)

<http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/videotape.pdf>

Focus: Characteristics of biological communities on deepwater coral habitats (Life Science)

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral communities, and discuss the meaning of “biological diversity.” Students will compare and contrast the concepts of “variety” and “relative abundance” as they relate to biological diversity, and given abundance and distribution data of species, will be able to calculate an appropriate numeric indicator that describes the biological diversity of a community.

**Treasures in Jeopardy**

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)

<http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf>

Focus: Conservation of deep-sea coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

**Come on Down!**

(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)

[http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal\\_gr7\\_8\\_l1.pdf](http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf)

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; students will calculate the density of objects by determining the mass and volume; students will construct a device that exhibits neutral buoyancy.

**Living by the Code**

(5 pages, 400k) (from the 2003 Deep Sea Medicines Expedition)

[http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds\\_LivingCode.pdf](http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_LivingCode.pdf)

Focus: Functions of cell organelles and the genetic code in chemical synthesis (life science)

In this activity, students will be able to explain why new drugs are needed to treat cardiovascular disease, cancer, inflammation, and infections; infer why sessile marine invertebrates appear to be promising sources of new drugs; and explain the overall process through which cells manufacture chemicals. Students will also be able to explain why it may be important to synthesize new drugs, rather than relying on the natural production of drugs.

**Life is Weird**

(8 pages, 268k) (from the 2006 Expedition to the Deep Slope)  
<http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Weird.pdf>

Focus: Biological organisms in cold seep communities (Life Science)

In this activity, students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment, and describe the process of chemosynthesis in general terms, and will be able to contrast chemosynthesis and photosynthesis.

**It's a Gas! Or Is It?**

(12 pages, 276k) (from the 2006 Expedition to the Deep Slope)  
<http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Gas.pdf>

Focus: Effects of temperature and pressure on solubility and phase state (Physical Science/Earth Science)

Students will be able to describe the effect of temperature and pressure on solubility of gases and solid materials; describe the effect of temperature and pressure on the phase state of gases; and infer explanations for observed chemical phenomena around deep-sea volcanoes that are consistent with principles of solubility and phase state.

**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://news.nationalgeographic.com/news/2007/12/071204-AP-bali-electrified.html> – Electricity Revives Bali Coral Reefs Pemuteran Bay, Indonesia, December 4, 2007

[http://www.gomr.mms.gov/index\\_common.html](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**

- Properties and changes of properties in matter

#### **Content Standard C: Life Science**

- Populations and ecosystems

#### **Content Standard E: Science and Technology**

- Understandings about science and technology

#### **Content Standard F: Science in Personal and Social Perspectives**

- Populations, resources, and environments
- Risks and benefits
- Science and technology in society

## Ocean Literacy Essential Principles and Fundamental Concepts

### Essential Principle 1.

#### The Earth has one big ocean with many features.

*Fundamental Concept g.* The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

*Fundamental Concept h.* Although the ocean is large, it is finite and resources are limited.

### 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:  
oceanexeducation@noaa.gov

### For More Information

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### Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: <http://oceanexplorer.noaa.gov>

## Corrosion to Corals

# Electrochemical Reactions Inquiry Guide

### Part I

#### Background

Electricity is a flow of electrons. In a battery, two different metals are placed in a solution in which electrons can flow. Usually, one metal will have a stronger attraction for electrons, and electrons will flow to the metal with the stronger electron attraction from the metal with the weaker electron attraction. This produces an electrical current.

#### Hands-On Inquiry

Your assignment is to investigate the electrical currents (if any) produced by different combinations of metals when they are placed in seawater.

#### Materials

- ✂ Voltmeter with at least 0.5 volt sensitivity
- ✂ 2 jumper cables (Radio Shack part number 278-1156, or equivalent)
- ✂ Plastic cup (approximately 9 oz capacity)
- ✂ 3 oz seawater or artificial seawater
- ✂ Metals for testing (e.g., galvanized nail, 3" length of copper wire, aluminum nail, lead fishing weight, brass screw, steel bolt)
- ✂ Small piece of emery paper or sandpaper, 100 grit or finer

#### Procedure



1. Start with two different metals. Set the voltmeter at its lowest setting, and connect the alligator clip on one end of a jumper cable to one of the probes from the voltmeter. Connect the alligator clip on the other end to one of the metals. Connect the alligator clip on one end of the other jumper cable to the remaining probe from the voltmeter, and connect the alligator clip on the other end to the other metal.



2. Pour about 100 ml of seawater into a plastic cup. Place the metals into the seawater so they are not touching, but are about 1 cm apart. Record the voltage reading on the voltmeter. If the needle on the voltmeter goes down or the reading is negative, reverse the probes.
3. Repeat Steps 1 and 2 with the other metals provided by your teacher until you have tested all possible combinations of the metals. It's a good idea to rub each metal briefly with a small piece of emery paper just before testing.

## Corrosion to Corals

# Electrochemical Reactions Inquiry Guide - continued

### Part II

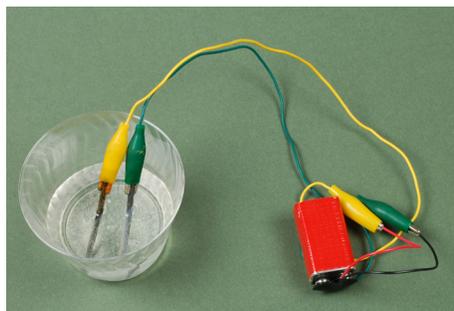
#### Background

Now we are going to see what happens when an electric current flows through seawater. For this part of the inquiry, we do not want to use a metal that will put additional ions into the water. Instead of metal electrodes, we will use electrodes made of carbon ( a non-metal).

#### Materials

- ✂ 9-volt battery
- ✂ 2 jumper cables (Radio Shack part number 278-1156, or equivalent)
- ✂ Plastic cup (approximately 9 oz capacity)
- ✂ 3 oz seawater or artificial seawater
- ✂ 2 Pencil “leads,” each approximately 3” length – a thick “lead” from a carpenter’s pencil is ideal (FYI: It is graphite—a form of carbon—not lead)

#### Procedure



1. Connect the alligator clips on one end of two jumper cables to two pencil “leads.” Connect the alligator clips on the other end to the positive (+) and negative (-) terminals of a 9-volt battery.
2. Pour about 3 ounces of seawater into a plastic cup. Put the pencil “leads” into the seawater so they are not touching, but are about 1 cm apart.
3. Observe what happens in the seawater over the next 20 minutes. Record your observations on the Data Sheet every five minutes.

4. What happens around the ends of the pencil “leads” in the seawater?

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5. Did the same thing happen near both ends?

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## Corrosion to Corals Electrochemical Reactions Data Sheet

### Part I – Metal Electrodes in Seawater

Metal 1	Metal 2	Voltage
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

### Part II – Carbon Electrodes Connected to 9 Volts

Observations:

- 5 min: \_\_\_\_\_
- 10 min: \_\_\_\_\_
- 15 min: \_\_\_\_\_
- 20 min: \_\_\_\_\_

### Analyze and Interpret

Based on the results of Parts I and II, how might shipwrecks contribute to the growth of deep-water corals?

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