Deepwater Coral Expedition: Reefs, Rigs and Wrecks

# Off Base

## Focus
pH, buffers, and ocean acidification

## Grade Level
9-12 (Biology/Chemistry/Earth Science)

## Focus Question
What processes regulate ocean pH and is the pH of the ocean changing?

## Learning Objectives
Students will be able to define pH.

Students will be able to define a buffer, and explain in general terms the carbonate buffer system of seawater.

Students will be able to explain Le Chatelier's Principle, and will be able to predict how the carbonate buffer system of seawater will respond to a change in concentration of hydrogen ions.

Students will be able to identify how an increase in atmospheric carbon dioxide might affect the pH of the ocean, and will be able to discuss how this alteration in pH might affect biological organisms.

## Materials
- ❒ Copies of Buffer Properties of Seawater Inquiry Guide; one copy for each student group
- ❒ Protective goggles and gloves; one set for each student and one for the teacher
- ❒ 100 ml glass beaker; one for each student group
- ❒ 100 ml graduated cylinder; one cylinder may be shared by several student groups, but have separate cylinders for distilled water and seawater
- ❒ 500 ml glass beaker
- ❒ 2 - 1 liter beakers or erlenmeyer flasks for mixing solutions
- ❒ Glass stirring rod; one for each student group
- ❒ Sodium hydroxide pellets, approximately 50 grams (see Learning Procedure Step 1)
- ❒ Solid citric acid (to neutralize sodium hydroxide spills); approximate 450 grams
- ❒ Distilled water; approximately 150 ml for each student group, plus 1.5 liters for making solutions (see Learning Procedure Step 1)
- ❒ Artificial seawater; approximately 150 ml for each student group, plus approximately 250 ml for demonstration
- ❒ pH test paper, wide range; one roll for each student group
- ❒ Dilute acetic acid solution in dropper bottles; one bottle containing approximately 50 ml for each student group (see Learning Procedure Step 1)
- ❒ 0.1 M sodium hydroxide solution in dropper bottles; one bottle containing approximately 50 ml for each student group (see Learning Procedure Step 1)

## Audio/Visual Materials
- ❒ Marker board, overhead projector with transparencies, or digital equivalent

## Teaching Time
Two 45-minute class periods, plus time for student research

### Seating Arrangement

Groups of 2-4 students

### Maximum Number of Students

32

### Key Words

Gulf of Mexico
Shipwreck
Buffer
pH
Calcium carbonate
Ocean acidification

### Background Information

In recent years, rising costs of energy and a growing desire to reduce the United States' dependence upon foreign petroleum fuels have led to intensified efforts to find more crude oil and drill more wells in the Gulf of Mexico. This region produces more petroleum than any other area of the United States, even though its proven reserves are less than those in Alaska and Texas. Managing exploration and development of mineral resources on the nation's outer continental shelf is the responsibility of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of the Deepwater Corals Expedition: Reefs, Rigs and Wrecks mission is to protect unique and sensitive environments where these resources are found.

To locate new sources of hydrocarbon fuels, MMS has conducted a series of seismic surveys to map areas between the edge of the continental shelf and the deepest portions of the Gulf of Mexico. These maps provide information about the depth of the water as well as the type of material that is found on the seafloor. Hard surfaces are often found where hydrocarbons are present. Carbonate rocks (such as limestone), in particular, are a part of nearly every site where fluids and gases containing hydrocarbons have been located. This is because when microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. This rock, in turn, provides a substrate where the larvae of many other deep sea bottom-dwelling organisms may attach, particularly corals. In addition to carbonate rocks associated with hydrocarbon seeps, deepwater corals in the Gulf of Mexico are also found on anthropogenic (human-made) structures, particularly ship wrecks and oil platforms.

Deepwater coral reefs (also called "cold water coral reefs") were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of shallow water coral reefs (also called "warm water coral reefs"), and have found deepwater coral species on continental margins worldwide. One of the most conspicuous differences between shallow- and deepwater corals is that most shallow-water species have symbiotic algae (zooxanthellae) living inside the coral tissue, and these algae play an important part in reef-building and biological productivity. Deepwater corals do not contain symbiotic algae (so these corals are termed "azooxanthellate"). Yet, there are just as many species of deepwater corals (slightly more, in fact) as there are species of shallow-water corals. Deepwater reefs provide habitats for a variety of plant, animal, and microbial species, some of which have not been found anywhere else. Branching corals and other sessile (non-motile) benthic (bottom-dwelling) species with complex shapes provide essential habitat for other organisms including commercially-important fishes such as longfin hake, wreckfish, blackbelly rosefish, and grenadiers. In addition, recent research has shown that less obvious, obscure benthic species may contain powerful drugs that directly benefit humans.

The long-term goal of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to develop the ability to recognize areas where deepwater corals are "likely to occur" in the Gulf of Mexico. Achieving this goal involves three objectives:

- Discover and describe new locations in the deep (greater than 300m depth) Gulf of Mexico where there are extensive coral communities;
- Gain a better understanding of the processes that control the occurrence and distribution of deepwater coral communities in the Gulf of Mexico; and
- Study the relationships between coral communities on artificial and natural substrates with respect to species composition and function, genetics, and growth rates of key species.

In addition to field investigations, the Deepwater Coral Expedition will include a series of laboratory studies to determine the effects of temperature, pH, dissolved oxygen, and electrical current on growth and survival of *L. pertusa*. Changes in pH are increasingly significant to deep water corals, because rising atmospheric $CO_2$ levels result in oceanic acidification which can affect the ability of corals (and other organisms) to produce body structures made of calcium carbonate. In this lesson, students will investigate some properties of the ocean's carbonate buffer system, and make inferences about how changes in atmospheric carbon dioxide levels may affect ocean pH and biological organisms that depend upon calcification.

## Learning Procedure

1. To prepare for this lesson:
   - Review introductory essays for the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html;
   - Review questions on the "Buffer Properties of Seawater Inquiry Guide;" and
   - Prepare solutions for student inquiries:
     (a) 4 M sodium hydroxide solution: Dissolve 40 g NaOH in 100 mL water, then dilute to 250 ml.
     (b) 0.1 M sodium hydroxide solution: Dilute 25 ml of 4 M sodium hydroxide solution to a volume of 1 liter. Transfer the solution to dropper bottles, one bottle for each student group.

     [NOTE: Be careful! Concentrated sodium hydroxide is dangerous. Use goggles and protective rubber gloves when working with solid chemicals and solutions, and be sure the surfaces of gloves and bottles are dry to avoid accidental slippage when bottles are handled. Any chemical that contacts the skin should be immediately washed off with copious quantities of water. Then apply dilute vinegar solution to neutralize traces of the alkali. Spills of alkalis should be diluted as above before mopping up. For large spills, solid citric acid should be used as a neutralizer.]

     (c) Dilute acetic acid solution: Transfer white vinegar to dropper bottles, one bottle for each student group.

     (d) Artificial Seawater: Follow directions on package to prepare required quantity (see Materials; typically, 1 liter of water will require about two tablespoons of the dry powder).

2. Briefly introduce the 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. Point out the variety of organisms found in these communities, and briefly discuss their potential importance. 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. Say that one of the primary

objectives of the Deepwater Coral Expedition is to determine the effects of temperature, pH, dissolved oxygen, and electrical current on growth and survival of deepwater corals. Review the concept of acids, bases, pH, and Le Chatelier's Principle (if a system that is in equilibrium is changed, the system will react in such a way as to undo the effect of the change). Ask students what might cause significant pH changes in the ocean. If students do not identify increased atmospheric carbon dioxide as a potential cause, do not prompt them on this point right now.

3. Tell students that their assignment is to investigate the some of the aspects of pH in seawater. Provide each student group with a copy of the "Buffer Properties of Seawater Inquiry Guide" and the materials listed on the worksheet.

4. When students have completed the procedures described on the worksheet, lead a discussion of their results. Students should have found that seawater is much more resistant to changes in pH than distilled water, and consequently is a good buffer. Write the following equation on a marker board or overhead transparency so that it is visible to all students:

| $CO_2$ | + | $H_2O$ | < > | $H_2CO_3$ | < > | $H^+$ | + | $HCO_3^-$ | < > | $H^+$ | + | $CO_3^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| carbon dioxide | | water | | carbonic acid | | hydrogen ion | | bicarbonate ion | | hydrogen ion | | carbonate ion |

Tell students that this equation describes the carbonate buffer system of seawater. The equation shows that carbon dioxide dissolves in seawater to form carbonic acid, a weak acid. Most of the carbonic acid normally dissociates to form hydrogen ions, bicarbonate ions, and carbonate ions. Be sure students understand that carbon dioxide, carbonic acid, bicarbonate ions, and carbonate ions are all present in normal seawater, although not in the same concentrations (bicarbonate and carbonate concentrations are much higher than carbon dioxide and carbonic acid). When these chemicals are in equilibrium, the pH of seawater is about 8.1 – 8.3 (slightly basic).

Considering Le Chatelier's Principle, students should realize that if hydrogen ions are added to normal seawater the system will react in a way that tends to remove hydrogen ions from solution, so the reactions will proceed to the left. Similarly, if a very basic solution is added to normal seawater students should predict that the system will react in a way that tends to add more hydrogen ions, and so the reactions will proceed to the right.

Students should predict that an increase in atmospheric carbon dioxide will result in an increase in carbon dioxide dissolved in the ocean, which in turn will drive the carbonate system to the right. This will cause an increase in hydrogen ions and a lower ocean pH. On June 5, 2008, NOAA Oceanographer Richard A. Feely told the U.S House of Representatives Subcommittee on Energy and Environment that the ocean currently absorbs 22 million tons of carbon dioxide daily, and that scientists estimate that the pH of ocean surface waters has already fallen by about 0.11 units from an average of about 8.21 to 8.10 since the beginning of the industrial revolution. Feely also said that if carbon dioxide emissions continue according to predictions, the surface water pH will decrease by about 0.4 pH units by the end of the century. "To put this in historical perspective, the resulting surface ocean pH would be lower than it has been for more than 20 million years," he said. Be sure students realize that while the term "ocean acidification" is commonly used, the ocean is not expected to actually become acidic (which would mean that the pH was below 7.0). "Acidification" in this case only means that the pH is declining.

The reactions included in the carbonate buffer system interact in a way that tends to resist changes in pH. This helps maintain a relatively constant hydrogen ion concentration in seawater, but there is another consequence that may present serious problems to organisms with shells made of calcium carbonate. At first glance, it might seem that the summary equation for the carbonate buffer system implies that increasing carbon dioxide will ultimately lead to an increase in carbonate ($CO_3^{2-}$) ions. But bicarbonate ions form much more readily than carbonate ions (under normal surface conditions, there are about 8.5 times more bicarbonate ions in seawater than carbonate ions). In fact, the hydrogen ions produced by the dissociation of carbonic acid tend to react with carbonate ions to form bicarbonate ions. The net result is a decrease in carbonate ions, which are essential to the process of calcification through which many organisms produce shells and other skeletal structures.

The concern is that reduced availability of carbonate ions will make calcification more difficult or impossible. This would affect organisms such as reef-building corals, shellfish, echinoderms, and many marine plankton. Pteropods are planktonic snails that are an important component of food chains in high-latitude regions, and have been shown to have pitted or partially dissolved shells in waters where carbonate ions are depleted. Corals provide habitats for thousands of other species, in deep waters worldwide as well as in shallow tropical regions. Shellfish and echinoderms are important components in many marine food webs. All of these groups are tied to food webs that produce species used for human food as well.

Another potential impact of decreased ocean pH is the effect on reproductive capacity. Researchers in Australia have found that sea urchin sperm swim more slowly and move less effectively under conditions of reduced pH, resulting in a 25% drop in reproductive capacity.

Make sure students realize that their investigation of buffer properites changed pH by adding hydrogen ions from a weak acid, but ocean acidification results from the response of the carbonate buffer system to an increase in dissolved carbon dioxide.

## The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Chemistry," or "Atmosphere" for links to resources about ocean chemistry or climate change.

## The "Me" Connection

Have students write a brief essay describing how buffer systems are of personal benefit, and how a change in ocean pH might have personal impacts.

## Connections to Other Subjects

English/Language Arts, Social Sciences

## Assessment

Written reports and class discussions provide opportunities for assessment.

## Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html to find out more about the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and to learn about opportunities for real-time interaction with scientists on the current expedition.

## Multimedia Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

## Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

### The Robot Archaeologist

(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

### 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

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.

### Where Am I?

(PDF, 4 pages, 344k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position finding (Earth Science)

In this activity, students identify and explain at least seven different techniques used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

### Do You Have a Sinking Feeling?

(9 pages, 764k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandsinking.pdf

Focus: Marine archaeology (Earth Science/Mathematics)

In this activity, students plot the position of a vessel given two bearings on appropriate landmarks, draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck, and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

### Where's My 'Bot?

(492kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wheresbot.pdf
Focus: Marine Navigation (Earth Science/Mathematics)

In this activity, students will estimate geographic position based on speed and direction of travel, and integrate these calculations with GPS data to estimate the set and drift of currents.

### The Big Burp: Where's the Proof?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf

Focus: Potential role of methane hydrates in global warming (Earth Science)

In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

### What's the Big Deal?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/deal.pdf

Focus: Significance of methane hydrates (Life Science)

In this activity, students will be able to define methane hydrates and describe where these substances are typically found and how they are believed to be formed. Students will also describe at least three ways in which methane hydrates could have a direct impact on their own lives, and describe how additional knowledge of methane hydrates expected from the Blake Ridge expedition could provide human benefits.

### 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
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.

### What's Down There?

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/whatsdown.pdf

Focus: Mapping Coral Reef Habitats

In this activity, students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs, and explain the need for baseline data in coral reef monitoring programs. Students also will be able to identify and explain five ways that coral reefs benefit human beings, and identify and explain three major threats to coral reefs.

### The Benthic Drugstore

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/drugstore.pdf

Focus: Pharmacologically-active chemicals derived from marine invertebrates (Life Science/ Chemistry)

Students will be able to identify at least three pharmacologically-active chemicals derived from marine invertebrates, describe the disease-fighting action of at least three pharmacologically-active chemicals derived from marine invertebrates, and infer why sessile marine invertebrates appear to be promising sources of new drugs.

### Watch the Screen!

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/watchscreen.pdf

Focus: Screening natural products for biological activity (Life Science/Chemistry)

In this activity, students will be able to explain and carry out a simple process for screening natural products for biological activity, and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

### Now Take a Deep Breath

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

Students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

### 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 deep-water coral reef communities.

### Submersible Designer

(4 pages, 452k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf

Focus: Deep Sea Submersibles

In this activity, students will understand that the physical features of water can be restrictive to movement, understand the importance of design in underwater vehicles by designing their own submersible, and understand how submersibles such as ALVIN and ABE, use energy, buoyancy, and gravity to enable them to move through the water.

### Living in Extreme Environments
(12 pages, 1Mb) (from the 2003 Mountains in the Sea Expedition)
http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_extremeenv.pdf

Focus: Biological Sampling Methods (Biological Science)

In this activity, students will understand the use of four methods commonly used by scientists to sample populations; understand how to gather, record, and analyze data from a scientific investigation; begin to think about what organisms need in order to survive; and understand the concept of interdependence of organisms.

### 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 $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ 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.

### How Diverse is That?
(12 pages, 296k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Diverse.pdf

Focus: Quantifying biological diversity (Life Science)

In this activity, students will be able to discuss the meaning of biological diversity and will be able to compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

### 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)

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://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 focussing on the exploration, understanding, and protection of Earth as a whole system

http://www.ucar.edu/communications/Final_acidification.pdf – "Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research;" report from a workshop sponsored by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey

Havenhand, J. N., F. R. Buttler, M. C. Thorndyke, J. E. Williamson. 2008. Near-future levels of ocean acidification reduce fertilization success in a sea urchin. Current Biology, 18:R651-R652.

http://www.terrain.org/articles/21/burns.htm – Article on ocean acidification from Terrain.org

http://www.oceana.org/climate/impacts/acid-oceans/ – Oceana article on ocean acidification

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

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.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.gomr.mms.gov/homepg/lagniapp/lagniapp.html – Kids Page on the Minerals Management Service Web site, with posters, teaching guides and other resources on various marine science topics

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 D: Earth and Space Science**
- Structure of the Earth system

**Content Standard F: Science in Personal and Social Perspectives**
- Populations, resources, and environments
- Science and technology in society
- Natural and human-induced hazards

**Content Standard G: History and Nature of Science**
- Nature of science

## 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 b.* Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

*Fundamental Concept c.* Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

*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 e.* The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

*Fundamental Concept f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

*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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# Student Handout

## Buffer Properties of Seawater Inquiry Guide

A buffer is a solution that tends to resist changes in pH. Your assignment is to investigate the some of the pH buffering capabilities of seawater. Questions 11 and 12 will require some Internet or library research.

### Materials

Distilled water, approximately 150 ml
Artificial seawater, approximately 150 ml
pH test paper
Dilute acetic acid solution in dropper bottle
0.1 M sodium hydroxide solution in dropper bottle
100 ml glass beaker
100 ml graduated cylinder
Glass stirring rod

### Procedure

1. **Wear eye protection and gloves throughout this experiment!**
   **Wash your hands thoroughly when you are finished!**
   **Do not eat, drink, or chew anything while you are in the laboratory!**
2. Measure 50 ml of distilled water into a 100 ml glass beaker. Test the pH by dipping a strip of pH test paper into the water and comparing the color of the paper to the chart on the test paper container. Record the pH on the data chart below.
3. Add one drop of dilute acetic acid to the beaker, stir with a glass stirring rod, test the pH, and record the result on the data chart.
4. Repeat Step 3 until 20 drops of dilute acetic acid have been added, testing and recording the pH after each drop.
5. Rinse the beaker, then repeat steps 2 through 4 using seawater instead of distilled water. Be sure to use a separate graduate cylinder for measuring the seawater.
6. Rinse the beaker and repeat steps 1 through 4 with distilled water and seawater (use a different graduated cylinder for each!), but use 0.1 M sodium hydroxide solution instead of dilute acetic acid.
7. Wash your hands thoroughly!
8. What do your data suggest about the buffer system of seawater compared to distilled water?
9. Recall Le Chatelier’s Principle. What do you think would happen if hydrogen ions were added to normal seawater?
10. What do you think would happen if a very basic solution (which tends to remove hydrogen ions from solution) were added to normal seawater?
11. How might increased carbon dioxide in the atmosphere affect ocean pH? Is there any evidence that ocean pH is changing?
12. How might changes in ocean pH affect marine organisms? Is there any evidence that any organisms are actually being affected?

## Student Handout

### Data Chart for Buffer Properties of Seawater Inquiry

| Drops Added | Test with Added Acetic Acid: Distilled Water pH | Test with Added Acetic Acid: Seawater pH | Test with Added Sodium Hydroxide: Distilled Water pH | Test with Added Sodium Hydroxide: Seawater pH |
|---|---|---|---|---|
| 0 | | | | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
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