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## Deepwater Coral Expedition: Reefs, Rigs and Wrecks

# What's Eating Your Ship?
## (adapted from the 2004 Return to *Titanic* Expedition)

### Focus
Biodeterioration processes

### Grade Level
9-12 (Physical Science/Biological Science)

### Focus Question
What biological processes can deteriorate shipwrecks?

### Learning Objectives
Students will be able to describe three processes that contribute to the deterioration of shipwrecks.

Students will be able to define and describe rusticles, and explain their contribution to biodeterioration of shipwrecks.

Students will be able to explain how processes that oxidize iron in deep-water shipwrecks differ from iron oxidation processes in shallow water.

### Materials
- ❒ Copies of "Shipwreck Deterioration Inquiry Guide," one copy for each student or student group
- ❒ Library and/or Internet access

### Audio/Visual Materials
Overhead or digital projector

### Teaching Time
One 45-minute class period, plus time for student research

### Seating Arrangement
Classroom-style or groups of 3-4 students

### Maximum Number of Students
32

### Key Words
Gulf of Mexico
Shipwreck
Rusticle
Biodeterioration

### 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 Coral 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 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 coral reefs in shallow waters, 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.

Because shipwrecks are a potential substrate for deep-water coral communities, these objectives include both biological and archeological questions. One of the key archeological questions is, "How are biofouling communities on shipwrecks affecting their stability and rates of deterioration?"

In this lesson, students will investigate another biological degradation processes that may account for much of the deterioration that takes place on deep-water shipwrecks.

## 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 "Shipwreck

Deterioration Inquiry Guide;" and

- Make and overhead transparency or digital copy of the photograph of the bow of the *Titanic* at http://news.nationalgeographic.com/news/2003/04/photogalleries/titanic/photo2.html.

Decide whether you will require written or oral presentation of students' inquiries.

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. Emphasize the importance of suitable substrates to the development of these communities, pointing out that both natural and human-made substrates may be suitable for coral larvae settlement. Ask students what types of artificial substrates might be found in the deep Gulf of Mexico. Shipwrecks should be among the possibilities. Show students the overhead transparency. Say that deterioration of the *Titanic's* hull appears to be increasing in recent years, and ask students to identify processes that might be responsible. Most students will identify "rusting" as one possibility. They may also identify galvanic action as a separate process from rusting, and (especially if you have serious *Titanic* fans among your students) may also identify biological processes as a third possibility. If students do not identify all three processes, let them discover these through their own inquiries. Say that one of the questions of the Deepwater Coral Expedition is, "How do biological communities growing on shipwrecks affect wrecks' stability and rates of deterioration?"

3. Provide each student or student group with a copy of the "Shipwreck Deterioration Inquiry Guide," and say that their assignment is to identify processes that may be responsible for the deterioration of shipwrecks. Assign written or oral formats for presenting the results of their inquiries.

4. Lead a discussion of students' inquiries. The following points should be included:
   - Galvanic exchange results from the presence of different metals in contact with seawater. Metals can be classified into an "Electromotive Series" according to the strength with which they "hold on" to their electrons. Metals higher in the Series tend to draw electrons away from metals that are lower in the Series. When two metals with different electromotive strengths are connected by an electrolyte (such as salt water), electrons will flow from the metal lower in the electromotive series, causing this metal to form oxides or other compounds in a process we know as corrosion (this is also the process through which batteries produce an electric current). Besides iron in the hull and elsewhere on the vessel, steel shipwrecks contain many other metals such as bronze and brass that are higher in the Electromotive Series than iron. As a result, the steel in the hull is degraded as iron is replaced by other compounds formed through galvanic exchange.

   - Rusting is an oxidation process whose primary product usually is $Fe(OH)_2$ , but iron can react with oxygen and water to produce other products including $Fe(OH)_3$ (hematite), $Fe_3O_4$ (magnetite), and $Fe_3O_4 \bullet H_2O$ (hydrated magnetite). Only iron and steel rust; other metals corrode.

   - Rusticles are structures produced by complex communities of bacteria and fungi that biodegrade shipwrecks. Rusticles superficially resemble icicles or stalactites, and are built up in ring structures that are highly porous with channels and reservoirs that allow water to flow through. Up to 35% of rusticles' mass consists of iron compounds (iron oxides, iron carbonates, and iron hydroxides). The remainder is biomass of bacteria and fungi.

- Oxidation of iron in *Titanic's* hull results from biological activity of rusticle communities under anaerobic conditions, and is a different process from rusting in shallow waters resulting from oxidation of iron by dissolved oxygen.

- Rusticles grown in laboratories have been found to continuously release a red, powder-like material as well as a yellowish slime. The iron content of these materials is 20 ± 5% and 8 ± 3% respectively. Daily iron released from rusticles was between 0.02% and 0.03% of the rusticles' biomass. So the amount of iron released by a rusticle biomass of 1,000 tons would be between 0.2 and 0.3 tons per day:
  0.0002 • 1,000 tons = 0.2 tons per day
  0.0003 • 1,000 tons = 0.3 tons per day

  So, to consume 40,000 tons of iron, a 1,000 ton biomass of rusticles would require between 365 and 548 years:
  (40,000 tons) ÷ (0.2 tons/day) = 200,000 days = 548 years
  (40,000 tons) ÷ (0.3 tons/day) = 133,333 days = 365 years

## The Bridge Connection

www.vims.edu/bridge/ – In the Navigation toolbar, click on "Ocean Science Topics," then "Human Activities," then "Heritage," then "Archeology."

## The "Me" Connection

Have students write a brief essay discussing whether or not artifacts should be removed from shipwrecks such as the *Titanic*, and why people may feel strongly about a wreck that happened nearly 100 years ago.

## Connections to Other Subjects

English/Language Arts, Earth Science, Social Studies, Life Science

## 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)

In this activity, 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)

In this activity, 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)

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://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.corrosion-doctors.org/ – A Web site about corrosion causes and solutions, with modules designed for training in corrosion science and engineering

http://www.encyclopedia-titanica.org/index.php — Encyclopedia Titanica Web site with biographies, research articles and ongoing discussions about the *Titanic*

http://score.rims.k12.ca.us/activity/bubbles/ – Marine archaeology activity guide based on investigations of the wreck of a Spanish galleon; from the Schools of California Online Resources for Education Web site

http://members.tripod.com/~hoko/index-4.html – *Titanic* Links

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**

- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder

**Content Standard C: Life Science**

- Interdependence of organisms
- Matter, energy, and organization in living systems

**Content Standard E: Science and Technology**

- Abilities of technological design
- Understandings about science and technology

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

- Natural and human-induced hazards

## 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:
oceanexeducation@noaa.gov

## For More Information

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## Student Handout

### Shipwreck Deterioration Inquiry Guide

Your assignment is to identify processes that may be responsible for the deterioration of shipwrecks. The following questions can help guide your investigations to solve this problem:

- What is "galvanic action," and how does it differ from "rusting"?
- What are "rusticles"?
- How is "rusting" that is taking place on *Titanic* different from rusting on shipwrecks in shallower waters?
- About how rapidly does biodeterioration remove iron from the hull of ships such as *Titanic*?
- If a ship's hull contained 40,000 tons of iron and is covered with 1,000 tons of biodeteriorating organisms, how long would it take for the hull to be completely dissolved by biodeterioration processes alone?