NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Section 6: Key Topic – Ocean Health

Build Your Own Ocean Ecosystem

Focus
Key functions of healthy ocean ecosystems

Grade Level
5-6 (Life Science)

Focus Question
What key functions are present in healthy ocean ecosystems?

Learning Objectives
- Students will identify key functions that are present in healthy ocean ecosystems.
- Students will discuss how these functions are met by living and non-living components in a model aquatic ecosystem.

Materials
- Copies of *Build Your Own Ocean Ecosystem Construction Guide*, one copy for each student group
- Materials for constructing model ecosystems

Materials for one model:
- 1 - 1 quart glass canning jar
- 3 - Plastic containers, 1 quart capacity or larger
- 12 (Approximately) - River pebbles, about grape-size; enough to cover the bottom of the glass jar in a single layer
- 3-4 - Small shells
- 1 - Amano shrimp, *Caridina multidentata* (from an aquarium store)
- 4 - Aquatic snails, each less than 1 cm overall length
- 8-inch stem of hornwort (*Ceratophyllum demersum*; from an aquarium store)
- Duckweed, approximately 2 inches x 2 inches (from an aquarium store or local pond)
- 2-8 - Amphipods (from a local pond)
- Student logbook for recording observations

Materials that may be shared by several groups:
- Fishnet or kitchen strainer
- Dechlorinating solution (for treating tap water; from an aquarium store)
- Solution of freshwater minerals (*e.g.*, "cichlid salts;" from an aquarium store)
- Calcium carbonate powder (from an aquarium store)
- Pond sludge

Ocean Exploration and Research

- Tablespoon measure
- Plastic bucket, 1 gallon or larger capacity

Audiovisual Materials

- None

Teaching Time

Four or five 45-minute class periods, plus time for student research and periodic discussion of model ecosystems

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words and Concepts

Ocean health	Invasive species
Model ecosystem	Climate change
Overfishing	Pollution
Habitat destruction	Ocean acidification

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

"The great mass extinctions of the fossil record were a major creative force that provided entirely new kinds of opportunities for the subsequent explosive evolution and diversification of surviving clades. Today, the synergistic effects of human impacts are laying the groundwork for a comparably great Anthropocene mass extinction in the oceans with unknown ecological and evolutionary consequences. Synergistic effects of habitat destruction, overfishing, introduced species, warming, acidification, toxins, and massive runoff of nutrients are transforming once complex ecosystems like coral reefs and kelp forests into monotonous level bottoms, transforming clear and productive coastal seas into anoxic dead zones, and transforming complex food webs topped by big animals into simplified, microbially dominated ecosystems with boom and bust cycles of toxic dinoflagellate blooms, jellyfish, and disease. Rates of change are increasingly fast and nonlinear with sudden phase shifts to novel alternative community states. We can only guess at the kinds of organisms that will benefit from this mayhem that is radically altering the selective seascape far beyond the consequences of fishing or warming alone. The prospects are especially bleak for animals and plants compared with metabolically flexible microbes and algae. Halting and ultimately reversing these trends will require rapid and fundamental changes in fisheries, agricultural practice, and the emissions of greenhouse gases on a global scale."

– Dr. Jeremy Jackson, Scripps Institution of Oceanography, 2008

Limacina helicina, a free-swimming planktonic snail. These snails, known as pteropods, form a calcium carbonate shell and are an important food source in many marine food webs. As levels of dissolved CO_2 in sea water rise, skeletal growth rates of pteropods and other calcium-secreting organisms will be reduced due to the effects of dissolved CO_2 on ocean acidity. Image credit: Russ Hopcroft, UAF/NOAA.
http://www.noaanews.noaa.gov/stories2006/images/pteropod-limacina-helicina.jpg

According to the Intergovernmental Panel on Climate Change (the leading provider of scientific advice to global policy makers), surface ocean pH is very likely to decrease by as much as 0.5 pH units by 2100, and is very likely to impair shell or exoskeleton formation in marine organisms such as corals, crabs, squids, marine snails, clams and oysters.

Large *Paragorgia* colonies on basalt substrate. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04mountains/logs/hirez/paragorgia_hirez.jpg

Unusual spiny crab spotted on NW Rota 1 volcano. Crabs are opportunistic predators at vent sites. The body of this crab is ~2 in. (~5 cm) across. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04fire/logs/hirez/spinycrab_hirez.jpg

At NW Eifuku volcano, mussels are so dense in some places that they obscure the bottom. The mussels are ~18 cm (7 in) long. The white galatheid crabs are ~6 cm (2.5 in) long. Image credit: NOAA. *http://oceanexplorer.noaa.gov/explorations/04fire/logs/hirez/mussel_mound_hirez.jpg*

The health of Earth's ocean is simultaneously threatened by over-exploitation, destruction of habitats, invasive species, rising temperatures, and pollution. Most, if not all, of these threats are the result of human activity. An overview of these issues can be found in Diving Deeper, page 33, and are discussed in greater detail in Allsopp, Page, Johnston, and Santillo (2007) and Jackson (2008). Most of these threats involve entire ocean ecosystems, which are highly complex and are not well-understood. Since Earth's ocean occupies more than 70% of our planet and the entire ocean is being affected, these issues inevitably will affect the human species as well.

As is true for many environmental problems, these threats do not exist because of a single, deliberate action, but are the result of numerous individual actions that take place over many years without any consideration for their collective impacts on Earth's ecosystems. Not surprisingly, effective solutions to these problems also usually involve numerous individual actions that by themselves seem insignificant, but collectively can have global impacts over time. Your students will be part of these solutions, which are rooted in an ecosystem perspective that understands our dependence on Earth's fundamental ecological systems and processes.

This activity guides a student investigation into some of these systems and processes, and may be a springboard for initiatives that can have a significant positive impact on the health of Earth's ocean.

Learning Procedure

Note: This activity is adapted from *Ecosystems Engineering* by Martin John Brown, which appeared in Volume 10 of *Make* magazine. In a followup comment, Brown says:

> ***"Most of the questions I've gotten have to do with switching ingredients or adding extra animals. The short answer is, DON'T. Making a bottle ecosystem is not the same as just throwing some stuff from the local pond in a jar, and it is nothing like running a regular fish tank. There is a reason for everything in the article. If you get too many animals or nutrients in there the animals are going to run out of oxygen pronto. You don't want your little civilization to just survive, anyway—you want it to thrive. It's a tenuous balance, but you can learn to walk it like a tightrope artist."***

You can download Brown's original article from *http://cachefly.oreilly.com/make/wp_aquanaut.pdf*.]

1. To prepare for this lesson:
   - Review introductory information on the NOAA Ship *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*. You may also want to consider having students complete some or all of the lesson, *To Boldly Go…*.
   - Review information in Diving Deeper, *Ocean Health Overview*,starting on page 33, and decide how to present this information to your students. One option is to divide the topics discussed in the *Overview* among individual student groups as subjects for group investigations. Another possibility is to assign sections of the *Overview* to student groups as background for group reports. A third option is to use Allsopp, Page, Johnston, and Santillo (2007) and Jackson (2008) as background materials. The most appropriate approach will depend upon the amount of class time available, students' reading capabilities and research skills, and availability of resources for student research.
   - Review procedures for constructing Tabletop Shrimp Support Modules in the *Build Your Own Ocean Ecosystem Construction Guide*, and assemble the

necessary materials for the number of modules that your students will construct. Pond sludge should be collected in the late afternoon (when pH is higher as plants have had the day to photosynthesize and produce oxygen), ideally from an area of the pond near aquatic plants, and it should contain a mixture of substrates such as sand, rock, and decaying wood. Collect the sludge from the pond bottom, and drag a fine-mesh net through the water as well. Ideally, you will collect a mixture of amphipods, copepods, and ostracods along with the sludge. You may also want to review the original article, available online at *http://cachefly.oreilly.com/make/wp_aquanaut.pdf*.

You may also want to check out Jeremy Jackson's *Brave New Ocean* presentation at *http://www.esi.utexas.edu/outreach/ols/lectures/Jackson/* (has links to a Webcast of the presentation).

2. If you have not previously done so, briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Lead a discussion of reasons that ocean exploration is important, which should include understanding ocean health issues.

3. Tell students that they are going to construct a functioning model of an aquatic ecosystem. To prepare for this assignment, their first task is to identify the key functions that are needed to make an ecosystem work, and how these functions can be provided in a model system. Show the glass jar that will be used to contain the system. Brainstorm these functions as a class activity.

   Students may recognize the need for a source of energy, and that the primary source of energy in most familiar ecosystems is sunlight which is converted to chemical energy by green plants through photosynthesis. Ask students to identify organisms that could provide an energy source for their model ecosystem. Algae (both microscopic and macroscopic) and other green plants are the most likely possibilities.

   So now we have the beginnings of a food chain for our model system. Ask students how many more links could reasonably be added to this food chain. You may need to remind them that energy transfer efficiency between trophic levels is less than 10% (*i.e.*, it takes at least 10 grams of primary producers to support 1 gram of herbivores, and 1 gram of herbivores can support less than 0.1 gram of primary carnivores, etc.). This means that the number of trophic levels in your model ecosystem may be limited. This also calls attention to the issue of size and types of organisms that should be included in the model ecosystem.

   Highly active organisms (such as fishes) will require a lot of food which may be difficult to provide in a total volume of one quart. This leads to the issue of waste disposal. Be sure students understand that the concept of "waste" is a human invention: in nature, by-products from one organism are raw materials for other organisms. This process is essential to natural recycling. Much of this work is done by microorganisms, which need to be present for a model system to work well.

   Discuss key physical factors. Temperature is one factor. Since the model systems will be maintained at room temperature, it is important to know how much that temperature changes over a 24-hour period, as well as over a weekly period (does your school turn off heating & cooling systems at night or over the weekend to save energy?) Light is another important factor when photosynthesis is involved. Natural sunlight contains substantially more blue wavelengths than most artificial lights, but if the model systems are placed in sunlight, temperature may be a problem. Water movement is also important in many natural aquatic systems. Since the model systems will have almost no water movement, except that created by mobile organisms, it is important to know that all of the potential occupants are okay with these conditions.

Oxygen may already have been mentioned in the context of energy from photosynthesis. Ask students how energy from photosynthesis is used by living organisms, which leads to the process of respiration, and the fact that carbon dioxide is a by-product of this process. Discuss the effects of carbon dioxide in an aquatic system. Students may say that carbon dioxide from respiration will be recycled through photosynthesis. This is true, but since photosynthesis needs light which is absent at night, this process cannot occur for about half of every day. But all of the organisms (including green plants) in the system will continue to respire during this period, which will cause carbon dioxide to build up in the system. At this point, you may want to show the effects of carbon dioxide on pH using the demonstration in Diving Deeper, page 41. It might be a good idea to include some way to reduce pH fluctuations in the model system.

Show students the materials (or the list of materials) that they will be using to construct their model ecosystems, and discuss how each of the key ecosystem functions they have identified will be met with these materials.

4. Provide each student group with a copy of the *Build Your Own Ecosystem Construction Guide*, access to necessary materials, and have each group assemble their model ecosystem. If all goes reasonably well, the model systems should function for at least several months. If a system fails before the end of the school year, discuss what might have happened. Students should realize that even if everything functions perfectly, the longevity of the system will eventually be limited by the lifespan of the organisms present.

5. Have student groups research topics of ocean health according to the plan identified in Step 1. Part of this assignment should be for each group to summarize their research in a written report that includes:
   - Causes of the problem;
   - What should be done to fix the problem; and
   - What individuals can do to be part of the solution.

   Since many of these problems exist on a global scale, it may be difficult for students to identify solutions and meaningful individual action. You may want to ask, "How do you eat an elephant?" The answer is, "One bite at a time." The key point is that these problems didn't happen all at once, so we probably shouldn't expect to fix them all at once.

   If you need to provide additional stimulus for student ideas, ask students to consider that most people are unaware of these problems, which means that there are opportunities for students to communicate their results to other audiences. In most cases, solutions involve public policy decisions that can be stimulated by large numbers of people expressing concern, or (even better) demanding that specific action be taken.

Students may also identify local, regional, or national organizations that are concerned with these issues and may have projects that involve individual participation. You may want to remind students that ocean health issues involve global ecosystems, so actions they take on their particular part of the globe are connected to the rest of the system. This is precisely why it is unlikely that ocean health issues can be resolved with a single action, and why numerous small actions in many different places can be the most effective means of improving the health of Earth's ocean.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," "Human Activities," then "Environmental Issue" for links to resources about pollution, conservation, bycatch, sustainability, and policy.

The "Me" Connection

Have students write a brief essay describing how they could have a personal impact on an issue affecting ocean health.

Connections to Other Subjects

English/Language Arts, Social Sciences, Physical Science

Assessment

Students' model ecosystems, written reports, and class discussions provide opportunities for assessment.

Extensions

1. Follow events aboard the *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
2. The abstract of Jackson's (2008) paper (quoted at the beginning of the Background section) provides a good opportunity for English/Language Arts and Science reading. Some suggested vocabulary terms are:

Mass extinction	Anthropocene
Diversification	Anoxic
Clade	Dinoflagellate
Synergistic	bloom

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 12 and 14 for interactive multimedia presentations and Learning Activities on Food, Water, and Medicine from the Sea; and Seamounts.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(Unless otherwise noted, the following Lesson Plans are targeted toward Grades 5-6)

Design a Reef! (Grades 7-8)

(from the 2003 Gulf of Mexico Deepwater Habitats Expedition)

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_aquarium.pdf

Focus: Niches in coral reef ecosystems (Life Science)

Students will compare and contrast coral reefs in shallow water and deep water, describe the major functions that organisms must perform in a coral reef ecosystem, and explain how these functions might be provided in a miniature coral reef ecosystem. Students will also explain the importance of three physical factors in coral reef ecosystems and infer the fundamental source of energy in a deepwater coral reef.

A Piece of Cake (from the 2003 Charleston Bump Expedition)
http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_cake.pdf
Focus: Spatial heterogeneity in deepwater coral communities (Life Science)
Students will explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deepwater hard bottom communities. Students will also explain how organisms, such as deepwater corals and sponges, add to the variety of habitats in areas such as the Charleston Bump.

Alien Invasion!
(from the 2003 Life on the Edge Expedition)
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/aliens.pdf
Focus: Invasive species (Life Science)
Students will compare and contrast "alien species" and "invasive species," explain positive and negative impacts associated with the introduction of non-native species, and give a specific example of species that produce these impacts. Students will also describe at least three ways in which species may be introduced into non-native environments and discuss actions that can be taken to mitigate negative impacts caused by non-native species.

Save A Reef!
(from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/savereef.pdf
Focus: Coral reef conservation (Life Science)
Students will design a public information program to improve understanding of the coral reef crisis, and things individuals can do to reduce stresses on coral reef systems.

Other Resources

See page 217 for Other Resources.

Next Generation Science Standards

Lesson plans developed for Volume 1 are correlated with *Ocean Literacy Essential Principles and Fundamental Concepts* as indicated in the back of this book. Additionally, a separate online document illustrates individual lesson support for the Performance Expectations and three dimensions of the Next Generation Science Standards and associated Common Core State Standards for Mathematics and for English Language Arts & Literacy. This information is provided to educators as a context or point of departure for addressing particular standards and does not necessarily mean that any lesson fully develops a particular standard, principle or concept. Please see: *http://oceanexplorer.noaa.gov/okeanos/edu/collection/wdwe_ngss.pdf.*

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

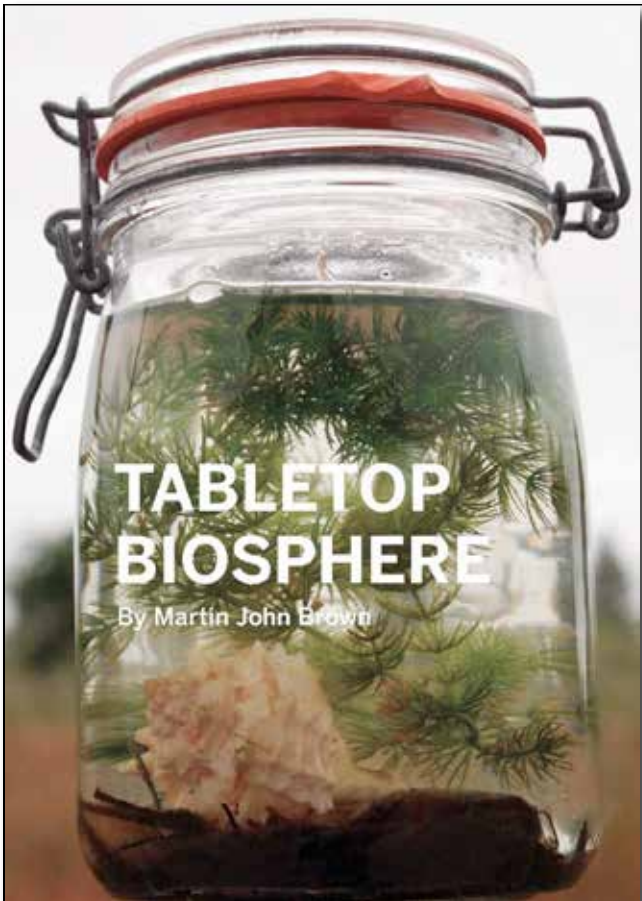
Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818 843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgments

Produced by Mel Goodwin, PhD, Marine Biologist and Science Writer, Charleston, SC for NOAA. Design/layout: Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: *http://oceanexplorer.noaa.gov*

Build Your Own Ecosystem Construction Guide

NOTE: These procedures are adapted from *Ecosystems Engineering*, an article by Martin John Brown that appeared in Volume 10 of *Make* magazine. The article can be downloaded from *http://cachefly.oreilly.com/make/wp_aquanaut.pdf*.



from *Make*, Volume 10

1. Obtain Amano shrimp, snails, hornwort, duckweed, and pond sludge from your teacher.

2. Make Nitrate-Poor Fresh Water (NPFW) by adding dechlorinating solution and mineral solution to a gallon of tap water according to directions on the packages. Your teacher may have you do this step with one or two other groups. The water from the pond or the aquarium store is likely to have a lot of algae and nitrates which would allow algae to take over the system. The use of NPFW helps to prevent this.

3. Rinse your 1-quart canning jar, rocks, and shells in the NPFW.

4. Fill your 1-quart canning jar halfway with NPFW. Put rocks in first, then shells, then the shrimp, snails, hornwort, duckweed, and 2 tablespoons of pond sludge. Be sure not to overload your system with extra animals or plants. Use only the amount specified!

5. Add more NPFW to your jar so that the top of the water is 1-inch below the top edge of the jar. Add 1 tablespoon of calcium carbonate powder (this will make the water cloudy for several hours because it dissolves slowly).

6. Place the cap tightly on the jar.

7. Place your ecosystem in a location that has temperature between 70°F and 80°F, and moderate light for about 12 - 16 hours per day. Do not put your system in direct sunlight.

8. Observe your ecosystem at least once each day, and record your observations in a logbook. Be sure to note what the animals are doing, whether they seem to be growing, and whether anything has died. Some of these ecosystems last for several months…how long will yours last?