www.oceanexplorer.noaa.gov

The NOAA Ship *Okeanos Explorer*


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*

Build Your Own Ecosystem

An essential component of the NOAA Office of Ocean Exploration and Research mission is to enhance understanding of science, technology, engineering, and mathematics used in exploring the ocean, and build interest in careers that support ocean-related work. To help fulfill this mission, the Okeanos Explorer *Education Materials Collection is being developed to encourage educators and students to become personally involved with the voyages and discoveries of the* Okeanos Explorer*—America's first Federal ship dedicated to Ocean Exploration. Leader's Guides for Classroom Explorers focus on three themes: "Why Do We Explore?" (reasons for ocean exploration), "How Do We Explore?" (exploration methods), and "What Do We Expect to Find?" (recent discoveries that give us clues about what we may find in Earth's largely unknown ocean). Each Leader's Guide provides background information, links to resources, and an overview of recommended lesson plans on the Ocean Explorer Web site (*http://oceanexplorer.noaa.gov*). An Initial Inquiry Lesson for each of the three themes leads student inquiries that provide an overview of key topics. A series of lessons for each theme guides student investigations that explore these topics in greater depth. In the future additional guides will be added to the Education Materials Collection to support the involvement of citizen scientists.*

This lesson guides student inquiry into the key topic of Ocean Health within the "Why Do We Explore?" theme.

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

Materials

- Copies of *Build Your Own 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:

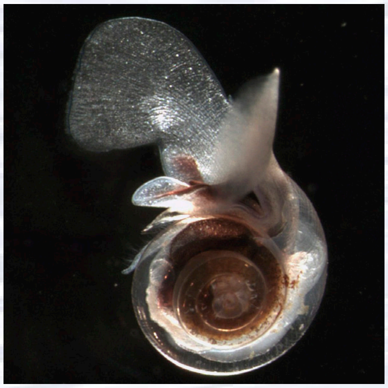
- Fishnet or kitchen strainer
- Dechlorinating solution (for treating tap water; from an aquarium store)
- Solution of freshwater minerals (e.g., “chichlid salts;” from an aquarium store)
- Calcium carbonate powder (from an aquarium store)
- Pond sludge
- Tablespoon measure
- Plastic bucket, 1 gallon or larger capacity

Audiovisual Materials

- None

Teaching Time

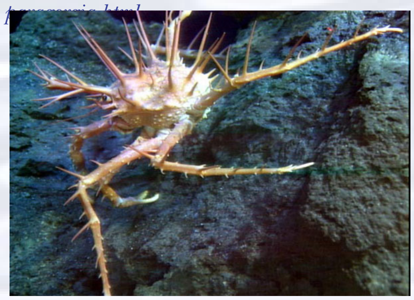
Four or five 45-minute class periods, plus time for student research and periodic discussion of model ecosystems



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. From the Mountains in the Sea 2004. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04mountains/logs/summary/media/paragorgia.html



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/march30/media/spinycrab.html

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words and Concepts

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

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/april11/media/mussel_mound.html

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. Appendix 1 provides an overview of these issues, which 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 inquiry 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 the issue 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."**

See the parallels to the human situation here? If you don't, then you really need to make this project.

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

1. To prepare for this lesson:

- If you have not previously done so, 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 Initial Inquiry Lesson, *To Boldly Go…* (http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09toboldlygo.pdf).
- Review information in Appendix 1, *Ocean Health Overview*, 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 inquiries. 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 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 lower 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) and/or http://www.esi.utexas.edu/outreach/ols/clicks.php?id=41a (PowerPoint® version 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 Appendix I of the Initial Inquiry Lesson, *To Boldly Go…* So, 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
   Diversification
   Clade
   Synergistic
   Anthropocene
   Anoxic
   Dinoflagellate bloom

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 12, 13 and 15 for interactive multimedia presentations and Learning Activities on Food, Water, and Medicine from the Sea; Ocean Pollution; 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!
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_aquarium.pdf
(5 pages, 408k) (from the 2003 Gulf of Mexico Deepwater Habitats Expedition)

Focus: Niches in coral reef ecosystems (Life Science - Grades 7-8)

In this activity, 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 be able to explain the importance of three physical factors in coral reef ecosystems and infer the fundamental source of energy in a deep-water coral reef.

A Piece of Cake
http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_cake.pdf
(4 pages, 244k) (from the 2003 Charleston Bump Expedition)

Focus: Spatial heterogeneity in deep-water coral communities (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deep-water hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Charleston Bump.

ALIEN INVASION!
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/aliens.pdf
(4 pages, 353k) (from the 2003 Life on the Edge expedition)

Focus: Invasive species (Life Science)

In this activity, students will be able to 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!
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/savereef.pdf
(PDF, 292kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)

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

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

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

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

Allsopp, M., R. Page , P. Johnston , and D. Santillo. 2007. Oceans in Peril. Worldwatch Report 174. Worldwatch Institute, Washington, DC. 56 pp. Available as a hard copy or e-book for $9.95 from http://www.worldwatch.org/node/5353

Jackson, J. B. C. 2008. Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences, August 12, 2008 Vol. 105 No. Supplement 1 11458-11465. Abstract available online at http://www.pnas.org/content/105/suppl.1/11458.

Historical Overfishing and the Recent Collapse of Coastal Ecosystems by Jeremy Jackson et al., Science, 293, 629 (2001) – http://www.palomar.edu/oceanography/www_resources/jacksonetal.pdf

http://cachefly.oreilly.com/make/wp_aquanaut.pdf – Ecosystem Engineering by Martin John Brown; article on which the hands-on activity in this lesson is based

http://www.esi.utexas.edu/outreach/ols/lectures/Jackson/ – Hot Science - Cool Talks Outreach Lecture Series Web page from the University of Texas at Austin for *Brave New Ocean*, a presentation by Dr. Jeremy Jackson, March 3, 2006, with links to webcasts and PowerPoint® versions of the presentation; you can hear Jeremy Jackson's presentation (without the slides) at http://www.youtube.com/watch?v=2fRPiNcikOU

http://www.esi.utexas.edu/outreach/ols/clicks.php?id=41a – Jeremy Jackson's PowerPoint® presentation, *Brave New Ocean*

Devine, J. A., K. D. Baker, and R. L. Haedrich. 2006. Fisheries: Deep-sea fishes qualify as endangered. Nature 439:29; abstract available online at http://www.nature.com/nature/journal/v439/n7072/abs/439029a.html

Hood, M., W. Broadgate, E. Urban, and O. Gaffney, eds. 2009. Ocean Acidification. A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO_2 World; available online at http://ioc3.unesco.org/oanet/OAdocs/SPM-lorezv2.pdf.

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

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

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Populations and ecosystems

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth— covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

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

Essential Principle 4.

The ocean makes Earth habitable.

Fundamental Concept a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

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.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

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 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, including how you use it in your formal/informal education setting.
Please send your comments to: oceanexeducation@noaa.gov

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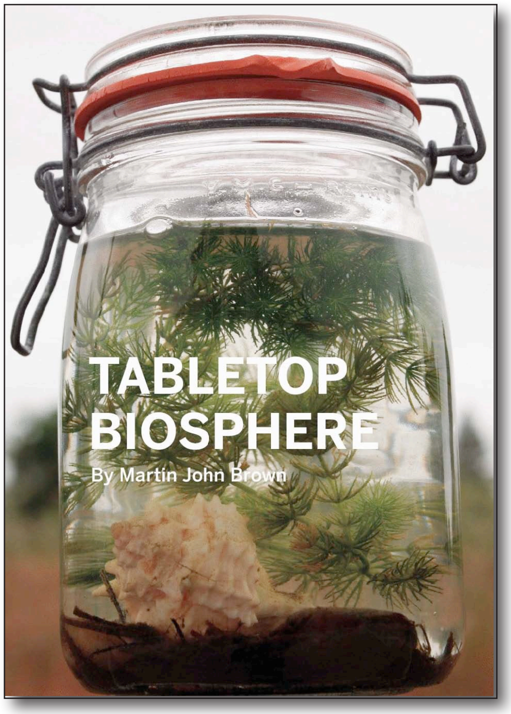
Build Your Own Ecosystem Construction Guide

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.

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



from *Make*, Volume 10

2. Make Nitrate-Poor Fresh Water (NPFW) by adding dechlorinating solution and mineral solution to a gallon of tap water according to directons 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?

Appendix A: Ocean Health Overview

Unless otherwise cited, the following information is from Allsopp, Page, Johnston, and Santillo (2007).

Overfishing

Global demand for seafood has grown steadily over the past century, resulting in increasingly sophisticated fishing industries that use powerful boats, freezer trawlers, acoustic fish finders, and other advanced technologies. In 2005, capture fisheries around the world harvested about 95 million tons of fish. In the same year, at least 76 percent of the populations that support those fisheries were considered fully exploited, overexploited, or depleted. In most cases, overfishing has been the primary cause for the declines, though in some cases environmental conditions have also contributed. Between 1950 and 2000, nearly one-fourth of all fisheries collapsed. Small fisheries, small fish stocks, and bottom-dwelling species were the most vulnerable. One of the best-known collapses took place in the Atlantic cod fishery, which collapsed in 1991.

Although fishery collapses may be reversible, it takes time. Although the Atlantic cod fishery was closed in 1992, there is little sign of recovery of offshore cod populations. A study of 90 collapsed fish stocks has shown that many bottom-dwelling fish showed little if any recovery, even after 15 years. Benthic fish stocks are particularly vulnerable to overfishing by deep-sea bottom trawling. For example, along the continental slope in the Atlantic waters of Canada, populations of roundnose grenadier were reduced by 99.6% between 1978 and 2003. Bottom trawling also causes severe impacts on deep-sea bottom habitats that are discussed below.

Many of these declines have taken place in fisheries that target large predators. In the north Atlantic over the past 50 years, the abundance of predatory fishes has declined by approximately two thirds (Devine, Baker and Haedrich, 2006). In the case of large, predatory, open-ocean fish, such as tuna, swordfish, and marlin, abundance has declined by approximately 90% since 1952.

In addition to the obvious impact of having fewer fishes, intensive fishing has other impacts as well:

- Selectively targeting larger, faster-growing fishes may change the genetic diversity within populations of these species and reduce their survival capabilities.
- As populations of large predators are depleted, fishing is moving farther down the ocean food webs, placing increasing pressure on populations of smaller, shorter-lived fishes and resulting in simplified food webs. These webs are less able to compensate for changes caused by climate shifts or other environmental alterations.

Appendix A: Ocean Health Overview – 2

- Overfishing herbivorous species can result in excessive growth of algae and other marine plants. This is a significant problem in coral reef ecosystems where removal of herbivorous fishes is resulting in corals being displaced by algae.
- Depletion of traditional fisheries is causing modern fishing vessels to move onto the high seas where there is little or no fisheries regulation or management.
- In addition to harvesting fishes that are valuable as food, industrial fishing is also targeting other species for conversion into fishmeal or fish oil. Since many of the latter species are low in ocean food webs, overfishing of these stocks can have serious impacts on many other species.
- Substantial numbers of seabirds, marine mammals, and sea turtles become entangled or hooked accidentally by fishing gear, causing further disruption to ocean food webs.
- Overcapacity in the world's fishing fleets (i.e., too many boats, not enough fish) is causing an increase in illegal, unregulated, and unreported (IUU) fishing, which may account for as much as 20 percent of the global fishery harvest. IUU fishing includes bottom trawling and other methods that cause severe damage to marine ecosystems, and are a serious threat to marine diversity, the livelihood of local fishing communities, the food security of coastal countries, and the entire concept of achieving sustainable fisheries.

Even as fish stocks decline, global demand for seafood continues to increase. This demand has fueled a rapid expansion in aquaculture over the past 30 years. Aquaculture produced about 40% of all fish harvested in 2005, consumes more than a third of the worldwide production of fishmeal, and is the fastest-growing animal-food production sector in the world. Like many other intensive food-producing industries that require high inputs, large-scale aquaculture is accompanied by its own set of environmental impacts, which include:

- **Net Food Loss**: Cultivating some marine species results in a net food loss, because the mass of fishmeal required to grow these species is greater than the mass of food that is produced. Marine finfish, shrimp, salmon, and trout, for example, requires 2.5 to 5 pounds of fishmeal for every pound of fish produced. Tuna ranches require 20 pounds of wild fish to produce one pound of tuna. The bottom line is that the expanding aquaculture industry is placing additional pressure on populations of wild fish that are already being harvested at or beyond sustainable capacity.
- **Depletion of Wild Stocks for Seed**: Marine aquaculture often relies on wild juvenile fish or shellfish to supply seed stock, and in some cases this has led to overexploitation.
- **Other impacts:** Habitat loss, nutrient pollution, and invasive species, which are discussed below.

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Habitat Destruction

Nearshore marine habitats are susceptible to damage or destruction by coastal development, especially in developing countries. Aquaculture for tropical shrimp and fish has led to the destruction of thousands of hectares of mangroves and coastal wetlands. Perhaps the greatest damage for the ocean as a whole comes from bottom trawling, a fishing method that uses a heavy net, weighted by anchors, which is dragged behind a boat along the sea floor. The result is that almost everything is removed from the ocean floor (only rocks remain), and the bottom is converted to mud that forms a plume behind the trawlers. Bottom trawling is analogous to clearcutting in old growth forests. Besides the impact on fish populations, bottom trawling causes severe habitat destruction, particularly in deep ocean coral reefs and seamounts that provide habitats for many species. Photographs of seafloor habitats off the coasts of Norway and the United Kingdom show trawl scars up to four kilometers long, some of which have destroyed reefs that were 4,500 years old. Off the Atlantic coast of Florida, an estimated 90–99 percent of reefs formed by the deep-water coral *Oculina* have been destroyed.

Invasive Species

Invasive species are non-native species that have been introduced to a region, have established thriving reproductive populations, and are expanding their range. Invasive species often have no natural predators in their new environment, and can successfully compete with and possibly replace native species. Invasive species are usually introduced accidentally or deliberately by humans. A particularly dangerous example is the Mediterranean Clone of Caulerpa (*Caulerpa taxifolia*), a marine alga containing a toxin that is lethal to some species and may interfere with the eggs of some marine mammals. *C. taxifolia* was accidentally introduced into the Mediterranean by a marine aquarium, and is now forming dense mats that displace invertebrates, fish, and native algae from the sea floor. Until recently, *C. taxifolia* was a popular species in aquarium stores. The European Green Crab (*Carcinus maenas*) is another invasive species, introduced to the U.S. over 150 years ago in the ballast and heavily fouled outer hulls of wooden ships coming from Europe. These crabs feed on a variety of organisms, including clams, oysters, mussels, marine worms and small crustaceans, and are a serious potential competitor for native fish and bird species. At the turn of the century, European green crabs almost destroyed the soft clam industry of Maine and surrounding waterways, and is at least partially responsible for the decline of scallop populations on Martha's Vineyard. In California, the green crab has caused the loss of as much as 50 percent of Manila clam stocks and declines in other crab populations. Lionfish (*Pterois volitans*) are native to the Indo-Pacific from Australia north to southern Japan and south to Micronesia, but have recently been seen along the Atlantic coast of the United States and in the Caribbean; probably introduced in

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ballast water or from marine aquaria. Lionfish feed on smaller fishes, shrimp, and small crabs. Venomous spines in the dorsal and pectoral fins are used to immobilize prey species, as well as to discourage potential predators. The ecological impact of invasive lionfish in the Atlantic and Caribbean is not yet known, but they may compete with many native species, including economically important species of snapper and grouper. Populations of prey species could be seriously affected as well.

Invasive species may also be introduced through aquaculture operations. In 1973, seaweed species being farmed in Hawaii escaped and spread across nearby coral reefs. The Japanese Pacific oyster, widely used in aquaculture, has now become established on almost all northern hemisphere coasts. Invasive species can also introduce new diseases. Serious epidemics of two diseases in Atlantic salmon have been linked to movements of fish for aquaculture and re-stocking. The whitespot virus has caused multi-million dollar losses in Asia's shrimp farming industry since the early 1990s and has been found more recently in Latin America and the United States, where it has caused losses in Texas shrimp farms and may also be killing wild crustaceans.

Toxins, Nutrients, Marine Debris

For thousands of years, Earth's ocean has provided a convenient means for disposing of unwanted products of human activity. The ocean's impressive size, coupled with the fact that it is largely out of sight, makes it easy to assume that this practice is of no particular consequence. But there is growing evidence that thousands of different chemicals, radioactive substances, nutrients, oil, and marine debris are having a significant impact.

Recent concerns about chemical contamination have focused on the impact of synthetic chemicals known as persistent organic pollutants (POPs), which are toxic, long-lived, often accumulate in the tissues of fish and other animals, and may travel long distances from their point of origin. POPs include chemicals that have significant benefits to humans, such as brominated flame retardants (BFRs), that are added to plastics, resins, textiles, paints, electronics, and other products to increase their fire resistance. Global use of BFRs doubled between 1990 and 2000, and they are known to contaminate marine organisms all over the world including those in the deep oceans and remote Arctic regions. Toxic effects have not been extensively studied, but there is evidence that they can disrupt endocrine systems, nervous systems, and immune functions.

Artificial radionucleides are another class of substances that have no natural counterparts, are extremely long-lived, and are known to cause cancers and mutations. Nuclear weapons testing between 1954 and 1962 has been the largest single source of artificial radionuclides to the ocean due to fallout,

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but contamination continues from nuclear power facilities and nuclear reprocessing plants.

Nutrient pollution, mainly nitrogen and phosphorous compounds, enters coastal waters via agricultural fertilizer run-off, sewage discharges, and atmospheric pollution from burning fossil fuels. Excess nutrients in coastal waters can cause massive blooms of phytoplankton and other marine plants. When these plants die, they sink to the bottom and are decomposed by microorganisms that consume oxygen. This is called eutrophication. In some cases, this decomposition process consumes almost all of the dissolved oxygen in the surrounding water. The result is the formation of vast, oxygen-depleted areas known as "dead zones." Around the world, the number of dead zones has risen every decade since the 1970s. One of the largest dead zones occurs in the northern Gulf of Mexico, and has been linked to massive increases in the use of fertilizers in the Mississippi River watershed which began in the 1950s.

Actually, dead zones aren't really dead; they often contain abundant populations of bacteria, jellyfish, and other species that can tolerate low-oxygen conditions. This replacement of populations of healthy aerobic populations with anoxia-tolerant bacteria and jellyfish has been called "the rise of slime" (Jackson, 2008). It has also been pointed out (Jackson, 2008) that dead zone ecosystems resemble ocean communities before the Cambrian explosion.

Oil spills are a well-known form of contamination as a result of the publicity that typically surrounds major spills. Less well known are much smaller spills that occur every day from ships, offshore drilling operations, and routine vessel maintenance. The amount of damage caused by an oil spill depends upon the size of the spill, type of oil involved, location of the spill, and weather conditions. Major spills have severe impacts on coastal wildlife, but long term continued exposure to low levels of oil can also have a significant effect on survival and reproduction of seabirds and marine mammals.

Marine debris is a pervasive problem affecting all of Earth's ocean, and injures and kills many different marine animals through drowning, suffocation, strangulation, starvation (through reduced feeding efficiency), injuries, and internal damage. Large quantities of marine debris are found in shipping lanes, near fishing areas, and in oceanic convergence zones. 80% of marine debris is from land-based sources; the rest comes from marine activities. Major sources include tourist-related litter, debris in sewage, derelict fishing gear, and wastes from ships and boats. Plastic bags are the major type of marine debris found on the seabed, especially in coastal areas. Derelict fishing gear can continue to trap and catch fish even when they are no longer tended

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by fishermen. This "ghost fishing," can capture large quantities of marine organisms. Marine debris can also act as rafts, possibly carrying marine animals and plants long distances to areas where they become invasive species.

Climate Change

An overview of climate change issues is provided in Appendix A of the lesson, *Where Have All the Glaciers Gone?* Major impacts on ocean health are related to increased temperature, sea level rise, and ocean acidification (which is discussed in a separate section below).

Global sea surface temperature is approximately one degree C higher now than 140 years ago. One degree may not sound like much, but the key point is the rate at which this increase has taken place. Over the past 25 years the rate of increase in sea surface temperature in all European seas has been about 10 times faster than the average rate of increase during the past century. Earth's ocean could warm by an additional 1 – 2 degrees C by the end of this century.

Many marine organisms live at temperatures close to their thermal tolerances, so even a slight warming could have serious effects on their physiological functioning and ability to survive. Coral reefs are a frequently-cited example. Shallow-water reef-building corals live primarily in tropical latitudes (less than 30 degrees north or south of the equator) where water temperatures are close to the maximum temperature that corals can tolerate. Abnormally high temperatures result in thermal stress, and many corals respond by expelling symbiotic algae (zooxanthellae) that live within the coral's soft tissues. Since the zooxanthellae are responsible for most of the corals' color, corals that have expelled their algal symbionts appear to be bleached. Zooxanthellae are important to corals' nutrition and growth, and expelling these symbionts can have significant impacts on the corals' health. In some cases, corals are able to survive a bleaching event and eventually recover. But if other types of stress are present and the stress is sustained, the corals may die.

Prior to the 1980s, coral bleaching events were isolated and appeared to be the result of short-term events such as major storms, severe tidal exposures, sedimentation, pollution, or thermal shock. Over the past 20 years, though, these events have become more widespread, and many laboratory studies have shown a direct relationship between bleaching and water temperature stress. In general, coral bleaching events often occur in areas where the sea surface temperature rises 1 degree C or more above the normal maximum temperature.

It is possible that corals' physiology might change to allow them to become acclimated to higher temperatures, or that populations might adapt if

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individual corals' ability to tolerate higher temperatures provided a survival advantage that allowed these corals to become more numerous. There is no indication, however, that either of these possibilities is actually happening. It is important to remember that the impacts of rising ocean temperatures are not confined to corals; corals happen to be very conspicuous and have been the subject of scientific research for many years, so changes are likely to be noticed. Similar impacts are almost certainly taking place in many other species that are less-studied or are presently unknown to science.

Even when individual species are able to tolerate increased temperatures, they may still be affected by changes within their food webs. For example, warmer waters in northwestern Europe have caused clams (*Macoma balthica*) to spawn earlier in the year, but blooms of phytoplankton on which the clams feed do not happen until later in the spring. Clam larvae also face increased predation from shrimp whose abundance has increased in early spring due to warmer temperatures.

Sea-level rise is caused by the expansion of sea water as it warms, as well as melting of ice on land (melting sea ice doesn't increase sea level, as you can demonstrate with ice cubes in a glass of water). Global sea level rose an average of 1.8 mm per year between 1961 and 2003, and is expected to continue rising for at least several decades. The amount of additional rise will depend largely on how much melting occurs at the polar ice caps. Even if greenhouse gas concentrations were stabilized immediately, sea level will continue to rise from thermal expansion, and ice sheets will continue to melt. Increased sea level will have significant impacts on low-lying coastal areas and on species whose habitats are in these areas.

Increased influx of fresh water from melting ice sheets coupled with warmer ocean temperatures may also cause changes in ocean currents, which are driven by temperature and salinity differences between large masses of seawater. Potential changes to the deep-ocean thermohaline circulation ("The Great Ocean Conveyor Belt") are described in the Leader's Guide, *Why Do We Explore?*

Some of the most rapid warming is taking place in Earth's polar regions. Continued loss of sea ice is expected to have negative impacts on species that depend upon the sea ice habitat, such as fishes, birds, seals, whales, and polar bears. These are discussed in *The Good, The Bad and The Arctic*, a lesson plan from the Ocean Explorer 2005 Hidden Ocean Expedition (http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_goodandbad.pdf).

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Ocean Acidification

Ocean acidification is “the other carbon dioxide problem,” additional to the problem of carbon dioxide as a greenhouse gas. Each year, the ocean absorbs approximately 25% of the CO_2 added to the atmosphere by human activities. When CO_2 dissolves in seawater, carbonic acid is formed, which raises acidity. Ocean acidity has increased by 30% since the beginning of the Industrial Revolution, causing seawater to become corrosive to the shells and skeletons of many marine organisms as well as affecting the reproduction and physiology of others. The present increase in ocean acidification is happening 100 times faster than any other acidification event in at least 20 million years.

Ocean acidification is a result of increased CO_2 emissions, and is not directly related to climate change. There are many uncertainties about the causes, extent, and impacts of global climate change; but these do not apply to ocean acidification which can be observed happening right now and is highly predictable into the future. Measures to reduce global temperatures or the concentration of other greenhouse gases will have no effect on ocean acidification. Only a reduction in atmospheric CO_2 concentrations will affect the acidification problem.

Research is just beginning on the impacts of ocean acidification on marine organisms and ecosystems (more than 60% of the research papers on this subject have been published since 2004). Impacts have been observed in many species, however, and range from interference with calcification processes to reduced resistance to other environmental stresses such as increasing temperatures and pollution.

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