COASTAL ECOSYSTEM SCIENCE LESSON PLAN

Getting Thirsty?

Theme

Drought

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/ecoscience/
http://www.ngdc.noaa.gov/paleo/drought/drght_what.html

Subject Area

Earth Science

Grade Level

9-12

Focus Question

What causes droughts, and how do they affect coastal ecosystems and human communities?

Learning Objectives

- Students will be able to define "drought" and explain how drought conditions may affect coastal ecosystems.
- Students will be able to discuss how drought conditions correlate with water temperature changes in the tropical Pacific Ocean.
- Students will be able to use various data sources to investigate streamflow and drought conditions in selected locations.

Materials Needed

- Copies of "Introduction to Drought as an Ecosystem Stressor" worksheet, one copy for each student or student group
- (optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and "Worksheets" and provide copies of these materials to each student or student group

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Classroom style or groups of 2-3 students

Maximum Number of Students

30

Key Words

Drought
Palmer Drought Severity Index (PDSI)
El Niño/Southern Oscillation (ENSO)
Hydrograph

Background Information

Coastal ecosystems provide many benefits to human communities, including food, ports, recreational opportunities, habitats for diverse plant and animal life, and minerals. But these systems are vulnerable to stress from natural processes and human activity. The National Ocean Service's (NOS) National Centers for Coastal Ocean Science (NCCOS) study five categories of ecosystem stress:

- Climate change, which may result in changes in sea level and ocean temperature;
- Extreme natural events, such as hurricanes, droughts, and harmful algal blooms;
- Pollution, such as fertilizers from agricultural and urban runoff;
- Invasive species, such as lionfish and zebra mussels; and
- Destructive uses of land and coastal resources, such as overfishing.

Drought is defined as a period of abnormally dry weather that persists long enough to produce a serious hydrologic imbalance (as indicated by crop damage, water shortage, etc.). To quantify drought, scientists consider precipitation, temperature, and soil moisture data over a period of several months.

The Palmer Drought Severity Index (PDSI) is a commonly used indicator of drought conditions that combines these factors. The value of the PDSI reflects how soil moisture compares with normal conditions, so a PDSI value represents recent conditions as well as current conditions. Calculation of PDSI is fairly complex; see *http://nadss.unl.edu/PDSIReport/pdsi/* for an in-depth discussion.

Although they are less spectacular than earthquakes or hurricanes, droughts affect more people in North America than any other natural hazard, and cost $6 – 8 billion in losses every year in the United States alone. The two major droughts of the 20th century occurred in the 1930s and 1950s. The 1930s drought combined with decades of poor land management to create the "Dust Bowl" that made ships 300 miles from shore in the Atlantic Ocean dusty with topsoil from the Great Plains. Midwestern settlers had plowed up grasslands in the late 1800s and early 1900s, then planted the land with cotton, wheat, and corn that depleted the soil of moisture and nutrients. When reduced precipitation made it impossible to grow these crops, there was nothing to prevent the soil from blowing away. In the 1950s drought, soil erosion was less severe thanks to improved agricultural practices such as crop rotation to avoid nutrient depletion and planting ground cover to stabilize soils. But despite these improvements, seven years of unusually high temperatures and unusually low precipitation devastated agriculture in the midwest: 244 of the 254 counties in Texas were declared federal drought disaster areas. Although the 1987-89 drought covered only 36% of the U.S., compared to the 70% covered during the Dust Bowl drought, the 1980s drought was accompanied by extensive wildfires and caused $39 billion in damage. This was the most costly natural disaster in U.S. history and was a strong indication that many parts of the country are more vulnerable to drought than ever before.

With this increased vulnerability, drought is becoming a more serious issue for coastal ecosystems. Historically, the devastating impacts of prolonged drought in the U.S. have been documented most often in the midwest. But while we don't often think of water shortage as a problem of coastal habitats, drought has a marked effect on coastal ecosystems. Droughts can alter the natural flow of streams and rivers that bring freshwater, nutrients and other materials into these systems. Estuaries and marshes, which provide important nursery areas and protect inland areas from erosion, are particularly susceptible to drought because they depend upon regular freshwater input. Droughts also increase the risk of fires and soil erosion, which can result in additional stress to coastal ecosystems from high levels of sediment influx. When droughts reduce river flow and the influx of freshwater to coastal ecosystems, seawater can intrude into marshes and estuaries causing massive mortalities of species that cannot tolerate high salinity levels. In the summer of 2000, these conditions severely damaged oyster resources in Louisiana. The same drought was responsible for widespread destruction of marsh grass and increased coastal erosion in places normally stabilized by the grasses. Reduced freshwater flows also allowed seawater to enter aquifers, contaminating wells used for irrigation and killing crops.

Recent climate studies at NASA's Earth Observatory suggest that drought problems are also extending to the Pacific northwest, an area usually thought of as rather wet. These studies show that coastal mountain ranges on the Pacific coast have lost 60 percent of their normal winter snowpack over the last 50 years, and that the amount of water stored as snow in these mountains may diminish by as much as 70 percent by the middle of the 21st century. Reduction in Western mountain snow cover will lead to increased fall and winter flooding accompanied by severe spring and summer droughts that will have serious impacts on West Coast fisheries, as well as agriculture and hydropower industries. See *http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2004/2004021616529.html* for additional information.

The causes of drought are not completely understood. Temperature variations in the tropical Pacific Ocean, however, have been found to correlate with drought conditions in North America. These events are popularly known as El Niño (unusually warm water temperatures in the eastern Pacific Ocean) and La Niña (unusually cool water temperatures in the eastern Pacific); oceanographers refer to the two events as the El Niño/Southern Oscillation (ENSO). Normally, Pacific trade winds cause surface waters in the eastern Pacific Ocean to move toward the west, resulting in the upwelling of cold bottom water along the eastern margin of the Pacific. During El Niño events, the trade winds are weaker than usual, so there is less upwelling and sea surface temperatures in the eastern Pacific are higher than normal. These abnormalities affect atmospheric circulation in the mid-latitudes (between 30° and 60° latitude), causing wetter-than-normal winters from California to the southeastern United States, and higher-than-normal temperatures from Alaska south through southwestern Canada and east to the Great Lakes. In contrast, during La Niña events, cooler-than-normal sea surface temperatures in the eastern Pacific make drought conditions likely across the southwestern and southeastern U.S., wetter-than-normal winters in the northwestern U.S., and lower-than-normal temperatures from Alaska to southwestern Canada and across the northern border of the U.S. A La Niña-like event is believed to have been at least partially responsible for the 1930s "Dust Bowl" drought.

NCCOS studies the effects of drought on U.S. coral reefs, the nation's estuaries, 13 national marine sanctuaries, 26 national estuarine research reserves, and ocean ecosystems. The purpose of this lesson is to introduce students to drought as an ecosystem stressor and to sources of data on current and historical drought conditions.

Learning Procedure

1.

Briefly review the concept of drought and its significance as a natural hazard. You may want to begin by asking students to identify the most expensive natural disaster in U.S. history, and perhaps include some images from the 1930s "Dust Bowl" drought. Ask students how drought might affect coastal ecosystems. Introduce the PDSI as an indicator of drought conditions.

2.

Have students complete the "Introduction to Drought as an Ecosystem Stressor" worksheet, either individually or in groups of 2-3 students.

3.

Discuss students' responses to questions on the worksheet. Key points include:

(1) A hydrograph is a graph that represents stream flow or average flow rates of a stream over a period of time.

(2) The most destructive climate-related event during the 20th century was the Yangtze River Flood of 1931 that impacted more than 51 million people and caused the deaths of 3.7 million people due to disease, starvation, or drowning. Note that this flood was preceded by a three-year drought.

(3) A drought in China during the early 1940s resulted in widespread starvation that caused the deaths of 3 million people.

(4) Possible reasons for the abandonment of Ancient Pueblo communities include drought, invasion by other tribes, volcanic activity that shortened growing seasons, or disease such as hanta virus.

(5) Oxygen isotope evidence from lake cores indicates a series of droughts that coincide with collapse of the classic Mayan culture.

(6) Prolonged periods of severe drought lasting three to six years coincided with the disappearance of the Roanoke Colonists.

(7) PDSI values reconstructed from tree-ring data indicate less severe drought conditions than PDSI values based on instrument measurements. This may reflect the ability of trees to withstand a certain amount of drought before these conditions have a significant effect on growth.

(8) La Niña events are typically accompanied by droughts in the southern U.S. and floods in the Pacific Northwest.

(9) Droughts in the western U.S. during the 1950s motivated intense dam-building for water storage and delivery.

10) Map 1 corresponds to the 1954 – 1956 interval; Map 2 to the 1985 – 1995 interval; Map 3 to the 1934 – 1939 interval.

(11) The Channel Islands National Marine Sanctuary was subjected to extreme drought conditions in 1777, 1782, 1794, and 1795.

According to instrument measurements, the area adjacent to the Channel Islands National Marine Sanctuary was exposed to extremely wet conditions in 1905, 1906, and 1941.

According to instrument measurements, the coast adjacent to Gray's Reef National Marine Sanctuary was exposed to lower-than-normal precipitation in six years of the "dust bowl" decade; 1930, 1931, 1933, 1934, 1935, and 1936.

Based on tree-ring data, students should infer that the Tijuana River estuary would probably have been quite dry in 1990, since the Tijuana River is described as "an intermittent stream," and the surrounding area had been exposed to a drought that began in 1985.

(12) The maximum streamflow recorded for the Pascagoula River was about 40,000 cubic feet per second (be sure students understand the logarithmic scale!). The minimum recorded streamflow was a little less than 350 cubic feet per second. In general, streamflows are at their maximum during the winter and early spring.

(13) "Surface water: Peak streamflow" will display the peak flow for each year; using this display, students should see that the longest interval in which peak flow did not reach 100,000 cubic feet per second was between 1957 and 1975.

Point out that droughts can result from human activity as well as natural causes. For example, when the Colorado River carved the Grand Canyon, tons of eroded material were carried to the mouth of the river at the northern end of the Gulf of California, Mexico. This material formed a large estuary, the Santa Clara Slough, which supported a highly productive shrimp fishery. During the last half of the 20th century, more and more water from the Colorado River was diverted to sprawling cities in California and Arizona. As a result, the Santa Clara Slough estuary practically disappeared, along with the shrimp fishery, an important economic resource for many Mexican coastal communities.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Atmosphere," then "Global Climate Change" in the menu bar at the top of the page for links to resources about climate change.

The Me Connection

Have students write a brief essay in the form of diary notes describing changes in their community resulting from a drought during which the PDSI was below -5.0 for five consecutive years.

Extensions

Have students explore additional sources of data linked to the Climate TimeLine Data Access page (*http://www.ngdc.noaa.gov/paleo/ctl/data.html*).

Resources

http://nerrs.noaa.gov/ – National Estuarine Research Reserve System website

http://www.ngdc.noaa.gov/paleo/ctl/drought.html – Climate TimeLine Drought Tutorial

http://www.ngdc.noaa.gov/paleo/drought/animation/pdsi_animation.html – "North American Drought Variability Table"; an animated map of PDSI values for the contiguous U.S. beginning in 1700

http://waterdata.usgs.gov/nwis – U.S. Geological Survey National Water Information System website

http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2004/2004021616529.html – Online article about anticipated droughts in the Pacific northwest

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard D: Earth and Space Science

- Energy in the earth system
- Geochemical cycles

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H1 – Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually results in a system similar to the original one.

5D/H2 – Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3 – Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

COASTAL ECOSYSTEM SCIENCE REVIEW SHEET

Introduction to Drought as an Ecosystem Stressor

Refer to the following Web pages for answers to these questions:

http://www.ngdc.noaa.gov/paleo/ctl/drought.html – Climate TimeLine Drought Tutorial

http://www.ngdc.noaa.gov/paleo/ctl/clisci10.html – Climate Science, 10 year time scale

http://www.ngdc.noaa.gov/paleo/ctl/100.html – Climate Summary, 100 year time scale

http://www.ngdc.noaa.gov/paleo/ctl/cliihis1000.html – Climate History, 1000 year time scale

http://www.ngdc.noaa.gov/paleo/drought/animation/pdsi_animation.html – North American Drought Variability Table

1. What is a hydrograph?

2. What was the most destructive climate-related event during the 20th century?

3. What happened during the early 1940s that caused the deaths of 3 million people in China?

4. What were four possible reasons for the Ancient Pueblo ("Anasazi") people of Mesa Verde to abandon their homes in Colorado and migrate south to New Mexico and Arizona?

5. What evidence is there for a relation between climate and the collapse of the classic Mayan culture?

6. What climatic events coincided with the disappearance of the Roanoke Colonists?

7. How do estimates of PDSI based on tree-rings compare with PDSI values calculated from actual measurements with scientific instruments?

8. What effects in the southern U.S. and Pacific Northwest would be expected during a La Niña event?

9. Droughts in mid-1950s in the western U.S. were the motivation for what human activity?

10. Refer to Maps 1, 2, and 3 on the “CTL and Drought - Part 3” page (*http://www.ngdc.noaa.gov/paleo/ctl/drought3.html*). Here’s how you can use NOAA’s “Climate Diagnostic Center’s Monthly Mean Compositing Page” (*http://www.cdc.noaa.gov/USclimate/USclimdivs.html*) to decide which of these maps corresponds to the periods 1934 – 1939, 1954 – 1956, and 1985 – 1995:

On the Climate Diagnostics Center page:

- select “Palmer Drought Severity Index” from the pull down menu next to “Variable?”;
- select “Dec” from the pull down menu next to “Ending month”;
- enter “1934” and “1939” in the boxes next to “Enter a range of years”; and
- Click “Create Plot”.

Compare the resulting map to Maps 1, 2, and 3 to decide which map corresponds to the 1934 – 1939 period. Repeat these steps for the other time periods.

11. Refer to the “North American Drought Variability” Table (*http://www.ngdc.noaa.gov/paleo/drought/animation/pdsi_animation.html*). Click on the animation graphic to display the “Reconstruction of Past Drought Using Instrumental and Tree-ring Data” window, and use the playback tools to find answers to the following questions:

(a) In which years between 1770 and 1800 was the coast adjacent to the area that is now the Channel Islands National Marine Sanctuary subjected to an extreme drought (PDSI = -4.0 or less)? See the map of National Marine Sanctuary sites at *http://sanctuaries.noaa.gov/oms/omsmaplarge.html* or *http://channelislands.noaa.gov/focus/about.html* to locate the Channel Island NMS.

(b) According to instrument measurements, in what years during the first half of the 20th century was the area adjacent to the Channel Islands National Marine Sanctuary exposed to extremely wet conditions (PDSI = 5 or more)?

(c) According to instrument measurements, in how many years during the "Dust Bowl" drought (1930 - 1939) was the coast adjacent to Gray's Reef National Marine Sanctuary exposed to lower-than-normal precipitation (PDSI less than 0)?

(d) Read the introductory page about the Tijuana River National Estuarine Research Reserve at *http://nerrs.noaa.gov/TijuanaRiver/welcome.html*. What do you think this estuary would have been like in 1990?

12. Here's how you can obtain a hydrograph that will give you an idea about freshwater inflows to the Grand Bay National Estuarine Research Reserve (Jackson County, Mississippi).
    - Refer to the Climate TimeLine Data Access page (*http://www.ngdc.noaa.gov/paleo/ctl/data.html*).
    - Click on "Find Your Place from NGDC."
    - Click on "U.S. Counties."
    - Choose "U.S. Stream Gauges" from the "Select" pull down menu on the left of the page.
    - Type "Mississippi" and "Jackson" into the "State Name" and "County Name" boxes.
    - Click "Select Data."
    - The program should return two Stream Gauge Stations that match the search criteria. Click on "Pascagoula River At Graham Ferry, Ms".
    - Select "Surface Water in the "Data Category" pull down menu at the top of the page.
    - Select "Surface-water: Daily streamflow" in the "Available data for this site" pulldown menu.
    - A new window should appear; click "Submit" to create a graph for all available data
    - You should see a graph of daily streamflow beginning in 1994.

(a) What was the maximum streamflow recorded?

(b) What was the minimum streamflow recorded?

(c) In general, at what time of the year are streamflows at their maximum?

13. The Padilla Bay National Estuarine Research Reserve is located in the Salish Sea near Mount Vernon, Washington. The Salish Sea is a large estuary fed by many fresh water sources including the Fraser and Skagit Rivers. What was the longest period of time since 1950 that the peak flow from the Skagit River did not reach 100,000 cubic feet per second?

Hints:

(a) If you don't enter a county in the fourth step (above) the program will return a list of all stream stations in the specified state.

(b) Consider selecting one of the other options under the "Available data for this site" pulldown menu instead of "Surface-water: Daily streamflow."