Climate Change and Ecosystems

A research and discussion activity directed at grade levels 9 – 12

Activity Summary:
Students research the interdependencies among plants and animals in an ecosystem and explore how climate change might affect those interdependencies and the ecosystem as a whole.
Original Source – Union of Concerned Scientists Curriculum Guide
http://www.climatehotmap.org/curriculum/index.html

Major Concepts Addressed: Ecosystem Change, Climate Change

Big Idea:

Climate change is likely to have considerable impacts on most or all ecosystems. The distribution patterns of many species and communities are determined to a large part by climatic parameters, however, the responses to changes in these parameters are rarely simple.

Key Concepts

- At the simplest level, changing patterns of climate will change the natural distribution limits for species or communities.
- The scenario becomes more complicated when you consider the complexity of species interactions and differential sensitivities to changing conditions between species. Certain species may rapidly adapt to new conditions and may act in competition with others.
- Rising sea temperatures will further affect the distribution and survival of particular marine resources. Corals have already shown an extremely high sensitivity to minor increases in temperature, while other studies have shown dramatic changes in the distribution and survival of the Pacific salmon.
- In addition to causing a warming effect, increased concentrations of atmospheric carbon dioxide are known to increase rates of photosynthesis in many plants and algae, as well as improving water use efficiency.

Essential Questions

- What are the most critical factors causing ecosystem changes?
- How do ecosystems change over time?
- What actions could be taken to limit harmful consequences of ecosystem degradation?
- Why can't ecosystems just adapt?

Knowledge and Skills

Students will:

1. Explore the complexity of ecosystem interdependencies ;
2. Explain how climate change could affect the components of an ecosystem; and

3. Suggest ways to detect the impacts of climate change on ecosystems.

Prior Knowledge

(*according to AAAS Atlas for Science Literacy Vol. 1 and 2 & National Science Education Standards*)

- K-2: Living things are found almost everywhere in the world. There are somewhat different kinds in different places.
- 3-5: Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful
- 6-8: Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming have changed the earth's land, oceans, and atmospheres…decreasing the capacity of the environment to support some life forms.
- 9-12: If a disturbance occurs…the affected ecosystem may return to a system similar to the original one or it may take a new direction…Changes in climate can produce very large changes in ecosystems.

Common Preconceptions

- *Only natural and wilderness areas are fully functioning ecosystems.* Students may some have difficulty in perceiving schoolyards as ecosystems (a vacant lot, or even a parking lot, is still an 'ecosystem').
- *Human impact results in the destruction or collapse of ecosystems.* Ecosystems do not 'collapse', but do change in function, structure and composition over time due to natural or human disturbance (drought, flooding, mowing, herbicides).

Background

Ecosystem science deals with the complex interactions between living organisms and their environment, particularly interconnections that allow organisms to change the physical and chemical properties of their environment. These interconnections involve 'feedbacks' when a change in environmental conditions affects organisms and ecosystems in ways that cause further changes in the environment. Interactions that amplify environmental changes are called positive feedbacks, whereas interactions that suppress changes are called negative feedbacks. For example, sunlight heating the ocean causes water to evaporate and form clouds, which blocks sunlight and cools the ocean, thereby leading to a negative feedback. In contrast, cold weather can allow snow to cover the ground, which reflects sunlight back into the atmosphere and causes temperatures to get colder, leading to a positive feedback on air temperature. Plants and animals can interact with these physical processes to strengthen or weaken either positive or negative feedbacks. Fortunately, in healthy ecosystems, most ecological processes involve negative feedbacks, which function to stabilize ecosystems. It is not yet clear, however, how much of this stabilizing function has been lost, given the large number of ecosystems globally that are already heavily influenced by human activities. (From Lucier, A., M. Palmer, H. Mooney, K. Nadelhoffer, D. Ojima, and F. Chavez. 2006. *Ecosystems and Climate Change: Research Priorities for the U.S. Climate Change Science Program. Recommendations from the Scientific Community.* Report on an Ecosystems Workshop, prepared for the Ecosystems Interagency Working Group. Special Series No. SS-92-06, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD, USA. 50pp.)

The geographic ranges of plant and animal species are affected by climatic factors such as temperature, precipitation, soil moisture, humidity, and wind. A shift in the magnitude or variability of these factors in a given location due to global climate change will likely impact the organisms living there. Species sensitive to temperature may respond to a warmer climate by moving to cooler locations at higher latitudes or elevations. (Examples of plant and animal range shifts can be found on the map *Global Warming: Early Warning Signs*).

Factors other than climate may limit the extent to which organisms can shift their ranges. Physical barriers such as mountain ranges or extensive human settlement may prevent some species from shifting to more suitable habitat. In the case of isolated mountain top species,

there may be no new habitat at higher elevation to colonize. Even in cases where no barriers are present, other limiting factors such as nutrient or food availability, soil type, and the presence of adequate breeding sites may prevent a range shift. (See the EPA's global warming web site for a discussion of factors that could limit a range shift for North American forests – http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsForests.html)

In addition to the direct effects of temperature on organism physiology, projected climate changes under an enhanced greenhouse effect might change the availability of food, space, shelter, or water; upset the predator/prey balance of an ecosystem; increase susceptibility to pests/disease; change the frequency of natural hazards such as fires, droughts, and flooding. These effects might lead to local population declines or extinctions for some species.

Materials

Regional nature guides; biology or environmental science textbooks
Computers with Internet access (desirable, but not necessary)
Global Warming: Early Warning Signs map
http://www.ucsusa.org/ssi/climate_change/global-warming-early-warning-signs-map.html

Activity Directions:

Introduction

Using their prior knowledge only, ask students to answer the following questions:

- In what ways does climate affect plants and animals?
- Consider how latitude and altitude determine what types of species live in a region.
- Look at a world map of vegetation and evaluate how climate influences the distribution of plants.
- Identify the ways in which temperature affects the life cycle of animals (for example, migration, hibernation, breeding).

Develop a list of climatic effects on plants and animals from student answers that can be used as a reference guide for student research.

Explore

1. Have students use their knowledge of their part of the country to name the ecosystems found in nearby natural areas (such as lakes, wetlands, fields, forests, a river, or seashore). Have the class vote on one ecosystem to study in more detail. Alternatively, if time and resources allow the teacher should pick an ecosystem that students can visit in one or two field trips to collect data.

2. Ask students to research as a class the basic components of the ecosystem they have chosen. Students should look for organisms in each category of *Producers, Herbivores, Omnivores, Carnivores*, and *Decomposers*. Nature guides, library books, and the Internet could all be sources of information for this exercise. The web sites of State Departments of Conservation or the local Audubon Society would be good resources. If at all possible, take students on a field trip to collect data on the types of plants and animals found in the ecosystem. Students or the teacher can design a species observation sheet, and guidebooks can be used to assist with identifications in the field. Supplement the field observations with Internet or library research, especially for the larger mammals or nocturnal animals (A good online field guide can be found at eNature.com – see *Suggested Resources*).

3. After the class has finished their research, have each student create a web / concept map (using drawings or pictures, for example) of the basic components of the ecosystem showing interrelationships. The web should include physical factors such as the Sun, atmosphere, water, soil, and nutrients. At this point, students can begin to develop hypotheses concerning how climate change might affect the ecosystem. Ask each student to read the text on Plant and

Animal Range Shifts from the *Global Warming: Early Warning Signs* map to learn some examples of how climate change affects organisms. Then have each student prepare a report to be presented orally to the class on how climate change could affect one of the plants or animals in the regional ecosystem. Give students some example questions to help them focus their research (See the student handout). Students can also use the information generated by the class in the Introduction activity above. Teachers should use the Regional reports of the U.S. National Assessment at http://www.usgcrp.gov/usgcrp/nacc/default.htm to find the projected climate changes for their region of the country. The table of climate changes in the example "Guidelines for Students" can then be modified to fit the regional projections.

4. Each student should present their research findings in the form of hypotheses concerning how the projected climate changes might affect their organism, and the reasoning behind the hypotheses. Tell the class that they will each be expected to write a summary essay in which they reflect on how the ecosystem as a whole might be different if the projected climate changes occur (see #5). In this way, each student will be responsible for understanding the material presented by other members of the class.

5. As a final exercise to hand-in, have each student prepare a description of the ecosystem as it is today, using their web for illustration, and a description of what they think the ecosystem might look like in 2100 if the projected climate changes occur, using a new web for illustration.

Assessment / Discussion Questions

1. Ask students to make a list of the measurements that could be taken to try to detect the beginning signs of climate change in the ecosystem. Ask them to consider physical, biological, and chemical measurement possibilities. This exercise could be done as a class activity, or this could be included in the writing assignment in #5 above.

2. Have students research the possible effects of climate change on an ecosystem significantly different from the one they have just studied. Depending on your school location this might be a coastal system, coral reef, desert, or mountainous area. If possible pick an area in a country other than the United States (i.e. Great Barrier Reef, Canadian Arctic). Ask students to compare and contrast the impacts in each of the two systems they have studied.

Vocabulary

Adaptation: Changes in an organism's structure or habits that allow it to adjust to its surroundings
Abiotic: A non living component of an ecosystem eg sunlight
Biotic: Living components of an ecosystem.
Climate: The meteorological elements, including temperature, precipitation, and wind, that characterize the general conditions of the atmosphere over a period of time at any one place or region of the Earth's surface
Ecosystem: A functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow.
Weather: Weather is the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season.

Additional resources

Related sites with further classroom applications
Exploratorium Global Climate Change Research Explorer
http://www.exploratorium.edu/climate/index.html

United Nations Environment Programme - World Conservation Monitoring Centre

http://www2.wcmc.org.uk/climate/impacts.htm

PBS Earth on Edge - Ecosystems
http://www.pbs.org/earthonedge/ecosystems/index.html

EPA Global Warming Impacts –A good starting point for student research on climate change impacts on ecosystems. Reports are available by ecosystem type (coastal zone, forests, wetlands,
etc.), by animal type (birds, fisheries), and by state.
http://yosemite.epa.gov/oar/globalwarming.nsf/content/Impacts.html

EPA Plant and Animal Impacts Bibliography – For in-depth research this site offers an extensive
listing of scientific articles about the impacts of climate change on wildlife.
http://yosemite.epa.gov/oar/globalwarming.nsf/uniqueKeyLookup/SHSU5BNJWW/$file/Bibliography.pdf?OpenElement

eNature Online Field Guides – A user-friendly site where students can see a picture and read about plant and animal species found in different habitats of North America (scroll down to the
"Habitat Guides" section). Teachers can also create a classroom species list.
http://www.enature.com/

Global Climate Change Online Resources – A comprehensive listing of online resources about global climate change, arranged by topic. Go to http://www.pacinst.org/resources/ to find specific
resources about the impacts of climate change on biodiversity and ecosystems.

The Intergovernmental Panel on Climate Change (IPCC) - Approximately every five years, IPCC releases an assessment of the state of climate change science. The latest assessment, Climate Change 2007: Mitigation of Climate Change, is available online. The summary for policymakers < http://www.ipcc.ch/SPM040507.pdf >.

Union of Concerned Scientists – The UCS web site contains many resources for teaching climate
change. Below are links to several of these.
Presentation Slides <
http://www.ucsusa.org/global_environment/archive/page.cfm?pageID=991>
Confronting Climate Change in the Gulf Coast Region < http://www.ucsusa.org/gulf/ >
Confronting Climate Change in California. < http://www.ucsusa.org/climatechange/california >
The Science of Climate Change.
< http://www.ucsusa.org/global_environment/global_warming/page.cfm?pageID=515 >
Fact vs. Fiction on Climate Change.
< http://www.ucsusa.org/global_environment/global_warming/page.cfm?pageID=498 >
Global Warming: Frequently Asked Questions
< http://www.ucsusa.org/global_environment/global_warming/page.cfm?pageID=497 >
Common Sense on Climate Change: Practical Solutions to Global Warming.
< http://www.ucsusa.org/global_environment/global_warming/page.cfm?pageID=793 >

Notes on Pedagogy:

This activity is from a collection of activities offered by the Union of Concerned Scientists. Consider using the complimentary activities in the guide to prepare a unit of study. A display size poster of the Climate Hot Map, highlighting fingerprints and harbingers of global warming is available. http://www.climatehotmap.org/curriculum/index.html

Use a case study to focus students in a particular ecosystem with specific issues. See PBS Earth on Edge site for sources of case studies.
http://www.pbs.org/earthonedge/ecosystems/index.html

Explore scientific data relating to the atmosphere, the oceans, the areas covered by ice and snow, and the living organisms in all these domains. Also get a sense of how scientists study natural phenomena—how researchers gather evidence, test theories, and come to conclusions, by using the Exploratorium's Research Explorer site. Contains case studies.

Student Activity Sheet: *CLIMATE CHANGE AND ECOSYSTEMS*

The state Department of Natural Resources has asked your class to evaluate how climate change due to an enhanced greenhouse effect might impact an ecosystem in your state. In a previous activity your class identified the major components of the ecosystem you have chosen to study. Because the organisms in the ecosystem function in a complex web of interdependencies, your class will need more information to evaluate how climate change would affect the system has a whole. Your task as a member of the climate impacts evaluation team is to describe in detail how the projected climate changes could impact one species in the ecosystem. You will present your findings to the class, and use this information and that of your teammates to construct "before" and "after" pictures of the ecosystem, using both text and illustrations. In your research, try to consider all of the ways in which climate could impact your species, both directly and indirectly. The questions below will help you get started, but you may be able to identify other important relationships between your species and climate. Be creative!

My species is _____.

Its place in the food web is (circle one) *Producer, Herbivore, Carnivore, Omnivore, Decomposer.*

Illustrate the function of this species in the ecosystem by sketching interrelationships with other organisms:

Climate can affect a species directly, for example by constraining organisms to areas within their temperature tolerances, or indirectly by affecting food supply, availability of shelter, or other factors necessary for survival. In order to determine how climate change might affect a particular species, scientists must first try to understand all of the ways in which present climate influences that species. Research the life cycle, habits, and physiological needs of your species in order to identify the ways in which climate affects it today. Use the following questions as a guide to get you started. List other questions that you think are important in the space provided below.

Life Cycle: What are the life stages of the species? When do changes from one stage to another take

place? How is the species affected by the seasons? How does the species reproduce? When and how often does it breed?

Food: What are the nutritional needs of the species? What are its preferred foods? What are other food sources? What do the young eat? Is the food supply influenced by the seasons?

Shelter: Where does the species live in the ecosystem? Does it share this space with other species? What kind of shelter does it need for breeding/raising its young?

Predators/Disease: What species, if any, depend on this species for food (or parasitic/symbiotic relationships)? What diseases or pests affect this species? What conditions make the species susceptible to disease?

Competitors: What species compete with this species for food, shelter, or other needs? What if anything, maintains a balance among these competitors?
Other Important Factors:

Evaluating Climate Change Impacts:
Now that you have learned more about your species' life habits and needs, it's time to consider how

global climate change might play a role in its future. Some scientific studies have suggested that climate change could change the distribution of species in an area because warmer temperatures would cause some species to shift their geographic ranges to cooler areas, either to higher latitudes or to higher elevations on mountain slopes. Other studies indicate that in areas where species are unable to move to accommodate changing climate conditions, for example, in places where their movement is blocked by large cities, population numbers could decline or local populations could become extinct. In fact, the impact of climate change on a species is likely to be complex because its survival is linked to many factors. You have identified some of the factors that are important to the survival of your species. Now look at the list of projected climate changes and evaluate how each of these changes might impact the species you studied.

Use the table provided to characterize the impact as "little or no impact," "moderate impact," or "significant impact."

Climate Change	**Impact: Little, None, Moderate, Significant**	**Nature of Impact: (i.e. range shift north, earlier egg laying, fewer breeding sites)**
		1.

Higher Temps/more heat waves		2. 3.
Change in drought frequency/severity		
Heavier snowfalls		
Change in flooding frequency/severity		
Change in fire frequency/severity		
Sea level rise		
Polar warming		