



Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Global Warming: Early Warning Signs

Exploring Climate Change Impacts

Curriculum Guide for High School Courses in Biology, Environmental Science, Geography, Earth Science and others focusing on the society- environment interface

Developed by the Union of Concerned Scientists
to accompany the world map
“Global Warming: Early Warning Signs”
www.climatehotmap.org

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About the Activities

This set of teaching materials is designed to accompany *Global Warming: Early Warning Signs*, a science-based world map depicting the local and regional consequences of global climate change. The map was produced as a collaborative project by the Union of Concerned Scientists and several environmental organizations, and has been peer-reviewed by scientists. It highlights recent events around the world in two broad categories: direct indicators of the observed long-term global warming trend (“fingerprints”), and events that are consistent with the projections for global climate change and are likely to become more frequent and widespread with continued warming (“harbingers”). The map is an exciting visual tool for learning about the impacts of global climate change.

The *Early Warning Signs* map was mailed to over 15,000 schools around the country for Earth Day 2000. The mailing packet included a short list of ideas for incorporating the map into a variety of classes in the natural, physical, and social sciences. The Union of Concerned Scientists has taken the lead in producing this new packet of more fully developed lessons. Each activity is structured to include an initial “Engagement” exercise, one or more steps of a Student “Exploration” project, and further ideas for extended study. The materials align with National Learning Standards for Science, Geography, Social Studies, Language Arts, Environmental Education, and Technology.

The teaching materials in this packet are geared towards students and teachers in grades 9-12, although individual exercises are adaptable to different grade levels. The activities engage students in an exploration of the impacts of global climate change on ecosystems and natural resources, on community, and on individuals and society. The first two activities look at the questions “What do we mean by global climate change?” and “How does the record of climate compare at local versus global scales?” Later activities address the impacts of climate change on natural ecosystems, human health, and economy and personal lifestyle.

Global Warming: Early Warning Signs can be viewed on the web at www.climatehotmap.org. The Web site also includes the complete list of scientific references for the events highlighted on the map. Additional copies of the 2’ by 3’ color poster are available from the Union of Concerned Scientists (there is a shipping fee).

Feedback on the map and teaching materials is welcome. Please send your comments to the contact address listed on the cover page of this document.

October 2000

References for National Learning Standards Alignment

Science

National Research Council, 1996. *National Science Education Standards*. National Academy Press, Washington, DC.

Social Studies

National Council for the Social Studies, 1994. *Expectations of Excellence Curriculum Standards for the Social Studies*, National Council for the Social Studies, Washington, DC.

Geography

American Geographical Society, Association of American Geographers, National Council for Geography Education, and National Geographic Society, 1994. *Geography for Life National Geography Standards*. National Geographic Research and Exploration, Washington, DC.

Technology

International Society for Technology in Education, 1998. *National Educational Technology Standards for Students*. International Society for Technology in Education (ISTE), NETS Project, Eugene, OR.

Environmental Education

North American Association for Environmental Education, 1999. *Excellence in EE – Guidelines for Learning (K-12)*. North American Association for Environmental Education, Rock Spring, GA.

English Language Arts

National Council of Teachers of English and International Reading Association, 1996. Standards for the English Language Arts. National Council of Teachers of English and International Reading Association, Urbana, IL and Newark, DE.

1. Climate Change in My City

Overview

Students use an historical climate index to analyze climate change at local, regional, and global scales.

Objectives

As a result of this activity, students will be able to:

1. Describe how global temperature has changed over the last 100 years;
2. Explain why long-term temperature records vary from one location to the next;
3. Demonstrate how different spatial scales affect the record of long-term temperature trends.

Prerequisite knowledge – Teacher

- ❑ Weather concerns the present and near-term future state of the atmosphere, whereas climate accounts for all past weather events as well as the future (in the form of climate model predictions).
- ❑ Scientists evaluate global warming by looking at trends in the *average global temperature*, which is the average of the highs and lows measured at thousands of different places around the earth. Observations collected over the last century suggest that the average land surface temperature has risen 0.45-0.6°C (0.8-1.0°F) in the last century. The surface of the ocean has also been warming at a similar rate. Studies that combine land and sea measurements have generally estimated that global temperatures have warmed 0.3-0.6°C (0.5-1.0°F) in the last century.
- ❑ Regional and local temperature trends will be different from the global average—over the last century some areas have warmed while others have cooled.

Prerequisite knowledge – Student

- ❑ Weather is the state of the atmosphere at a specific time and place whereas climate is the average weather taken over a long time period for a given place or region. Climate change is the long-term alteration in the average weather conditions for a particular location.
- ❑ Historical temperature and precipitation data are evaluated relative to a “normal,” which is the average for a particular sub-period of time or the average of all the years of record.

Materials

Computers with Internet access

Global Warming: Early Warning Signs map (for extension activities).

Procedure

ENGAGE

Have students think about the weather in their state over the last year. Ask them what stands out in their mind, e.g. warm winter, rainy spring, a heavy snowfall, etc. Then ask them to make a judgment, based on their own observations, as to whether the previous season was warmer or colder than “normal,” and whether it was drier or wetter than normal. Ask them to consider what factors might influence their response, i.e. how much time they spend outside, how much their lifestyle depends on the weather, etc. Have each student record their observations on a sheet of paper and then tally the results for the entire class.

EXPLORE

Task 1

1. Have students compare their predictions to the actual data available from the National Climatic Data Center. This information can be found by first going to <http://www.ncdc.noaa.gov/ol/climate/climateresearch.html>. Click on the link for “Climate of 2000” (or appropriate year). Scrolling through this page you will find links to monthly or seasonal reports. For example, click on “Climate of 2000: June - August in Historical Perspective” to find information on summer 2000 temperature and precipitation relative to historical averages. Click on “U.S. Regional/Statewide Analyses” to find information on a state-by-state basis. This page has color-coded maps showing which states were warmer/colder than normal and which states were wetter/drier than normal. Make sure students also note what data are being used to calculate the normal, i.e. 1961-1990 or entire record.
2. Ask students to write a short essay comparing their predictions to the actual data. Ask them to comment on the reliability of human memory versus measurements taken with a thermometer or rain gauge.

Task 2

1. Students compare the seasonal climate data at different spatial scales. For the example given above, again direct students to the “Climate of 2000: June - August in Historical Perspective.” Then ask them to determine whether the average temperature was above/below normal for at least three different spatial scales: State or region, U.S national, and global. Repeat the analysis for precipitation. The U.S. information can be found under the heading “U.S. National Analysis,” and the Global information can be found under “Global Analysis.” Prior to conducting the research, ask students to formulate an hypothesis concerning whether or not they expect to find different results at the different scales.
2. Ask students to construct a chart that summarizes the information they collect. An example might look like this:

Time Period	Temp. (Above/Below Normal?)	Basis For Normal	Precipitation (Above/Below Normal)	Basis For Normal
June-August 2000				
Regional		1895-1999		1961-1990
Northeast	Below		Above	
South	Above		Below	
West	Above		Below	
National	Above	1895-1999	Below	1961-1990
Global	Above	1880-1999	Below	1961-1990

- Students should analyze the data and draw conclusions related to their hypothesis.

Task Extension:

- Divide the class into small groups and assign each group a different region of the country or world. Ask them to prepare a 5-10 minute news report to present orally to the rest of the class that summarizes the climate for that region for a particular month, season, or year. The report should include temperature, precipitation, and any unusual or extreme events, and how the climate for the chosen period compares to long-term averages. The NCDC web site can be a primary resource for this exercise, as can newspapers and magazines and other weather-related web sites.

Task 3

- Students use the Internet to determine changes in climate for their city or town (or one that is nearby) during the past 100 years. The “Common Sense Climate Index” is a measure of whether an area has experienced a temperature change that should be noticeable to most people who have lived at that location for a few decades.
- NASA’s Goddard Institute for Space Science maintains a web site with clickable maps in which students can search for the Common Sense Index for U.S. and world cities. Go to www.giss.nasa.gov/data/update/csci/ and click on “World and U.S. Maps.” Scroll to the bottom of the page for the U.S. map. Major cities are shown as a guide, but students can click anywhere on the map to bring up the city or town closest to them. Clicking on the station name brings up the Climate Index and seasonal temperature curves for that station.

Students should work individually or in pairs to answer these questions on a worksheet:

- Describe the Climate Index curve for their city: What is the overall trend? Are there particular periods in the past when temperatures were increasing or decreasing?
- Describe the seasonal curves for temperature in the same manner. How do the trends differ among the different seasons?
- Compare the curve for the town/city to the U.S. and global average curves (found at <http://www.giss.nasa.gov/data/update/csci/bargraphs/>). How are they similar? How are they different? Suggest reasons for any differences.

d. A useful comparison curve is the Climate Index for Barrow, Alaska. This region has been experiencing significant warmth since the mid-1970s. Based on the Climate Index data for this city, is it likely that the climate change is noticeable to people living in this region?

EXTEND

Students use the map *Global Warming: Early Warning Signs* and other resources to evaluate how global climate change might impact the region where they live.

Have students examine the Global Warming map to determine the kinds of impacts expected in a world with increasing global temperatures. From the nine categories listed, ask students to consider which impacts are most relevant for their region of the country. Students can then explore the impacts for their region in detail at the U.S National Assessment web site: <http://www.usgcrp.gov/usgcrp/nacc/default.htm>

Suggested Resources

NCDC Extreme Weather and Climate Events – This website is a gateway to climatic data and reports on extreme weather events throughout the U.S. and the world.
<http://www.ncdc.noaa.gov/oa/climate/severeweather/extremes.html>

National Weather Service Heat Stress Information – Describes the “heat index” and heat stress, and provides links to forecasts and further information about heat waves.
<http://weather.noaa.gov/weather/hwave.html>

Karl, T.R., N. Nicholls, and J. Gregory, 1997. The Coming Climate. *Scientific American*, 78-83. This article describes the climate changes projected to occur as Earth warms.

Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12)

- Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12):

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

Earth and Space Science, Content Standard D (9-12):

- Energy in the earth system

Science in Personal and Social Perspective, Content Standard F (9-12):

- Environmental quality
- Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 1: World in Spatial Terms. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 17: Uses of Geography. How to apply geography to interpret the past.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Technology Foundation Standards

Standard 1: Basic operations and concepts

Students are proficient in the use of technology.

Standard 3: Technology productivity tools.

Students use technology tools to enhance learning, increase productivity, and promote creativity.

Standard 5: Technology research tools

Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

1.1 The Earth as a physical system

2.4 Environment and society

Strand 3: Skills for Understanding and Addressing Environmental Issues

3.1 Skills for analyzing and investigating environmental issues

Standards for the English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment)

2. Oral History Project: Climate Then and Now

Overview

Students interview older residents in the community about climate changes during their lifetime and compare the results to a climate change index that is based on historical temperature measurements.

Objectives

Students will:

1. Explore the factors that determine human perceptions of weather and climate;
2. Compile community survey results on local climate change;
3. Examine the historical record of climate change in their area;
4. Discuss the implications of human perceptions of local climate change on global climate change policy.

Prerequisite knowledge – Teacher

- Weather is the state of the atmosphere at a specific time and place whereas climate is the average weather taken over a long time period for a given place or region. Climate change is the long-term alteration in the average weather conditions for a particular location. To evaluate whether or not climate is changing, scientists study historical records of temperature and precipitation or the timing of weather-related events such as lake ice formation and ice-out, animal breeding or migration, and the length of the growing season.
- The “Common Sense Climate Index” has been proposed as a measure of whether an area has experienced a temperature change that should be noticeable to most people who have lived at that location for a few decades. A positive value for the index means that climate is warmer than average (The average value for the index is zero. It is based on the average value of the index for the period 1951 to 1980). The scientists who developed the index hypothesize that a persistent index value of +1 or greater represents a climatic warming noticeable to the people of a region.

Prerequisite knowledge – Student

- Weather is the state of the atmosphere at a specific time and place whereas climate is the average weather taken over a long time period for a given place or region. Climate change is the long-term alteration in the average weather conditions for a particular location.
- Historical temperature and precipitation data are evaluated relative to a “normal,” which is the average for a particular sub-period of time or the average of all the years of record.

Materials

Computers with Internet access
Survey form for interviews

Teacher Note:

This activity can be completed independent of other activities in this packet, or it can be done as a follow-up to Activity 1, *Climate Change in My City*. If desired, some of the tasks in the previous activity could be incorporated into this activity. For example, the ENGAGE exercise in Activity 1 is also appropriate for this oral history project, and could be combined or substituted for the engagement activity presented here.

Procedure

ENGAGE

Ask the class to characterize the climate of their region. They should consider such factors as the average temperature and precipitation, the magnitude of the temperature change from one season to another, the seasonal distribution of precipitation, the nature of the air masses that affect the climate, proximity to the ocean, large mountain ranges, or large lakes, etc. Then ask each student to list the ways in which this climate directly affects his or her life (for example, winter snow allows me to go skiing, mild climate lets me bike to school year-round, spring rain floods the soccer field). Next have the students make a judgment, based on their own observations, as to whether climate now is significantly different from when they were younger, and if so what was different about it. Have each student record their answer on a sheet of paper and then tally the results for the entire class. Ask students to write a short essay discussing the results of the class survey. The essay should include a discussion of any similarities and differences among individual responses, in particular considering how different lifestyles affect how people perceive weather and climate and how their own lifestyle influenced their perception of climate change.

EXPLORE

1. Lead a class discussion about the reliability of the results of the class survey on climate change. In addition to lifestyle differences, students should recognize that the time frame over which people evaluate climate change influences the results. Ask the class how they might design a study to look more closely at human perceptions of climate change.
2. For a class project, students can interview older local residents to see if they have perceived any changes in climate during their lifetimes. They will then compare the results of the survey to climate change in their region as measured by the “Common Sense Climate Index.” The tabulated results of the survey could eventually be written up as an article for the school or local newspaper, or as a presentation to a local radio or television station.
3. Divide the class into small groups to work on the design of the survey. The goal is to determine if people living in the area for a long time believe there has been a noticeable change in climate. Ask students to take into account the results from the ENGAGE activity (that is, students will need to include a question about the resident’s lifestyle). When each group has finished a draft survey, bring the class back together to decide which questions should be included and how they will be presented. This could be done

by class discussion and vote. See the example “**Climate Change Survey**” provided on page 14 for key elements the class may wish to include.

4. Ask each student to interview two or three older residents, depending on the size of the community. If possible, students should interview people who have been in the area for at least three decades. Students should make it clear to the interviewees that their answers are completely anonymous, and students should not write the names of the residents anywhere on the data sheet.
5. Have students debrief in the classroom to share their experiences of how the interviewing went and to compile and analyze the group results. Depending on the survey design, the class might want to create an overall continuum or some other chart of opinions—for example, “no change-----some change-----significant change-----very large change.”
6. After students have compiled the survey results they can compare the data to the Common Sense Climate Index for their city. Go to www.giss.nasa.gov/data/update/csci/ and click on “World and U.S. Maps.” Scroll to the bottom of the page for the U.S. map. Major cities are shown as a guide, but students can click anywhere on the map to bring up the city or town closest to them. Then click on the station name to bring up the Climate Index for that station.
7. Ask students to summarize the comparison between the survey results and the Climate Index in the form of either a scientific journal article or an informative news article. The article should incorporate answers to the following questions:
 - What were the results of the resident survey? Was there a clear opinion on change in climate or did answers differ from one resident to another? If they differed, were there any clear patterns relating the answers to the length of time the resident lived in the area, lifestyle, occupation, or other factors?
 - What does the Climate Index say about climate change? Has climate been warming, cooling, fluctuating, or more or less consistent (both over the entire period of record, and for the period of record that corresponds to the lifetime of the interviewed residents)? According to the index, should the climate changes over the last few decades be noticeable to older residents (i.e. has the Climate Index been persistently greater than 1, or less than 1?)
 - Do the results between the survey and the Climate Index agree? If they do agree can you say anything about the usefulness of the Climate Index, or do you still need more information? If they do not agree, can you suggest reasons for the disagreement (i.e. people’s perceptions are not always consistent with reality, Climate Index is not a perfect measure of noticeable climate change, etc.)?

Putting it all together: After students have completed all the exercises, have a final discussion on how perception of climate change might affect a person’s position on climate change policy. For example, people who believe there has been a noticeable change in local climate might be more interested in supporting efforts to curtail greenhouse gas emissions. (This is, of course, only one of many possible factors that influence political position—encourage students to list other factors affecting opinions on climate change policy).

EXTEND

1. The results of the class project could be written up as an article for the school or local newspaper, presented to local radio or television stations, or posted on the Web. If an article is written for the local newspapers or posted on the Web, students could also include a copy of the survey for others to fill out and return to the school. In this way students could add to the results from their interviews.
2. Invite a local weather service employee or weather newscaster to speak about his or her job and opinions of the ways in which climate influences people's lives. Ask the speaker to show weather service data on local historical climate trends. If desired, these data could supplement the Climate Index data in the assignment.
3. Find a partner school in another region of the U.S. or in another country to complete the Climate Change Survey. Compare the results between the two classes by posting them on the Internet. If the Climate Index for your region does not indicate a "noticeable" climate change, try choosing a school where the Climate Index has been persistently near or above +1, such as some Alaskan and Canadian sites. The teacher can browse the Climate Index web site to locate potential partner sites where results might be significantly different.

Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12)

- Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12):

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

Earth and Space Science, Content Standard D (9-12):

- Energy in the earth system

Science in Personal and Social Perspective, Content Standard F (9-12):

- Environmental quality
- Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 2: Time, Continuity, and Change

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 6: Places and Regions. How culture and experience influence people's perceptions of places and regions.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Technology Foundation Standards

Standard 1: Basic operations and concepts

Students are proficient in the use of technology.

Standard 3: Technology productivity tools.

Students use technology tools to enhance learning, increase productivity, and promote creativity.

Standard 4: Technology communications tools (for Extension activities)

Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.

Standard 5: Technology research tools

Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

2.1 The Earth as a physical system

2.4 Environment and society

Strand 3: Skills for Understanding and Addressing Environmental Issues

3.1 Skills for analyzing and investigating environmental issues

Standards for the English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

Climate Change Survey

How long have you lived in the area?

What is your occupation? Has your occupation changed?

How much time do you spend outdoors now? Did you spend more/less time outdoors in the past?

How much would you say your life today is affected by climate? Significantly/Somewhat/Not at all

How much was your life in the past affected by climate? Significantly/Somewhat/Not at all

How often do you follow weather forecasts?

Overall, would you say that climate has changed significantly during your lifetime? If so, how has it changed?

How would you respond to the following statements?

Compared to the past, today's summer temperatures are

Much hotter somewhat hotter same somewhat cooler much cooler not sure

Compared to the past, today's winter temperatures are

Much colder somewhat colder same somewhat warmer much warmer not sure

Compared to the past, the number of unusually hot days now is

Much more somewhat more same somewhat fewer fewer not sure

Compared to the past, the number of unusually cold days now is

Much more somewhat more same somewhat fewer fewer not sure

Compared to the past, our climate today is

Much wetter somewhat wetter same somewhat drier much drier not sure

Compared to the past, the first frost now occurs

Much earlier somewhat earlier same time somewhat later much later not sure

Compared to the past, bird migration in the spring now occurs

Much earlier somewhat earlier same time somewhat later much later not sure

Compared to the past, ice breakup in spring now occurs

Much earlier somewhat earlier same time somewhat later much later not sure

We have more heavy downpours now than in the past

Strongly agree Agree Disagree Strongly disagree not sure

We have more droughts now than in the past

Strongly agree Agree Disagree Strongly disagree not sure

We have more snow now compared to the past

Strongly agree Agree Disagree Strongly disagree not sure

3. Climate Change and Disease

Overview

Students research the relationship between hosts, parasites, and vectors for common vector-borne diseases and evaluate how climate change could affect the spread of disease.

Objectives

Students will:

1. Explain how vector-borne diseases are transmitted;
2. Describe how climate affects the life cycle of vectors;
3. Explore how social factors affect the occurrence and spread of disease.

Prerequisite knowledge – Teacher

- Climate models project a global mean warming by 2100 in the range of 1 to 3.5 C. Increasing temperatures will be accompanied by changes in rainfall and humidity, including a likely increase in the frequency of heavy precipitation events. Some areas will become drier because higher temperatures also increase evaporation.
- A vector-borne disease is one in which the disease-causing microorganism is transmitted from an infected individual to another individual by an arthropod (e.g. mosquito or tick) or some other agent. Other animals, wild and domesticated, sometimes serve as intermediary hosts. Key vector-borne diseases of concern include malaria, Lyme disease, dengue fever, yellow fever, hantavirus pulmonary syndrome, and several forms of encephalitis.
- Climate constrains the range of many vector-borne diseases. VBDs are currently found mainly in tropical and subtropical countries and are relatively rare in temperate zones. Mosquitoes, for example, are limited to seasons and regions where temperatures stay above a certain minimum. Winter freezing kills many eggs, larvae, and adults. Climate also influences the availability of suitable habitat and food supply for vectors.
- Weather affects the timing and intensity of disease outbreaks. Within their temperature range of tolerance, mosquitoes will reproduce more quickly and bite more in warmer conditions. Warmer temperatures also allow the parasites within mosquitoes to mature more quickly, increasing the chances that the mosquito will transfer the infection. Floods can trigger outbreaks by creating breeding grounds for insects. Droughts can reduce the number of predators that would normally limit vector populations.
- Several modeling studies have predicted that increasing temperatures will lead to the spread of malaria and other diseases into previously unaffected areas. Climate change may also affect the severity of the disease at a given location. Due to the complexity of the relationships, the models do not account for all of the ways in which climate can affect the vector, human host, and parasite, and the interactions among them.
- Socioeconomic factors also affect the distribution of vector-borne diseases. A good public health infrastructure, including prompt treatment of cases to reduce the risk of spread of the disease and mosquito-control measures, help to limit disease

transmission in developed countries. For example, malaria once extended into the northern U.S. and Canada, but by 1930 was confined to southern regions of the U.S., and by 1970 had been eradicated. International travel increases the likelihood of an outbreak in nonendemic areas (although weather also plays a role by making conditions suitable for the spread of the disease). An increase in drug and pesticide resistance as a consequence of overuse makes control of vector-borne diseases more difficult. Land-use by humans can change the availability of habitat for vectors.

Prerequisite knowledge - Student

- ❑ Students should understand the concept of an ecosystem, including the relationship between abiotic and biotic factors and how a food chain works.
- ❑ Students should know the physical/atmospheric measurements that are used to characterize a region's climate.

Materials

Access to the Internet, or school and public library for research.

Maps of malaria distribution (these can be printed from the Internet--see *Suggested Resources*)

Procedure

ENGAGE

Have students look over maps of the present-day distribution of malaria in order to characterize the countries where malaria occurs. Specifically, they should consider the climate of the country, such as average annual temperatures, average nighttime (low) temperatures, and precipitation, and whether it is a developing or developed nation. [A world atlas with maps of global temperature and precipitation distribution is probably the easiest way to search for this information. General information on climate for individual countries can be found in the CIA's World Factbook at <http://www.odci.gov/cia/publications/factbook/>. Climate statistics for world cities can be found at <http://www.weatherbase.com/>.] Ask students to write a short essay comparing countries with malaria to those without malaria, and suggesting possible reasons for the differences between the two groups.

EXPLORE

1. Write the names of different vector-borne diseases, along with the name of the vector, onto 3 x 5 index cards (see list of diseases below). Assign students into pairs and have each pair pull an index card out of a box. One student in the pair should research how the disease spreads from one human to another, and another student in the pair should research the life cycle of the vector. Ask the students to create a poster or diorama that illustrates the relationships between the host, parasite, and vector, and how the disease can be transmitted from one human to another. The students should present their findings orally to the class.

2. Bring the class together as a group and ask them to use what they have learned from the oral presentations to brainstorm about how climate might influence the spread of the diseases discussed. Guide the discussion by having students consider the question from three perspectives:
 - a. How does climate impact the vector directly?
 - b. How does climate impact the vector's (or intermediary host's) habitat?
 - c. How does climate impact the parasite?

Students should consider the role of climatic factors such as temperature, precipitation, presence of surface water, humidity, wind, soil moisture, and frequency of storms or droughts. Record ideas on an overhead at the front of the room, and provide a summary sheet for the students to use as reference.

3. Divide students into new groups of four to explore in more detail the impact of climate on vectors. Assign each group a specific vector: tick, rodent, mosquito, snail, bird. Ask the students to fill out a chart highlighting how projected climate changes due to an enhanced greenhouse effect might impact their vector. This can be done as an in-class group activity, with students drawing on the ideas and examples from the previous exercises. Alternatively, students could research the vector in more depth individually as a take-home assignment, and then complete the chart as a group during the next class period. An example chart format is shown on the following page. Students can either read the map *Global Warming: Early Warning Signs* to learn about overall projected climate changes, or they can research climate changes for their region of the country by reading the U.S. National Assessment reports (<http://www.usgcrp.gov/usgcrp/nacc/default.htm>). Students may not be able to fill in all of the spaces in their chart for their vector, but they should try to fill in as many as possible.
4. Have each student write a reflective essay in which they comment on the group's predictions of the potential effects of climate change on disease transmission. Questions to consider include: How easy/difficult was it to evaluate the impacts on the vector and vector habitat? How easy/difficult was it to evaluate the impacts on disease transmission? What, if anything, made the evaluation difficult? How accurate does the group think their predictions are? What additional information would the group like to have to complete the chart? If possible, the teacher should follow up this activity with a discussion on the use of models to predict the impact of climate change on disease. A color map showing model projections of changes in malaria distribution with a warming climate can be found in the Epstein (August 2000) *Scientific American* article.

< <http://www.sciam.com/article.cfm?colID=1&articleID=0008C7B2-E060-1C73-9B81809EC588EF21> >

EXTEND

Students can examine a specific example of how weather affects disease by reading about the West Nile virus outbreak in New York City (see <http://www.globalchange.org/impactal/westnile.htm>) or hantavirus pulmonary syndrome in the U.S. Southwest. The sequence of extreme weather events that likely contributed to the outbreaks is described in the passage “Opportunists Like Sequential Extremes” from the Epstein (2000) article. Have the students read this passage and draw a timeline or flow diagram illustrating the sequence of events leading to the outbreak. An example for the West Nile virus outbreak is shown in the article. Then ask students to look at their diagrams and mark places where changes in human behavior (both individual and community level) could have helped curb the spread of the disease. As a final assignment to turn in, students redraw their first diagram incorporating the changes in human behavior and illustrating how those changes influenced the outcome.

VECTOR-BORNE DISEASES	
<u>Disease</u>	<u>Vector</u>
Malaria	<i>Anopheles</i> mosquito
Yellow fever	mosquito
Dengue fever	<i>Aedes</i> mosquito
Schistosomiasis	water snails
West Nile virus	<i>Culex</i> mosquito
Leishmaniasis	Sand flies
Lyme disease	Tick
Plague	Flea/Rodent
Japanese encephalitis	<i>Culex</i> mosquito
African trypanosomiasis	Tsetse flies
Hantavirus pulmonary syndrome	Rodents
St. Louis encephalitis	<i>Culex</i> mosquito
Dracunculiasis	<i>Cyclops</i> (minute crustacean)
Onchocerciasis	blackflies

Student Name _____ Group _____

Climate Change	Direct Impact on Vector	Impact on Vector Habitat	Impact on Parasite	Potential Impact on Disease Transmission
More heat waves				
Change in flooding				
Change in drought frequency				
Heavier snowfalls				
Sea level rise				
Extreme weather				

Suggested Resources

Malaria Maps:

The Center for Disease Control's "Yellow Book," entitled *Health Information for International Travel, 1999–2000*, can be downloaded for free at <http://www.cdc.gov/travel/reference.htm>. This resource includes a section on malaria and a map showing countries in which malaria is endemic. A separate listing at the front of the book shows disease risk for specific countries.

A world map showing countries in which malaria is endemic can also be found at the Malaria Database, "Introduction" section.
<http://www.wehi.edu.au/MalDB-www/intro.html>

General Information on Vector-borne Diseases:

Division of Vector-Borne Infectious Diseases, Centers for Disease Control and Prevention

<http://www.cdc.gov/ncidod/dvbid/index.htm>

This site provides fact sheets, images, and world maps showing the distribution of several types of vector-borne diseases. A good resource for student research.

Malaria Foundation International

<http://www.malaria.org/>

Provides basic information about malaria, including answers to frequently asked questions, a comprehensive glossary of terms, and links to other sites with information about malaria.

West Nile Virus Information

<http://www.globalchange.org/impactal/westnile.htm>

A site with numerous links to information about the West Nile Virus outbreak in the U.S.

Vector Life Cycles:

What's All the Buzz about Mosquitoes?

<http://www.nysipm.cornell.edu/publications/mosquitobro/index.html>

Mosquito Bytes

<http://whyfiles.org/016skeeter/index.html>

Climate Change and Human Health:

Epstein, P.R., 2000. Is global warming harmful to health? *Scientific American* (August 2000)

<http://www.sciam.com/2000/0800issue/0800epstein.html>

Epstein, P.R., 1997. Climate, ecology, and human health. *Consequences* 3 (2), Global Change Research Information Office.

<http://www.gcrio.org/CONSEQUENCES/vol3no2/climhealth.html>

The Physicians for Social Responsibility

<http://www.psr.org/climate1.htm>

Links to facts sheets, individual state reports (NH, ME, OH, MI, GA, NM, and WA currently available), and other resources on climate change and human health.

U.S. National Assessment Health Sector

<http://ehis.niehs.nih.gov/topic/global/patz-full.html>

Executive Summary of the report from the health sector of the U.S. National Assessment. Includes a section on vector-borne diseases, as well as adaptation and prevention strategies.

Epstein, Paul R. 1999. Enhanced: Climate and Health. *Science* 285, 347-348. This enhanced electronic version provides an extensive list of additional websites and literature on the topic.

<http://www.sciencemag.org/cgi/content/full/285/5426/347>

World Health Organization – Climate and Health

http://www.who.int/peh/climate/climate_and_health.htm

Web page providing information on the effects of climate on human health and links to WHO publications. The report *Climate Change and Human Health: Impact and Adaptation* contains an informative section (Chapter 3) on the impacts of climate change on vector-borne diseases. It can be downloaded as a pdf file at

http://www.who.int/environmental_information/Climate/climchange.PDF

Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12)

- Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12):

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

Life Science, Content Standard C (9-12):

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

Earth and Space Science, Content Standard D (9-12):

- Energy in the earth system

Science in Personal and Social Perspective, Content Standard F (9-12):

- Personal and community health
- Environmental quality
- Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

- Strand 3: People, Places, and Environments
- Strand 8: Science, Technology, and Society
- Strand 9: Global Connections

National Geography Standards

- Standard 1: World in Spatial Terms. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
- Standard 4: Places and Regions. The physical and human characteristics of places.
- Standard 15: Environment and Society. How physical systems affect human systems.
- Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Technology Foundation Standards

- Standard 1: Basic operations and concepts
Students are proficient in the use of technology.
- Standard 5: Technology research tools
Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

- Strand 1: Questioning and Analysis Skills
- Strand 2: Knowledge of Environmental Processes and Systems
 - 2.1 The Earth as a physical system
 - 2.2 The living environment
 - 2.3 Environment and society
- Strand 3: Skills for Understanding and Addressing Environmental Issues
 - 3.1 Skills for analyzing and investigating environmental issues
 - 3.2 Decision-making and citizenship skills

Standards for the English Language Arts

- Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.
- Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
- Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

4. Climate Change and Ecosystems

Overview

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.

Objectives

Students will:

1. Explore the complexity of ecosystem interdependencies ;
2. Explain how climate change could affect the components of an ecosystem;
3. Suggest ways to detect the impacts of climate change on ecosystems.

Prerequisite knowledge – Teacher

- ❑ 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.

Prerequisite knowledge – Student

- ❑ Students should understand the concept of an ecosystem, including the relationship between abiotic and biotic factors and how a food chain works.
- ❑ Students should know the physical/atmospheric measurements that are used to characterize a region's climate.

Materials

Regional nature guides; biology or environmental science textbooks

Computers with Internet access (desirable, but not necessary)

Global Warming: Early Warning Signs map

Procedure

ENGAGE

Using their prior knowledge only, ask students to answer the question: In what ways does climate affect plants and animals? Ask them to consider how latitude and altitude determine what types of species live in a region. Have students look at a world map of vegetation and evaluate how climate influences the distribution of plants. Ask students to 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 (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 example handout, “Guidelines for Students”). Students can also use the information generated by the class in the “ENGAGE” 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.

EXTEND

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). The World Wildlife Fund web site is a good source for information on climate change impacts in international protected areas. Ask students to compare and contrast the impacts in each of the two systems they have studied.

Suggested Resources

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](http://yosemite.epa.gov/oar/globalwarming.nsf/uniqueKeyLookup/SHSU5BNJWW/$file/Bibliography.pdf?OpenElement)

World Wildlife Fund Climate Change Campaign – This site is a gateway to several WWF online reports on the impacts of climate change on wildlife and protected areas. Of particular note for student research are the reports on bird migration and forests.

http://www.panda.org/about_wwf/what_we_do/climate_change/what_we_do/impacts_adaptation_s/index.cfm

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/cc_2.html to find specific resources about the impacts of climate change on biodiversity and ecosystems.

<http://www.pacinst.org/ccresource.html>

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 2001: Impacts, Adaptation and Vulnerability, is available online. The summary for policymakers < <http://www.ipcc.ch/pub/wg2SPMfinal.pdf> >, The full report < http://www.grida.no/climate/ipcc_tar/wg2/index.htm >.

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 >

Standards Alignment

National Science Education Standards

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Science as Inquiry, Content Standard A (9-12):

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

Life Science, Content Standard C (9-12):

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

Earth and Space Science, Content Standard D (9-12):

- Energy in the earth system

Science in Personal and Social Perspective, Content Standard F (9-12):

- Environmental quality
- Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 8: Physical Systems. The characteristic and spatial distribution of ecosystems on the Earth's surface.

Technology Foundation Standards

Standard 1: Basic operations and concepts

Students are proficient in the use of technology.

Standard 5: Technology research tools

Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

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Standards for the English Language Arts

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Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

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

Climate Change	Impact: (Little or None; Moderate; or Significant)	Nature of Impact: (examples: range shift north, earlier egg-laying, fewer breeding sites)
Higher Temps. /More heat waves		1. 2. 3.
More heavy downpours		
Change in drought frequency/severity		
Heavier snowfalls		
Change in flooding frequency/severity		
Change in fire frequency/severity		
Sea level rise		
Polar Warming		