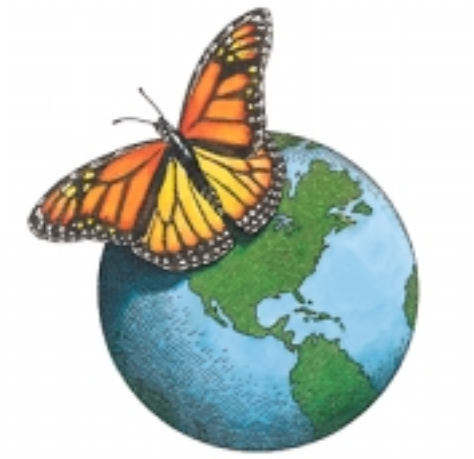

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Confronting Climate Change in the Gulf Coast Region

Prospects for Sustaining Our Ecological Heritage

Curriculum Guide

for High School Courses in Biology, Geography, General Science, Earth Science and other courses focusing on the society-environment interface

Developed by the Union of Concerned Scientists
to accompany the 2001 UCS/ESA report
"Confronting Climate Change in the Gulf Coast Region"

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Overview and Invitation

This curriculum guide was developed to accompany *Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage*—a report jointly produced by the Union of Concerned Scientists (UCS) and the Ecological Society of America (ESA) in 2001. *Confronting Climate Change in the Gulf Coast Region* was co-authored by nationally and internationally renowned climate scientists and ecologists based in Gulf Coast states. Written in a readily accessible and attractive manner for the general public, the report is also appropriate for state and national policymakers and business leaders. The report is intended to raise awareness and understanding of global warming and its potential impacts on the environment that citizens of the Gulf Coast love and depend upon, with the hope that decisions affecting the environment will be better informed in light of this global threat.

The Union of Concerned Scientists is pleased to be able to extend the reach of the report to future generations who will have to deal with the impacts of climate change. The resulting curriculum guide consists of a set of 10 classroom activities which are closely tied to, and build upon, the report. These are accompanied by a teacher's guide to the report and helpful hints for teaching about climate change. The teaching materials are geared towards students and teachers in grades 9–12, although individual exercises are adaptable to grade levels both higher and lower.

Teachers will find the student-oriented activities both educational and engaging. The material is made accessible for teachers by:

- Tying each activity to the content and skills standards set by the states of Alabama, Florida, Louisiana, Mississippi, and Texas as required for grades 9–12;

- Providing sufficient background information and resources for teachers to feel comfortable teaching this complex, and frequently controversial, topic; and

- Offering several alternatives and/or extensions to each activity to facilitate their application in varying teaching contexts—e.g. class size, available resources, grade level, skill level, subject matter, etc.

Using the Curriculum Guide

Global change will affect every citizen, every part of the environment and our natural resources, and thus practically every aspect of our lives—our economy, our urban and suburban development patterns, natural areas we protect, and our life styles. Thus, every subject matter in high school offers opportunities to create linkages to climate change. You may use the entire set of activities or select only some of the activities. We encourage you to adapt them to your specific circumstances. You may, for example, want to focus more specifically on the physical or chemical aspects of atmospheric change; emphasize more strongly the ecological impacts or the economic or social implications;

or encourage a critical discussion of the ethical side of this global phenomenon, including the political and technological challenges in finding solutions. This curriculum guide aims to help make these linkages and adaptations, but the suggestions, instructions, and resources leave each teacher much freedom to adapt the activities to meet the specific needs of your students.

Studies synthesizing student understanding of global warming report that *scientists and teachers* are the most trusted sources for information on climate change. Classroom teachers are therefore faced with an opportunity, and responsibility, to provide timely and accurate materials to guide student learning. The activities presented in this curriculum guide engage students in an analysis of global warming as it pertains to the Gulf Coast region in which they live. Approaching the topic from the perspective of regional or local impacts can reduce the perceived "intangibility" of global climate change, reinforcing to students its scope and significance as one of the most critical, long-term environmental problems humanity has ever faced.

Additional copies of the report can be downloaded in pdf format from the UCS web site at http://www.ucsusa.org/environment/gulf.html. This website contains the complete report text, including color graphics. If you reproduce the graphics for use in your class, we ask that you acknowledge UCS and ESA as the source.

Introduction: Climate Change in the Classroom

Global climate change is a challenging topic to teach and to learn. As climate change science rapidly advances, it is essential for educators to have up-to-date, relevant teaching materials that present the basic concepts in ways that stimulate student interest. At the same time, it is important to recognize that students as well as teachers often have misconceptions about global warming that can negatively impact the construction of new knowledge. By understanding these misconceptions, teachers are in a better position to devise strategies for successfully addressing them in the classroom. Although challenging to teach, the complexity of global climate change offers an opportunity to engage students in higher order thinking skills and in an interdisciplinary and multidisciplinary analysis of the issues. In this section we present basic information on the state of the science, background on common misconceptions, and possible assessment strategies for the activities in this guide.

Climate Science Primer

Today's observed and projected changes in the global climate are different from those of any other time in the Earth's history because they are now attributable to human activity. Earth's climate does vary naturally, of course; it has changed in the past and will continue to change in the future. We know about past climate history from scientific analysis of tree rings, coral, ice cores and rocks. All of these sources show that our climate has cycled through ice ages and warm periods during the last 100 million years. In the past, natural variations in the Earth system have driven these climate changes. Some of these natural mechanisms are well understood—like the role of the sun and of volcanoes—while others are less well understood—such as the role that plants and animals play, and the links between the atmosphere and the ocean.

One thing we know for sure is that seemingly small changes in global average temperatures can make a huge difference for life on Earth. The last ice age, for example, was at its peak about 18,000 years ago. During this time sea level was much lower (since much of the Earth's water was locked up as ice), the atmosphere was drier and windier, and the global average temperature was just 7°F colder than today.

An important discovery about past climate is that certain heat-trapping gases (like carbon dioxide and methane) also cycle with climate. When the Earth is warm, there are more heat-trapping gases in the atmosphere than when Earth is cool. These gases act like a 'blanket' and trap outgoing heat to keep our atmosphere (and us) warm. Without them, humans could not inhabit Earth. Human activities, however, are rapidly increasing the atmospheric concentration of these gases, as well as adding new heat-trapping gases that are not found in nature. Over the last two hundred years, burning of fossil fuels and land-use changes (such as deforestation) have altered the atmosphere enough to produce a warming trend in global climate that is distinct from natural variation. Global average

temperature has increased by 1°F over the last century and is projected to rise by 2.5–10.4°F over the next century, comparable to the change seen between ice ages. [Note: For more information on the science of global warming, see the misconceptions text.]

A Note on Nomenclature

In this Guide (and in much of the material currently available on this subject) you will find a variety of terms used fairly loosely and sometimes interchangeably to describe the phenomenon of 'global warming'. It is not our intention to be scientifically rigorous in our use of terms, nor is it our intention to be confusing – but we do point out that the meaning of a particular term is sometimes contextual. The following definitions are outlined for clarification:

Climate change is often used to describe any kind of change in climate that may be natural or human-induced. In the context of this guide, it is often used to describe the 'human-induced' climate change in place of the term 'global warming'.

Global warming refers only to the human-induced climate change that is predicted to have an overall warming effect on Earth's average temperature.

Understanding Student Misconceptions

Educational research on student awareness and understanding of global atmospheric issues has revealed some common misconceptions that should be addressed in any lesson or unit on climate change. Three predominant misconceptions among students are:

- Depletion of the stratospheric ozone layer ("ozone hole") is a direct cause of global warming.
- All types of pollution cause global warming (aerosols, acid rain).
- Weather and climate are the same (global warming is about weather).

Confusion between the stratospheric "ozone hole" and global warming

Confusion between the ozone hole and global warming, and the various pollutants that are involved in either phenomenon, has been widely reported in age groups ranging from fifth-graders to university students and among the general public. The ozone hole, more accurately described as 'ozone depletion,' is the thinning of a layer of protective gas high in Earth's stratosphere about 20 miles above Earth's surface. The depletion occurs seasonally and mainly above the North and South poles and is due to human use of ozone-depleting chemicals such as chlorofluorocarbons (CFCs). In contrast, global warming occurs worldwide in the lower eight miles of the atmosphere and is due to increasing concentrations of greenhouse gases, some of which are (coincidentally) human-produced CFCs.

To help clarify the differences between the two phenomena, educators suggest a distinct separation in time between units on ozone depletion and global warming, and the use of different teaching materials. (See Additional Teacher Resources below.)

Additional Teacher Resources:

- For a brief overview of how the ozone hole and global warming are different but also connected phenomena, see http://www.ucsusa.org/environment/gw.faq.html#8

- For more information about ozone depletion, see http://www.cs.ruu.nl/wais/html/na-dir/ozone-depletion/.html

- For more information on ozone depletion and human health effects, see http://sedac.ciesin.org/ozone/
- To learn more about the discovery of the ozone hole, see http://www.atm.ch.cam.ac.uk/tour/index.html

Confusion about air pollution and global warming

Many students believe that what they generally understand to be pollution and toxic chemicals are major contributors to climate change. In fact, most pollutants from industrial processes—such as carbon *mon*oxide, organic carbons, sulfate, soot, and some oxides of nitrogen—are not greenhouse gases.

The major contributor to global warming is carbon dioxide—a colorless, odorless, naturally occurring gas. In addition to natural sources, carbon dioxide is also released during the burning of coal, oil, and gas to produce energy for electricity, heat, and transportation. Unlike the air pollutants that create visible smog, carbon dioxide forms an unseen heat-trapping layer within the atmosphere, which increases Earth's surface temperature.

Although air pollution does not cause global warming, these two phenomena are connected. Industrial pollutants can, for example, affect the lifetimes of other greenhouse gases in the atmosphere, and therefore play an indirect role in climate change. Further, higher temperatures are likely to make air pollution worse. [Please refer to Chapter 4 of *Confronting Climate Change in the Gulf Coast Region* for more information on this connection.]

Additional Teacher Resources:

- For a brief summary clarifying human activities that contribute to climate change, see http://www.gcrio.org/ipcc/qa/04.html

- The US Environmental Protection Agency has a clearinghouse of information about air pollution and air quality, see http://www.epa.gov/ebtpages/air.html

- For a description of the major pollutants emitted from motor vehicles, see http://www.ucsusa.org/vehicles/cars.html

Confusion between weather and climate
Classroom discussions of global climate change should include a clarification of the difference between weather and climate. Weather is the day-to-day variations in atmospheric conditions, while climate is the average background within which weather occurs. The type and intensity of weather patterns that result depend, to a certain degree, on this background. The release of fossil fuels into the atmosphere forces a gradual change in climate over longer time periods. Since the climate system is finely balanced, small changes in the background state can have potentially large influences on weather in a particular location. Confusion arises because all our direct experience is with weather, so it is difficult for people to accept that such a large problem as global warming could result from such "small" predicted changes in temperature. The Gulf Coast region climate impacts report can help students make the connection between a rise in global average temperature and potential impacts on climate and weather in a specific location.

Additional Teacher Resources:
For basic explanations of the difference between weather and climate, see
http://www.explorit.org/science/weather.html
http://www.ngdc.noaa.gov/paleo/globalwarming/paleo.html
http://weathereye.kgan.com/cadet/climate/climate_vs.html
http://www.epa.gov/globalwarming/kids/climateweather.html

Understanding Related Public Misconceptions

Additional misconceptions about global warming are prevalent in the general population and may influence student learning. These misconceptions can stem from a person's physical senses and learned understanding of her environment. Or, they may be generated and perpetuated by media depiction and policy treatment of the global warming debate. The media often, for example, presents both sides of this issue without qualifying or quantifying either, leading to the belief that there are large and relatively equal groups of researchers on both sides (Gilmore, 2000). Some common public misconceptions to be aware of:

- The atmosphere is so vast that humans cannot affect it.
- The timeline for the consequences of global warming is a long way in the future (hundreds of years).
- The temperature changes are so small and so gradual that plants and animals can adapt.
- There are no solutions to global warming.
- Global warming can be addressed gradually.

Misconception: *The atmosphere is so vast that humans cannot affect it.*

Reality*: Human activities are rapidly increasing the atmospheric concentration of greenhouse gases as well as adding new heat-trapping gases that are not found in nature.*

While many greenhouse gases (e.g. carbon dioxide, methane, and nitrous oxide) are produced naturally, human activities such as the burning of fossil fuels and land-use changes (such as deforestation) add significantly to atmospheric concentrations of these gases. The present atmospheric concentration of carbon dioxide is unprecedented in the last 420,000 years and likely the last 20 million years, and the rate of increase is faster than at any time during the last 20,000 years (IPCC, 2001). About three-quarters of the CO_2 added to the atmosphere by humans comes from the burning of fossil fuels. Just over half of the current methane emissions are from human activities (e.g. fossil fuels, cattle, rice agriculture, and landfills), and about one-third of nitrous oxide emissions are human-caused (e.g. agriculture, cattle feed lots, and chemical industry).

For more information, see the report of Working Group I of the Intergovernmental Panel on Climate Change (IPCC), Summary for Policymakers, at: http://www.ipcc.ch/pub/spm22-01.pdf

Misconception: *The timeline for the consequences of global warming is a long way in the future (hundreds of years).*

Reality: *The consequences of global warming are already evident.*

The consequences of global warming have already been observed and are quantifiable today—so much so that the most authoritative scientific body on this issue has stated that "an increasing body of observations gives a collective picture of a warming world and other changes in the climate system" (IPCC, 2001). Global average surface temperatures have increased by 1° Fahrenheit this century. Snow cover and sea-ice thickness have decreased. Mountain glaciers in all parts of the world have retreated. Global average sea level has risen and ocean water temperature has increased. These changes have led to physical and ecological changes such as thawing permafrost, a lengthening growing season, and shifts in the geographical range of some species of animals and plants. These observations are consistent with a warming world.

For more information see the reports of IPCC Working Groups I and II, Summary for Policymakers, at: http://www.ipcc.ch/pub/spm22-01.pdf and http://www.ipcc.ch/pub/wg2SPMfinal.pdf

For specific examples of the early warning signs of climate change see: http://www.climatehotmap.org

Misconception: *The temperature changes are so small and so gradual that plants and animals can adapt.*

Reality: *The projected rate of climate change is more rapid than any that has occurred in the last 10,000 years and may overwhelm the ability of plants and animals to adapt.*

Global average temperatures are projected to rise by 2.5–10.4°F over the next century. Even a small increase in global temperature can change the climate dramatically. At the peak of the last Ice Age (18,000 years ago), for example, the temperature was only 7ºF colder than it is today, yet large glaciers covered much of the world. Most past climate changes have occurred slowly, allowing plants and animals to adapt to the new conditions or to move elsewhere. The very fast environmental changes projected to occur with global warming threaten the survival of some species.

Those species that exist and/or reproduce within a very narrow set of conditions (e.g. salt level for aquatic species, narrow temperature range, or certain requirements for water availability) may need to shift their ranges to keep up with a changing climate. However, a number of factors can limit a species' ability to move, including: lack of suitable habitat to move to; barriers between the current and potentially available new habitat, such as wide roads, dense development, bulkheads and seawalls; competition for space, nutrients, light, etc. from other moving or already established species in the new habitat; increased or unprecedented predation from other moving or already established species; and changes in or loss of beneficial relationships that help some species to survive, thrive, or have a competitive advantage. Moreover, because many species are already under stress from pollution and human alteration of the land, they are less resilient to further change.

For more information:

- *Global Warming and Terrestrial Biodiversity Decline*, World Wildlife Fund report –http://www.panda.org/resources/publications/climate/speedkills/index.cfm

- "Why can't ecosystems just adapt?" http://www.ieagreen.org.uk/11.htm

Misconception: *There are no solutions to global warming.*

Reality: *Solutions exist and are being implemented worldwide.*

The most important action to take to slow global warming is to reduce emissions of heat-trapping gases. This can be done at the individual, business, and government levels. Individuals can drive less, drive more-efficient and less-polluting cars, and use less electricity in general. Currently many industries are looking to replace fossil fuel dependence with new technologies like fuel cells, whose only emission is water vapor. This clean technology is already being used to power vehicles in many countries worldwide. Governments can increase energy efficiency standards, encourage the use of renewable energy sources, and protect forests.

For more information:

- UCS Common Sense on Climate Change – http://www.ucsusa.org/environment/solutions.html

- EPA Global Warming Action – http://www.epa.gov/globalwarming/actions/index.html

- Climate Change Solutions – http://www.climatechangesolutions.com/english/individuals/default.htm

Misconception: *Global warming can be addressed gradually.*

Reality: *Steps to curb global warming are needed now.*

Scientists predict that even if human emissions of greenhouse gases stopped immediately, the climate would not stabilize for many decades because the gases already released into the atmosphere will stay there for years or even centuries. If we reduce emissions of heat-trapping gases significantly, the warming may be less or it may occur at a slower rate than predicted, but global temperatures cannot quickly return to today's averages. The longer we wait to implement solutions, the more the Earth warms, and the greater the chances for some irreversible climate changes.

Using the Guide

The *Confronting Climate Change in the Gulf Coast Region* report and the activities in this curriculum guide can be used as a stand-alone unit or as a supplement to other teaching materials on climate change. The activities specifically address the misconceptions outlined above and transform climate change from an abstract concept to a real phenomenon with tangible effects on peoples' lives. We suggest prefacing the activities in this guide with a student questionnaire on key concepts related to global warming. (See the Appendix for an example.) Including a student questionnaire at the beginning of a lesson can help identify any misconceptions and alert the teacher to the need to clarify concepts. Using that same questionnaire again after teaching the unit will help assess students' learning.

The activities in the guide are organized as follows:

- Media depiction of global warming
- Basics of climate science
- Impacts of global warming on people, ecosystems, and individual species
- Analysis of global warming solutions

In **Activity 1**, students examine global warming as a topic depicted in the news media and compare it to the current scientific consensus. This activity is an opportunity for students to analyze the variety of opinions on this issue, thus better understanding the

different stakeholders and their interests. **Activity 2** can be used as a framework for clarifying the causes of global warming, specifically the human contribution to global warming and the sources of carbon dioxide. Students calculate carbon dioxide contributions from their personal lifestyles or from motor vehicles, thus making the link from individual actions to a global process.

In **Activities 3-8,** students explore the unique characteristics and functions of Gulf ecosystems, and evaluate what global warming might mean for plants and animals, for Gulf Coast region citizens, and for their personal lifestyles. These activities will help dispel the notion that the temperature and other changes associated with global warming will have little impact. In addition, teachers can broaden their focus by introducing students to other regions (e.g., Alaska, mountain areas, low-lying Pacific islands experiencing sea-level rise) where larger temperature increases and other physical changes are already manifest and quite large, suggesting that the process is well underway and other people already feel these changes in their daily lives. This also typically serves as a useful baseline from which to explore questions like: imagine what would happen if the warming doubled, tripled, or increased ten-fold (as models project if emissions are not significantly reduced).

As a final synthesis of the topic, **Activities 9-10** ask students to explore some potential solutions for reducing greenhouse gas emissions, at a variety of levels from individual to state or federal governments, and to consider options for reducing the stresses on ecosystems that increase vulnerability to climate change.

Assessing Student Understanding

Teaching about climate change impacts goes beyond helping students understand the climate system and the various types of methods used to analyze Earth systems. It should also cover the consequences of climate change on ecosystems and on social systems, including economies, communities and entire nation-states. It can even involve helping students understand the political debates over possible response options to climate change and the policies pursued to date from the local to the international level. This complexity yields a rich array of potential topics to incorporate into the normal school curriculum in a wide variety of courses, and also presents some challenges for assessment of student learning. The topic can be taught in ways that allow both simple testing of key terminology, concepts, and analytic skills, but also assessment of critical thinking, communication, and creative skills.

Concept Mapping

Concept mapping, which allows students to "map" the interconnecting ideas associated with a topic, is one recommended approach for evaluating student emergent understanding of complex subjects. Concept mapping in its simplest form involves the following steps:

1. Students write down the most important terms or concepts related to the topic they are trying to understand.

2. Students draw lines connecting the terms or concepts to show relationships among them. The lines are also labeled to show the nature of that relationship.

3. Students both revise and expand their maps by adding secondary concepts, or adding or modifying relationship lines as their understanding of the topic deepens on a continual basis, or do so to conclude a unit, which allows the teacher to assess the gain in knowledge from the beginning to the end of the unit.

Mapping can be done using paper and colored pencils, or with post-it notes or index cards that can be rearranged.

Concept mapping has been associated in educational settings with "systems" analysis and thinking. A system approach to the study of science is a unifying concept of the National Science Education Standards:

> "SYSTEMS, ORDER, AND ORGANIZATION - The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigation can be referred to as 'systems.' A system is an organized group of related objects or components that form a whole." (NRC, 1996)

For Earth's natural environments, systems thinking can be applied at any scale, and is particularly relevant to the topic of climate change as presented in the Gulf Coast region impacts report. In the classroom, climate can be presented as a system, composed of interconnecting parts that act as a whole, that in turn affects many other systems (biomes, ecosystems, communities, agriculture, tourism, states, etc.). By extending this line of thought, students are able to appreciate that a change in any one component of the climate system is likely to lead to changes in the systems that are interconnected with it.

Using Concept Mapping

Concept mapping can be used in conjunction with the activities in this guide in two ways. First, students can construct maps before and after a lesson has been completed, as a pre- and post-assessment tool. In this way teachers can determine which concepts students have learned and whether any misconceptions remain. Second, students can use their maps during an activity to evaluate the potential response of a system to a climate perturbation. For example, by understanding the interconnecting ways in which water flow sustains Gulf Coast ecosystems, students may be better able to grasp the consequences of a change in precipitation patterns.

Some helpful resources on using concept mapping in the classroom, with example maps, are:

The Concept Mapping Homepage
http://users.edte.utwente.nl/lanzing/cm_home.htm

NASA Classroom of the Future

http://www.cotf.edu/ete/pbl2.html

Concept Mapping and Curriculum Design (University of Tennessee at Chattanooga)
http://www.utc.edu/Teaching-Resource-Center/concepts.html

Using Concept Mapping
http://tiger.coe.missouri.edu/~vlib/matthew.html
(also includes suggested evaluation criteria for student maps)

Field-tested Learning Assessment Guide (FLAG) - Concept Mapping
http://www.wcer.wisc.edu/nise/CL1/flag/cat/conmap/conmap1.htm

References and Suggested Reading

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Activity 1: Warming Up to Global Warming – What Is It and Why Should I Care?

Objectives

- To raise awareness of global warming as one of the biggest scientific and political challenges of our times.
- To build an understanding of the controversies surrounding the topic of climate change.
- To develop a healthy critical perspective in students as they read and hear about climate change.

National Science Education Standards

- Science in Personal and Social Perspective

Curriculum Standards for Social Studies

- Strand 8: Science, Technology, and Society
- Strand 9: Global Connections

Specific Skills

- Media observation (following newspaper and other media coverage)
- Critical thinking
- Group discussion (listening, formulating arguments, debating, finding consensus)

Materials

Access to newspapers, radio, TV, magazines, possibly also the web
Confronting Climate Change in the Gulf Coast Region report, pages 4-5

Time

1 class session
Additional time outside the classroom searching and reviewing news coverage on global warming

Background Information

This activity is recommended for students who are relatively unfamiliar with the issue, or simply as an introduction to the issue to pique students' interest, and for teachers, to gauge their knowledge and understanding to get a baseline for assessing students' learning. It can be used in combination with any of the other activities in this set. For teachers unfamiliar with the topic, we recommend several resources to prepare and to become familiar with the basic scientific and political issues and controversies involved. You may also want to review some scientific, governmental, and climate contrarian web sites—see Appendix and Additional Resources below—and to follow the news for a while (and/or review recent news coverage at the informational climate change sites listed in the Appendix). This will provide you with sufficient background on where the science stands at present, who the "skeptics" are, who the environmental advocacy groups are, which interests they represent, and what is being done in industry and in national and international politics about global warming.

Key teacher resources
Objective, succinct, easily accessible and readable background information include the following:

1) Office of Science and Technology. 1998. *Climate change: State of knowledge*. Washington, DC. (Available at http://www.usgcrp.gov/usgcrp/nacc/default.htm)

2) UCAR/JOSS and NOAA/Office of Global Programs. 1997. *Report to our nation: Our changing climate*. Washington, DC.

3) IPCC. 2001. *Climate change 2001: The scientific basis. Summary for policymakers* (A Report of Working Group I of the Intergovernmental Panel on Climate Change). WMO, UNEP. (Available at http://www.ipcc.ch/pub/spm22-01.pdf)

4) IPCC. 2001. *Climate change 2001: Impacts, adaptation, and vulnerability. Summary for policymakers* (A Report of Working Group II of the Intergovernmental Panel on Climate Change) WMO, UNEP. (Available at http://www.ipcc.ch/pub/wg2SPMfinal.pdf)

5) United Nations Environment Program. *Vital Climate Graphics*. (Available at http://www.grida.no/climate/vital/)

6) The New York Times and the Washington Post both have climate change websites where they gather their coverage of the issues. These are easy-to-find examples of media coverage of science and climate issues.

Activity Guide
Ask students to observe current, and to research past, news coverage (say over the past year) on global warming. Ask them to make lists of the topics covered (new scientific discoveries, national and international political developments, discussion of climate change impacts, etc.), the people interviewed, the general positions they hold, and so on. Students should bring those to the class session as background.

Pick one recent news item, and explore it together in the same fashion in class. Ask students to summarize what the global warming news is about—what's the issue? What's at stake? Did the issue make waves in the news, and if so, why? What's the tone of the news coverage—gloom and doom, speculative, sincerely concerned, a wake-up call, a call to action? How has the news coverage changed over time? How is the climate issue presented— with a focus on what's known or on what's uncertain? What are the scientific uncertainties, and why do they tend to be so prominent in the news coverage? Why are these uncertainties so hard to resolve? How do new discoveries revise our knowledge base? Who are the different interest groups involved in the debate and what is at stake for them?

Ask students to formulate what they think about the issue, whether they care about the debate, or about climate change. Why or why not? Help them identify what is at stake for them personally. Also help them identify why different interests have such opposing views. Conclude the class with a discussion (and resolution) of how best to approach information about climate change (careful, critical, etc.).

Teaching Strategies

Prior to starting this activity, we recommend asking students to complete the Questionnaire on Climate Change (see Appendix), which will help identify any preconceptions or misconceptions regarding the topic. Students can then refer back to their answers to the questionnaire after completing this activity to assess if their knowledge and/or attitudes have changed (see Climate Change in the Classroom, page 5, for more information).

The news analysis can be modified for group work by asking students to bring one news item of interest to class. In class have students give a 30-second summary of their item, and list the topics covered on the board by category (new scientific discoveries, political developments, economic impacts, impacts on ecosystems, possible mitigation strategies, etc.). Assign students to groups according to their interest in a particular topic. Ask students to work as a group to summarize the issues in their category—the controversies, interest groups, remaining questions, ongoing studies, etc. Ask each group to present their analysis to the rest of the class.

Students should come away with an understanding of the current scientific consensus on climate change. Depending on the news items students collect, it may be necessary to provide additional reading so that students can critically analyze the media coverage as it relates to scientific understanding. The box on pages 4-5 of the Gulf report could serve as an in-class reading to provide an overview of the current scientific consensus and the process by which it was developed.

Additional Resources

- Many climate contrarians have elaborate web sites. Examples include:
  1) Center for the Study of Carbon Dioxide and Global Change at http://www.co2science.org/
  2) The Science & Environmental Policy Project at http://www.sepp.org/
  3) The Greening Earth Society at http://www.CO2andClimate.org/

- Several web sites aim at sorting out the controversial issues debated in the media. See for example:
  1) Environmental Protection Agency at http://www.epa.gov/globalwarming/index.html
  2) UNEP/WMO at http://www.gcrio.org/ipcc/qa/cover.html
  3) PBS: “What’s up with the weather?” at http://www.pbs.org/wgbh/warming/
  4) Union of Concerned Scientists at http://www.ucsusa.org

Activity 2: Understanding Climate Change – The Greenhouse Effect and How Humans Contribute to It

Objectives

- To understand the basics of global climate change, including the difference between natural and enhanced greenhouse effect.
- To appreciate the importance of the atmosphere for life on Earth.
- To appreciate how minor changes in the composition of the atmosphere change the effectiveness of the global greenhouse.
- To understand the Gulf Coast region and students' personal contribution to global warming.

National Science Education Standards

- Earth Science: Energy in the Earth System
- Earth Science: Geochemical Cycles
- Earth Science: Origin and Evolution of the Earth System
- Science in Personal and Social Perspective

Specific Skills

- Conceptual, analytical, and critical thinking
- Making connections across scales
- Basic mathematical calculations
- Reading comprehension

Materials

- See the Appendix for reproducible figures of the greenhouse effect (as hand-outs or overheads).
- For Activity extension #1, students require access to the web.
- For Activity extension #2, students may require calculators, but calculations are simple and can be done "by hand."

Time

1 class session or less, depending on science background and existing knowledge of climate change.

Background Information

This activity clarifies the concepts of the natural and enhanced greenhouse effect, laying the foundation for future study of the potential impacts of climate change in the Gulf region. Student misconceptions regarding the causes of global warming can be addressed here through the extension activities, which show the link between energy use and the emissions of greenhouse gases. The teacher should decide, based on the existing knowledge and understanding of climate change among students, whether to supplement teacher explanations with one or more additional short readings from the sources provided under Additional Resources.

Key Teacher Resources
A resource for downloadable figures on the greenhouse effect appropriate for middle and high school classrooms is http://www.fsl.noaa.gov/~osborn/CLIMGRAPH2.html
(See also Appendix for additional resources.)

Activity Guide
Acquaint students with the basic components of the atmosphere, its structure and composition. Then walk students step by step through the basic processes underlying the greenhouse effect and the radiative budget. Explain to students how much colder it would be on Earth if there were no natural greenhouse effect, how life could not have evolved on Earth if there were no greenhouse effect. If available, take students to a near-by greenhouse to make the global greenhouse effect more tangible (a classroom window may serve as a proxy). Alternatively, build a little greenhouse in the classroom (e.g., plastic bag over an indoor plant, taking temperatures in and outside of the bag; see additional Teaching Resources on Global Change in the Appendix). Help students understand which human activities produce gas emissions that enhance the natural greenhouse effect and how relatively small increases in atmospheric greenhouse gas concentrations can produce significant warming and other climate changes.

Extension 1: Personal contributions to climate change
Students estimate how much CO_2 they personally contribute to the atmosphere every year. The activity can be made more difficult by estimating the student's family's contribution. One web-based climate change calculator is available at http://www.climatestar.org/calculator.asp
(See Additional Resources for an alternative emissions calculator.)

Extension 2: Contributions from cars alone in the Gulf Coast region or US
Provide students with the following information:

a) Number of registered cars in your state (or a subregion, e.g., county, or for the entire US) (See Additional Resources for further information.)
b) Current cost of gasoline (average in the area of interest)
c) Average gas mileage of a vehicle (25 miles per gallon)
d) Approximate vehicle length (15 feet)
e) Average miles driven per vehicle per year (12,000 miles)
f) Pounds of CO_2 produced per gallon of gasoline (~20 lbs.)

You may let students estimate some of these numbers to enhance the "aha!" effect.

Ask students to calculate several figures based on these variables:

1. Estimate how long a line of cars would be (in miles) if all cars of the state were stuck "bumper to bumper" on a highway at the same time.
   [number of cars] * [car length/car] * [1 mile/5280 feet] = [miles of "car string"]

2. Using an atlas or a web-based distance calculator, compare how far this line of cars would stretch across the country or around the globe. (Compare the result, e.g., to long distances across the entire United States, or to the circumference of the Earth at the equator, or to the number of repeat trips from your location to a well known, nearby city. Example: 10,000 miles equals roughly 57 trips from Pensacola, FL to Tallahassee, FL (as the crow flies).)

3. If each of the state's cars travels 12,000 miles/year, how much gasoline is used per year?
   [no. of cars] * [12,000 miles/year] * [1 gallon/25 miles]=[gallons of gas/year]

4. What would be the total cost for all the gasoline used?
   [gallons of gas used] * [average price of gas/gallon] = [total gasoline cost]

5. How much carbon dioxide is produced by these vehicles per year?
   [gallons of gas used/year] * [20lbs CO_2/gallon] = [total amount of CO_2 /year]

6. How many acres of forest need to be protected to absorb the amount of carbon dioxide that these vehicles emit each year?
   [no. of acres protected] =
   [total amount of CO_2 in pounds/year]/[16000 pounds per acre/year]

For this last exercise you will need to explain to students the concept of carbon sequestration in the biosphere – the storage of carbon in trees, soil, the ocean and sediments. Then explain that a typical acre of sixty-year old Douglas-fir forest uptakes around 8 tons (16000 pounds) of carbon dioxide per year (See Additional Resources). In addition 500 gallons of gas produces 10,000 pounds of carbon dioxide. While this exercise is very simplistic, it exposes students to the basic idea of removing carbon dioxide from the atmosphere. Carbon sequestration in the biosphere (the storage of carbon in trees, soil, the ocean and sediments) is a complex process, but understanding it is an integral part of finding solutions to global warming.

Teaching Strategies

The objective of activity Extensions 1 and 2 is to help make the concept of global warming more tangible to students—they will begin to see the relationship between personal actions and emissions of greenhouse gases into the atmosphere. A student worksheet for Extension #2, along with discussion questions, is provided in the Appendix. The activity can be completed as homework or in small groups. Students may also be interested in how the numbers compare to total greenhouse gas emissions for the U.S. (see http://www.eia.doe.gov/oiaf/1605/ggrpt/tbles1.html).

To test their understanding of the subject, ask students to construct a concept map of global warming (see "Assessing Student Understanding" in the Introduction section of this curriculum guide for more information on concept mapping). Have them begin by listing words that describe the most important concepts or terms related to global warming. Students should draw connections from the topic word to the most important

concepts using arrows. Each connecting line should be labeled with a word that describes the relationship between the two connected concepts. Students then add secondary concepts to expand the map. An example global warming concept map template, with some concepts intentionally left blank, can be viewed at the CLIMGRAPH site: http://www.fsl.noaa.gov/~osborn/CG_Figure_45.gif.html

Additional Resources

- A very comprehensive, science-based climate change information web site. The first section is focused on understanding the basics of global warming and the greenhouse effect; later sections deal with trends, modeling, impacts, and adaptation options – http://www.pacinst.org/ccresource.html

- A clear explanation of the natural and enhanced greenhouse effect, and additional information and graphics (from the Australian Consortium of Scientific and Industrial Research Organizations, CSIRO) – http://www.dar.csiro.au/cc/default.htm

- A beginner's guide to understanding the greenhouse effect from the Woods Hole Research Center – http://www.whrc.org/globalwarming/warmingearth.htm

- Information on how much carbon dioxide is emitted by vehicles and household electricity use can be found at the American Forests website- http://www.americanforests.org/shaklee/carbcalc.php3

- An additional emissions calculator is available at http://www.climatestacalc.net/eng/Intro_1.html

- Information on carbon dioxide sequestration can be found at the U.S. Department of Energy website http://www.fe.doe.gov/coal_power/sequestration/index.shtml

- Information on restoration and preservation of forests can be found at the Pacific Forest Trust website http://www.pacificforest.org/publications/index.html

- Statistics on the number of registered vehicles in the entire US can be obtained from the US Bureau of Transportation Statistics http://www.bts.gov/btsprod/nts/ (For the most recent year of data available, 1998, registered passenger cars =131,838,538 and registered 2-axle, 4-wheel trucks=71,3330,205). Average weekly gasoline price for the US is available at http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp

- Statistics on the number of registered motor vehicles for individual states:
  Florida: http://www.hsmv.state.fl.us/reports/facts_mv.html
  Texas: http://www.dot.state.tx.us/vtrinfo/vtrinfo.htm
  Alabama: http://www.ador.state.al.us/motorvehicle/mvd_main.html
  Mississippi: http://www.mstc.state.ms.us/mvl/stats/main.htm
  Louisiana: see Louisiana Teacher's Supplement
  http://www.ucsusa.org/environment/gcteachers.html

Activity 3: Gulf Coast Climate and How It May Change In The Future

Objectives

- To gain an appreciation for the physical-geographical and cultural characteristics that define the Gulf Coast region.
- To begin to understand the relationship between climate and Gulf Coast ecosystems.
- To appreciate climate as a driving force of change in the environment.

National Science Education Standards

- Life Science: Interdependence of Organisms

Curriculum Standards for Social Studies

- Strand 2: Time, Continuity, and Change
- Strand 3: People, Places, and Environment

Specific Skills

- Creative thinking
- Prediction
- Class discussion (listening, critical analysis)

Materials

- Map of Gulf Coast region
- *Confronting Climate Change in the Gulf Coast Region* Report
- Several large sheets of paper (easel-sized) and markers

Time

1-2 class sessions

Background Information

This activity builds on student understanding of the greenhouse effect, asking them to consider the implications of globally warmer temperatures for climate-related processes such as precipitation and runoff, storminess, and sea-level rise. Students should be or be made familiar with the climate concepts presented in Chapter 1 of the Gulf Coast report, including the major components of the hydrologic cycle (Figure 5 in the report).

Activity Guide

Begin the activity by orienting students to thinking about the Gulf Coast region as an interconnected system. Ask students to locate their school on a Gulf Coast map and brainstorm the physical, cultural, and other characteristics that connect their area to the region as a whole-- physical geography, waterways, climate, history, transportation networks, economy, communication systems such as mail, phone, and e-mail, etc. Make a list on the board or overhead with students help and to refer to during the remainder of the exercise. Then provide students with an overview of the Gulf Coastal Plain and its major geographic features (outlined on pages 2-3 of the Gulf Report), including the Mississippi River watershed (a schematic of the Gulf Coast region is available on the UCS web site; maps of the entire Mississippi watershed are available, for example, at

http://whale.wheelock.edu/watersheds/mississippi/basin.html or at http://www.nwrc.nbs.gov/fringe/mississi.html). In a geography or ecology class, you may spend some time explaining the various factors that combine to create the Gulf Coast region's climate (using Figure 3 in the Gulf report).

Extension: Climate Future Wheel

Provide students with a listing of potential climate changes for the Gulf Coast region due to global warming, including temperature increase, precipitation change (increase, decrease, and more frequent heavy rainfalls), sea level change, change in storms, change in El Niño frequency, etc. (these are described in Chapter 1 of the Gulf Coast report and summarized on p.8 of the report. Simplify this listing – for example from most certain to less certain – if you do not want to go into a discussion of different climate models projecting somewhat different climate futures.). The teacher should pick one climate change for the class to focus on in more depth. Divide the class into groups of four, and provide each group with some blank index cards. The students will then use a "future wheel" activity to analyze how sea-level rise might affect the Gulf Coast region. Ask each student to start with one blank index card. On the card they should write one consequence of sea-level rise for the Gulf Coast. Stimulate students' imaginations by asking them to consider the various stakeholders – residents who live on the coast, coastal planners, businesses that depend on coastal tourism, industries that depend on coastal infrastructure, etc. One example is that sea-level rise might reduce the salt marsh habitat. After students have written one consequence, ask them to pass their card to the person next to them. Instruct the students to draw an arrow extending downward from the first consequence, written by their neighbor, and to add to the card a new consequence that might result from the first. For example, a reduction in the area of salt marshes might reduce breeding grounds for fish. The activity continues in a similar manner for a few more rounds, perhaps 4 or 5. Finally, ask the group to construct a "master wheel," with sea-level rise at the center and the four possible future scenarios constructed by the group. Have each group present their wheel to the rest of the class, or use the findings from all of the groups to create a larger master wheel.

Teaching Strategies

The extension is an adaptation of the "future wheel" technique used by scientists and philosophers studying the future and by strategic planners to evaluate potential outcomes of an event or action. It is essentially a modified concept map and can be used similarly, as described in the Introduction section of this guide, for assessing understanding or as an ongoing tool for exploring an issue and interpreting information. As homework, students could construct their own future wheel using the information from class and/or readings in Chapter 1 of the Gulf report. The assignment should be followed up with an essay in which students specify the scientific facts to support the predictions and the pros and cons of different outcomes. In later activities students can look back at their wheel and consider modifications or additions as they build new understanding. See Additional Resources for ways to assess students' learning through/in this activity.

For more advanced students it may be appropriate to follow up the class activity by reading all of Chapter 1 as a homework assignment. This provides students with an

opportunity to compare the class predictions with information in the report. Possible discussion or essay questions for this chapter include:

1) Compare/contrast the terms "climate variability" and "climate change"

2) Describe the Gulf region temperature graph for the last 100 years (Figure 4 in the report). How does this compare to the global temperature curve for the same time period? (This graph can be found at a number of web sites: http://lwf.ncdc.noaa.gov/oa/climate/research/2000/perspectives.html or http://www.fsl.noaa.gov/~osborn/CG_Figure_27.gif.html or http://www.ipcc.ch/pub/spm22-01.pdf)

3) What is a climate model? Why are climate models used?

4) For future climate in the Gulf region, what do the models agree on, and what do they disagree on? What is the reason for the differing projections? Why is it more prudent to look at both scenarios rather than just at one of the two?

5) What are some of the ways in which humans have altered the landscape in the region where you live? How have natural ecosystems changed as a result? What have humans gained and what have they lost from this alteration?

6) What makes people and/or ecosystems vulnerable to impacts from climate change (make a list)? Do you believe we are vulnerable now? Do you think we may be more or less vulnerable in the future?

Additional Resources

- Examples of student future wheels can be found at http://dev.planet-tech.com/cpf/student_wheels.html

- An activity that can help students understand the concept of climate variability can be found at http://www.ucar.edu/learn/1_2_2_9t.htm

Activity 4: Know Thy Home – The Gulf Coast's Unique Ecosystems

Objectives

- To understand the concepts of ecosystem and biome.
- To understand and articulate the relationship between climate and biome.
- To gain an initial understanding of landscape change.
- To appreciate (personal) benefits from Gulf Coast (local) ecosystems.

National Science Education Standards

- Life Science: Interdependence of Organisms

Curriculum Standards for Social Studies

- Strand 3: People, Places, and Environment

Specific Skills

- Map reading and interpretation
- Data gathering
- Working collaboratively
- Analytical thinking
- Oral reporting

Materials

- Map of Gulf Coast ecoregions (see also Additional Resources)
- Atlas of one or more Gulf states, preferably including historical maps
- *Confronting Climate Change in Gulf Coast Region* Report
- Optional access to internet for information gathering on specific ecosystems (see Additional Resources for examples of relevant web sites)

Time

1-2 class sessions, possibly with some homework between sessions or afterwards

Background Information

This activity builds student understanding of the natural ecosystems that comprise the Gulf Coast region. Students can draw from personal experiences in their local environment, or study the diversity of ecosystems that comprise their state or the entire Gulf Coast region. Pages 15-17 of the Gulf Coast report summarize predominant categories of ecosystems of the region. These ecosystems can be categorized as:

Upland ecosystems	temperate hardwood forests, pine flatwoods (or barrens), scrub forests, and coastal prairies
Freshwater ecosystems	swamps, freshwater marshes, lakes, rivers, springs, and underground aquifers

Coastal and Nearshore Marine barrier islands, mangroves, salt marshes, seagrasses, estuaries, bays, lagoons, and coral reefs

Depending on students' understanding of ecology, pages 15-17 or all of Chapter 2 of *Confronting Climate Change in the Gulf Coast Region* might be appropriate background reading prior to the activity.

Activity Guide

This activity depends in part on the context in which students live. Inner-city or urban students may find it difficult to name, and describe experiences in, natural places. Teachers must judge from their knowledge of students' lives and the range of plausible life experiences they might have had whether students should begin this activity from option 1 or 2.

Then begin the activity in one of two basic ways: (1) by asking students to name (and locate on a map) their favorite natural places to visit, hike, explore, etc. Ask them about the places where they have already been, what they looked like, what they liked and remembered about them—guiding them toward talking about the environment (landscape features, bodies of water, vegetation, animals they observed, particular weather patterns they experienced, general climate, work they did there, etc.). Or (2) by using historical maps, possibly movies depicting the region before significant urban development, books, nature writing, old photographs, and/or their imagination to visualize the "natural Gulf Coast" that once was. Discuss with them the ways in which humans have altered the landscape, what has been lost and what has been gained. (See also Extension 2 below.)

Then introduce the concepts of ecosystem and biome to the students (using any biological textbook), and help them name and identify ecosystems of the Gulf Coast (using a map or atlas). Split the class into several groups (up to four students per group), each one responsible for gathering additional information on a particular ecosystem. Students can use maps, an atlas, or the web for this information search. On a hand-out (see Appendix), students compile information on where the ecosystem can be found in the Gulf Coast region, annual average temperature and temperature range, precipitation totals and seasonal distribution, soil or water characteristics, typical vegetation/plant communities, and characteristic or unique animals. (The compiled information can be made available to every student in hand-outs or on wall posters created by the students.) Once students have all needed information, they present a profile of the ecosystem to the rest of the class. Ask students to rank the ecosystems according to their dependence on fresh water. How much rain does the ecosystem need? Do plants and animals depend on fresh water for habitat or food supply? Is the ecosystem a freshwater or saltwater environment? Ask them to trace a water molecule's path as it travels through the system, or to construct a diagram of the hydrologic cycle for their particular ecosystem.

Extension 1: Guidebook to Natural Places

To engage students more creatively and hone their analytic and writing skills, you may extend this activity by asking students to collectively prepare a guidebook to the "best natural places in the Gulf Coast" (or more locally). This can be done in a number of ways—very personal, experiential and fun, or more scientific, involving extra research on

the natural history and ecology of these places (see Additional Resources and State Teacher Supplements).

Extension 2: Class Discussion

This extension may be a good follow-up to the second option described above for how to begin this activity. Based on the information gathered about the natural environment, students brainstorm the benefits they personally, or society at large, derive from these ecosystems. Then they discuss the implications of human impacts on the ecosystems (as discussed in Chapter 1, pages 13-14 of the Gulf report or in Chapter 2, pages 17-20). Students should get a good understanding of the complexity of the human-environment interaction. There are many benefits we derive from unaltered natural environments—so-called "ecosystem services" such as natural flood control, buffer against coastal storms, carbon sequestration, pollination, water and air purification, aesthetic pleasure, habitat for important commercially harvested fish and wildlife, etc. We also gain much from managing the environment for specific purposes—forestry, agriculture, fisheries, urban areas, transportation, etc.—although frequently our use and manipulation of the environment produces negative consequences as well (see Additional Resources). Ask students to list both benefits and negative side effects of using the environment. Activity 5 offers a more structured activity designed to give students an appreciation of ecosystem goods and services.

Teaching Strategies

A fun and creative way for students to present their findings to the rest of the class is by developing a skit, in which different members of the group take on roles of different components of the ecosystem. For each "character" students must explain/act out who they are, what their function is in the ecosystem, and how they interact with other characters. Students will need to take on multiple roles, and each should be responsible for researching their characters in detail. This format requires 1-2 additional class sessions for students to plan and practice their skits, as well as time for student research outside of class. The skits can be evaluated according to the number and importance of characters (ecosystem components) identified, accuracy of their identified function(s), and number, significance, and complexity of the interactions presented.

Additional Resources

- Descriptions of ecoregions for the United States, including the Gulf Coast region – http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html

- Map of average annual precipitation for the US – http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/precip.htm

- Links to Gulf region natural areas such as state parks and wildlife areas can be found at the website of the Gulf Ecological Management Sites Program – http://www.epa.gov/gmpo/gem2.html

- Make your own custom maps showing forest cover types – http://www.nationalatlas.gov/

- Map showing the location of Gulf of Mexico estuaries – http://www.epa.gov/owow/estuaries/sheds/gom.gif

- Additional information, background information, and resources on ecosystem services can be found at the following sources:

  Daily, Gretchen (ed.). 1997. *Nature's services: Societal dependence on natural ecosystems*. Island Press, Washington, DC.

  Costanza, Robert et al. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

  Ecological Society of America. 1997. *Ecosystem services: Benefits supplied to human societies by natural ecosystems*. Issues in Ecology, No.2. ESA, Washington, DC.
  (Available at http://www.esa.org/issues.htm)

  Union of Concerned Scientists and the Ecological Society of America. *Communicating Ecosystem Services: Tools for Scientists to Engage the Public*.
  (Available at http://www.esa.org/ecoservices)

Activity 5: Nature's Bounty – Goods and Services of Gulf Coast Ecosystems

Objectives

- To understand the concept of ecosystem services.
- To understand how humans use and place values on the natural environment.
- To gain an initial understanding of the vulnerability of ecosystem services to human and climate factors.

National Science Education Standards

- Life Science: Interdependence of Organisms
- Science in Personal and Social Perspectives

Curriculum Standards for Social Studies

- Strand 3: People, Places, and Environment
- Strand 7: Production, Distribution, and Consumption

Specific Skills

- Working collaboratively
- Analytical thinking
- Oral reporting

Materials

- *Confronting Climate Change in Gulf Coast Region* Report. Available on the web at http://www.ucsusa.org/environment/gulf.html
- *Confronting Climate Change in Gulf Coast Region* State Summary guides. Available on the web at http://www.ucsusa.org/environment/gulf.html
- Maps or atlases showing local or regional nature areas; some Gulf states also have this type of information on state agency web sites (see the individual state teacher's supplements)
- Optional access to internet for information gathering on specific ecosystem functions (see Additional Resources for examples of relevant web sites)

Time

1-2 class sessions, possibly with some homework between sessions or afterwards

Background Information

This activity promotes student thinking about the benefits humans derive from the natural environment. Chapter 2, pages 17-20, of *Confronting Climate Change in the Gulf Coast Region* introduces the many goods and services provided by Gulf Coast ecosystems, organized by economic sectors—agriculture, forestry, fisheries, energy and transportation, and recreation and tourism. The chapter can be used as a reading prior to the activity, or after the first 2 worksheet exercises as a way to broaden understanding of the concepts.

The Gulf Coast report uses the phrase "ecosystem goods and services" to refer to the societal benefits received from the natural environment. Two other commonly used terms in ecology are "ecosystems functions" and "ecosystem values." It is important to be as

consistent as possible in the use of these terms to avoid student confusion. *Function* refers to the physical, chemical, and biological processes or characteristics that sustain an ecosystem. Ecosystem *services* are the beneficial outcomes of an ecosystem function for humans or the natural environment. For example, one function (process) of ecosystems is carbon cycling. In the context of rising carbon dioxide in the atmosphere, forest carbon cycling is a service to humans in the form of sequestration of carbon dioxide from the atmosphere into organic tissues. For an ecosystem to provide a service to humans there must be an interaction with or appreciation by humans. Ecosystem *goods* are the plants and animals, and products derived from them, that are used directly by humans (seafood, timber, natural fibers, wild game). Some writers may refer to the "production of goods" as an ecosystem service.

An ecosystem *value* is an estimate of worth, merit, quality, or importance, and is often subjective. For ecosystem services, it can be thought of as a measure of how important a particular service is to people. It is easier to place values on ecosystem goods because they are bought and sold. In contrast, the value of an ecosystem service is an estimate of how important that service is to people—what they are willing to pay to preserve or enhance it. This estimation is not straightforward. For example, it is difficult to place a value on a day of bird watching or a view of an intact, unobstructed coastal landscape.

Activity Guide

Begin the activity by asking the class to brainstorm about the ways they personally or society benefits from natural ecosystems, and the plants and animals that comprise them. Make a list on the board, and clarify as a group those items on the list that represent direct use of plants and animals or their products ("ecosystem goods") and those that represent a benefit of an ecosystem function ("services"). Make sure students understand this more abstract concept and can distinguish it from "goods." Most importantly, convey that there are many services that we may take for granted because they cannot be bought or sold, and yet these services play a critical role in supporting life on Earth and our economy, and hence our life styles (for example, purification of water, pollination of crops and natural vegetation).

Next choose a natural area near the school, perhaps one that students have been to on a field trip, and ask them to consider how human use of the land has changed through time. Break the class into small groups, and ask each group to record some possible human uses of the land using the *Historic Land Use* worksheet (see Appendix). They should speculate about past, present, and future uses, from prehistory cultures (see Additional Resources) and Native Americans to the present community. They can fill out the timeline chart using color-coding or by labeling the bars. As a class tally the different land uses. Explain to students that the human uses of the land represent ecosystem goods and services. Discuss how and why land use has changed through time. If it has not changed, ask students to try to find reasons for that as well (most of the Gulf region has been altered by human activity, and very little area is protected in private or public trust).

For the next part of the activity ask the class to name some other natural areas in their region, either from their own experiences or through research on the web or regional

nature guides (see Activity 4). Allow each group to pick an area for further study. They should identify it by ecosystem type (upland hardwood forest, coastal mangrove swamp, etc.). Tell the groups that they will be responsible for identifying and reporting to the class on the ecosystem services provided by this area, and who benefits. Explain the concept of "value," as a subjective measure of importance or worth (for definitions see above). Ask the students to complete the *Ecosystem Services and Values* worksheet (see Appendix). This could be done through research outside of class, as a follow-up to Activity 4, or as a group brainstorming activity. Students should have an understanding of some of the projected climate changes for their region, either through previous activities or readings, or by reading the appropriate State Summary of the Gulf Coast report.

Bring the class together and ask the groups to report their findings to the rest of the class. Ask the groups to give their rationale for the values assigned to the services. As a final group discussion, ask students to consider how our use of an ecosystem influences our understanding and interest in it (and how we value it). For example, for many years wetlands were considered undesirable because they were unsuitable for building. As a result many of them were drained and filled in order to be used for purposes thought more important or valuable. As our understanding of wetland services has grown, so has our interest in preserving them and our perception of their value.

Extension: Community Education Project

Ask students to devise some strategies for raising awareness about ecosystem services in their school or in their community. This might be through informational brochures, bulletin board displays, poster presentations, visits with local officials, etc. For a group class project, allow the students to present their materials to the community, or hold a "class fair," in which members of the class and/or invited guests "judge" the projects according to which are most effective in communicating the concept of ecosystem services and their importance.

For suggestions on how to communicate ecosystem goods and services, go to http://www.esa.org/ecoservices

Teaching Strategies

After completing the activity, students can read Chapter 2 of the Gulf Coast report to learn more about ecosystem goods and services in the entire Gulf Coast region. Some questions for homework or discussion in class are:

1) What is meant by the terms "ecosystem goods and services"?

2) What are some ecosystem goods and services you didn't think of (if the activity has already been completed)? or: Can you think of additional ecosystem services?

Additional Resources

- Background information on ecosystem services can be found at the following sources (see also Activity 4):

  Ecological Society of America. 1997. *Ecosystem services: Benefits supplied to human societies by natural ecosystems*. Issues in Ecology, No.2. ESA, Washington, DC. Available at: http://www.esa.org/issues.htm

  Union of Concerned Scientists and the Ecological Society of America. *Communicating Ecosystem Services: Tools for Scientists to Engage the Public*. Available at: http://www.esa.org/ecoservices/

- The EPA has a web-based module about wetland functions and values: http://www.epa.gov/watertrain/wetlands/index.htm

- Gulf Region Heritage describes the prehistory cultures present in the Gulf region http://www.epa.gov/gmpo/edresources/heritage.html

Activity 6: What Could Happen Here? – Exploring Ecosystem Changes

Objectives

- To understand the basic effects of climatic changes on individual species.
- To understand the complex interactions of climatic changes with entire biotic communities.
- To gain deeper familiarity with individual species or ecosystems in the region.

National Science Education Standards

- Life Science: Interdependence of Organisms
- Life Science: Matter, Energy, and Organization in Living Systems
- Earth Science: Geochemical Cycles

Specific Skills

- Essay or research report writing
- Basic research skills (data gathering through interviews, web or library searches, analysis and presentation of findings)
- Critical thinking
- Class discussion (argument formulation, oral expression, listening, etc.)

Materials

Confronting Climate Change in the Gulf Coast Region report (especially Chapter 3)
Depending on adaptation of activity, access to books, magazine articles, the Internet for student research

Time

Adaptable from one to several class sessions; additional time for homework

Background Information

In this activity students are asked to examine in more detail the effects of climate change on individual plant and animal species and the implications for ecosystems as a whole. Background information for teachers can be found in Chapter 3 of *Confronting Climate Change in the Gulf Coast Region*, which describes the potential effects of climate change on ecosystems, both general cross-cutting impacts (changes in water availability and flow, sea-level rise, and changes in biodiversity/species composition), and impacts according to ecosystem-type (upland, freshwater, and coastal/marine). Students should understand that climate model projections for the Gulf Coast region agree on an increase in temperature and sea-level rise, but projections for precipitation changes vary by region and according to the model used. This can be put into context by asking students to imagine that they are a wildlife manager in charge of protecting a species from the negative consequences of climate change in the Gulf. How would they handle the possibility of precipitation changes? How would they handle the fact that current scientific understanding does not allow them to choose one model over the other? What would they try to plan for both scenarios?

Activity Guide

Recall the climate projections from Chapter 1 of the report (summarized on p.8 of the report), or from the state summary guides, to (re)familiarize students with some of the basic changes to be expected with global warming in the Gulf Coast region—increase in CO_2, summer and winter warming, changes in rainfall, increase in freshwater and ocean temperatures, faster sea-level rise, changes in storminess, fire regimes, etc. Examine with students what these types of changes in principle would mean for plants, insects, fish, birds, large wildlife, etc. Let them brainstorm, speculate, analyze, and recall from previous studies what types of changes might be expected—e.g., species range shifts to more northern locations (and where possible in the region, to higher locations), species extinction, changing productivity, vulnerability to pests, diseases, fire, etc.

To deepen students' understanding, use one or more specific species as examples (e.g., any of those mentioned in *Confronting Climate Change in the Gulf Coast*) to explore and illustrate these effects. This can also be done over one or more class periods using the worksheet "Climate Change Impacts on Ecosystems" provided in the Appendix. Ask students to discuss what the ramifications of these changes would be for them personally, for their state, for the Gulf Coast region, or even beyond.

Extension: Essay

Ask students to write a short essay after the in-class data-gathering work of Activity 4 and the above discussion on selected aspects of the relationship between ecosystems and climate (see the objectives above for possible foci for such an essay). The purpose of this exercise is to deepen the students' understanding gained through previous exercises, and the students may have to do some additional research. How dependent, for example, is the ecosystem on different aspects of the current climate (e.g., some species are most sensitive to changes in temperature while others are more sensitive to changes in water availability or sea level), or how much change in temperature or precipitation could it cope with? Are there known limits to what species or ecosystems can cope with?How often does the ecosystem (on average) experience drought, flooding, fire; and what might happen if any of these changed in the future? Do all plants and animals in an ecosystem react in the same way to higher temperatures? And if they don't, how would that affect the interactions among different species? (See Additional Resources for websites that could serve as starting points for student research.)

Teaching Strategies

There is considerable flexibility in the way this activity can be presented and assessed. It can be completed as a class discussion, as described above, or in small groups with a report-out from each group at the end of class. Create a master list from the discussion that students can keep in their notebooks. For homework, ask students to read Chapter 3 of the Gulf Report, or just pages 21-23, and comment on how the ideas generated in the class discussion compare to the findings in the report. Possible questions for homework/discussion are:

1) Are there additional impacts in the report that you didn't think of so far? Conversely, did you come up with some impacts not mentioned in the report?

2) What factors can limit species' abilities to shift their ranges?

3) What is the potential impact of invasive species on an ecosystem's ability to adapt to changing climate?

4) How might the ecosystem changes described in the report affect the Gulf region's economy?

5) What are the reasons why it is quite difficult to predict how an ecosystem might react to a changing climate?

6) How might scientists monitor the environment to detect ecosystem changes due to a warming climate?

For a more detailed analysis let the class pick a single ecosystem to study. Divide the class into small groups and have them research the components of the ecosystem and their climate dependence using the worksheet in the Appendix. Ask each group to present their findings to the class, and then check understanding by asking each student to draw a "web" illustrating the ecosystem as it is today, and how it might look in the year 2100 if the projected climate changes occur (students should indicate these changes for each of the two precipitation scenarios presented in the report).

Additional Resources

- A United Nations Environment Program Fact Sheet on climate change and possible impacts on biological diversity – http://www.unep.ch/iuc/submenu/infokit/fact12.htm

- Global Change Research Information Office: *Why can't ecosystems just adapt?* Available at: http://www.gcrio.org/ipcc/qa/11.html

- USGS web-based atlas of the *Relations Between Climatic Parameters and Distributions of Important Trees and Shrubs in North America* is available at: http://greenwood.cr.usgs.gov/pub/ppapers/p1650-a/

- The Sierra Club's summary of potential impacts of climate change on plants and animals – http://www.sierraclub.org/globalwarming/habitat/

- Additional resources or readings can be selected from an extensive scientific bibliography on climate change impacts on wildlife – http://www.pacinst.org/wildlife.html

- For further examples from across the United States of climate change impacts on natural and managed ecosystems, see the short summary guides to the regional and sectoral impacts examined in the recently released *US National Assessment of the Potential Consequences of Climate Change and Variability* – http://www.climatehotmap.org/impacts

- Climate Protection Institute. 1991. *Global warming: High school science activities*. San Francisco, CA. This somewhat dated but still useful handbook for teachers includes an activity exploring the effects of temperature change on living organisms.

- 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://www.epa.gov/globalwarming/impacts/

- 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://www.epa.gov/globalwarming/impacts/imp_blio.html

- 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/climate/impacts.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

- Invasive Species Issue Brief – An on-line introduction to the issue of invasive species. http://www.ucsusa.org/environment/bio_invasives.html

Activity 7: Early Warning Signs – Searching for Indicators of Climate Change in the Gulf Coast Region

Objectives

- To understand the concepts of climate change "signals" or "fingerprints."
- To identify whether climate change is already apparent in the Gulf Coast region.
- To understand the concept of "endangered species" and what causes drive endangerment.

National Science Education Standards

- Life Science: Matter, Energy, and Organization in Living Systems
- Earth Science: Energy in the Earth System
- Science in Personal and Social Perspectives

Curriculum Standards for Social Studies

- Strand 3: People, Places, and Environment

Specific Skills

- Data search
- Interviewing
- Analytical thinking
- Written or oral presentation of findings
- Working cooperatively and collaboratively with classmates

Materials

- Suggested Readings (see below)
- Access to the internet, libraries, and local experts on wildlife and native plants

Time

One class session to explore the notion of climate change signals. The follow-on activity could be assigned as homework and requires one class session to present the findings. Alternatively, the activity could be designed as a longer group project engaging students for some time over the course of the year.

Background Information

- Students read or are familiar with Chapters 2 and 3 of *Confronting Climate Change in the Gulf Region.*

- Background information on "indicators" or "fingerprints" of climate change. We recommend two short readings, accessible at http://www.climatehotmap.org/fingerprints.html and http://www.climatehotmap.org/harbingers.html

- A teacher resource: The technical summary of Working Group 2 of the IPCC (pages 24-25) describes the use of indicator species or systems to detect climate change: http://www.ipcc.ch/pub/wg2TARtechsum.pdf

- To stimulate critical analysis and to build an understanding for why scientists debate over the best indicators of climate change, you may want to work with students using other scientific articles on "early indicators" of climate change as well as views from climate contrarians who maintain that it is not possible to detect climate change or to attribute any causes at this time. Possible sources include:

  1) NASA Goddard Institute for Space Studies. *A Common Sense Climate Index: Is Climate Changing Noticeably?* Available at: http://www.giss.nasa.gov/research/intro/hansen.04/

  2) Several climate change detection studies are referenced at: http://www.lmd.jussieu.fr/pcmdi-mirror/pcmdi/detection.html

  3) Contrarian views on the topic are available, for example, at: http://www.rppi.org/peg3central.html or http://www.sepp.org/books/gwubtoc.html (others can be explored through their links)

  4) The following IPCC reference will help teachers and thus help students to evaluate these claims http://www.ipcc.ch/pub/wg2TARtechsum.pdf

Activity Guide

During class time, help students understand—based on the Gulf report and any of the suggested additional readings—how climate change differs from climate variability (see also Activity 3), and how one might detect actual climate change against a backdrop of a typically variable climate. Students should understand that not every little year-to-year variation means that the overall climate is changing, or vice versa, that ups and downs in temperature, rainfall, etc. from year to year contradict an overall trend. Then have individuals, or small groups of students choose a particular environmental resource (e.g., fresh water, oceans, forests), a species mentioned in the Gulf report, or any other plant or animal typical in their state. They will then learn more about the resource or the species, its habitat, biological and climatic "needs," and whether recent climatic changes have already had any effects on the resource or species. Students might have to consult experts at local nature conservancies, wildlife preserves, parks, forests, or coastal conservancies. Students might also interview older residents about changes they might have observed over their lifetimes.

Students should also gather data (e.g., from web sites of state and federal agencies gathering relevant information or from individuals interviewed for the project) on the underlying drivers behind the detected changes. These might include data on air and water temperature changes; precipitation changes; changes in dates of last and first frosts; changes in snow cover; habitat fragmentation or destruction through development, agriculture, other human activities; replacement by invasive exotic species; specific impacts from hunting, fishing, trapping, or other use, etc. Ask students to critically

examine whether these underlying causes have indeed brought about the changes for the resource or species under consideration. Frequently, several causes interact to bring about an observed change.

Extension #1: Impacts on already endangered species

Besides the impacts on common species, climate change is of particular concern with regard to endangered species. Explore with students the reasons why species become endangered and how climate change can aggravate the conditions for species survival. Different students or groups of students can explore some common and some endangered species in the exercise above (see Additional Resources for relevant data sources and readings). You may also want to draw on the Gulf Coast climate impacts report because it makes the case throughout that climate change impacts on Gulf Coast ecosystems must be seen in the context of other stresses on these systems originating from human development and land and resources use.)

Extension #2: Journal

Ask students to keep a journal of news items, scientific reports, and information from other sources related to effects of climate change in the Gulf Coast region. After a specified period of time, ask the students to look for patterns in the reported items. Can they draw any conclusions about which species or systems are being affected most or considered most at risk? Can they make any predictions about future trends? Ask them to discuss and defend their conclusions with other members of the class.

Additional Resources

- The Union of Concerned Scientists, together with a number of other environmental organizations, has produced a science-based map of "Early Warning Signs" of climate change for the world. This map is available on-line, together with extensive explanations of the choice of indicators and a reference to the scientific literature – http://www.climatehotmap.org

- In the United Kingdom, a long-term research project is under way that aims to identify and measure climate change indicators. The study provides many ideas for students as to the kinds of indicators they may look for (and how difficult it is to do so) – http://www.ecn.ac.uk/Education/indicators_of_climate_change.htm

- The US Fish and Wildlife Service provides an index of federally listed threatened and endangered plant and animal species (by state or region): http://ecos.fws.gov/webpage/

- Czech, Brian, Paul R. Krausman, and Patrick K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *BioScience* 50(7): 593-601. (Note: Some articles in *BioScience* are accessible online at www.aibs.org/bioscienceonline/)

Activity 8: Climate Change and Me – Time Warp to 2050

Objectives

- To make the impacts of global warming real in the context of students' lives.
- To appreciate the uncertainties contained in projections of climate change and its impacts.

Curriculum Standards for Social Studies

- Strand 1: Culture
- Strand 2: Time, Continuity, and Change
- Strand 4: Individual Development and Identity
- Strand 8: Science, Technology, and Society

Specific Skills

- Essay writing
- Critical and imaginative thinking
- Group discussion (listening, formulating arguments, debating, finding consensus)

Materials

- A copy of the appropriate state summary guide of *Confronting Climate Change in the Gulf Coast Region*.
- (optional) Two supplementary documents: *Gulf Coast's Most Precious Resource: Fresh Water* and *Global Warming and Sea-Level Rise in the Gulf Coast Region*

(All state summaries and supplemental materials are available on the web at http://www.ucsusa.org/environment/gulf.html)

Time

1 class session for explaining and discussing the potential impacts from climate change on a particular state (or resource). Time needed for the completion of assignment depends on scope expected by teacher. The activity can be done as a creative writing assignment for homework, or for a year-end project.

Background Information

This activity asks students to apply their knowledge of potential climate change impacts to consider what global warming will really mean for them personally. Climate change becomes more tangible, as students deepen their understanding of the ways in which they interact with the environment. Prior to the activity students should have an understanding of projected climate change impacts for the Gulf Coast region or their state, either through previous activities or by reading Chapters 3 and 4 of *Confronting Climate Change in the Gulf Coast Region* or the relevant state summary. The two additional supplementary documents on sea-level rise and freshwater impacts may also be appropriate.

Activity Guide

Engage students by using the schematic "Potential Impacts of a Drier or Wetter Future for the Gulf Coast Region," (back page of the freshwater supplementary material) as a starting point for a "future wheel" activity (see also Activity 3). Present students with the upper part of the diagram (climate changes and "implications"), while blocking out the "possible societal impacts," and ask them to work in groups to fill in potential effects following from the first set of implications. (Note: you may use a transparency or direct students to this diagram on the web at http://www.ucsusa.org/evironment/gcfreshwater.pdf.) Ask them to think about the changes in the context of their own daily lives. Remind them of recent weather events or observed changes in the environment similar to those projected for the future. (Make sure students understand that it is not possible to attribute any one of these weather events or occurrences to climate change, but that they are quite consistent with what climate models project. So, more of what they have already seen may occur in the future.) Ask each group to report 3 or 4 of the most interesting potential impacts to the rest of the class.

Next show the students the societal impacts reported on the graphic. Explain that these are based on the findings of Gulf Coast scientists, and represent projections of likely changes based on current scientific understanding. Be sure students understand which of the projected changes scientists are highly confident about (temperature change and sea level rise), and which ones less so (to get a sense for scientists' confidence in the projected changes, see the Gulf report, on pp. 60-61).

As the homework assignment, ask students to write an essay on "A day in my life in 2050," "A vacation on the beach in 2050," "The opportunities and threats of daily life in 2050," or some similar topic. Encourage them to be creative and imaginative within the boundaries of the likely climate and societal changes described in the report. Also ask students to record the web sites and other sources they consult in writing their essay, and to evaluate them in terms of scientific credibility (you may direct them to the report's confidence table (pp.60-61). This will allow you to assess whether students are beginning to develop an ability to critically differentiate credible information from fiction and interest-driven propaganda.

Extension #1: Group discussion of benefits and losses of such a future world

The writing assignment can be extended with a group discussion either before or after the writing. A discussion before could serve a brainstorming function, which helps students to imagine a significantly different future world. A discussion after could serve a debriefing function to let students air emotions about the world they imagined, or to stimulate a discussion about how desirable such a future world may be, and what to do now to influence the course of history.

Activity 9: Reducing Our Impact on the Global Climate – Possible Solutions

Objectives

- To identify possible solutions that would reduce the amount of greenhouse gases emitted into the atmosphere and thus slow global warming.
- To develop an initial appreciation for the complexities of designing and implementing such solutions.
- To promote critical understanding of the steps some cities in the Gulf Coast region have taken to date to address the emission of greenhouse gases.
- To understand solution-related concepts such as energy efficiency, renewable energy, net reduction of energy use, tailpipe emissions standards, etc.
- To increase students' awareness of their ability to contribute to the solution of the problem.

National Science Education Standards

- Earth Science: Energy in the Earth System
- Earth Science: Geochemical Cycles

Curriculum Standards for Social Studies

- Strand 8: Science, Technology, and Society
- Strand 9: Global Connections

Specific Skills

- Web search
- Group discussion (listening, formulating arguments, debating, finding consensus)
- Critical thinking
- Rating relative importance of different solutions

Materials

- Suggested readings
- Access to the internet

Time

Time for research outside the classroom; 1 class session for discussion and evaluation of options

Background Information

- Students should read Chapter 5 of *Confronting Climate Change in the Gulf Region.*

- Students prepare for the class by searching the web or library books and articles for "solutions to the climate problem." Ask them to read through some of the materials they find, which will help them get better acquainted with the topic of solutions.

Activity Guide

Offer students a number of web sites and/or keywords to search for possible solutions to global warming, i.e., to the processes and actions that create and could slow this global problem. Each student should come prepared to the next class with a list of at least 10 concrete actions each—anything from personal lifestyle changes to state and national efforts. Collect all suggestions on an overhead, then have students assess the relative importance of each action by voting on each: how many students think the action is "most important," "somewhat important," "not very important," "totally unimportant." When you have collected the votes, use this assessment for an in-class discussion of why students think the actions are as important as they believe. This will help you gauge students' underlying understanding of the importance of certain activities or economic sectors contributing to global greenhouse gas emissions. Near the end of the discussion, help students come to a consensus on at least the key elements of a "solution package." You may compare the students' suggestions to what is being done to date to reduce emissions (see Additional Resources and the Teacher's Supplement for your state). During the discussion, ensure that students have a good understanding of solution-related concepts, like "energy efficiency," "renewable energy," "zero emission vehicles," "tailpipe emissions standards," etc.

Extension: Commit to one change!

If students contributed several suggestions for personal life style changes or smaller actions any individual could take, ask them if they would commit to making that change for at least one day, one week, one month, or one school year. If they agree to do so, ask them to keep a "Contributing to the Solution" journal in which they briefly note every day how they are doing. At the end of the agreed-upon period, ask them to write a short summary of their experience. Ask them to be honest so that they can really see how easy or difficult some of these changes would be.

Additional Resources

- For suggested actions to reduce GHG emissions see the following small sample of web sites:
  http://www.climatestar.org/choices.asp
  http://www.climatechangesolutions.com/english/individuals/default.htm
  http://www.enviroweb.org/edf/dosomething/dosomething_frameset.html (note the underscore "_" between something and frameset)
  http://www.cru.uea.ac.uk/tiempo/floor2/educ/diy/diy.htm
  http://www.climatehotmap.org/impacts/solutions.html

  The number of other web sites on solutions is enormous. Look through any of the Additional Resources in previous activities or in the Appendix for further web sites, or search with key words, such as "climate change mitigation," "climate change solutions", "reducing fossil fuel use/dependence," etc.

- For examples of steps taken by cities in the Gulf Coast Region see the Cities for Climate Protection Campaign at http://www.iclei.org/us/US_ccp.html.
  For example, New Orleans Climate Protection Program:
  http://int.new-orleans.la.us/cnoweb/oea/cgi-bin/climate.pl
  Austin, Texas Clean Cities Program: http://www.ci.austin.tx.us/cleancities/
  Miami-Dade County, Florida:
  http://www.co.miami-dade.fl.us/derm/environment/home.htm (keyword: global warming)

- To learn more about fuel economy, see: http://www.fueleconomy.gov/feg/

- To learn more about alternative ways to manage our transportation system, see: http://www.best.bc.ca/ or http://www.ccities.doe.gov/

- To learn more about renewable energies and energy efficiency, start here (but many more web sites exist):
  http://www.ucsusa.org/energy/energy-home.html
  http://www.nrel.gov/
  http://www.iclei.org/efacts/content.htm
  http://www.ase.org/links.htm
  http://www.aceee.org/

Activity 10: Reducing Our Impact on the Local Environment – Possible Solutions

Objectives

- To understand the concepts of "local stresses," "vulnerability," "resilience," "prevention," "precaution," and "adaptation."
- To recognize certain human activities as contributors to stresses and vulnerability.
- To identify feasible actions to reduce local stresses on the environment.

National Science Education Standards

- Life Science: Interdependence of Organisms
- Science in Personal and Social Perspectives

Curriculum Standards for Social Studies

- Strand 3: People, Places, and Environment
- Strand 8: Science, Technology, and Society

Specific Skills

- Small group discussion and team work
- Reading and interpreting cartographic information (thematic maps)
- Critical and analytical thinking

Materials

- Atlas of the Gulf region or any of the Gulf states
- Suggested readings
- Optional access to the internet

Time

1-2 class sessions, depending on adaptation of the activity

Background Information

- Students read Chapters 1 (especially pp.13-14) and 5 of *Confronting Climate Change in the Gulf Coast Region.*

- An additional reading could be the following recent article: Sarewitz, Daniel and Roger Pielke, Jr. 2000. Breaking the global-warming gridlock. *The Atlantic Monthly*, July. Online at http://www.theatlantic.com/issues/2000/07/sarewitz.htm. The authors suggest that if we reduced the stresses on our current environmental and social systems, we would not only produce benefits now, but also be in a better position to cope with the possible impacts of climate change.

Activity Guide

This activity is a good follow-on exercise to previous activities where students became intimately acquainted with various ecosystems (Activity 4) or species (Activity 6). Recall those examples, and ask students to collect various types of information from the atlas

about those areas where the studied species live—i.e., about land use, resource extraction, population density and growth rates, human alteration of the environment (e.g., dams, changes to waterways, roads, hardening of the shoreline, etc.), incidences of air or water pollution, and so on. If available, collect information on the types and sizes of habitats remaining in a given geographic area. Discuss with students how these human activities affect the biomes, species, and habitats. Those that appear to have negative consequences for the environment will be listed as "local stresses" on the environment.

Now recall the list of potential consequences of climate change on the Gulf Coast region. Ask students to examine, in small group discussion, how the projected climatic changes would affect these stressed local environments or species, and ask them to compare the ecosystem responses of a non-stressed and a stressed environment. Support students' emerging understanding by introducing the concepts of "vulnerability" and "resilience." Either as homework or continued small-group teamwork, ask students to make separate lists of suggested actions to reduce local stresses.

- List A would be a list of measures to minimize the impact of human land and resource use on the environment (e.g., establish preserves, limit sprawl, reduce or eliminate local air and water pollution, restore sediment flow to coastal areas to help restore degraded wetlands).

- List B would be a list of adaptive measures to help biomes/species to cope with the projected climate changes (e.g., establish migration corridors, plant better adapted species, move species to new locations, change the way forests are managed).

The suggestions should be presented and debated in class. A number of valuable extensions are described below.

Additional Resources

- The concepts of "vulnerability," "resilience," and "adaptation" are used quite differently across different disciplines and over time. They are key concepts in the *US National Assessment of the Potential Consequences of Climate Variability and Change* (http://www.gcrio.org/NationalAssessment). These definitions are more or less congruent with the usage in the most recent work of the Intergovernmental Panel on Climate Change (e.g., in the Third Assessment Report released in 2001). See http://www.ipcc.ch: Working Group 2's Summary for Policymakers (Box SPM-1 lists the definitions).

- Many local environmental groups or land trusts provide information on needed environmental protection measures. Students could explore a number of sources for such information, including the web or newsletters from local groups; or the teacher could invite a representative from those groups to speak in the classroom on the specific species or biome they choose to work on (see possible extension below).

Extension #1: Making someone else think about climate change
If the teacher already invites a representative of a local environmental group or land trust into the classroom, one interesting extension is the following: Have students ask that representative whether his or her group has begun to think about how climate change might affect their work, and if so, how. If not, create a non-accusatory space in which students and the NGO representative begin to brainstorm together. Lead questions may include: what is the core mission of this environmental group? How might climate change potentially affect the group's ability to carry out its core mission and goals? What opportunities are there to take climate changes into account in the group's work? Maybe they can get a commitment from the representative to take the climate issue to the leaders of the group to discuss further.

Students will likely find such a discussion quite rewarding in that they have an opportunity to bring their knowledge to someone else and get them to think about the climate issue. Students will feel that they are making a difference outside the classroom.

Extension #2: Walking in a Water Manager's Shoes
This extension may take 1-2 class sessions.

Confronting Climate Change in the Gulf Coast Region makes it amply clear that potable water is one of the key concerns for the future of the region. In this or previous activities, students may have already familiarized themselves with the hydrologic cycle, with the many ecosystem goods and services dependent on ample fresh water, and they may have already seen or used the Supplementary Material focused on "The Gulf Coast's most precious resource: fresh water." Good preparation for this activity is critical, so ask students to read that supplementary material again and/or review the key issues with them before launching this activity. As part of this review, establish who the most important water users are (e.g., farmers, urban residents, industries needing water, hydroelectric power producers, fishermen, but also those representing the interests of recreation and tourism along lakes, streams, and freshwater marshes, and ecosystems dependent on fresh water).

This activity places students in the position of water users and water managers. Once you identified, with students' help, the main water users, split the class into equally sized groups each representing these water users. Also have one group representing water managers who have to split up the available water resources. Ask each group to brainstorm among themselves for a few minutes what exactly they need water for and when they need it (water needs may differ from season to season).

The teacher will then set the stage:

1) 100 water units are available for the entire year. But because of the particular seasonal patterns of rainfall in your state, these units are available in unequal portions through the four seasons (e.g., in Florida with its wet season in the summer, more units would be available than compared to the winter dry season). Use state

climatological information (see state-specific teacher's supplements for further information) to establish 2 or 4 seasonal sub-portions.

2) Each water user group must make a case to the water manager group why they need water (what for) and when they need it. For example, the farmers group may argue that they need most water in the spring and early summer, but less in the winter.

3) After each water user group has made its case, the water managers group must deliberate amongst themselves how many water units each user group gets during the seasons.

4) Once they announce their decision to the water users, ask the water managers group first to justify why and how they made their decision. Then ask the water user groups how they feel about the decision. Help students debrief from the exercise as it may stimulate – as in the real world – disagreement and anger about whether or not the decision is just and reasonable. At the end of this discussion, you may ask the water managers group whether they would reconsider their apportionment given what they have heard.

5) Then ask students to consider together ways to ensure that everyone gets the water they need, which will make students think about water conservation, more efficient use, better timing, better advance planning, etc.

6) Finally, ask students to consider that climate change may bring more or less water to the state/region. Ask them how either scenario alleviates or aggravates the situation, and what ideas they may have to address these changes. How would water management have to change if the climate were to become more extreme: sometimes bringing excessive amounts of water (in the form of intense rainfall events and floods), at other times longer periods of dry weather.

Extension #3: Walking in a Coastal Manager's Shoes

An alternative to extension #2 is to use the already occurring process of sea-level rise, which is virtually certain to accelerate under all warming scenarios.

Confronting Climate Change in the Gulf Coast Region makes it amply clear that sea-level rise is one of the key concerns for the future of the region. In this or previous activities, students may have already familiarized themselves with coastal processes, how a warming climate will lead to higher sea levels, and with the many ecosystem goods and services that Gulf Coast residents derive from healthy coasts. Students may have already seen or used the Supplementary Material focused on "Global warming and sea-level rise in the Gulf Coast region." Good preparation for this activity is critical, so ask students to read that supplementary material again and/or review the key issues with them before launching this activity. Make sure students recall the range of likely impacts from an accelerating rate of sea-level rise on coastal ecosystems and human uses of the coast. As part of this review, establish who the most important interest groups are who would be affected by sea-level rise (e.g., tourists and tourism establishments, developers, coastal residents, the insurance industry, rice farmers, fishermen, industries located along the

shoreline, but also those with an interest in the maintenance of natural ecosystems with healthy beaches, dunes, coastal wetlands).

This activity places students in the position of coastal dwellers (in the broadest sense) and coastal managers. Once you identified, with students' help, the main interest groups, split the class into equally sized groups, each representing these groups. Also have one group representing coastal managers who have to decide how the coast can be used now and in the next 1-2 decades. Ask each group to brainstorm among themselves for a few minutes what exactly they derive from being right along the shore, and why they should be allowed to use the coastal areas for their purposes.

The teacher will then set the stage:

1) Coastal areas provide numerous services to society, all of which have some benefit, some of them to only a small group of people, others to the larger public. It is the responsibility of coastal managers to ensure that private and public uses are balanced. Coastal uses are constrained by the following coastal management goals:
    - environmental protection
    - public safety
    - economic benefits for the greatest number of coastal users (private and public)

2) Sea-level rise will increase coastal erosion and coastal flooding during storms because of higher storm surges; if wetlands cannot keep up with the rate of sea-level rise, wetlands may be lost. Also, some species require brackish water – neither too salty nor too fresh.

3) Ask each coastal user group to brainstorm among themselves for several minutes what they derive from using the coast and its resources, whether they are dependent on a particular location along the coast and why or what alternatives they may have, and whether they anticipate any changes in their use of the coast over the next 2 decades.

4) Then have each coastal user group make its case to the coastal managers. When all groups have made their case, the coastal managers group must deliberate among themselves how they anticipate to accommodate these uses while balancing them with the management goals they have to meet (environmental protection, public safety, economic benefit for as many private and public users as possible). Encourage the managers group to think about conditions on a particular use (e.g., you can build here, but if your house gets damaged in a storm you will have to find a safer location farther back from the shoreline).

5) Once they announce their decision to the coastal users, ask the coastal managers group first to justify why and how they made their decision. Then ask the coastal user groups how they feel about the decision. Help students debrief from the exercise as it may stimulate – as in the real world – disagreement and anger about whether or not the decision is just and reasonable. At the end of this discussion, you may ask the

coastal managers group whether they would reconsider their decisions and/or conditions, given what they have heard.

6) Then ask students to consider together ways to ensure that coastal areas and uses remain healthy and available into the indefinite future – an exercise that will make students think about environmental protection, more comprehensive planning, and forward thinking beyond the next few years, etc.

7) Finally, ask students to consider that climate change may accelerate sea-level rise and some associated coastal problems, such as erosion, flooding during storms, wetland degradation, and ultimately land loss. Ask them what ideas they may have to address these changes – likely to accelerate in future decades. How would coastal management have to change if the projected changes were to come true?

Appendix

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.

Annotated List of Selected Web Resources

- The EPA's Global Warming Information Center. Check their "Links" section and the "Annotated summary of climate change resources" – http://www.epa.gov/globalwarming/index.html

- Woods Hole Oceanographic Institution beginner's guide to global warming – http://www.whrc.org/globalwarming/warmingearth.htm

- This is a very comprehensive, science-based, climate change information web site. The first section is focused on understanding the basics of global warming and the greenhouse effect; later sections deal with trends, modeling, impacts, and adaptation options – http://www.pacinst.org/ccresource.html

- For a wide selection of recent scientific studies and news stories on climate change – http://www.TheEnergyGuy.com/Links_ClimateChange.html

- For a wide selection of web-based information sources on climate-related issues—from health to El Niño, from agriculture to satellites, and weather and climate news from all over the globe—see http://www.internets.com/climate.htm

- One of the most comprehensive, frequently updated information sources on global change, put together by the Pacific Institute for Studies in Development, Environment, and Security – http://www.globalchange.org/

Additional Teaching Materials on Global Change

- Mortensen, Lynn L. (ed., 1999). Global change education resource guide. NOAA, OGP, Silver Spring, MD – contains a great number of activities and teaching materials on global change in general. Also lists a great number of additional resources.

- Environmental Education on the Internet – http://www.eelink.net/

- Classroom of the Future (COTF) program is helping to bridge the gap between America's classrooms and the expertise of NASA scientists (NASA) – http://www.cotf.edu/

- Another NASA site is the Teaching Earth Science web site – http://www.earth.nasa.gov/education/index.html
- The Virtual Geography Department is a gateway to numerous relevant teaching materials. Click on "Earth's Environment and Society" and then on "Other resources" – http://www.colorado.edu/geography/virtdept/contents.html

- EPA's Environmental Education Resource Center – http://www.epa.gov/teachers/index.html

- American Association of Geographers: Hands-on Teaching Modules on the Human Dimensions of Global Change (for undergraduate college, but easily adapted to high school level) – http://www.aag.org/HDGC/Hands_On.html

- The Inspire Project – an extensive list of courses and teaching materials used by a variety of faculty across the United States, also adaptable to high school level – http://psclasses.ucdavis.edu/GAWS/inspire.html

- Watershed Education Resources – http://www.green.org/resources/

- World Resources Institutes Education Center – http://www.wri.org/wri/enved/index.html

- Earth System Science Education (online) provides access to all federal agencies, research institutes and other organizations providing educational resources on the environment. A treasure trove – http://www.usra.edu/esse/essonline/

- EPA's Student Center – www.epa.gov/region5/students/

Figure References

Figures to illustrate concepts and systems referred to in this curriculum guide are available from many sources, some of which are restricted in terms of reproduction due to copyright protection. Generally, graphics produced and published by federal and state government agencies are not restricted in this way.

Thus we suggest as supporting graphics to illustrate the greenhouse effect and emission and temperature trends the following source:

CLIMGRAPH - Educational graphics on global climate change and the greenhouse effect. Osborn, J., Forecast Systems Laboratory, National Oceanographic and Atmospheric Administration
http://www.fsl.noaa.gov/~osborn/CLIMGRAPH2.html

The White House. 1998. *Climate Change: State of Knowledge*. Washington, DC.
This publication is readily available on the web at:
http://clinton5.nara.gov/Initiatives/Climate/content.html
The figures can be freely reproduced with acknowledgment.

Name_____
Date_____

Questionnaire on Global Warming

1. When you think about global warming, what thoughts or ideas come to mind?

2. What is global warming?

3. What are the causes of global warming?

4. Besides temperature, in what other ways might climate change because of global warming?

5. What are 3 ways in which global warming might affect your home state?

6. What are 3 ways in which global warming might affect you personally?

7. What do you think can be done about global warming?

8. What can you yourself do about global warming?

9. Do you think action should be taken now to slow the pace and magnitude of global warming? Explain your position.

Name_____
Date_____

Worksheet: Motor Vehicle CO_2 Contributions

The burning of fossil fuels such as gasoline is one of several ways in which carbon dioxide, a greenhouse gas, is added to the atmosphere by humans. How much carbon dioxide is emitted just from the cars in your state?

I. Estimation

Provide some plausible estimates for the following variables. Your teacher will then give you actual numbers of these variables. Compare your estimates with the numbers given in class. How close are you? Were you surprised by any of the actual numbers?

	Estimate	Actual
Number of registered cars in your state (i.e., cars actually being driven on the road)		
Current cost of gasoline (average $ per gallon of regular gas)		
Average gas mileage of a vehicle (miles that a car can drive per gallon of gas)		
Approximate vehicle length (in feet)		
Average miles driven per vehicle per year*		
CO_2 produced per gallon of gasoline (lbs)**		

* You may want to think first about all the trips your family typically takes in just one week and then multiply that total number of miles by 52.
** Gasoline is a fluid that is made up of different chemical substances, many of which contain carbon (C). When you burn gasoline, each molecule containing C combines with 2 molecules of oxygen (O) from the air and becomes carbon dioxide (CO_2).

II. Calculation

Now use the actual numbers for the variables listed in the table above to solve the following problems:

a. Calculate how long a line of cars would be (in miles) if all cars of the state were stuck "bumper to bumper" on a highway at the same time. First, collect all the numbers you need for this equation, and then think through all the necessary steps to arrive at the correct answer.

b. Using an atlas, compare how far this line of cars would stretch across the country or around the globe. (Compare, e.g., to the "as-the-crow-flies" distance between the east and the west coast of the United States, or to the circumference of the Earth at the equator.)

c. If each of the state's cars travels 12,000 miles/year, how much gasoline is used per year?

d. What would be the total cost for all the gasoline used?

e. How much carbon dioxide is produced by these vehicles in just one year?

III. Analysis

Did anything surprise you about these calculations? If so, what was surprising and why?

If your state decided to reduce carbon dioxide emissions from motor vehicles by 25%, how could this be accomplished?

How much money would be saved over the period of 1 year by driving a vehicle that averages 35 mpg instead of 25 mpg? How many pounds of CO_2 would be saved?

What other ways can you think of to reduce the number of miles people travel without restricting their freedom to get to where they want to go?

Trees take up carbon in the atmosphere and store it long-term in their organic tissues and in the soil. About 15 trees need to be planted to absorb every 10,000 pounds of CO_2 emitted. How many trees need to be planted to absorb the carbon dioxide emitted from motor vehicles in your state?

What recommendations would you make to lawmakers in your state and in Congress concerning ways to reduce motor vehicle CO_2 emissions? Give your rationale.

Name_____
Date_____

Worksheet: Gulf Coast Ecosystems

In your group, find the following information for the ecosystem you are working on. Then compare your ecosystem profiles.

Ecosystem name:_____

****

Temperature

What is the annual average temperature? _____

What is the seasonal temperature range (what are the coldest/warmest average temperatures and in which months does each occur)?
Warmest: _____
Coldest: _____
Difference: _____

What is the daily temperature range? _____

Which range is larger—the seasonal or the daily temperature range? _____

****

Precipitation

What is the annual average precipitation total? _____

Which are the driest months and which are the wettest months, and what are their precipitation totals?
Driest: _____ Total _____
Wettest: _____ Total _____

How big is the difference in monthly precipitation totals between the driest and the wettest month?
Difference: _____

****

Rocks and Soils

What types of rocks are typical in this region? _____
_____

What can these rocks be used for? _____

What types of soil are typical in this region? _____
_____

What can these soils be used for? _____

****

Ecosystems

Typical vegetation/plant communities _____
_____
_____

Characteristic or unique animals _____
_____
_____

****

Water moving above and below ground is often an important force driving ecosystem processes.

Can you identify the 'drivers' of your system (wind, groundwater discharge, river input, tidal range, etc.)?

What is the seasonal variation in these drivers?

Name_____
Date_____

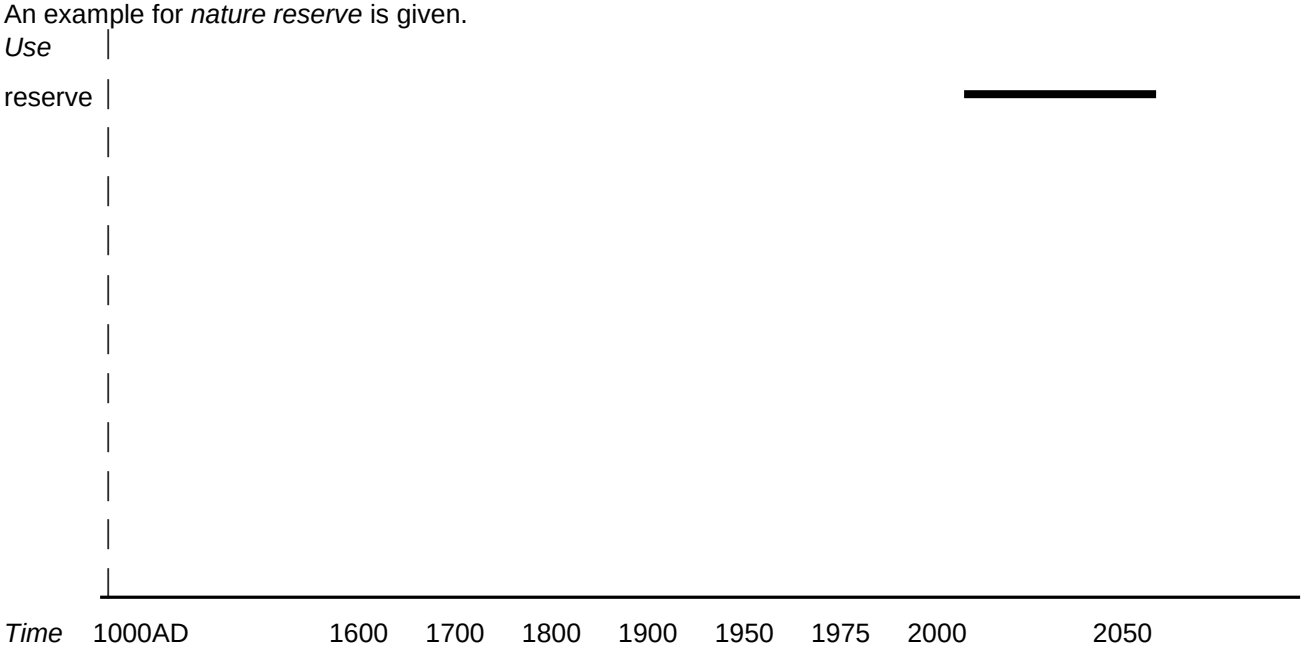
Worksheet: Historic Land Use and Land-use Change

Land Area and Type of Ecosystem: _____

List some possible human uses of a particular ecosystem or of the land around your home or school from the past to the present. For example, one possible use of land is as a nature preserve or as a conservation area. Other areas are used for agriculture, or they have become developed for housing and industry. Think about the area: what it may have looked like before humans came here, and, once they arrived, how they started changing the land over time. Alternatively, start from what you see now, and then imagine what that piece of land was like before that house/school was put on it, before that field of crops was grown there, before that forest was cut down, and so on back through time... What was it like 100 years ago? What might it have been like 1000 years ago (when Native Americans would have used the land)? Think also about how this piece of land may likely be changed and used by people in the next 10 years, 20 years, 50 years.

1. 6.
2. 7.
3. 8.
4. 9.
5. 10.

Use a bar graph to place these uses on the time line figure below.
An example for *nature reserve* is given.



(time line not to scale)

Examine your time line. Has land use changed through time? Are there any patterns in the ways in which the land/ecosystem has changed, or in the timing of any shifts? Compare your timeline to those of other students. Do any broader patterns emerge? Can you give some possible reasons for the changes in land use?

Name(s)_____
Date_____

Worksheet: Ecosystem Goods, Services and Values

The ecosystems of the Gulf Coast contribute to the region's economies and culture through the many goods and services they provide. For an ecosystem in your area, list below as many ecosystem goods and services as you can think of. Then rank the goods and services (one to four stars) based on how important you think that function is for your community. Finally, give a rating based on how vulnerable you think that service is to climate change.

Example: One ecosystem service of a forest reserve is that of providing wildlife habitat.

Your list:

Service	Value to Community (1 to 4 ☆ 's)	Vulnerability to Climate Change ("low," "medium," "high")
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		

Choose one of the services you rate as having a "high" vulnerability to climate change and explain here why you think it is so vulnerable. Be as specific as possible.

Can you think of actions your community might take to avoid the loss of this service if the climate were to change in a way that negatively impacted that ecosystem and its service?

Name(s)_____
Date_____

Worksheet: Climate Change Impacts on Ecosystems

The state Department of Natural Resources has asked your class to evaluate how climate change due to an enhanced greenhouse effect could impact a specific ecosystem in the Gulf Coast region. Your task as a member of the climate impacts 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.

Species Name _____

Ecosystem Type and Geographic Location(s)_____

When scientists are faced with a problem to study, they first must determine what they already know, and what information they need to gather to solve the problem.

Describe in your own words the problem to be studied.

What information do you already have that is relevant to the problem?

What additional information do you need to know? What questions need to be answered?

In your group, develop a plan for gathering the information you need to move forward with your study. Make sure that you specify how this information needs to be gathered and who will be responsible for each task.

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 habitat, or other factors necessary for survival. In order to determine how global warming 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? Where does the species spend its time during each phase/stage? 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? What other species does it share this space with? 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:

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 in the landscape. 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 roads, large roads, or entire 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 consider the list of projected climate changes and evaluate how these changes might impact the species you studied.

Climate Change	Type of Impact: (examples: range shift north, earlier egg-laying, fewer breeding sites)
Summer Warming	1. 2. 3.
Winter Warming	
Sea-level rise	

Increased frequency of heavy rainfalls	
Increased drought frequency/severity	
Change in natural fire frequency/ severity	
Change in flooding frequency/severity	