Annenberg Media
Professional Development Course

The Habitable Planet

A Systems Approach to Environmental Science

Produced by the Harvard-Smithsonian Center for Astrophysics in association with the Harvard University Center for the Environment.

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is produced by the Harvard-Smithsonian Center for Astrophysics
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ISBN: 1-57680-885-8

Funding for
The Habitable Planet
is provided by Annenberg Media.

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About the Course

Course Overview

Earth is probably unique in the solar system, if not in the universe, because it is a platform that can support complex life forms. Conditions on Earth (temperatures, atmosphere, availability of minerals essential to life) are all maintained by a series of global cycles that link geological systems (plate tectonics, weathering, ocean, and atmospheric transport) with the diverse forms of life (particularly bacteria) that are present in almost every available niche.

The course will begin by asking "What makes Earth unique among planets?" We will then go on to answer that question through the first four units, which provide a background for understanding and discussing the natural functioning of the different Earth systems: geophysical systems, the atmosphere, the oceans, and, finally, natural ecosystems. The next two units ("Human Population Dynamics" and "Risk, Exposure, and Health") introduce humans as part of the overall ecosystem and look at what is needed to sustain human life. These are followed by a series of units that each deal with the effects of human actions on different natural systems: land use, air and water pollution, biodiversity decline, the extraction of resources, and finally, global issues such as climate change. The final unit looks toward the future and discusses in scientific terms what can be predicted, given current trends, as well as what might be expected if humans act in concert to mitigate their impact on the planetary system.

Accompanying each unit are video case studies that describe current, on-going research programs. Together, these case studies represent a fair cross section of the current "state of the art" in environmental science research. Designed to provoke curiosity and give a human face to many of the issues raised in the units, these videos will motivate and stimulate viewers to explore the themes through further readings and discussion. Five interactive web simulations will also reinforce the concepts we introduce, as well as teach about modeling environmental systems by providing opportunities to manipulate and experiment with natural systems.

Unit Descriptions

Unit 1. Many Planets, One Earth

While astronomers have discovered dozens of planets orbiting other stars and space probes have explored the edges of our solar system, so far no place in the universe we have discovered is suitable for complex life—except Earth. In this introduction to the course, examine the physical description of our planet, its history, and the unique characteristics that make it habitable.

Video 1. Many Planets, One Earth

The early Earth was a much different planet than the one we know today. Ancient rocks provide evidence of the emergence of oxygen in the atmosphere and the deep freeze of a Snowball Earth. Can these clues help explain the rise of complex animal life?

Andrew Knoll and Paul Hoffman, Harvard University

Unit 2. Atmosphere

Earth's atmosphere is one of the critical systems that make life possible on our planet. Together with the oceans, the atmosphere shapes Earth's climate and weather patterns, transporting heat from the tropics to the poles. But Earth's climate is not static. How does the atmosphere control climate? Learn how heat transport in the atmosphere contributes to the planet's habitability.

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Video 2. Atmosphere

The atmosphere makes the earth habitable. Heat trapping gases allow for ecosystems to flourish. Weather patterns, including hurricanes, help to regulate global climate. How might human emissions of greenhouse gases affect the balance of these natural systems?

Pieter Tans, Global Monitoring Division, NOAA
Kerry Emanuel, Massachusetts Institute of Technology

Unit 3. Oceans

The oceans cover three quarters of Earth's surface, and large scale ocean circulation plays an important role in regulating temperature and weather patterns on land. Even so, much of the deep ocean remains unexplored. Learn about a microscopic phytoplankton that contributes almost 25 percent of Earth's photosynthesis and that scientists discovered only a few years ago.

Video 3. Oceans

Ocean systems operate on a wide range of scales. Every few years, El Niño affects weather across the globe. On the small scale, tiny photosynthetic organisms near the ocean surface live and die over a 24-hour cycle. How do ocean systems regulate themselves and thus help maintain the planet's habitability?

Mark Cane, Lamont Doherty Earth Observatory, Columbia University
Penny Chisholm, Massachusetts Institute of Technology

Unit 4. Ecosystems

How living things interact with each other and how they participate in fluxes of matter and energy are key to understanding both abundance (why there are so many of a species) and diversity (why there are so many different species). See how ecologists study these factors to predict how ecosystems will change over time and how habitats might respond to human interactions.

Video 4. Ecosystems

The abundance of diversity in tropical rainforests is astounding. How can so many species co-exist when they are competing for the same resources? And in North America, why did removing just one species change the distribution of plants and animals up and down the food web?

Stuart J. Davies, Smithsonian Tropical Research Institute
Robert Crabtree, Yellowstone Ecological Research Center

Unit 5. Human Population Dynamics

How does human population growth and decline influence economic and social well-being? Does urbanization pose an environmental problem for humans or a pathway to better living conditions? Given current birthrates, what are the obstacles to preserving open space for future generations? Discover the ways that demographers approach these questions and more through the study of population dynamics.

Video 5. Human Population Dynamics

The human population of our planet now exceeds 6.5 billion and is rising. Much of this growth is projected for the most environmentally fragile regions of the world. Will studying the history of the world's population growth help predict the Earth's "carrying capacity"?

Martha Farnsworth Riche, U.S. Census Bureau
Deborah Balk, Baruch College, City University of New York

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Unit 6. Risk, Exposure, and Health

Humans' exposures to chemicals through pollutants and the food supply have been linked to health risks. What are the general classes of environmental agents that harm health, how do they enter the body, and how do they damage cells once they are present? Learn how dangers are assessed, exposures reduced, and the risks to human health managed.

Video 6. Risk, Exposure, and Health

In order to survive, we require food, air, and water– all of which are contaminated to some extent by man-made pollutants. We are exposed to these products all our lives, even before birth. How are these exposures impacting health, and what can be done to reduce these risks?

Howard Hu, Harvard School of Public Health
Robin Whyatt, Columbia University

Unit 7. Agriculture

The Earth's population will peak at 10 billion or more this century, but the amount of new agricultural land that can be brought into production is limited. In countries around the world, efforts to feed a growing population are leading to the intensification of agriculture—growing ever higher yields of food and products from lower inputs of land, water, and labor. Learn about physiological and environmental factors that limit crop growth, and visit places where agricultural research is helping farmers maximize their harvests and at the same time reduce environmental damage.

Video 7. Agriculture

Will world population outrun food resources? The green revolution of the 20th century multiplied crop yields, in part through increasing inputs of pesticides and fertilizers. How can farmers reduce their use of agricultural chemicals and still produce enough food?

Peter Kenmore, United Nations Food and Agriculture Organization
Pamela Matson, Stanford University

Unit 8. Water Resources

Rivers, lakes, and underground aquifers supply fresh water for industry, irrigation, drinking, and sanitation, but diversion, over-use, and pollution threaten irreplaceable water resources in many parts of the globe. This unit describes the world's major water reserves. See how scientists are grappling with the problems posed by water extraction, salinization, pollution, and water-related diseases.

Video 8. Water Resources

While essential to the lives of humans and animals, freshwater only accounts for 6 percent of the world's water supply. Over-use and agricultural pollution threaten water resources around the globe. How can we provide the water needed for cities and crops while ensuring the survival of the ecosystems that depend on natural water supplies?

Thomas Maddock, University of Arizona
Wendy Graham, University of Florida

About the Course

Unit 9. Biodiversity Decline

While biologists are still trying to learn how many species exist on Earth, a broad trend is clear: extinctions are occurring today at an exceptionally high rate. This unit examines how scientists define and measure biodiversity and how biodiversity is distributed geographically around the globe. Discover the important connection between biodiversity and the stability of ecosystems.

Video 9. Biodiversity Decline

Species are being lost at an extremely rapid rate in rainforests and coral reefs. With so many species yet to be discovered, scientists struggle to keep ahead of the bulldozers on land and the "rise of slime" in the sea. How can we protect the biodiversity of these vulnerable ecosystems?

William Laurance, Smithsonian Tropical Research Institute
Jeremy Jackson, Smithsonian Tropical Research Institute, Scripps Institute

Unit 10. Energy Challenges

Industrialized nations rely on vast quantities of readily available energy to power their economies and produce goods and services. As populations increase and citizens demand better standards of living, global energy consumption will continue to rise, accompanied by ever-higher demands for non-fuel mineral resources such as iron and steel. Learn about future technologies that can produce ample supplies of energy without some of the environmental costs linked to current energy resources.

Video 10. Energy Challenges

Global energy use increases by the day. Polluting the atmosphere with ever more carbon dioxide is not a viable solution for our future energy needs. What new technologies will help provide the energy we need without pushing the concentrations of CO_2 to dangerous levels?

Neeraj Gupta, Battelle Memorial Institute and Department of Energy
Andy Aden, National Renewable Energy Laboratory

Unit 11. Atmospheric Pollution

Air pollution is a global issue, with emissions from East Asia impacting the day-to-day air quality of cities in North America. At the same time, greenhouse gases such as carbon dioxide and methane are changing the climate, while other man-made compounds destroy the ozone layer at high latitudes. Discover how pollutants released from smokestacks and tailpipes undergo a complex chemistry that transforms them into dangerous toxins—with widespread detrimental effects on human health.

Video 11. Atmospheric Pollution

Once released, air pollution reacts chemically to form even more dangerous secondary pollutants. And these travel: nitrogen oxides from Asia affect the long-term health of Californians. How do we use what we can learn about air pollution transport to better control its impact?

Charles Kolb, Aerodyne Research, Inc.
Luisa Molina, Massachusetts Institute of Technology

About the Course

Unit 12. Earth's Changing Climate

For the first time in the history of our species, humans are now impacting the habitability of Earth on a planetary scale. Fossil fuel combustion has increased concentrations of greenhouse gases to levels that no human has yet experienced while, at the same time, studies have shown Earth's past climate to be an exquisitely sensitive system subject to dramatic shifts over timescales of a few decades. In this unit, examine the science behind global climate change and explore its possible impact on natural ecosystems and human societies.

Video 12. Earth's Changing Climate

Tropical glaciers are the world's thermometers; their melting is a signal that human activities are warming the planet. Will natural ecosystems be able to absorb enough additional carbon dioxide from the atmosphere to mitigate the full impact of human-induced greenhouse gas emissions?

Lonnie Thompson, The Ohio State University
Chris Field, Stanford University

Unit 13. Looking Forward: Our Global Experiment

Emerging technologies offer potential solutions to environmental problems. Over the long-term, human ingenuity may ensure the survival not only of our own species but of the complex ecosystems that enhance the quality of human life. In this unit, examine the wide range of efforts now underway to mitigate the worst effects of man-made environmental change, looking toward those that will have a positive impact on the future of our habitable planet.

Video 13. Looking Forward: Our Global Experiment

Earth's essential systems are being stressed in many ways. There are many tipping points in the environment, beyond which there could be serious consequences. Will human ingenuity, resiliency, and cooperation save us from the worst outcomes of our global experiment?

John Holdren, Harvard University
Daniel Pauly, University of British Columbia
Ann Pringle, Harvard University
Daniel Schrag, Harvard University
E.O. Wilson, Harvard University

Course Components

On Site Activities

The Habitable Planet Professional Development Guide is intended to provide structure, resources, and activities for use in teacher professional development. The course consists of thirteen two-and-a-half hour sessions, each of which includes pre- and post-viewing group activities and discussions that complement the half-hour video. Each session addresses specific content from that unit's video and text and has a consistent structure that includes key content questions, activities, and resources for extending personal understanding and teaching the unit topic.

Background (Pre-Workshop)

Prior to arriving at the on-site session, participants should read the background sections of the assigned unit. Participants will also have completed the between-session assignment from the previous session.

Introduction

The introduction to each unit is a short summary and overview of the entire unit. The major themes of the unit are identified.

Essential Questions

The essential questions section contains several key questions that address the unit topic. The questions are intended as advanced organizers to start you thinking about the specific unit topic. They are global in nature and attempt to focus your attention on the big picture when reading the text, watching the video, and conducting online simulations. For example, in Unit One, "Many Planets, One Earth," an essential question is, "How does evidence of the deep past inform us about today's ecological conditions?" In the text and video, you will read, see, and hear about the use of fossils and geologic formations to explain the extensive climate changes that have helped create the abundance and diversity of life on Earth.

The Content

The content section of each unit guide contains a brief summary of the text and video for the unit that focuses on key science concepts. Each video focuses on two distinguished research scientists who describe their work as it relates to the unit topic. The videos present interdisciplinary subjects and diverse methodological relationships in unique ecological settings.

Learning Goals

Learning goals are presented as potential outcomes for participants in The Habitable Planet professional development workshops. For each unit, we present three types of expected science education outcomes, including knowledge, skills, and dispositions. Many of the goals are directly related to national standards in science education. Knowledge refers to specific science content. Skills refer to science process skills, such as experimental techniques, evaluation of results, and outcomes and communication. Dispositions refer to attitudes and values related to science and the specific research findings.

Key Concepts

Key concepts are listed to focus the learner on specific ideas that are presented in the text and video. In many cases, the key concepts correspond to specific sections of the unit text.

Misconceptions

Each unit includes a section on misconceptions related to the unit topic. Misconception research indicates that these commonsense but incorrect explanations of the world interfere with new learning. We want you to be aware of these ideas for your own personal learning and to consider them as you prepare lessons for your students. In most cases, we have identified a misconception, suggested why it may be prevalent, and explained the scientifically accepted understanding.

Course Components

Getting Ready (On-Site)

In preparation for watching the video, you will engage in forty-five minutes of investigation through activity and discussion. Typically, we present three activities that the facilitator of the group will lead. Activity One and Activity Two are consistent throughout the entire course, while Activity Three changes to fit the specific unit topic.

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

Assessing learners' prior knowledge is considered one of the most important factors in meaningful learning because the knowledge that the learner brings to the topic will influence any new learning. At the start of each session, the facilitator will distribute three index cards to each participant. On the first card, participants should indicate something they know to be true about the unit topic. On the second card, each participant should write one question he or she has about the specific unit topic. On the third card, each person should describe a direct experience related to the unit topic.

For example in Unit 12, "Global Climate Change," a participant might write:

> Climate change is occurring faster than ever.
>
> What causes climate change?
>
> It seems the winters are warmer with less snow.

When the participants have completed their three cards, the group tapes the cards onto the wall or blackboard, grouping similar ideas, questions, and experiences. Statements, questions, and experiences may be grouped in a variety of idiosyncratic ways. Participants should look for relationships and discuss similarities and differences. They should begin to see patterns of understandings and experiences. The group can use chalk, markers, or tape to indicate logical groupings and relationships between ideas. Participants may add or delete cards. They can move cards around. Some of the most interesting aspects of this activity are associated with the dynamic interaction of participants. Often cross-links between various groups of ideas indicate very creative associations and relationships. The group can return to this wall diagram after viewing the video to discuss their original ideas and add new ones.

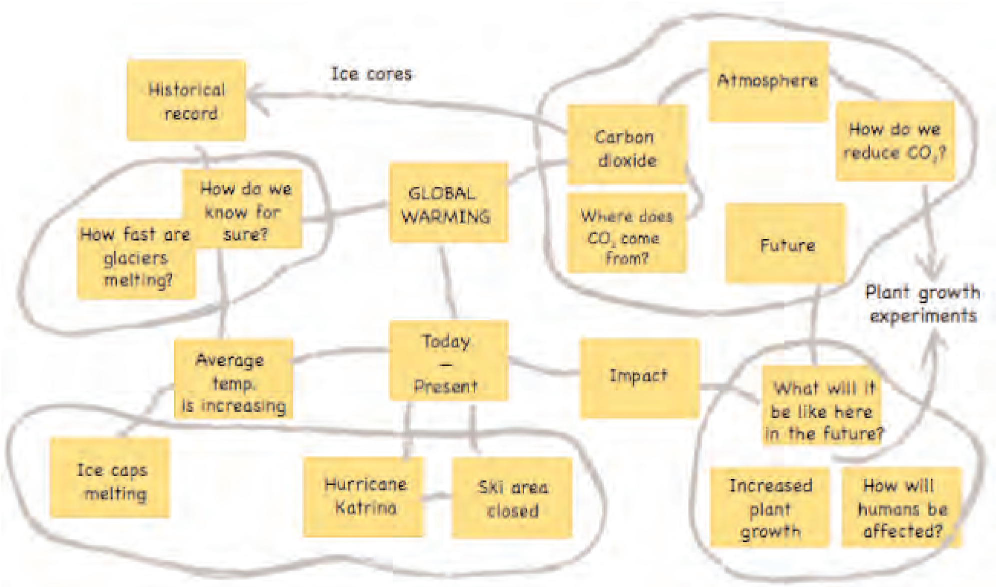


Figure A. This example from Unit 12, "Earth's Changing Climate," illustrates a potential outcome of Activity One: Assessing Prior Understanding. Consider the individual cards and how they might be grouped. This is only one possibility for their organization. Each week the goal is that the participants will reflect on their personal understandings, questions, and experiences and share them in a way that creates dynamic interactions.

Course Components

Activity Two: Current Events and Editorial Cartoons

Participants share an article or cartoon that they have found related to the week's topic. Newspapers, magazines, and the Internet can provide many popular perspectives on topics related to The Habitable Planet. Each participant should be asked to read aloud the headline of his or her article. The facilitator should ask a few people to summarize their articles, asking for comments from others with related articles. As the group discusses the articles, a participant should record a list of key concepts.

Activity Three: Pre-Video Demonstration or Activity

The third activity before the viewing of the video is typically a demonstration, discussion, or online simulation related to the unit topic. In most cases, the facilitator will need to set up the demonstration before the group arrives and have it ready for viewing and discussion by the participants. The objective is to illustrate related science concepts and discuss key ideas and various perspectives as they relate to the video. An example of this approach is the greenhouse demonstration in Unit 12. Although a very simple activity, this demonstration clearly indicates how light energy is captured and thus causes temperature increase. Participants will discuss how this can happen in natural settings, which leads into the Unit 12 video on global climate change. When an activity involves using The Habitable Planet Interactive Labs, the facilitator will ensure that, at a minimum, a single computer with Internet access is available for the group. Participants will use the simulation to control variables, predict outcomes, and visualize results.

Activity Four: Watch the Video

In each session, we have provided questions to consider while watching the video. These questions are fairly specific and help focus the viewer's attention on key parts of the video. The facilitator and participants should consider the questions before the start of the video.

Activity Five: Discuss the Video

We have provided questions that are more general and intended to stimulate discussion following the video. These questions focus on analysis or synthesis and ask the participants to compare and contrast the ideas or methodologies the researchers present.

Activity Six: Going Further

This activity includes discussions, experiments, or demonstrations to conduct following the viewing of the video. The activities should be prepared by the facilitator before the professional development workshop session convenes. Each activity is intended to build upon key ideas and extend participants' understanding.

Activity Seven: Return to Essential Questions

Before the conclusion of the session, participants should return to the essential questions posed in the background section of the professional development guide.

Activity Eight: Discuss Classroom Supplementary Activities

In each session, we have provided a number of supplementary activities that can be used in middle and secondary school science classrooms. The facilitator should take a brief amount of time to have participants discuss the activities and how they might be implemented in the classroom.

Between Sessions (Post-Workshop)

These activities should be completed before the group convenes to address the next unit. Assignments prepare the participants for effective participation in the next professional development session.

Next Week's Topic

Each participant should read the entire Online Text for the next unit as well as the misconceptions section in the Background section of the guide.

Course Components

On-Line Simulation
If there is an online Interactive Lab for the next unit, participants should complete the simulation, write a paragraph summary of what they learned, and bring it to the next meeting of the workshop group.

Current Events, Popular Articles, and Cartoons
Each participant should bring a newspaper or magazine headline, article, or editorial cartoon related to the next unit topic.

About the On-Site Activities

Helpful Hints

Included in the materials for each session you will find detailed instructions for the content of your Getting Ready and Going Further activities. The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator
Each week, one person should be responsible for facilitating the session (or you might select two people—one to facilitate Getting Ready and the other to facilitate Going Further). The facilitator does not need to be the same person(s) each week. We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Activities and Bring the Necessary Materials
Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each workshop. The sessions will be the most productive if you and your colleagues come to the workshops prepared for the discussions. A few of the activities require special materials. The facilitator should be responsible for bringing these when necessary.

Keep an Eye on the Time
Thirty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything within the two-and-a-half hour session. You may want to use a small alarm clock or kitchen timer as a reminder.

Record Your Discussions
We recommend that someone take notes during each Site Discussion or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as "make-up" materials in case anyone misses a session.

Share Your Discussions on the Internet
The Site Activities are merely a starting point. We encourage you to continue your discussions with participants from other sites through the course email discussion list. Participants can join this list through the course home page on www.learner.org.

Materials

For each session

3 index cards per participant for each session

Unit 1: Many Planets, One Earth

Activity Three: Geologic Time Scale Activity

- One roll of toilet paper (231 sheets or more)
- Felt-tip marker(s), preferably several colors
- Clear tape for repairs

Activity Six: Carbon Cycle and Human Influence

- Three easily acquired, inexpensive, and uniform objects for each participant—e.g., small rocks, pencils, pens, shells, etc.
- Poster board or large pieces of paper labeled as carbon pools, atmosphere, biomass, soil, ocean, fossil fuel deposits, and underground rocks

Unit 2: Atmosphere

Activity Four: Demonstrating the Carbon Cycle

- At least 15 black balloons to represent carbon. One red balloon (equals 48 black balloons) and one white balloon (represents 66,000 black balloons); balloons should be filled with air
- String or tape to attach balloons
- Large index cards identifying the principal carbon reservoirs: Atmosphere; land biomass (plant or animals); ocean; fossil fuel; rock
- Drawing paper and markers

Activity Six: The Effect of Surface Type on Heating

For each group of four participants:

- Six 1-liter bottles
- Six thermometers
- Tape
- White paint and brushes
- Three cups of dark soil
- Three cups of white sand
- Water and dump buckets
- One 150-watt floodlight bulb
- Portable reflector lamp
- Stand to support lamp set-up
- Graph paper

Materials

Unit 3: Oceans

Activity Three: Ocean Currents Demonstration

- Large, shallow watertight container
- Food coloring
- Fan
- Water
- Stopwatch

Activity Six: Stratification of a Water Column

- A watertight column (such as settling tubes, clear PVC, or a very large graduated cylinder)
- 4 small glass vials with screw-on lids
- Fine sand
- Food coloring (optional)
- Water

Unit 4: Ecosystems

Activity Six: Determination of Species Diversity and Abundance Using Owl Pellet Data

- Copies of Table 4.1 for each participant
- Owl pellets

Unit 5: Human Population Dynamics

Activity Three: Changes in Human Population

- Copies of tables and graphs in Activity Three

Activity Six: Spatial Demographics Activity

- One set of fact sheets for each participant, listing the environmental and natural resources for the seven countries featured in the Interactive Demographics Lab
- A computer and Internet access in order to run the Interactive Demographics Lab

Unit 6: Risk, Exposure, and Health

None

Materials

Unit 7: Agriculture

Activity Three: A Sustainable Agricultural Land-Use Scenario

- A large number of small objects of two different colors, such as small garden decorating stones, marbles, or candies
- Paper bags—one per group

Activity Six: Bioaccumulation

- Oil
- Red dye
- Five 100 ml beakers
- Two 400 ml beakers
- Fishing pole
- 16 test tubes
- Red marker
- 1-liter beaker
- Stirring rods
- Pipettes
- Fish consumption advisories (one per participant)

Unit 8: Water Resources

Activity Three: What is a Watershed?

- Stream table, children's pool, or large plastic container
- Crumpled newspaper
- Saran wrap
- Spray bottle
- Blue colored water
- Clear acetate sheet for each participant
- Erasable markers

Unit 9: Biodiversity Decline

Activity Six: Timber Harvesting Community Role Play

Set of role cards for each group of nine participants

Unit 10: Energy Challenges

None

Materials

Unit 11: Atmospheric Pollution

Activity Three: Tree Leaf Symmetry

- Topographic map of local area of study, areas marked leaves

Activity Six: Discussion of Local and National Air Quality

- A report for air quality in cities in the USA. *Print out the report found at the EPA Web site for the United States, Air Quality Index Report, Metropolitan Statistical Area (MSA) summary type, for the year of 2006 (or later, if available)*
- Reports for the specific location of the group

Unit 12: Earth's Changing Climate

Activity Three: Greenhouse Demonstration

- 2 identical containers
- 2 covers
- Clock
- Light source
- Matches
- Vinegar
- Baking soda
- 2 shallow dishes
- 2 thermometers

Activity Six: Historical Climate Statistics

- Graph paper

Unit 13: Looking Forward: Our Global Experiment

None

About the Contributors

Course Developer

Daniel P. Schrag, Harvard University

Daniel Schrag is professor of Earth and planetary sciences and environmental engineering at Harvard University and the director of the Harvard University Center for the Environment. Schrag studies climate and climate change over the broadest range of Earth history. Schrag received a B.S. from Yale in 1988. He majored in political science and geology, beginning an interest in science and policy that continues to this day. As a graduate student at Berkeley, Schrag was introduced to geochemistry and paleoclimatology through his work developing new methods for reconstructing ancient climates. After receiving his Ph.D. in 1993, Schrag taught at Princeton until 1997, when he moved to Harvard's Department of Earth and Planetary Sciences. In his research, Schrag applies a variety of techniques from analytical chemistry to a wide range of Earth materials including trees, corals, and deep sea sediments, using the data to understand the chemical and physical evolution of the atmosphere and ocean and the relationship to the evolution of life. He has studied the physical circulation of the modern ocean, focusing on El Niño and the tropical Pacific. He has worked on theories for Pleistocene ice-age cycles over the last few hundred thousand years. He helped develop the Snowball Earth hypothesis, proposing that a series of global glaciations occurred between 750 and 580 million years ago that may have contributed to the evolution of multicellular animals. He has also worked on the early climates of Earth and Mars nearly 4 billion years ago. He is currently working with economists and engineers on technological approaches to mitigating future climate change. Among various honors, Schrag was awarded a MacArthur Fellowship in 2000.

Content Developers

Units 1, 12, 13
Daniel P. Schrag (see above)

Unit 2
Steven C. Wofsy, Harvard University

Steven Wofsy is professor of atmospheric and environmental science at Harvard University. His work focuses on the chemical composition of the atmosphere, both regionally and globally, and is motivated by the need for scientific information and analysis to make wise decisions on the future development of the world's resources. His group projects include developing new airborne sensors to make accurate measurements of CO_2, CH_4, CO, and N_2O and devising new analysis and modeling procedures to extract quantitative information about sources, sinks, transformations, and transport of atmospheric trace gases. The long-term goal of these efforts is to understand the factors that regulate atmospheric composition and to help design programs to mitigate undesirable change.

Unit 3
James J. McCarthy, Harvard University

James McCarthy is an Alexander Agassiz Professor of Biological Oceanography and director of Harvard University's Museum of Comparative Zoology. He holds faculty appointments in the Department of Organismic and Evolutionary Biology and the Department of Earth and Planetary Sciences and is the head tutor for degrees in environmental science and public policy. His research interests relate to the regulation of plankton productivity in the sea, in particular the cycling of nitrogen in planktonic ecosystems. He was the founding editor of the American Geophysical Union (AGU) Global Biogeochemical Cycles journal. For the past five years, he has served as co-chair of the Intergovernmental Panel on Climate Change (IPCC), Working Group II, which has responsibilities for assessing impacts of and vulnerabilities to global climate change. He has been elected a fellow of the American Association for the Advancement of Science, a fellow of the American Academy of Arts and Sciences, and a foreign member of the Royal Swedish Academy of Sciences. In 1997, he was the recipient of the New England Aquarium's David B. Stone award for distinguished service to the environment and the community.

About the Contributors

Unit 4
Paul R. Moorcroft, Harvard University

Paul Moorcroft is a professor of biology at Harvard University who specializes in terrestrial ecosystem dynamics. His research investigates how ecological processes affect the structure, composition, and functioning of terrestrial ecosystems at regional to global scales. He has published a book with Mark Lewis on animal movement, entitled *Mechanistic Home Range Models: From Individual Behavior to Large-scale Pattern*.

Unit 5
David E. Bloom, Harvard University

David Bloom is Clarence James Gamble Professor of Economics and Demography and chairman of the Department of Population and International Health at the Harvard School of Public Health. His recent work has focused on the links among population health, demographic change, and economic growth, and on primary, secondary, and higher education in developing countries. He has been on the faculty of the public policy school at Carnegie Mellon University and the economics departments of Harvard University and Columbia University. He is a fellow of the American Academy of Arts and Sciences, where he co-directs the Academy's project on Universal Basic and Secondary Education.

Unit 6
John D. Spengler, Harvard University

John Spengler is the Akira Yamaguchi Professor of Environmental Health and Human Habitation in the Department of Environmental Health at the Harvard School of Public Health. His research activities are directed at the assessment of population exposures to environmental contaminants that occur in homes, offices, and schools, and during transit, as well as in the outdoor environment. Although he is investigating the effects of pollutants of outdoor origin (ozone, acidic particles, PCBs), he is particularly interested in pollutants of indoor origin (fungi, dust mites, nitrogen dioxide, tobacco smoke, radon, and others). He is also investigating ways to promote improved air quality through sustainable development strategies. Dr. Spengler's objective is to construct the framework for linking zoning, purchases and practices, construction and appliance specifications, and pricing and tax strategies to energy and pollution consequences. He believes that the concepts of pollution prevention, environmental cost accounting, risk-reducing based decision making, and life-cycle analysis have to mature from academic concerns to functional activities within the public and private sectors of a market-driven economy.

Unit 7
Noel Michele "Missy" Holbrook, Harvard University

Missy Holbrook is professor of biology and the Charles Bullard Professor of Forestry in the Department of Organismic and Evolutionary Biology at Harvard University. Her research interests include long-distance transport physiology in plants; root physiology: interactions between uptake and growth; water relations associated with flowering and flower production; biomechanics of growth and development; and factors that control uptake and movement of water in tropical trees.

Unit 8
Charles F. Harvey, Massachusetts Institute of Technology

Charles Harvey is the Doherty Associate Professor in Civil and Environmental Engineering at the Massachusetts Institute of Technology. He is a hydrologist concerned with groundwater and the fate and transport of chemicals in the subsurface environment. His research projects include investigations into the arsenic contamination of Bangladesh's water supply, the flux of nutrients in coastal ocean waters, and the fundamental physical and chemical processes that transform pollutants within soils and groundwater.

About the Contributors

Unit 9
Anne Pringle, Harvard University

Anne Pringle is an assistant professor of organismic and evolutionary biology at Harvard University and an associate member at the Broad Institute. Her research explores evolution as it happens in wild populations of fungi. Current work in her laboratory focuses on an introduced symbiont currently expanding its range on the West Coast of North America, cooperation between germinating spores of the genetic model Neurospora crassa, and immortality within filamentous fungi.

Unit 10
John P. Holdren, Harvard University

John Holdren is Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy at the Kennedy School, as well as professor in Harvard's Department of Earth and Planetary Sciences. He is also director of the Woods Hole Research Center, chairman of the board of the American Association for the Advancement of Science, and co-chair of the independent, bi-partisan National Commission on Energy Policy. His work has focused on causes and consequences of global environmental change, analysis of energy technologies and policies, ways to reduce the dangers from nuclear weapons and materials, and the interaction of content and process in science and technology policy.

John H. Shaw, Harvard University

John Shaw is the Harry C. Dudley Professor of Structural and Economic Geology and Chair of the Department of Earth & Planetary Sciences, Harvard University. Prior to joining the faculty at Harvard, Professor Shaw worked as an exploration and production geologist in the petroleum industry. Shaw directs an active research program that investigates the nature of oil and natural gas deposits in basins throughout the world. His research group works to develop more efficient methods of finding and exploiting these resources, as well as mitigating the environmental impacts of these operations. Professor Shaw's additional research and teaching interests include alternative energies and material resources, as well as the environmental impacts of resource exploitation.

Unit 11
Daniel J. Jacob, Harvard University

Daniel Jacob is a professor of atmospheric chemistry and environmental engineering at Harvard University. The goal of his research is to understand the chemical composition of the atmosphere, its perturbation by human activity, and the implications for climate change and life on Earth. His approaches include global modeling of atmospheric chemistry and climate, aircraft measurement campaigns, satellite data retrievals, and analyses of atmospheric observations.

Professional Development Guide Developers

Michael J. Brody, Montana State University

Michael Brody is an associate professor of education in the College of Education, Health, and Human Development at Montana State University, where he teaches courses in the environment, science education, and educational research at the graduate and undergraduate levels. He received his Ph.D. from Cornell University (1985) in science and environmental education. Brody has worked with teachers throughout the Russian Federation, Morocco, and Thailand and has developed the Ecological Field Studies Program, which connects environmental educators through global networks. He is a research associate of the Museum of the Rockies in Bozeman, Montana, where he helped design the permanent exhibit Landforms/Lifeforms. He is a member of the North American Association for Environmental Education (NAAEE) Research Commission and received the NAAEE Outstanding Contributions to Research Award in 2006. Presently, he is working on the development of Project Archaeology and researching science learning outcomes in both formal and informal settings. Brody is the executive editor of ARexpeditions, an online action research journal for professional educators.

About the Contributors

Warren Tomkiewicz, Plymouth State University

Warren Tomkiewicz is professor of Earth system science and chair of the Environmental Science and Policy Department at Plymouth State University in Plymouth, New Hampshire. He teaches undergraduate courses in Earth system science, environmental science, and ocean studies, and graduate courses in science education. He is also graduate coordinator for the MS and MAT programs in science education. Tomkiewicz has been the recipient of several grants funding professional development institutes, courses, and workshops for science teachers in New Hampshire and Maine. His current research interests include effective teaching and learning strategies in undergraduate Earth system science and environmental science courses. He coordinates an action research project with science teachers on teaching and learning science as inquiry. He received an Ed.D. from Boston University, MS from Northeastern University, and BS from Plymouth State College.

Mary Ann McGarry

Mary Ann McGarry is an associate professor of science education at Plymouth State University in New Hampshire. As an undergraduate at Dartmouth College in 1980, she designed a special major in environmental education and has been pursuing the field ever since, earning a Masters in Earth Sciences and a Doctorate in Science/Environmental Education. After serving as a faculty member on several campuses for the University of Maine System, in 2004 she joined the newly founded Center For The Environment at Plymouth State University (PSU) in New Hampshire, working on a new MS in Environmental Science and Policy degree. She continues to work internationally on environmental stewardship issues, fulfilling a residential fellowship for the Cypriot government, serving as a faculty instructor for the month-long PSU Pakistani Educational Leaders' summer institutes, and leading regular travel study courses for educators within the United States, Costa Rica, and Ecuador. In the fall of 2007, McGarry became the Director of Education for the Hubbard Brook Research Foundation, while remaining a faculty member at PSU.

Penny Juenemann

Penny Juenemann lives with her family in Two Harbors, Minnesota, where she teaches at Two Harbors High School. She received a BS in biology, a BAS in life science teaching, and a BAS in physical science teaching from the University of Minnesota Duluth in 1994. Juenemann started her teaching career at the Fond du Lac Ojibwe School by Cloquet, Minnesota, and in 1997 began teaching in Two Harbors. She received her MS in science education from Montana State University-Bozeman in 2004.

Jessica Krim

Jessica Krim earned her BA in Earth Science Education from the University of Delaware in 1997. She then taught Earth Science and Life Science on the Hopi Reservation in Keams Canyon Arizona and Earth Science in Wilmington, Delaware. In 2003, she returned to school to complete her MA in Physical Science and in 2005 began work on her doctoral degree in Curriculum and Instruction at Montana State University in Bozeman, Montana.

Judith Pyle

Judith Pyle earned a BS in medical technology from Temple University (1979) and an MS in infectious disease from the University of Pennsylvania (1984). She has been teaching honors and AP Biology at Abington High School in Abington, Pennsylvania, for 16 years, has taught at the University of Pennsylvania, and has served as an online adjunct instructor for Montana State University.

Notes

Unit 1

Many Planets, One Earth

Background

Introduction

This unit of The Habitable Planet introduces the origin of planet Earth and some of the theories about how it has changed over time to develop a hospitable environment and a fantastic number of different life forms. Although the universe has countless celestial bodies, Earth is the only known planet supporting life as we know it. What has led to the remarkable phenomenon of life on Earth? The history of this process is found in Earth's geologic record, which gives us evidence of both physical and biological evolution. Proceeding through a variety of global phenomena, from the creation of the atmosphere to an apparent ice-ball, the Earth's surface climate has been regulated by the geologic carbon dioxide cycle. As a result of catastrophic occurrences and the resilience of life on Earth, we now live in the balance of the Habitable Planet.

Essential Questions

- How is it that a one-time collection of cosmic dust has gradually changed over time and produced this incredible planet with its tremendous biological diversity?
- What transitions has Earth gone through and why?
- How does evidence of the deep past inform us about today's conditions?
- How does the Earth's geological carbon cycle act as a thermostat?

Content

The Unit 1 video presents two perspectives on the ancient history of planet Earth. First, Professor Andy Knoll, a Harvard University paleontologist, describes how investigations of fossils not only give us clues about the shape, size, and function of ancient animals and plants, but also show the biological responses to geologic changes. He describes how geologic history gives evidence for the rise of living organisms and how physical events influence evolution. These past events have given rise to our present condition. Dr. Ann Pearson then describes how the biological evidence found in fossils can help explain physical phenomena such as the formation of our atmosphere. In particular, she discusses how sterols help explain when free oxygen became available in the atmosphere.

In the second part of the video we are introduced to the Snowball Earth Theory. Professor Paul Hoffman, a Harvard University geologist, explains how Earth's so-called thermostat went haywire and resulted in Earth being entirely covered by glaciers—thus, Snowball Earth. He goes on to explain how the thermostat eventually kicked in and the climate was restored, melting the glaciers and releasing tremendous biological evolutionary potential. Specifically, Dr. Hoffman explains the geologic carbon cycle and how it created our atmosphere and to this day regulates climate on Earth.

Background

Learning Goals

During this session you will have an opportunity to build your understanding of the following:

a. Knowledge
   i. Geologic carbon cycling and its relation to maintaining Earth's habitable environments
   ii. Composition and formation of the atmosphere, especially as it relates to free oxygen
   iii. Geologic records as evidence of both physical and biological evolution
   iv. Evolutionary processes throughout Earth's history
   v. Snowball Earth Theory
   vi. Cambrian Explosion and its relation to climate change
b. Skills
   i. Understand scientific research as a descriptive process
   ii. How scientists collect evidence of ancient land and life forms
   iii. How science helps explain current events
c. Dispositions
   i. Appreciate the diverse and robust nature of life on Earth
   ii. Value the fact that evidence from the deep past gives understanding of our present situation

Key Concepts

Albedo	Extremophiles	Prokaryotes
Archaea	Geochemical cycling	Radiometric dating
Bacteria	Heterotrophs	Snowball Earth
Cambrian explosion	Oxidation	Stratigraphic
Cyanobacteria	Phylum	Carbon Cycling
Eukaryotes	Plate tectonics	Diversification

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Earth and its History

The most pervasive misconceptions about Earth, its formation, and its history will be primarily derived from creationist arguments about evolution. Although people may disagree about whether these are misconceptions or beliefs, the fact is that they will interfere with new scientific learning, especially as it relates to this unit. The five statements below seem to be the most common misconceptions based on a creationist version of Earth's history and development. You will also find counter-arguments to each point.

Evolution has never been observed.
Evolution is gradual over time; things do not change before our eyes.

Evolution violates the second law of thermodynamics.
This is probably more a misconception about thermodynamics than evolution since it relates directly to physical rather than biological phenomena.

There are no transitional fossils.
Evolution does not claim transitional forms.

Life originated, and evolution proceeds, by random chance.
This ignores the fundamental roles of natural selection.

Evolution is only a theory; it hasn't been proved.
Evolution is technically the change in allele frequencies over time, which is a fact.

Unfortunately, in addition to these commonly held beliefs, misconceptions about evolution are ever-present. A common misconception is that evolution proceeds in a specific direction leading to the improvement of organisms. This is often stated as "climbing an evolutionary ladder." This is not the case. Organisms either adapt to environments that are always undergoing change or they risk extinction. The very diversity of life allows the struggle for survival to take place. Common misconceptions about fossils include the following claims, which we clarify.

Fossils are pieces of dead animals and plants.
Fossils are not actually pieces of dead animals and plants. They are only the impression or cast of the original living thing. The actual living parts decay away but their shape is permanently recorded in the rock as it hardens.

Fossils of tropical plants cannot be found in deserts.
Fossils record ancient environments present at the time the rocks were deposited.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants indicate something they know about Earth's formation and history. On the second, they write one question they have about Earth's formation and history. And on the third card, they describe a direct experience that they have had that relates to Earth's formation and history. For example, an individual might write:

- Earth formed from cosmic dust and gradually evolved into the planet today.
- What caused Earth to go through ice ages?
- I found fossils in the sea cliffs on the coast of Oregon.

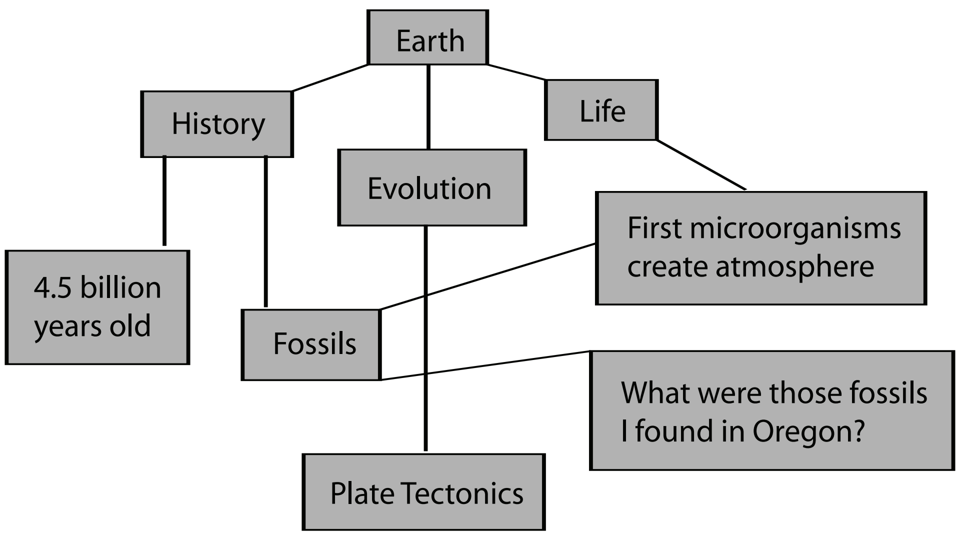


Figure 1.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found related to the week's topic. Everyone in the group will share his or her headline for the articles. The leader should ask a few people to summarize their articles, asking for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a related cartoon or an editorial instead of an article.)

Getting Ready

Activity Three: Toilet Paper Geologic Time Scale

This activity is a graphic demonstration of the enormous extent of geologic time compared to recent time. You will need: one roll of toilet paper (231 sheets or more), felt-tip marker(s), preferably several colors, and clear tape for repairs. Check the markers to make sure they write without damaging the surface below and test them for clarity and marking the surface.

FACILITATOR: On a flat, protected surface, unroll the first sheet of the roll. Using the perforations between sheets as a ruler (the first is zero), mark the dates and names of items as listed in the table below. The scale of 20 million years per sheet of toilet paper makes the conversion obvious. Re-roll the toilet paper. If it tears, repair with tape.

Starting at one end of a long hallway, the group should unroll the toilet paper to the end. Note the varying distances. As a group, go through the events and dates described in the text for Unit One. Place markers at the appropriate place on the timeline for each event described in the text.

Sheets	Event	Geological time (Number of years before present)
0.00	Present	0
0.0005	Modern man	10,000
0.01	Neanderthal man	100,000
0.07	Homo erectus	1,300,000
1.15	Beginning of Quaternary Period	23,000,000
0.50	Beginning of Antarctic ice caps	10,000,000
1.15	Beginning of Tertiary/Neocene Period	23,000,000
1.25	First evidence of ice at the poles	25,000,000
2.50	Early horses	50,000,000
3.00	Early primates	60,000,000
3.25	Beginning of Cenozoic Era	65,000,000
3.25	Dinosaurs became extinct	65,000,000
4.00	Rocky Mountains form	80,000,000
7.00	Cretaceous Period begins	140,000,000
7.50	Early flowering plants	150,000,000
9.00	Early birds and mammals	180,000,000
10.40	Jurassic Period begins	208,000,000
12.25	Triassic Period begins	245,000,000
12.25	Beginning of Mesozoic Era	245,000,000
14.00	Final assembly of Pangaea	280,000,000
14.50	Beginning of Permian Period	290,000,000
16.25	First reptiles	325,000,000
16.15	Beginning of Pennsylvanian Period	323,000,000
18.15	Beginning of Mississippian Period	363,000,000
20.45	Beginning of Devonian Period	409,000,000
21.50	Early land plants	430,000,000
21.95	Beginning of Silurian Period	439,000,000
24.50	Early fish	490,000,000
25.50	Beginning of Ordovician Period	510,000,000
28.50	Early shelled organisms	570,000,000
28.50	Beginning of Cambrian Period	570,000,000
28.50	Beginning of Paleozoic Era	570,000,000
28.50	Beginning of Paleozoic Eon	570,000,000
35	Early multicelled organisms	700,000,000
40	Breakup of early supercontinent	800,000,000
70	Formation of early supercontinent	1,400,000,000
60	First known animals	1,200,000,000
125	Beginning of Proterozoic Eon	2,500,000,000
135	Buildup of free oxygen in atmosphere	2,700,000,000
170	Early bacteria and algae	3,400,000,000
190	Oldest known Earth rocks	3,800,000,000
200	Beginning of Archeon Eon	4,000,000,000
230	Precambrian time begins	4,600,000,000
230	Origin of earth	4,600,000,000

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Why is it that among all the celestial bodies in the universe, Earth appears to be the only one with a life-sustaining environment?
2. Why are the environments so different in various parts of Earth?
3. How did Earth's atmosphere form and why is it so important?
4. How has climate changed over the history of Earth?
5. What is the evidence for the evolution of life and how do we interpret it?
6. What do fossils tell us?
7. When and how did life form?
8. Why does Earth have a relatively stable climate?
9. How does atmospheric carbon dioxide influence Earth's temperature?
10. What is the relationship of atmospheric carbon dioxide to Earth's surface temperature?
11. Where does carbon dioxide primarily come from?
12. How is carbon dioxide consumed on Earth and where does it go?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. What does the Snowball Earth Theory claim?
2. What is the evidence in the geologic record for climate change and biological evolution? How do these two relate to each other?
3. What is the Cambrian Explosion and how does it relate to both geologic and biological evolution?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Carbon Cycle and Human Influence

FACILITATOR: Conduct this activity with the participants immediately after they see the video. Doing so will help focus attention on the carbon cycle and the path that carbon follows. The activity can be adapted to reflect the effects of various human influences such as deforestation and burning fossil fuels. Be sure to try to model scenarios described in the video.

Materials

Three easily procured, inexpensive, and uniform objects for each participant—e.g., small rocks, pencils, pens, shells, etc.—and poster board or large pieces of paper labeled as carbon pools, atmosphere, biomass, soil, ocean, fossil fuel deposits, and underground rocks.

1. Based on the video, review the carbon cycle and the major reservoirs. Participants should draw what they think the cycle looks like and then compare diagrams as a formative mid-lesson assessment.
2. Give all participants their objects and tell them that each object represents one carbon unit.
3. Form groups of six and give each person a reservoir pool sign.
4. Form a circle of six.
5. Act out the natural carbon cycle by having each person pass one carbon unit to the next person. Be sure to order the pools so that atmosphere goes to biomass to soil to ocean to atmosphere. Discuss the parts, processes, and outcomes of the natural cycle as it progresses. (Everyone still has three carbon units.)
6. Mimic trades between aspects of the cycle. For example, sometimes atmosphere trades with biomass, as in respiration and photosynthesis, or atmosphere trades with soil as in nitrogen fixing bacteria, plants, and photosynthesis. Discuss how trades are made. Everyone still has three carbon units and the cycle remains in equilibrium.
7. Model what happens when things are not in equilibrium. A familiar and understandable example might be to mimic deforestation. In this case, biomass (trees) releases a carbon unit to the atmosphere. Atmospheric carbon dioxide increases. Discuss what happens to climate. Another example might be burning fossil fuels. Carbon is released into the atmosphere. Discuss potential climate change.
8. Model the examples from the video. What happened when all the land masses were together? How did the carbon change pools and what were the effects? Discuss how Earth's thermostat then helped to moderate the Snowball Earth.

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary school science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Next Week's Topic Overview

Read Unit 2 before the next session. In Unit 2, the emphasis is on the Earth's atmosphere. Sub-topics will examine the structure of the atmosphere, the greenhouse effect, atmospheric feedback mechanisms, and the global carbon cycle and circulation patterns. Some of the sub-topics are linked to projections into the future, and the uncertainties with predicting future global climate change will be a key part of the discussion.

On-Line Computer Simulation

Carbon Cycle Lab

Read the introduction to the simulation.

Run the simulator to the year 2100 while maintaining the current parameters.

- What happens to the coal, oil, and gas reserves?
- What happens to the oceanic carbon dioxide concentration? Why?
- What happens to atmospheric carbon dioxide?
- Predict what will happen to global temperatures.

Continue the simulation past the year 2100.

What happens to atmospheric carbon dioxide? Why?

Notice that the goal (in green) is set at 550 parts per million (ppm) of carbon dioxide.

Determine where you have to set the parameters to make this goal.

Why is deforestation one of the parameters?

What kind of changes will people have to make to meet this goal?

Research and diagram the carbon cycle. Include the following terms in your diagram: carbon dioxide, fossil fuels, ocean, decomposition, photosynthesis, and cellular respiration. In your diagram, draw pictures and use arrows to show the path of the carbon dioxide.

Read for Next Session

Read the Unit 2 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about Earth's atmosphere. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article, cartoon, or editorial related to Earth's atmosphere.

Supplementary Classroom Activity 1

Explaining Fossil Footprints

In this activity, students observe and interpret fossil evidence. From the evidence, students propose hypotheses or explanations for events that took place in the ancient past.

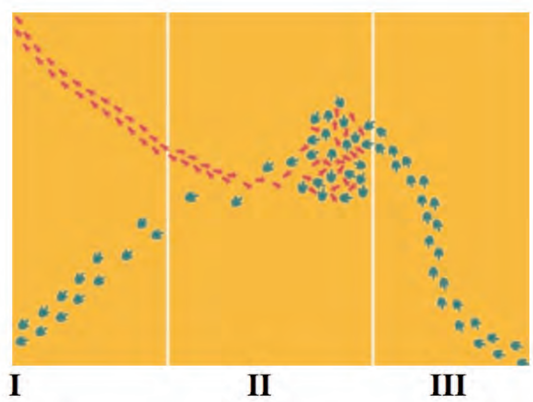


Figure 1.2 Use this diagram to observe, predict, hypothesize, and infer about the animals' activities from secondary evidence.

Students will:

- Propose explanations and make predictions based on evidence.
- Recognize and analyze alternative explanations and predictions.
- Understand that scientific explanations are subject to change as new evidence becomes available.
- Understand that scientific explanations must meet certain criteria. They must be consistent with experimental and observational evidence about nature, and they must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public.

Procedure

Hand out a copy of the figure above to each student or use an overhead transparency. Separate each of the three sections of the figure.

- Reveal Section I of the figure and ask students to explain what is happening. Be sure to differentiate between observations and inferences.
- Reveal Section II of the figure and again have students make observations and inferences about what happened.
- Reveal Section III of the figure and ask students to describe what they think happened and hypothesize about the entire sequence.
- Discuss how the students' observation, inferences, and hypotheses change based on the evidence.

Supplementary Classroom Activity 2

Cupcake Geology

Students' understanding of their environment must include some knowledge of the section of Earth on which they live. Knowing about differences in the Earth's structure and understanding the processes of scientific investigations are essential for knowledgeable citizens. Among these processes are hypotheses about unknown conditions and plans to investigate these unknowns. Sampling is a critical concept in these investigations.

This lesson is fun for students and actively engages them in scientific investigations.

Purpose

- The students will learn that the earth and soil are made up of various substances in different arrangements.
- Students will learn how to hypothesize an outcome of an investigation, plan a sampling strategy, and test their hypothesis.
- Students will understand the value of systematic sampling.
- Students will become familiar with soil and be encouraged to ask questions about things they might not understand.

Materials

- Cake mix or recipe, frosting
- Food colorings
- Straws

Prepare a white cake mix recipe and divide into several batches. Add various food colorings to each batch of cake mix. Add small amounts of each colored batch to a cupcake pan. Bake. Top cupcake with frosting.

Figure 1.3 Cupcakes at various stages of the investigation

Supplementary Classroom Activity 2

Procedure

1. Pass out napkins, straws, and a cupcake to each student.
2. Ask the students to predict what the inside of their cupcake looks like and to draw a picture.
3. Explain to the students that geologists don't know what the inside of Earth looks like; they must somehow predict or guess what it looks like.
4. Demonstrate how to sample the cupcake with a straw and explain that this is similar to a core sample of Earth. Insert the straw into the cupcake, remove, and gently squeeze out the sample.
5. Have the students take one core sample of their cupcake.
6. Have the students draw a picture of what they think the inside of the cupcake looks like based on their one core sample.
7. Direct the students to take four more core samples in any way they want. Encourage them to record how they take the samples.
8. Have the students draw another picture of what they think the inside of the cupcake looks like based on their five samples.
9. Discuss how their predictions have changed based on their samples.
10. Have the students cut their cupcake in half and record the actual cross section of their cupcake.
11. Discuss with the students the results of their investigation and the importance of sampling in understanding unknown situations.

Action

Have students dig a hole in the soil near school and near their home. They should then draw or diagram the layers of soil they find and compare the differences.

Evaluation Strategies

Collect the students' diagrams of the investigation and have them explain how sampling is essential to scientific investigations.

Notes

Unit 2
Atmosphere

Background

Introduction

The atmosphere consists of an envelope of gases whose composition has remained relatively stable through most of Earth's history. Differential heating and rotation of our planet contribute to the dynamic nature of our atmosphere, and consequent changes in force, pressure, and temperature create climate zones, weather patterns, and storms on our planet. Physical and chemical reactions in the atmosphere help shape life on Earth. In relatively recent history, human activities are believed to be influencing the dynamic balances in the atmosphere, causing global surface temperatures and precipitation patterns to change.

Essential Questions

What key functions does the atmosphere serve that enable life to exist on the planet?

How does the atmosphere shape Earth's climate and weather?

What can cause the dynamic balance in the atmosphere to change and what influence do humans have?

Content

Unit 2 focuses on the chemical and physical characteristics of the envelope of gases surrounding our planet that make life possible. The text for Unit 2 introduces the composition and layers of the atmosphere, how particular gases in the atmosphere heat Earth, how interactions between variables impact the heating process, how rising carbon dioxide levels affect the cycling of carbon, a building block for life on the planet, and how moving and circulating air causes weather and climate. The many processes that influence weather and climate are covered. Questions are raised about the dynamic aspect of the climate and which physical factors control climate and interact with one another. This lays a foundation for Unit 12: Earth's Changing Climate.

The Unit 2 video illustrates the process of doing atmospheric field research and shows how scientists go about collecting and verifying field data to address hypotheses. Part One shows Pieter Tans discussing important concepts in greenhouse gases and regulation of atmospheric temperature, interaction between the atmosphere and oceans, and long-term green house gas data summaries. Part Two features Kerry Emanuel discussing hurricanes.

Background

Learning Goals

During this session, you will have an opportunity to build understandings, skills, and dispositions.

a. Knowledge

i. The atmosphere is one of Earth's critical systems that makes life possible on our planet.

ii. The atmosphere is dynamic because of the number of factors that affect the gaseous envelope, such as pressure and temperature, which change with altitude and latitude due to Earth's rotation.

iii. Atmospheric CO_2 levels are controlled by the dynamic balance among living and inorganic processes that make up the carbon cycle.

iv. Positive and negative feedback interactions between variables, such as temperature, vegetation, and precipitation, drive atmospheric changes.

v. Severe weather is the result of interactions among atmospheric variables concentrated in a specific geographic region.

b. Skills

i. Atmospheric science is an interdisciplinary study because of the complex interactions of the various Earth systems.

ii. A spatial approach is critical when studying the atmosphere because of the dynamic, circulating, three-dimensional nature of the atmosphere.

iii. Both spatial and temporal dimensions need to be considered in order to understand feedback mechanisms.

c. Dispositions

i. Human actions are influencing key dynamic balances in the atmosphere.

ii. Human activities have changed the concentrations of heat-trapping substances in the atmosphere.

Key Concepts

Atmospheric layers

Greenhouse gases

Atmospheric pressure

Radiative balance

Global mean temperature

Ozone depleting chemicals

Positive and negative atmospheric

Feedback mechanisms

Global carbon cycle

Atmospheric circulation

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions About the Earth's Atmosphere

Examples of common misconceptions pertaining to the atmosphere include the following.

- A common misconception is that land plants generate most of the oxygen in the atmosphere. People do not understand the capacity of the ocean to generate oxygen into the atmosphere for the planet. Research indicates that 75 percent of respondents incorrectly identify forests as generating more oxygen than oceans, when in fact oceans generate 70 percent of the planet's oxygen supply.
- Most people falsely believe that direct sunlight heats the atmosphere. People do not understand the differences or contributions of the three kinds of heat transfer mechanisms—conduction, convection, and radiation—and how they apply to warming the atmosphere. Many, therefore, do not appreciate that the atmosphere is heated from the ground up, even though the original energy comes from the sun.
- Another common misconception is that greenhouse gases make up a major portion of the atmosphere. In fact, the major constituents in the atmosphere are nitrogen and oxygen, which compose 99 percent by volume. Gases like water vapor and carbon dioxide, which are present in minute amounts, receive much of the public's attention because they operate as greenhouse gases that absorb radiation.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants indicate something they know about the atmosphere. On the second, they write one question they have about atmospheric systems. And on the third card, they describe a direct experience that they have had that relates to the atmosphere. For example an individual might write:

The atmosphere is made up of high and low pressure air masses that move around and cause weather.

How thick or thin is the atmosphere?

When the air has more moisture it feels more oppressive or thicker.

Getting Ready (45 minutes)

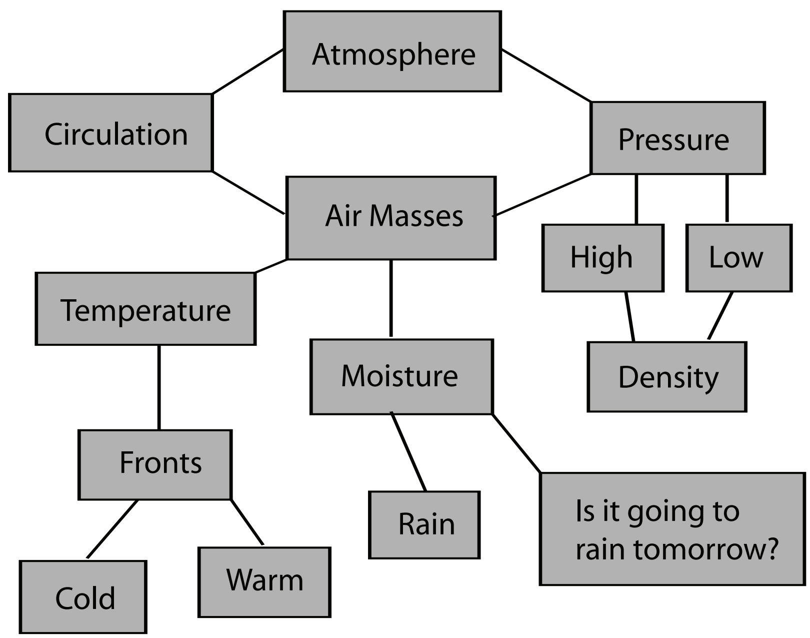


Figure 2.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events and Editorial Cartoons

Participants will share an article that they have found that is related to the week's topic. All the group members will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial that is related to the week's topic instead of an article.)

Activity Three: On-line Computer Simulation

Participants will share their diagrams of the carbon cycle. Discuss the results of running the simulation to 2100. Discuss what is necessary to reach the goal of 550 parts per million of carbon dioxide.

Activity Four: Demonstrating the Carbon Cycle

All living organisms are based on the carbon atom. Carbon can help form solid minerals, plants, and animals, and can be dissolved in water or carried around the world through the atmosphere as carbon dioxide gas. The movement of carbon through the Earth's interconnected systems is known as the carbon cycle. The paths taken by carbon atoms through this cycle are extremely complex and may take millions of years to come full circle. Carbon may be stored for extended periods (the "sinks") and eventually released to the atmosphere (the "source"). The triggers of those sources (the "release agents") are also part of the carbon cycle.

Getting Ready (45 minutes)

Materials

- At least 15 black balloons to represent carbon. One red balloon (equals 48 black balloons) and one white balloon (represents 66,000 black balloons). Balloons should be filled with air.
- String or tape to attach balloons.
- Large index cards that identify the principal carbon reservoirs (Atmosphere; Land Biomass (plant or animals); Ocean; Fossil Fuel; Rock).
- Drawing paper and markers.

Carbon Reservoirs

1. Briefly review the carbon cycle as presented in the Unit 2 text. Explain that one black balloon represents 1 carbon unit.
2. Assign five locations within the room for the different carbon reservoirs. Place identifying signs in each location.
3. Place the following number of balloons in each location:

   1 black balloon in the Atmosphere location. (Indicate that this represents all the carbon in the atmosphere in the form of carbon dioxide gas.)

   4 black balloons in the Land Biomass location.

   1 red balloon and 2 black balloons in the Ocean reservoir.

   7 black balloons in the Fossil Fuel reservoir. (Note that fossil fuel carbon is not part of the current carbon cycle flows unless people bring it to the surface.)

   1 white balloon in the Rock reservoir.
4. Ask participants if they agree with the number of balloons in each location and to offer any changes they think should be made with an appropriate explanation.

Questions for Discussion

1. Describe two important "sinks" (parts of Earth that store carbon), two important "sources" (parts of Earth that release carbon), and one important "release agent" (conditions that trigger release) for carbon.
2. Currently it seems that CO_2 sources are out of balance with CO_2 sinks. If more CO_2 is produced than sinks can remove, CO_2 in the atmosphere increases. What might happen if the reverse were true and sinks took up more CO_2 than sources released?
3. Why is knowledge about the carbon cycle important for helping scientists understand global climate change?

The Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Why is CO_2 the key greenhouse gas that is monitored when there are other greenhouse gases in the atmosphere?
2. Why does scientist Tans believe the role of carbon, cycling through natural systems, like the oceans and forests, is important when talking about CO_2 as a greenhouse gas?
3. What factors cause greenhouse gas concentrations to vary over the globe?
4. What factors go into the selection of places to monitor greenhouse gases?
5. Why do scientists focus on understanding sinks instead of concentrating solely on humans' role as a source of CO_2?
6. What is significant about the two questions Professor Emanuel from MIT poses?
7. Why does hurricane researcher Emanuel distinguish between using models to make forecasts and using models to understand phenomena better?
8. Why is sea spray a confounding factor in understanding how hurricanes work?
9. What is the evidence that hurricanes cause the mixing of ocean currents and how do large computer models accounted for this?
10. How does Emanuel explain evidence that 50 million years ago the temperature in the tropics was the same as today but the temperature in polar regions was much warmer?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. In what ways do humans influence the role that natural ecosystems play as a sink for CO_2?
2. Do hurricanes affect the climate in important and profound ways?
3. When models behave differently than the real world, how does the inconsistency help scientists?
4. What is the value of long term monitoring?
5. Why should scientists continue to monitor CO_2 concentrations in the same way when there are new and different questions that have emerged that can't be answered by the old way of monitoring?

FACILITATOR: Refer back to the Misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make to the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: The Effect of Surface Type on Heating

In this activity, participants will form their own conclusions as to how different surface and cover types affect heating.

Learning Goals

Participants will be able to:

1. Identify at least three factors that affect the heat-trapping ability of a greenhouse.

2. Explain the factors that are important in the atmosphere's heat trapping ability.

3. Describe the influence of albedo on the Earth's temperature.

Materials for Each Group of Four Participants

- Six 1-liter bottles
- Six thermometers
- Tape
- White paint and brushes
- Three cups of dark soil
- Three cups of white sand
- Water and dump buckets
- One 150-watt floodlight bulb
- Portable reflector lamp
- Stand to support lamp set-up
- Graph paper

FACILITATOR: To save time, prepare the model greenhouses in advance. Each team will need six bottles (experimental chambers). The upper third of three of the bottles for each group should be painted white.

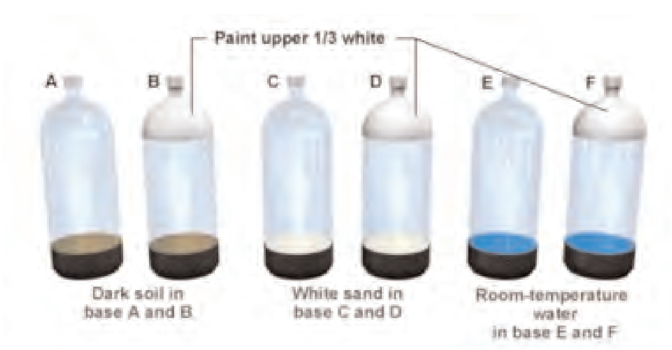


Figure 2.1 Materials Set-up

Going Further

Set-up

1. Label the bottles A, B, C, D, E, and F so that bottles B, D, and F contain the white paint.
2. Fill the base of bottles A and B with dark soil, bottles C and D with white sand, and bottles E and F with room-temperature water.
3. Tape a thermometer (using transparent tape or light-colored masking tape) to the inside of each bottle (facing out).
4. Place the bottle tops in the bases. Make sure the bottles are capped.
5. Make sure the bulbs of the thermometers are just above the top of the bases. If the bulbs are below the base, the thermometer may record the heat absorbed directly by the soil or water, complicating the results.
6. Ask participants to predict which bottle will get hotter. Why? Record predictions.
7. Have each team set up a graph of time (in minutes) versus temperature to record their observations.
8. Each participant should have a specific responsibility during the experiment, either keeping track of the time or recording the temperature for the different bottles.
9. Place the bottles approximately six inches away from the lamp with the thermometer facing away from the light. Record the baseline temperatures.
10. Turn on the light and begin recording the temperatures every two minutes. Continue for at least 20 minutes

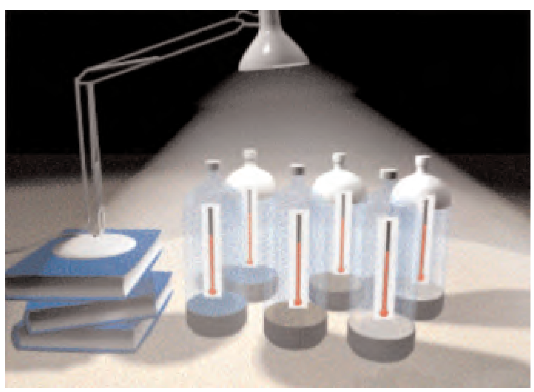


Figure 2.3 Experiment Setup

NOTE: If your lamp is not big enough, six bottles may be too many to have under the light at the same time. The ones further from the light may not get the same intensity of heat as the bottles closer to the light, thereby compromising the experiment. You may have the participants use a sub-set of the bottles at one time. Another technique is to suspend the light in the middle of a circle of containers so they are equidistant from the light.

Observations and Questions

1. Compare the graphed information from data collected using the different bottles.
2. Discuss the results and propose possible explanations.
3. Relate the factors that affect the model greenhouses to the factors that affect the "global greenhouse." Which factors are the same? Which are different?
4. Discuss how this demo relates to the video and text.

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 3 before the next session. Unit 3 explores the working of ocean currents and circulation patterns and their influence on global climate change. Further details about how global climate change affects the ocean will be found in Unit 12: Earth's Changing Climate and Unit 13: Looking Forward: Our Global Experiment.

Read for Next Session

Read the Unit 3 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about oceans. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to human impact on the oceans.

Supplementary Classroom Activity

Radiosondes

Background information

A radiosonde is a small package of measurement instruments that is carried upward into the atmosphere by a balloon. The radiosonde is designed to measure the vertical changes in temperature, pressure, and humidity from Earth's surface into the upper atmosphere, approximately 30 km. Eventually, the balloon carrying the radiosonde bursts and the radiosonde falls back to Earth. Radiosondes are launched every 12 hours at numerous weather stations around the world. Dropwindsondes are released from aircraft to collect similar data over oceans.

Air temperature usually decreases with altitude. Earth's surface is heated by the sun during daylight hours and loses that heat at night. The lower atmosphere warms as the surface heats the air next to it during the day. This warming of the atmosphere decreases as one increases in altitude.

Sunlight falls more directly on different parts of Earth during the year, so some places on Earth are warmer than others at times when the sun's rays are more direct. In addition, air masses expand as they rise, causing temperatures to decrease. Scientists divide the atmosphere into different layers whose boundaries are defined by changes in temperature. These layers, from the surface up, are the troposphere, stratosphere, mesosphere, and thermosphere. Temperature generally decreases in the troposphere and mesosphere, but increases in the stratosphere. Sometimes the radiosonde data will show a high-altitude increase of temperature with increasing altitude. This happens when ultraviolet radiation is absorbed by the ozone in the stratosphere.

Radiosondes usually travel to altitudes of 30,000 meters, and so they break before traveling far into the stratosphere. Not all data for all locations shows the temperature increase at the end. Radiosondes typically measure pressure and humidity in addition to temperature. The movement of radiosondes can also be tracked for information on wind speed and direction.

Objectives

Students will be able to:

1. Examine radiosonde data from at least two locations, local and distant, of their choosing to determine how air temperature changes with altitude.
2. Make summary statements about reasons for variability of radiosonde data.
3. Appreciate the multiple ways in which atmospheric data is collected and how methods evolve with changes in technology.
4. Identify and access Web-based resources that share radiosonde data.

Materials

Graph paper, colored pencils, access to the Web

Supplementary Classroom Activity

Procedure

1. Students should make a chart that lists at least two locations with columns under each location for temperature and altitude. Students can plot the data for each location on separate sheets of graph paper or multiple locations on one map using different colors for each location. Students can obtain radiosonde data from the Plymouth State University website, http://vortex.plymouth.edu. Scroll down on the left side under Plymouth Wx Pages to "Make Your Own." Then scroll down to RAOB Soundings and click on Diagrams/Data. Then go to "Check a map or this table for possible station identifiers." You can select a region anywhere in the world and identify a four or five digit or letter code. For Type of Output, select "sounding data." The height will be in meters and the temperature in Celsius. Not all locations will generate complete and suitable data, so students may have to try several identifier codes before turning up data sets that can be compared.

   (Note: Students can also graph the data in Excel.)

2. Temperature should be plotted on one axis and altitude on the other. Plotting altitude vertically makes the most logical sense. Axes and graphs should be labeled.
3. Students can also print off the maps with the data already graphed and create overheard transparencies to overlay one on the other.
4. Discuss the commonalities and differences among the various data sets or graphs.
   a. How does temperature change with altitude?
   b. Can you connect the results with anything you have experienced firsthand? Have you been at different altitudes and noticed changes?
   c. Does the air temperature generally increase or decrease?
   d. Is there a dominant pattern across multiple locations?
   e. How do the data sets vary from location to location?
   f. What factors should you consider in selecting various locations where differences might be more pronounced? For example, do you look at data from different latitudes?
   g. What might account for variations?
   h. Is there an increase in temperature with altitude in lower parts of the atmosphere at any locations you've selected?
   i. How can you explain consistent changes in the data or graphs?
   j. Looking at descriptions of various layers of the atmosphere, how do these layers correspond to the data?
   k. What are the limitations of the equipment used?
   l. What would an inversion look like and what would cause this phenomenon?
   m. Why does anyone care about how temperature changes with altitude? How is the information used?

Notes

Unit 3
Oceans

Background

Introduction

The increase in world population and the continued rise of industrialization have resulted in a need to further understand the world's oceans. One of the most important factors that impact the biosphere is the condition of the world's oceans. A basic understanding of the structure and composition of the ocean and knowledge of how life in the ocean affects life on land can increase the extent to which we are able to protect this important natural resource and the life that depends on it.

Essential Questions

What have we learned about the oceans over the course of Earth's history?

How does today's increased population and industrial use impact the oceans?

What does the future hold in terms of ocean quality, use, and preservation?

Content

Unit 3 seeks to create a general understanding of the world's oceans. In the past, the exploration of the oceans has been limited due to their size and depth, and so there is still much to be learned. The unit begins with the basic structure and composition of the ocean and discusses the basic principles of oceanic pressure and temperature. Oceans content relates to Unit 8, "Water Resources," and Unit 9, "Biodiversity Decline," leading to a contextual understanding of preserving this important natural resource. In the video for Unit 3, you will be introduced to Mark Cane and Steve Ziebiac, who have developed a model that attempts to predict the occurrence of El Niño. By making the model public, they have enabled people to prepare for this event, saving many lives. The second part of the video discusses the ocean system "biological pump," where nutrients from the upper layers of the ocean are forced downward to nourish the life below. Penny Chisholm, professor at MIT, explains the essential role of phytoplankton in maintaining life on Earth. The recent discovery of a species of phytoplankton, Prochlorococcus, which is the most efficient light-absorber of all phytoplankton, has enabled scientists to understand nutrient sources in the ocean to a much greater extent.

Background

Learning Goals

During this session, you will have an opportunity to build understandings of the following.

a. Knowledge

i. The specific structure and composition of the ocean is based on temperature, salinity, and increasing pressure with depth.

ii. The thermohaline circulation of the ocean has an impact on global weather and climate.

iii. The ocean supports a great diversity of life and ecosystems, all of which are directly or indirectly nourished by plankton.

b. Skills

i. Science is a process that is both descriptive and experimental, and it helps explain current events.

ii. Oceanographic science is an interdisciplinary study because of the complex interactions with other Earth systems.

c. Dispositions

i. Change in the oceans has a direct impact on life in the ocean as well as life on land.

ii. Oceanic research provides new knowledge that improves life and enhances our understanding of oceanic processes.

iii. When studying the ocean, a spatial approach is important because of the dynamic, circulating nature of the ocean.

Key Concepts

Oceanic zones	Ocean currents	Ocean floor characteristics
Forces	Circulation	El Niño southern oscillation (ENSO)
Temperature	Salinity	Climate
Biological pump	Buoyancy	Oceanic ecosystems
Algal blooms	Gyre	Compensation zone
Coriolis force	Ekman spiral	Marine snow
Phytoplankton	Zooplankton	Specific heat capacity
Thermocline	Upwelling	Thermohaline circulation

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions and Oceans

As the public becomes more educated about our natural resources, it is important that educators address common misconceptions that their participants hold about the world's oceans. The root causes of misunderstanding seem to stem from the misinterpretation of terms that are currently used, world maps, and participants' own observations and experiences.

The general understanding is that the ocean surface has no actual relief of its own and therefore is flat. This understanding leaves out changes due to waves, tides, surges, etc. In reality the ocean surface has "hills" as well as "depressions" with a maximum variation of approximately eight feet. This is the direct result of the circular pattern of surface currents, or gyres, that produce areas of water convergence (high areas) and divergence (low areas).

Another misunderstanding that people often have is that tides are caused by the action of the wind. Actually, tides are not caused by the wind, but by the gravitational pull of the moon and sun on the Earth. Quite often, people think that waves are caused by the moon. However, tides are caused by the moon, and breaking waves are caused by the wind and the slope of the shoreline. Other misconceptions include the understanding of currents and the influence of specific currents on land climate and the commonly held beliefs that the ocean depths are devoid of life and that the seafloor is flat and the same age as the continents.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the group. On the first card, ask participants to indicate something they know about oceans. On the second, they should write one question they have about oceans. And on the third card, they should describe a direct experience that they have had that relates to oceans. For example an individual might write:

The different oceans are connected somehow.

What type of life lives in the ocean?

The ocean has a high and low tide.

The oceans influence weather patterns.

Getting Ready

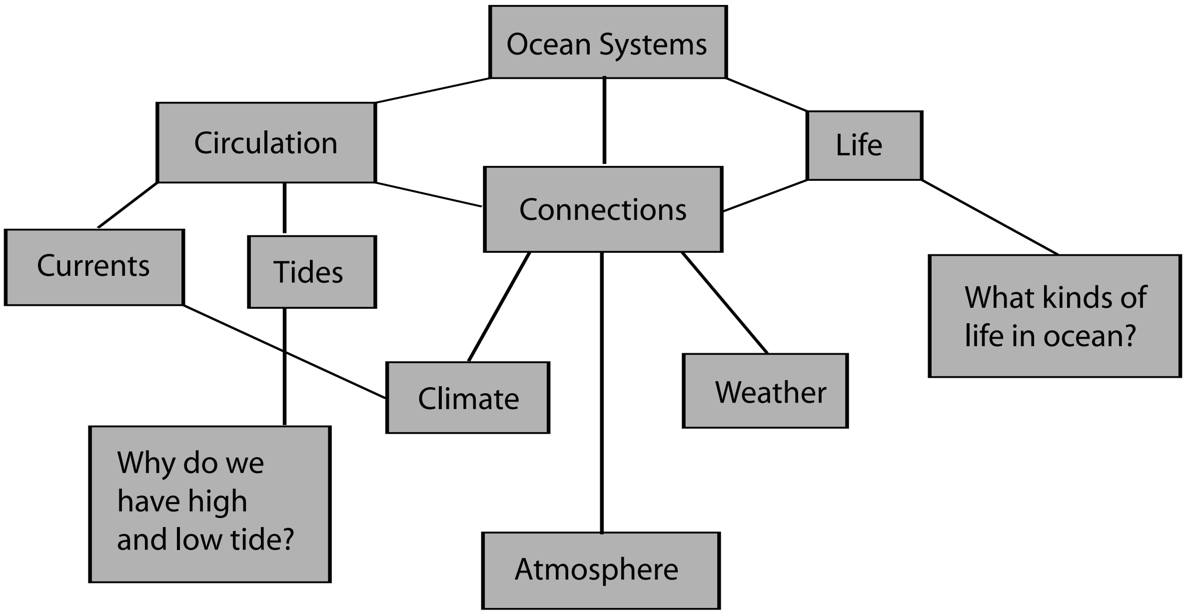


Figure 3.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Ocean Currents Demonstration

This activity addresses surface circulation and the movement of ocean waves. It is also an introduction to teaching about the Ekman spiral.

Materials

Large, shallow watertight container

Food coloring

Fan

Water

Stopwatch

Getting Ready

Setup

1. Prepare a shallow container with water and place it near a fan.
2. Ask participants to make observations about what will happen when the fan is turned on.
3. Turn the fan on low.
4. Ask participants to make observations and draw pictures about what they think is happening to the water.
5. Participants should then write a hypothesis about what is occurring.

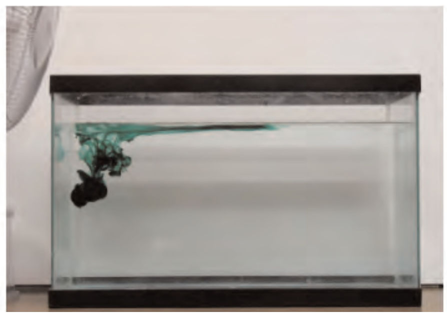


Figure 3.2 Current Demonstration time = 4 seconds

(this figure can be a simple line diagram)

Procedure

Participants will test their hypotheses using food coloring to more easily track the circulation of the water. They should draw a diagram about what is happening after the food coloring is dropped into the water. Repeat this experiment with the fan turned on at progressively faster speeds. (A stopwatch may be useful to time the dispersion of food coloring in the tank.)

Discussion

1. Compare and contrast the various hypotheses formulated by participants.
2. Discuss how ocean surface circulation affects distribution of temperature and associated organisms.
3. How can human activities affect ocean circulation and what are the consequences?

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. What conditions allowed the crew on board the RV Conrad to realize that an El Niño event was occurring?
2. How do we use the information derived from the retrospective forecast models of Cane and Zebiak to predict and prepare for an El Niño?
3. What role does Prochlorococcus play in the ocean ecosystem?
4. Why did it take so long for marine scientists to realize the presence of and identify Prochlorococcus?
5. What factors appear to regulate the population of Prochlorococcus?
6. What is the relationship between the simplicity of the structure of Prochlorococcus and its ability to survive in a "biological desert"?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. What are the conditions that allow oceanographers to predict an El Niño event?
2. Discuss the overall ocean-atmosphere interaction during an El Niño event.
3. What is the impact of the complex, co-evolved system in maintaining the balance of carbon dioxide in the oceans?
4. Why do the researchers consider Prochlorococcus a model to apply to systems biology?
5. Discuss the methods that oceanographers use to conduct research. How are these different or similar to other science research?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Stratification of a Water Column

This demonstration encourages participants to start thinking about density differences in the ocean and introduces the idea of thermohaline circulation and ocean layer stratification.

Materials

Watertight column (such as settling tubes, clear PVC, or a very large graduated cylinder)

4 small glass vials with screw-lids

Fine sand

Food coloring (optional)

Water

Going Further

Setup

Using three buckets, fill one with cold salty water, the second with cold tap water, and the third with warm tap water. To insure that the cold salty water has a distinct high density, dissolve as much salt as possible into warm/hot water and then cool the solution in a refrigerator over night.

Prepare 4 small vials. Carefully add sand to one vial (marked "1") until it sinks in the cold salt water. Continue with the next vial (marked "2") until it sinks in the cold fresh water and floats in the cold salt water. Fill the next vial (marked "3") until it sinks in the warm fresh water but floats in the cold fresh water. The last vial (marked "4") will need to float in the warm fresh water. Getting the vials to sink and float is a matter of trial and error, adding and removing sand as needed. The lids on these vials must be tight before you use them in the water column to prevent water from entering and changing the density of the vials. One option is to create two of each of the four vials. Each pair will be similar but float at slightly different levels. Two vials at each level will add more complexity to the demo.

After you prepare the vials, transfer the water from the buckets to the large clear cylinder with as little mixing of layers as possible. Tilt the column and slowly add the water for the next layer. Again tilt the column and slowly slide the vials into the water. It is possible to construct a device using a funnel and rubber tubing to easily fill the column and minimize mixing. It is important to construct the water column and add vials quickly. As the water mixes and cools to room temperature, the composition of the column and the location of the layers will change. Since this demonstration takes some skill to construct, be sure to have extra prepared water on hand in case you need it.

Procedure

Participants will observe the water column and diagram the demonstration, take notes, and try to explain what is happening.

Participants will develop a hypothesis to explain what they are seeing.

Participants should consider these questions:

What do you think is in the water column?

What do you think is in the vials?

Why do you think the vials float at different levels?

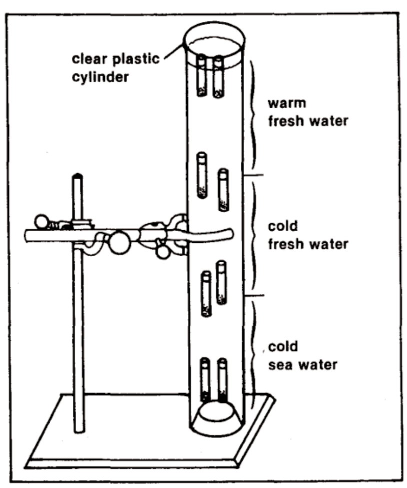


Figure 3.4 Diagram of water column

Going Further

Discussion

What will happen when the water eventually mixes and has the same temperature and salinity throughout?

What does this example imply about oceans, seas, and estuaries? Where is the salinity greater or less in the marine environment? Why?

What does this example imply about freshwater habitats? Where is the temperature greater or less in a large lake or pond? Why? When and how can it change?

In the ocean, what would cause the different temperature or salinity layers to mix? Does this happen naturally? If so, why and when does it happen?

Why are layers based on temperature and salinity a critical part of marine and freshwater systems? How do temperature and salinity gradients affect aquatic and marine life?

How does thermohaline stratification affect the distribution of nutrients?

Extension

Place colored ice cubes in the top of the column and observe. Predict what will happen. Are there equivalent phenomena in nature?

Color each bucket of water with food coloring to make the layers distinct.

Let the water column sit until your next meeting. What will happen to the layers over time? Predict how long it will take for the layers to mix completely.

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

In Unit 4, the emphasis is on ecosystems. Sub-topics will each examine a different area of concern, and examples are given. All of the sub-topics are linked to projections of the future, and the uncertainties with predicting the future will be a key part of the discussion.

Read for Next Session

Read the Unit 4 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about ecosystems. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to human impact on ecosystems.

Supplementary Classroom Activity 1

Ocean Currents and Circulation

A Model Area: Gulf of Maine Ocean Observing System (GoMOOS)

In this activity, students will become familiar with the type of on-going research that physical oceanographers are carrying out in the Gulf of Maine. Examples of other monitoring regions are available, such as the Monterey Bay, CA system.

www.GoMOOS.org

www.mbari.org

Go the Gulf of Maine website and search for oceanographic information from the menu in the left column or the thematic sections.

Participants should answer these questions:

1) What is GoMOOS? What is the rationale or purpose of this research effort?
2) Sketch a map of the GoM.
3) Draw in the major surface currents for the GoM.
4) Select an ocean buoy and record the data for that station.
5) What are the current atmospheric conditions?
6) Check out the remote sensing data for SSTs, color, and winds. Record.
7) Read the section About the GoM. Enlarge the maps to see some details of the area.

Supplementary Classroom Activity 2

Biogenic Ooze

This activity explains to participants what happens to phytoplankton after they die. It also informs participants of the many types of zooplankton and phytoplankton.

Materials

Access to the Internet

Setup

The teacher should explain to students that phytoplankton (plants) and zooplankton (animals) are the major food source for life in the ocean. Biogenic ooze on the ocean floor consists of 70 percent inorganic mud and 30 percent skeletal debris of microscopic organisms, such as phytoplankton or zooplankton.

Procedure

Students will conduct research on the Internet to complete the chart below:

	Zooplankton or Phytoplankton?	Made of Calcite or Silica?	Picture
Foraminifera			
Pteropods			
Radiolarians			
Coccoliths			
Diatoms			

Results

Students will present their findings and discuss the role of these organisms.

Unit 4

Ecosystems

Background

Introduction

The abundance of a species and species diversity affect how natural resources are processed within an ecosystem. This pattern of processing contributes to functional and compositional characteristics of an ecosystem. But many ecosystems around the world are currently experiencing significant changes in species composition, abundance, and diversity due to the influence of human activity. These changes have, more often than not, led to a reduction in species diversity. Changes in species composition, species richness, and/or functional type affect the efficiency with which resources are processed within an ecosystem, raising the issue of whether the biogeochemical functioning of an ecosystem will be impaired by a loss of species or the introduction of a new species.

Essential Questions

Why do ecosystems like Tropical Rainforests have such immense diversity?

What have scientists discovered that determines how many individuals of a species can be supported within an ecosystem?

How does science restore the diversity to areas where human activity has interfered with the natural structure of a habit/ecosystem?

Content

Unit 4 addresses two fundamental questions that ecologists seek to answer: Why is there so much diversity within ecosystems and why are so many species in such abundance? Today ecosystems are shaped and characterized by complex interactions among social, economic, institutional, and environmental variables. The effects of anthropogenic habitat loss or degradation on the numbers and types of species in an ecosystem are still unfolding.

The video introduces us to Stuart Davies, director of the Center for Tropical Forest Science (Smithsonian Tropical Research Institution), who studies tropical rain forests, one of the most diverse biomes on Earth. Davies and his research team are conducting a worldwide tree census in an attempt to discover how such a wide range of species competing for the same resources can successfully co-exist. These scientists are trying to understand this by studying energy flow and biogeochemical cycling concepts, niche evolution and partitioning in forests, and the role of predators and pathogens in maintaining diversity (Janzen-Connell effects) and species abundance. The second case study focuses on the rise and fall of different populations in a riparian habitat as a result of a wolf re-introduction project in a temperate ecosystem. Robert Crabtree, chief scientist and founder of The Yellowstone Ecological Research Center, untangles the cascading effect in Yellowstone National Park after the wolf was removed and 70 years later reintroduced. By looking at the balance that exists between species, both scientists wish to learn how to manage and protect any ecosystem from becoming permanently and irreversibly destroyed.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. Global circulation patterns and geography create the basic conditions that determine abundance and diversity.

ii. Decomposers are more important than organisms at any trophic level when it comes to flow of energy through a food chain or food web.

iii. Bioaccumulation of a toxin in the lower trophic levels can lead to biomagnifications in a predator.

iv. Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite (carrying capacity).

v. Organisms with a narrow niche are the most sensitive to environmental changes.

vi. A disruption of ecosystem interactions impacts the natural selection process.

b. Skills

i. Ability to recognize the mechanism responsible for the elevated absorption of carbon by land ecosystems.

ii. Ability to understand how to "harvest" a population without disrupting its natural growth rate.

c. Dispositions

i. Alteration of ecosystem interaction has a direct impact on social, economic, and political systems.

ii. Human alteration of ecosystem interactions through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and, if not addressed, ecosystems will be irreversibly affected.

Key Concepts

Bioaccumulation	Latitudinal biodiversity gradient
Biome	Life history strategy
CO_2 fertilization	Mimicry
Co-evolution	Nitrogen fixation/denitrification
Competitive exclusion principal	Niche (fundamental/realized)
K-selected	Niche partitioning
Primary production (gross/net)	R-selected
Succession	Trophic level

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Ecosystems

Although misconceptions can be a result of a misunderstanding or misinformation, some have their beginnings in the attitudes held by people with a personal interest. Misconceptions are scientifically inaccurate assumptions or explanations of facts that are gathered by an individual through his/her experiences or perceived experiences. Misconceptions involving ecological phenomena are particularly important to overcome because ecology teaches individuals how they are affected by, and have an effect on, the ecosystems. Ironically, we are simultaneously the most potent forces within most ecosystems and yet nearly oblivious to the ecological effects of our daily lifestyles. There has never been a time when a deep understanding of ecosystems and our roles within them has been more critical.

Below is a list of common misconceptions about ecosystems. The facilitator should lead a discussion on how the following misconceptions might have come to be. Participants should look at public or private factors such as attitude, personal motive, lack of information, and total ignorance.

- Ecosystems are not an organized whole, but a collection of organisms.
- Forest fires are harmful to terrestrial ecosystems and should not be allowed to burn.
- An organism cannot change trophic levels.
- An animal that is high on the food web preys on all populations below it.
- The top of the web has the most energy.
- Characteristics of a population are created according to the needs of the individual or according to a predetermined grand plan.
- Characteristics are passed on by the bigger, stronger organisms.
- Species live together in an ecosystem because they have compatible needs and behaviors.
- A change in the prey population has no effect on the predator.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about ecosystems. On the second, they write one question they have about ecosystems. And on the third card, they should describe a direct experience that they have had that relates to ecosystems. For example an individual might write:

The pond in my neighborhood is an aquatic ecosystem.

Is my neighborhood part of a larger ecosystem?

I enjoyed scuba diving on coral reefs.

Getting Ready

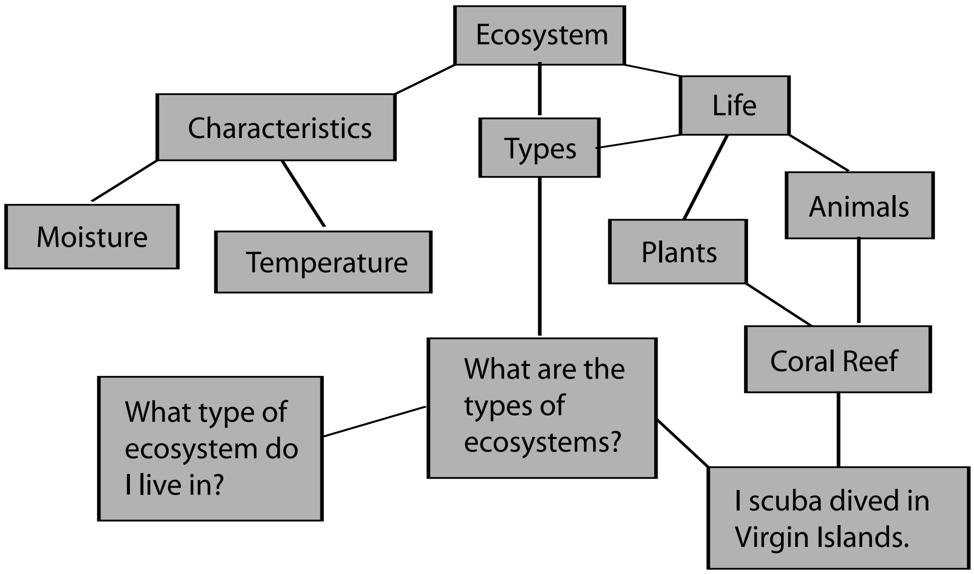


Figure 4.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas from the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Ecology Lab Simulation

During this activity, the participants will use the Interactive Lab: Ecosystems (www.learner.org/channel/courses/envsci/interactives/ecosystems) to construct a computer-simulated food web that will put Plants B and C in a growth pattern that is normal for an imaginary habitat. For this particular ecosystem, Plant B and C population numbers typically cycle in an inversely proportionate relationship—when one type is at its highest, the other is at its lowest; in between, the numbers are equal. The cycle continues to repeat over and over. The pattern is similar to a series of continuous infinity (∞∞∞∞) symbols. In this habitat, Plant A exists only when it is transported in the feces of a specific species of migrating birds, Cedar Waxwings. Plant A, being an opportunist, easily out-competes Plants B and C if natural controls are not in place and Plant C can quickly become extinct as a result of competitive exclusion.

Under normal circumstances, Plant A populations never become a significant competitor because the deer populations tend to favor Plant A over Plants B and C. For the past five years, a disease has been keeping the deer populations below normal numbers and, consequently, Plant A has predominated. Now the deer populations are healthy again.

The objective in this simulation is to construct a food web that restores Plants B and C to their normal population cycles and excludes Plant A sometime after Day 70.

Getting Ready

FACILITATOR

1. Divide participants into groups depending on the number of computers available in the room. Show them where to find the Ecology Lab simulation module. Have the participants click on the "Tableau" drop down menu and select plants.
2. Announce that all trophic levels must be used and no species may be excluded via competitive exclusion until after Day 70. The inverse relationship between Plants B and C must exist until the end of the simulation run through Day 100.
3. If participants are having trouble finding a web, give hints that will allow them to find a food web to achieve the Plant B to C growth pattern. The following is one example: Plants A and B would be preyed on by all five possible predators and Plant C would have no predation. The herbivore predators are as follows: Herbivore A is prey to the top predator; Herbivore B is prey to Omnivore A; and Herbivore C is prey to the top predator. Out of the two omnivores only Omnivore A is preyed on by the top predator. Omnivore B has no predators.
4. Have the participants use the above scenario but another feeding relationship. What happens when Omnivore B preys on Omnivore A? Is this a more stabilized food web?

Discussion Questions

1. Following Plant A's extinction, what other species will eventually disappear at approximately 85 days? Why did this happen?
2. Predict what would happen if the deer were removed from this food web. How are the producers affected? What other cascades occur?
3. In this food web, which species has the highest population number? What happens if it is removed from the food web?
4. In this food web, which has the biggest impact on the food web, removal of Herbivore B (the snail) or Herbivore C (the deer)? Does population size or individual size have the greatest impact? Explain your answer.

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. What is the function of the Center for Tropical Forest Science (CTFS)?
2. Why are the trees given the title of "engineers" of the tropical rain forest?
3. What is the Barrows Colorado Island (BCI Plot) CTFS project and what are some of the significant findings about diversity and abundance in ecosystems such as BCI?
4. Why does a high density species suffer greater mortality rates than rare density species?
5. What is the focus of Robert Crabtree's research project in Yellowstone National Forest?
6. What were some of the Park's initial management strategies during the early 1900s to help preserve this national resource?

7. What was the cascade effect of the elimination of the Park's wolf population after 1926? Consider the following in your answer: willow, beaver, and elk populations.
8. Food chains and webs can be shaped from the "top down" or from the "bottom up." Which of these two categories best describes the wolf reintroduction project of 1995 and 1996?
9. What are the "hot spots" in Yellowstone and how are they important to the wolf reintroduction research project?
10. What is meant by "escape height" and what additional parameters are used to measure the cascade effects of the wolf reintroduction process?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. Why do tropical rainforests have such immense diversity? How do they maintain their diversity?
2. What role do tropical forests play in stabilizing climate and atmosphere? Can we take advantage of and enhance their ability to store carbon? Why is this important?
3. How can the data from a tropical rainforest that explains species diversity and abundance be helpful in managing and protecting temperate forests such as those in Yellowstone National Park or any other ecosystem on planet Earth?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make in the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Determination of Species Diversity and Abundance Using Owl Pellet Data

Background Information

In this activity, barn owl pellet data are used to determine an ecosystem's degree of biodiversity. The barn owl (tyto alba) swallows small birds and rodents whole, and the resulting pellets generally contain the complete skeletons of the owl's prey. While carnivorous mammals, such as bobcats and wolves, have teeth to grind up bones and claws and a digestive tract adapted to pass these ground parts, owls do not have teeth for grinding and cannot safely pass whole bones and claws through their digestive tract. Instead, these materials form a bolus (or pellet), which is surrounded by the hair or feathers of their prey and orally expelled. Barn owls can expel one to two pellets per day. Scientists take advantage of this adaptation by examining the pellet's contents. Since barn owls are not very selective feeders, these pellets can be used to estimate the diversity of available prey within their feeding range. The contents are also a direct indicator of what an owl has fed on—information that is crucial for species management and protection.

There are many genera of prey that occur in both the Northwest (Washington, Oregon) and Southeast (Mississippi, Alabama, Louisiana), as well as several that are exclusive to one of these areas. The owl pellet table seen below contains 14 mammalian prey types that account for approximately 95 percent of the prey found in each of the two habitats. Other prey consists of birds, bats, insects, crayfish, and small reptiles.

Going Further

Procedure

The facilitator should copy Table 4.1, Owl Prey Data, for all participants in the group and explain the background information about owl pellets and how they relate to the video and the text. (If possible, it would be interesting to have some owl pellets available so participants could see the general appearance and samples of remnant prey.) Depending on time, the facilitator may provide the chart below with all of the data and calculations or give the participants a chart in which they have to do the biomass calculations: genera, group, and regional totals. The facilitator may want to have students work in groups to divide up the tasks.

Table 4.1 Owl Prey Data and Calculations

	Northwest United States				Southwest United States			
Prey: Groups and Genera	No. per 50 pellets [1]	Prey Weight [2], grams	Total genera biomass, grams	Total group biomass, grams	No. per 50 pellets [1]	Prey Weight [2], grams	Total genera biomass, grams	Total group biomass
Pocket Gopher Thomomys	7	150	1,050	1,050	**		0	0
Rat				450				1,890
Sigmodon	**				11	100	1,100	
Oryzomys	**				8	80	640	
Rattus	3	150	450		1	150	150	
Vole Microtus	12	40	480	480	8	40	320	320
Mice				386				402
Peromyscus	4	22	88		6	22	132	
Mus	7	18	126		11	18	198	
Reithrodontomys	6	12	72		6	12	72	
Perognathus	4	25	100		**			
Mole				110				165
Scapanus	2	55	110		**			
Scalopus	**				3	55	165	
Shrew				24				192
Blarina	**				7	20	140	
Cryptotis	**				11	4	44	
Sorex	6	4	24		2	4	8	
Other Prey				162				148
Bats	4	7	28		2	7	14	
Birds	6	15	90		4	15	60	
Insects	4	1	4		4	1	4	
Crayfish	4	5	20		2	5	10	
Small Reptiles	1	20	20		3	20	60	
Total Habitat Biomass / 50 pellets / region					2,662			3,117

Notes:

1. Assume each owl expels two pellets per day. Assume there is one owl per sample area. Data represents 25 feeding days.
2. Prey weight is the average for each species.

** Does not occur

Going Further

Questions about Data

Which type of prey contributed the most by number for each region?

Did the same prey type contribute the most by number for both regions?

Which prey type contributed the most in biomass for each region? Did this same prey type contribute the most in biomass for both regions?

If an owl needs 100 grams of food per day, how many Sorex does it need to capture? How many Sigmodon?

Assume an owl eats 100 grams of insects and one 100 gram rat. Which prey contributed the most to the owl's diet? Explain.

Is quantity or quality of prey more important? Why?

Diversity and Stability

Both the video and the text have emphasized that increased diversity leads to increased stability. If a predator has only one prey type available in its habitat, then a decline in that prey will lead to a decline in the predator. If the prey is eradicated through disease or over hunting, then the predator will have to relocate and find a substitute food source or it may become extinct. On the other hand, if a predator feeds equally on all available prey types, a decline in one or two may create only small problems for the predator due to the presence the remaining prey types.

As demonstrated in the video, diversity increases as one nears the equator. Alaskan owls feed almost exclusively on lemmings. As seen in the data chart above, the owls in the southwestern states have over 12 different prey types while those that live on the equator typically feed on 15 to 20 prey types that range in size from insects to opossums.

Construct Two Food Webs

Participants should be able to put together a food web that has three to four trophic levels. Within each working group the participants will construct a web for each of the two regions. The facilitator should have the groups put the food webs on large newsprint and post them around the room when complete. The first group will present their food webs. Subsequent groups will point out the differences in their webs from webs constructed by the other participants.

Discussion

Which region has the most complex food web?

Which region has the most stability?

Would a crash in the shrew (Blarina, Cryptotis, Sorex) population seriously affect either region? Why?

Would a crash in the vole (Microtus) population seriously affect either region? Why?

Some owls produce 2 pellets per day. Assume each pellet represents 80 grams of biomass. Also assume that one 40 gram vole can cause 50 cents of crop damage to a farm per season. If a barn owl family of seven (2 adults and 5 young) lives on a farm for 12 weeks and feeds exclusively on voles, how much will the farmer save in crop damages?

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

In Unit 5, "Human Population Dynamics," the key themes are the fundamental principles of population dynamics and the environmental consequences of population growth. Sub-topics will examine areas of concern such as threats to health, baby booms and busts, human life span, and population migrations.

On-line Simulation

After reading Unit 5, complete the lessons for Interactive Lab: Demographics for next week and bring a half page summary of your experience and results.

Read for Next Session

For the next session, be sure to read the Unit 5 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about population dynamics. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to population dynamics.

Supplementary Classroom Activity 1

Ecosystems

Objectives

1. Students will learn about species that are native to their backyard.
2. Students will understand that a small habitat can contain wide biodiversity of plant life.
3. Students will learn that individual ecosystems contain diversity within each species population.

Materials

Undisturbed or unmanaged part of a school grounds or a local park

Plastic bags for carrying leaf specimens

Tree and shrub field guides

Procedure

1. Choose a site that is relatively undisturbed. Determine beforehand that the area does not contain any poisonous plants.
2. At the site, ask students to collect as many different leaf types (representing distinct species) as they can. If the area has several distinct habitats, have different groups sample different areas: meadow, riparian, wet land, or forest. Students should note whether the leaf is simple or compound and its arrangement around the twig (alternate, opposite, or whorled).
3. Back in the classroom, make a list of the leaves. Set up a dichotomous key. First divide by simple or compound, next divide those two categories into alternate, opposite, and whorled. Then students should use such characteristics as leaf shape, leaf edges, veination patterns, color, hairiness, etc. to separate even further. If time permits, they can name by genus and species.
4. Allow students to observe other collections to see if there are any species that are not contained in their samples.
5. Lead a discussion about their findings in an attempt to assess the plant biodiversity of their community or city as a whole.
6. Choose one or two of the most commonly occurring species in the collections.
7. Ask the students to look for differences within the same species. This activity will help them understand the second level of biodiversity—that each ecosystem will contain evidence of diversity within each species.

Adaptations

In addition to selecting the leaves, students should bring drawing pads and pencils in order to sketch insects in this ecosystem. As with the leaves, they should identify as many of the species they've drawn as possible. They can also look for evidence of other organisms by searching for tracks or scat.

Supplementary Classroom Activity 1

Discussion

1. Valleys such as Death Valley, the Mississippi River Valley, and the Hudson River Valley are homes to a wide variety of plants and animals. Discuss how abrupt changes in elevation make vastly different habitats possible.
2. The popular opinion is that pre-Columbian Native American culture was much more "in tune" with nature than modern American culture. Is this true?
3. Ansel Adams made his fame, in part, through his photographs of the Yosemite Valley. Discuss why so many artists find inspiration in using natural scenes in their artwork. What creative, artistic, or inspiring qualities does nature possess?
4. Yosemite National Park attracts around five million visitors per year, making it one of the most visited places on Earth. Such a large number of visitors cannot help but cause damage to this wilderness area. For the sake of preservation, should human travel in wilderness areas be restricted by law? Why or why not?
5. John Muir, the founder of the Sierra Club, said, "Any fool can destroy a tree. It cannot run away." He was referring to loggers, who he believed would rather make a profit from the wilderness than preserve and enjoy it. Create a list of businesses that could use the wilderness areas of America without destroying them—while still making a profit. Explain your ideas in each case.

Supplementary Classroom Activity 2

Planning a Park

New National Park

National parks in any part of the United States are created by an act of Congress. Behind every national park is a story about how it was founded. Have your students visit the Web site of the U.S. National Park Service to locate information about the history, habitats, and natural features of a nearby national park. When their research is complete, divide your students into planning groups and challenge each group to develop a proposal for establishing a new national park in your state or county.

You may ask students to begin this project by examining a state population map and finding areas where population is low. Then ask them to determine what unique features the new park will offer. They can create a map of the natural features of their park, name it, and establish wildlife habitats for various species within its borders. Finally, ask students to write up a rationale for creating a new national park in a specific location and adding it to the existing parks system.

Notes

Unit 5
Human Population Dynamics

Background

Introduction

Human population dynamics is a field that tracks factors related to changes in population such as fertility rate and life expectancy. Predicting population changes is important because these demographic trends impact economic, social, and environmental systems. An increase in human population can impact the quality of natural resources like biodiversity, air, land, and water.

Essential Questions

What are the trends in human population growth? How fast is the population growing? Has it always grown at this rate and how can we predict the population in the future?

Are the populations of different countries growing at different rates?

What do factors like human population density, movement, and composition mean for the sustainability of the planet?

What is meant by the Earth's carrying capacity?

Content

Unit 5 looks at the interconnecting variables that influence population trends across the globe and how the various factors impact the environment. Obviously, rising populations put increasing demands on natural resources such as land, water, and energy supplies. However, the intensity of consumption and the technologies involved also must be considered. Changes in population size, age, and distribution affect issues ranging from food security to climate change. Population variables interact with consumption patterns, technologies, and political and economic structures to influence environmental change. This interaction helps explain why environmental conditions can deteriorate even as the growth of population slows.

Carrying capacity is considered to be the population that the Earth can support on a continuing basis. Carrying capacity depends on much more than food production; it also involves subjective measures like quality of life. This is why the term "ecological footprint" is important as humans consider their impact on the planet's resources and ecosystems. This unit introduces the concept of demographic convergence and identifies factors such as pandemics, political instability, wars, and poor climate and land resources that disrupt the economies of countries moving from developing to developed status.

The unit 5 video introduces three different demographers who explore such issues as the interaction of death rate, life expectancy, and immigration in determining population dynamics for an area, specifically in the United States.

Background

They discuss ecological and economic carrying capacity and the relationship between population growth and consumption rates, in particular the special impacts of megacities and even larger metacities as the population becomes more urban.

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. For much, perhaps most, of human history, demographic patterns were fairly stable; the human population grew slowly and age structures, birth rates, and death rates changed very little, but these trends are no longer considered stable.

ii. World population growth has been and will continue to be unevenly distributed across the globe.

iii. Infant and child mortality rates decline as a result of improved nutrition, public health interventions related to water and sanitation, and medical advances, such as the use of vaccines and antibiotics.

iv. America's relatively high rate of population growth, natural resource consumption, and pollution, in combination create one of the largest environmental impacts of any country at present.

b. Skills

i. Demographers use mathematics to determine human population dynamics and trends and summarize data in charts and graphs for the public.

ii. The more forces that are identified that affect human population dynamics, the more difficult it becomes to predict demographic changes.

c. Dispositions

i. To understand human population trends, one has to appreciate how social, political, economic, and cultural factors can shape events.

ii. Providing information about population, health, and the environment empowers people around the world to use the information to advance the well-being of current and future generations.

iii. Countries can carefully select and protect surface area to contribute to environmental sustainability.

Key Concepts

Birth rate
Overpopulation
Carrying capacity
Death rate
Infant mortality rate
Population density
Population distribution
Ecological footprint
Resource consumption
Population growth
Demographic transition
Demographic dividend
Dependency ratio
Demographic Convergence
Global demographics
Land use patterns
Resource consumption
Human quality of life
Indicators
Population trends

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Human Population

There are many different kinds of misconceptions related to understanding human population issues, some of which result from lack of clarity about terms. Whenever the term "human population growth" is used, misunderstandings arise. Population growth is defined as the limiting of population increase to the number of live births needed to replace the existing population. However, focus on "population growth" can be perceived to be a need to control human reproduction rights and use of the word "control" sets off a red flag, especially for countries based on democratic principles.

There can also be a lack of clarity when people use the term rate of population growth or decline. People need to be aware that the rate of human population growth can decline, while the absolute number of people on Earth can continue to increase. Also important to recognize is that areas experiencing rapid population growth are also often areas where the majority of Earth's remaining biodiversity can be found.

Another misconception about population growth occurs when people assume that developing countries must go through the same processes, steps, or trends that developed countries have gone through. "Leapfrogging," a concept that developing countries can adopt modern systems without going through all the intermediary steps, is an important process when thinking about global development and population issues.

The idea that population problems of developing countries are not a problem for the United States is a misconception. The scale of human activities is now so large that humans are appreciably affecting the climate and ecosystems in the U.S. and the world. The total impact of people on the environment is proportional to the number of people and the average impact of each person. If we are to reduce the total impact of people on the global environment, we must address both factors.

Another popular misconception is that the world's worst population problem is found in developing countries. The United States has a high per capita resource consumption. Some estimates say a person in the United States has 30 times or more impact on world resources than does a person in an underdeveloped nation.

The notion that all growth is good is a misconception. Steady growth of towns and cities has often been the goal to which communities aspire. If a town's population is growing, the town is said to be "healthy" or "vibrant," and if the population is not growing the town is said to be "stagnant." However, something that is not growing could alternately be viewed as "stable" and good.

Getting Ready (45 minutes)

Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about population dynamics. On the second, they should write one question they have about population dynamics. And on the third card, they should describe a direct experience that they have had that relates to population dynamics. For example an individual might write:

For the human population to become stable, individuals can think about replacing themselves; hence a couple can have two children during their lifetime.

What is an effective way that one country can assist another in helping it manage its natural resources?

Cities have more problems than rural areas related to large populations—poor air quality, water rationing, and congested traffic.

Getting Ready

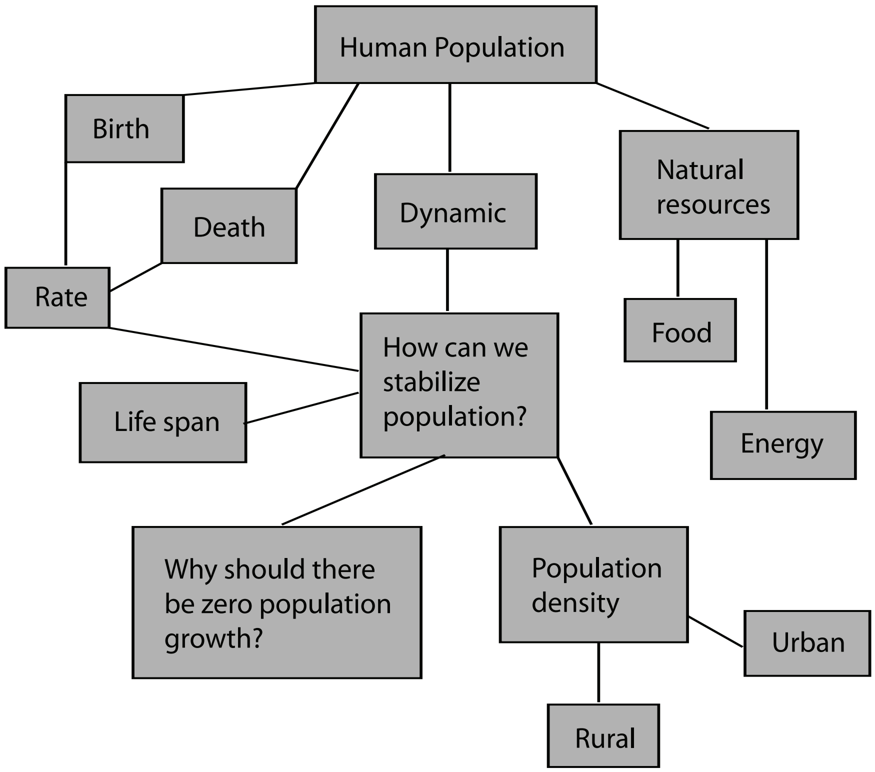


Figure 5.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Changes in Human Population

Part 1. Exponential Growth

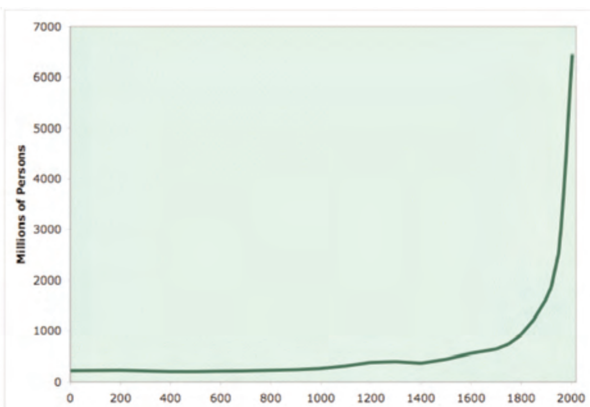
FACILITATOR: Bring copies of the table and graphs in Activity Three. Have the participants read the table on the history of human population growth based on 2002 data.

Getting Ready

THE HISTORY OF HUMAN POPULATION GROWTH

Years Elapsed	Year	Human Population
10,000	1 A.D.	170 Million
1,800	1800	1 Billion
130	1930	2 Billion
30	1960	3 Billion
15	1975	4 Billion
12	1987	5 Billion
12	1996	6 Billion

1. Point out trends, especially how many years elapsed between the milestones in human population growth.
2. Discuss milestones in human civilization, including the agricultural and industrial revolutions. Did these have dramatic effects on world population?
3. Project population size into the future. Specify years and the expected population.
4. Discuss the graph of human population growth below. Describe the pattern or shape of the graph. Compare and contrast variables that influence the pattern. Why are line graphs suited for showing population growth? What two factors need to be depicted? What do the numbers across the bottom— the x axis—represent?



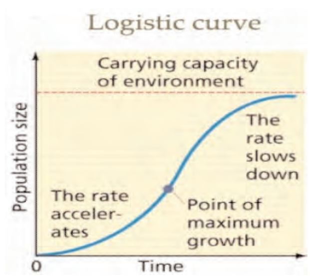
Exponential growth, or j curve growth patterns, can be viewed as unrestricted growth. Why is this true for humans or is this actually true for humans in the long run? What role has technology played in the human population curve?

Getting Ready

Part 2. Population Dynamics

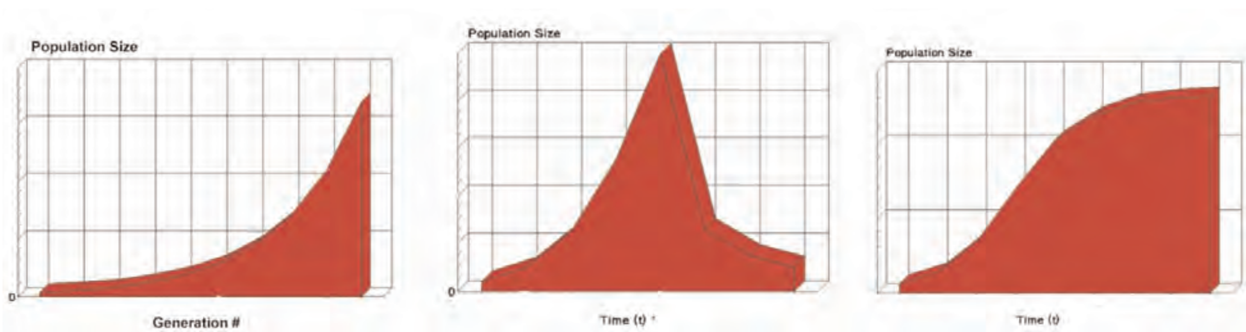
Background

In population ecology, a population is a group of individuals of the same species living in the same geographic area. Populations are said to undergo three distinct phases of their life cycle: growth, stability, and decline. The study of factors that affect growth, stability, and decline of populations is called population dynamics. Nearly all populations tend to grow exponentially as long as there are resources available. Stability is usually the longest phase of a population's life cycle. Decline is the decrease in the number of individuals in a population. The Logistic curve (also



known as an S-curve) shows the effect of a limiting factor (which can be the carrying capacity of the environment).

The logistic curve is frequently used to model biological growth patterns where there is an initial exponential



growth period followed by a leveling off as more of the population is infected or as the food supply or some other factor limits further growth.

Scientists studied the Kaibab Plateau of northern Arizona between the years of 1907 and 1939. In 1907 the deer population was unusually low with only 4,000 head. The carrying capacity was 30,000 at this time, so a massive campaign was waged against the natural enemies of the deer. Between the years of 1907 and 1923, the natural predators of deer (mountain lions, wolves and coyotes) were eliminated by hunters in order to increase the deer population. The deer population increased rapidly to 100,000 by 1924, but then died off rapidly to a mere 10,000 by 1939. Because of severe overgrazing by excessive populations of deer, the carrying capacity of this region was reduced to approximately 10,000 in 1939, and the deer population was reduced accordingly.

Discussion

Examine the three graphs above and discuss which best fits the Kaibab Plateau scenario.

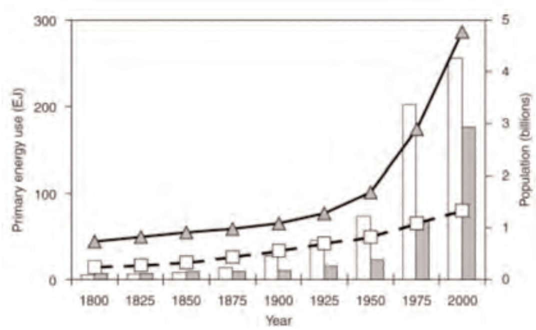
Could this happen to the human population?

How is human population growth more complicated than simple geometric progressions? Look at the shapes of the three graphs above. Which one best describes the deer scenario?

Getting Ready

Part 3. Population and Energy Resource

Discuss possible ecological scenarios that might result in the population and time relationships illustrated in each of the three graphs.



Discuss the energy, population, and time graph below. Consider how energy resources will impact human population growth over time. Notice the changing relationship in energy use between industrialized and developing countries.

In this graph you can see growth in world population (shown as lines and referring to the scale on the right-hand axis) and primary energy use (shown as bars and referring to the scale on the left-hand axis), industrialized (open squares and bars) versus developing (closed triangles and bars) countries, 1800–2000.

1. Describe the trends in energy use and population growth in both developed and undeveloped countries between 1800 and 2000.
2. Describe the relationship between developed and undeveloped countries up to 1950.
3. What happens between 1975 and 2000 in terms of the relative size of the open (industrialized countries' energy use) and closed (developing countries' energy use) bars?
4. Do you think this will continue? What could happen if more countries increase their energy use?
5. Discuss alternatives to continuation of these trends. How can these trends be changed? What would the outcomes be?

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions:

1. What is the value of census information?
2. What kinds of problems do social demographers help solve?
3. Why focus on U.S. population dynamics in particular?
4. Why is there disagreement about the carrying capacity of the Earth?
5. What assumptions are used to determine sustainability?
6. How does an increasing global market influence sustainability of the planet?

Video

7. How does technology relate to sustainability of the planet?
8. What is meant by market based solutions to sustainability?
9. As demographers, what do Martha Farnsworth Riche and Deborah Balk have in common? How does their work differ? What are each of their specializations? As a demographer, how does David Bloom's focus differ from Farnsworth Riche's and Balk's?
10. What are the trends as a region moves from pre-industrial to industrial characteristics or from rural dominated populations to urban concentration?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. How do death rate, life expectancy, and immigration and emigration figure into determining population dynamics for an area?
2. What is the impact of megacities on the environment?
3. What is meant by the ecological and economic capacity of an area?
4. How are population growth and consumption rates related?
5. What is meant by carrying capacity? Do you think the Earth has reached its carrying capacity? Why are there so many differing opinions about this?

Going Further (60 minutes)

Activity Six: Spatial Demographics Activity

The goal of this activity is to compare specific environmental and natural resource conditions and population growth in a variety of countries.

In the Unit 5 video on human population dynamics, Deborah Balk, who studies spatial demographics, talks about how environmental conditions and population growth interact, specifically focusing on population and geographical characteristics. For example, the video claims that throughout the world, population density is associated with coastal environments. The research objective is to study environmental characteristics associated with population characteristics.

Going Further

The online Interactive Lab: Demographics gives the population characteristics for seven specific countries. In this activity participants will relate the population characteristics from the Lab with the general environmental and natural resource characteristics of those countries.

Population and Growth Data from Online Interactive Lab

Country	Population	Population Growth/year
China	1.3 B	.6%
Egypt	78 M	2%
India	1.1 B	1.5%
Italy	58 M	.35%
Mexico	106 M	1.41%
Nigeria	129 M	2.46%
USA	296M	.92%

Materials

One set of fact sheets for each participant, listing the environmental and natural resources for the 7 countries featured in the Interactive Lab

A computer and Internet access in order to run the Demographics Lab

Procedure

1. As a group, run the online Interactive Lab: Demographics for each country using the pre-set criteria for population growth in each country for 45–90 and 180 year increments.
2. Describe and summarize what the population characteristics are for each country. Consider the population graph and population by age group graphs and describe the characteristics.
3. Examine the environmental and natural resource fact sheets provided from the World Factbook.
4. Discuss these questions:

   How does climate relate to population growth?

   What is likely to be the effect of population trends on natural resources in each country?

   What geographical characteristics are related to the growth trends and population characteristics?

   How will population growth influence current environmental concerns?

   What is the future for land use in these countries?

Further Investigation and Discussion

Modify the parameters for birth and death rate for each country and relate the changes in growth and age distribution to natural resource information.

Consider the developed countries (USA & Italy) and developing countries (Egypt & Nigeria). How do the natural resource and population characteristics compare?

Compare the relatively stable population countries (USA & China) to the fastest increasing population countries (Egypt & Nigeria). How do the natural resource and population characteristics compare?

Going Further

China

Natural Resource Fact Sheets adapted from United States Central Intelligence Agency, The World Factbook 2007, Washington, DC; retrieved: 6-7-07 from:

https://www.cia.gov/library/publications/the-world-factbook/index.html.

Location: Eastern Asia, bordering the East China Sea, Korea Bay, Yellow Sea, and South China Sea, between North Korea and Vietnam

Geographic coordinates: 35 00 N, 105 00 E

Area—comparative: slightly smaller than the US

Coastline: 14,500 km

Climate: extremely diverse; tropical in south to subarctic in north

Terrain: mostly mountains, high plateaus, deserts in west; plains, deltas, and hills in east

Natural resources: coal, iron ore, petroleum, natural gas, mercury, tin, tungsten, antimony, manganese, molybdenum, vanadium, magnetite, aluminum, lead, zinc, uranium, hydropower potential (world's largest)

Land use: *arable land:* 14.86% *permanent crops:* 1.27% *other:* 83.87% (2005)

Irrigated land: 545,960 sq km (2003)

Environment —current issues: air pollution (greenhouse gases, sulfur dioxide particulates) from reliance on coal produces acid rain; water shortages, particularly in the north; water pollution from untreated wastes; deforestation; estimated loss of one-fifth of agricultural land since 1949 to soil erosion and economic development; desertification; trade in endangered species

Geography—note: world's fourth largest country (after Russia, Canada, and U.S.); Mount Everest on the border with Nepal is the world's tallest peak

Going Further

Egypt

Location: Northern Africa, bordering the Mediterranean Sea, between Libya and the Gaza Strip, and the Red Sea north of Sudan, and includes the Asian Sinai Peninsula

Geographic coordinates: 27 00 N, 30 00 E

Area—comparative: slightly more than three times the size of New Mexico

Coastline: 2,450 km

Climate: desert; hot, dry summers with moderate winters

Terrain: vast desert plateau interrupted by Nile valley and delta

Natural resources: petroleum, natural gas, iron ore, phosphates, manganese, limestone, gypsum, talc, asbestos, lead, zinc

Land use: *arable land:* 2.92% *permanent crops:* 0.5% *other:* 96.58% (2005)

Irrigated land: 34,220 sq km (2003)

Environment —current issues: agricultural land being lost to urbanization and windblown sands; increasing soil salination below Aswan High Dam; desertification; oil pollution threatening coral reefs, beaches, and marine habitats; other water pollution from agricultural pesticides, raw sewage, and industrial effluents; very limited natural fresh water resources away from the Nile, which is the only perennial water source; rapid growth in population overstraining the Nile and natural resources

Geography—note: controls Sinai Peninsula, only land bridge between Africa and remainder of Eastern Hemisphere; controls Suez Canal, a sea link between Indian Ocean and Mediterranean Sea; size, and juxtaposition to Israel, establish its major role in Middle Eastern geopolitics; dependence on upstream neighbors; dominance of Nile basin issues; prone to influxes of refugees

Going Further

India

Location:	Southern Asia, bordering the Arabian Sea and the Bay of Bengal, between Burma and Pakistan
Geographic coordinates:	20 00 N, 77 00 E
Area—comparative:	slightly more than one-third the size of the U.S.
Coastline:	7,000 km
Climate:	varies from tropical monsoon in south to temperate in north
Terrain:	upland plain (Deccan Plateau) in south, flat to rolling plain along the Ganges, deserts in west, Himalayas in north
Natural resources:	coal (fourth-largest reserves in the world), iron ore, manganese, mica, bauxite, titanium ore, chromite, natural gas, diamonds, petroleum, limestone, arable land
Land use:	*arable land:* 48.83% *permanent crops:* 2.8% *other:* 48.37% (2005)
Irrigated land:	558,080 sq km (2003)
Environment —current issues:	deforestation; soil erosion; overgrazing; desertification; air pollution from industrial effluents and vehicle emissions; water pollution from raw sewage and runoff of agricultural pesticides; tap water is not potable throughout the country; huge and growing population is overstraining natural resources
Geography—note:	dominates South Asian subcontinent; near important Indian Ocean trade routes; Kanchenjunga, third tallest mountain in the world, lies on the border with Nepal

Going Further

Italy

Location: Southern Europe, a peninsula extending into the central Mediterranean Sea, northeast of Tunisia

Geographic coordinates: 42 50 N, 12 50 E

Area—comparative: slightly larger than Arizona

Coastline: 7,600 km

Climate: predominantly Mediterranean; Alpine in far north; hot, dry in south

Terrain: mostly rugged and mountainous; some plains, coastal lowlands

Natural resources: coal, mercury, zinc, potash, marble, barite, asbestos, pumice, fluorspar, feldspar, pyrite (sulfur), natural gas and crude oil reserves, fish, arable land

Land use: *arable land:* 26.41% *permanent crops:* 9.09% *other:* 64.5% (2005)

Irrigated land: 27,500 sq km (2003)

Environment—current issues: air pollution from industrial emissions such as sulfur dioxide; coastal and inland rivers polluted from industrial and agricultural effluents; acid rain damaging lakes; inadequate industrial waste treatment and disposal facilities

Geography—note: strategic location dominating central Mediterranean as well as southern sea and air approaches to Western Europe

Going Further

Mexico

Location: Middle America, bordering the Caribbean Sea and the Gulf of Mexico, between Belize and the U.S. and bordering the North Pacific Ocean, between Guatemala and the U.S.

Geographic coordinates: 23 00 N, 102 00 W

Area—comparative: slightly less than three times the size of Texas

Coastline: 9,330 km

Climate: varies from tropical to desert

Terrain: high, rugged mountains; low coastal plains; high plateaus; desert

Natural resources: petroleum, silver, copper, gold, lead, zinc, natural gas, timber

Land use: *arable land:* 12.66% *permanent crops:* 1.28% *other:* 86.06% (2005)

Irrigated land: 63,200 sq km (2003)

Environment—current issues: scarcity of hazardous waste disposal facilities; rural to urban migration; natural fresh water resources scarce and polluted in north, inaccessible and poor quality in center and extreme southeast; raw sewage and industrial effluents polluting rivers in urban areas; deforestation; widespread erosion; desertification; deteriorating agricultural lands; serious air and water pollution in the national capital and urban centers along U.S.-Mexico border; land subsidence in Valley of Mexico caused by groundwater depletion
note: the government considers the lack of clean water and deforestation national security issues

Geography—note: strategic location on southern border of U.S.; corn (maize), one of the world's major grain crops, is thought to have originated in Mexico

Going Further

Nigeria

Location: Western Africa, bordering the Gulf of Guinea, between Benin and Cameroon

Geographic coordinates: 10 00 N, 8 00 E

Area—comparative: slightly more than twice the size of California

Coastline: 853 km

Climate: varies; equatorial in south, tropical in center, arid in north

Terrain: southern lowlands merge into central hills and plateaus; mountains in southeast, plains in north

Natural resources: natural gas, petroleum, tin, iron ore, coal, limestone, niobium, lead, zinc, arable land

Land use: *arable land:* 33.02% *permanent crops:* 3.14% *other:* 63.84% (2005)

Irrigated land: 2,820 sq km (2003)

Environment —current issues: soil degradation; rapid deforestation; urban air and water pollution; desertification; oil pollution—water, air, and soil; has suffered serious damage from oil spills; loss of arable land; rapid urbanization

Geography—note: the Niger enters the country in the northwest and flows southward through tropical rain forests and swamps to its delta in the Gulf of Guinea

Going Further

United States of America

Location: North America, bordering both the North Atlantic Ocean and the North Pacific Ocean, between Canada and Mexico

Geographic coordinates: 38 00 N, 97 00 W

Area—comparative: about half the size of Russia; about three-tenths the size of Africa; about half the size of South America (or slightly larger than Brazil); slightly larger than China; more than twice the size of the European Union

Coastline: 19,924 km

Climate: mostly temperate, but tropical in Hawaii and Florida, arctic in Alaska, semiarid in the great plains west of the Mississippi River, and arid in the Great Basin of the southwest; low winter temperatures in the northwest are ameliorated occasionally in January and February by warm chinook winds from the eastern slopes of the Rocky Mountains

Terrain: vast central plain, mountains in west, hills and low mountains in east; rugged mountains and broad river valleys in Alaska; rugged, volcanic topography in Hawaii

Natural resources: coal, copper, lead, molybdenum, phosphates, uranium, bauxite, gold, iron, mercury, nickel, potash, silver, tungsten, zinc, petroleum, natural gas, timber

Land use: *arable land:* 18.01% *permanent crops:* 0.21% *other:* 81.78% (2005)

Irrigated land: 223,850 sq km (2003)

Environment —current issues: air pollution resulting in acid rain in both the U.S. and Canada; the U.S. is the largest single emitter of carbon dioxide from the burning of fossil fuels; water pollution from runoff of pesticides and fertilizers; limited natural fresh water resources in much of the western part of the country require careful management; desertification

Geography—note: world's third-largest country by size (after Russia and Canada) and by population (after China and India); Mt. McKinley is highest point in North America and Death Valley the lowest point on the continent

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 6 before the next session. In Unit 6, the emphasis is on risk, exposure, and health issues. Sub-topics will include exposure to environmental hazards, risk tradeoffs, and risk perception.

Read for Next Session

Read the Unit 6 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about risk and exposure. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to risk, exposure, and health issues.

Supplementary Classroom Activity 1

Analyzing Population Growth Rates

Learning Objectives

Students will be able to:

- identify factors that influence birth and death rates in human population growth rates
- describe relationships between birth and death rates and how they both affect human population growth rates
- explain factors that affect population growth rates in addition to birth and death rates

Part 1. World Birth and Death Rates

The natural increase of a population depends on the number of births and deaths. If the number of births is greater than the number of deaths at any given point in time, there will be a natural increase in the number of people. Typically, the growth rate of a population is given in terms of the birth rate (number of births per 1000 people per year) and death rate (number of deaths per 1000 people per year).

Use the information below or have students research birth and death rates for different countries of their choice. Compare and contrast birth and death rates and speculate and research on why the rates differ. Students can report on what they've learned about each country. The group can explore which countries are similar and which are strikingly different from the United States. For example, why do some countries have double the death rate of other countries? Which countries have better health services, better sanitation, and better nutrition?

1. Mark all of the countries listed below on a map of the world.
2. Group countries by continent, compare average birth and death rates, and discuss possible causes for the differences.
3. Group countries by north or south of the equator, compare average birth and death rates, and discuss possible causes for the differences.
4. Group the countries according to developed and undeveloped, compare average birth and death rates, and discuss possible causes for the differences.
5. Compare the birth and death rates of individual countries.
   a. Order the birth rates from lowest to highest.
   b. Order the death rates from lowest to highest.
   c. Compare lists.
   d. Compare other countries to the United States.

Supplementary Classroom Activity 1

BIRTH AND DEATH RATES BY SELECTED COUNTRY

Source: United States Census International Programs Center, 1992

Country/region	Birth rate	Death rate
Afghanistan	41.0	17.4
Argentina	18.2	7.6
Australia	12.7	7.3
Austria	9.6	9.7
Belarus	9.9	14.0
Belgium	10.6	10.1
Bhutan	35.3	13.7
Bolivia	26.4	8.1
Botswana	28.0	26.3
Brazil	18.1	9.3
Cameroon	35.7	12.1
Canada	11.1	7.5
Chile	16.5	5.6
China	15.9	6.8
Colombia	22.0	5.7
Denmark	11.7	10.8
Egypt	24.4	7.6
France	11.9	9.0
French Guiana	21.7	4.8
Gabon	27.2	17.6
Gaza Strip	41.9	4.1
Germany	9.0	10.4
Ghana	28.1	10.3
Guinea	39.5	17.2
Guinea-Bissau	39.0	15.1
Guyana	17.9	9.3
Haiti	31.4	14.9
Honduras	31.2	5.7
Hungary	9.3	13.1
India	23.8	8.6
Indonesia	21.9	6.3
Iran	17.5	5.4
Iraq	34.2	6.0
Ireland	14.6	8.0
Israel	18.9	6.2
Italy	8.9	10.1
Japan	10.0	8.5
Jordan	24.6	2.6
Kazakhstan	17.8	10.7
Kenya	27.6	14.7
Korea, North	18.0	7.0
Korea, South	14.6	6.0
Kuwait	21.8	2.5
Liberia	46.0	16.1
Mexico	22.4	5.0
Moldova	13.8	12.6
Nepal	32.9	10.0
Niger	50.0	22.3
Nigeria	39.2	14.1
Norway	12.4	9.8
Peru	23.4	5.7
Philippines	26.9	6.0
Poland	10.3	10.0
Portugal	11.5	10.2
Russia	9.7	13.9
Saudi Arabia	37.3	5.9
Slovakia	10.1	9.2
Slovenia	9.3	10.1
Solomon Islands	33.3	4.2
Somalia	46.8	18.0
South Africa	20.6	18.9
Spain	9.3	9.2
Sri Lanka	16.4	6.5
Sudan	37.2	9.8
Suriname	20.0	5.7
Swaziland	39.6	23.3
Sweden	9.8	10.6
Switzerland	9.8	8.8
Syria	30.1	5.1
Taiwan	14.2	6.1
Tajikistan	33.0	8.5
Tanzania	39.1	13.0
Thailand	16.4	7.6
Togo	36.1	11.3
Tonga	24.1	5.6
Tunisia	16.8	5.0
Turkey	18.0	6.0
Turkmenistan	28.3	8.9
Tuvalu	21.4	7.5
Uganda	47.2	17.5
Ukraine	9.6	16.4
United Kingdom	11.3	10.3
United States	14.1	8.7
Uruguay	17.3	9.0
Uzbekistan	26.1	8.0
Vanuatu	24.8	8.3
Venezuela	20.2	4.9
Vietnam	20.9	6.1
Virgin Islands	15.9	5.6
West Bank	34.9	4.3
Yemen	43.3	9.3
Zambia	41.0	21.9
Zimbabwe	24.6	24.1

Supplementary Classroom Activity 1

Part 2 Birth and Death Rate Demonstration

This demonstration illustrates different human population growth rates for different countries. Bring to the study group several clear containers at least 1 quart in capacity. Label the containers to represent individual countries. Fill the containers with colored water. Have several same size cups available for students.

The objective is to add or take away water from each container in direct proportion to the actual birth and death rates. Use the table below to determine how much water is put in or taken out for each generation. This is the ratio between birth and death. For example, for Afghanistan, one student can add one cup of water to represent the birth rate of forty one. Another student can remove approximately half a cup of water representing the death rate of seventeen. These two students can keep doing this each time representing a generation. The class can observe and record what happens over time.

If new countries are added to the list below, students can calculate what size measuring cup and amounts of water will be added and removed. For every amount of water added to represent the birth rate, water representing the death rate must be removed. Students should continue until a trend is clear or one or the other containers is getting ready to overflow. Several countries can be done at the same time to compare outcomes.

	Birth Rate	Death Rate	Birth to Death Ratio
Afghanistan	41/1000	17/1000	41 to 17
China	16/1000	7/1000	16 to 7
Germany	9/1000	10/1000	9 to 10
India	24/1000	9/1000	24 to 9
Pakistan	30/1000	9/1000	30 to 9
Uganda	47/1000	18/1000	47 to 18
United States	14/1000	9/1000	14 to 9

Ask students to discuss the following questions:

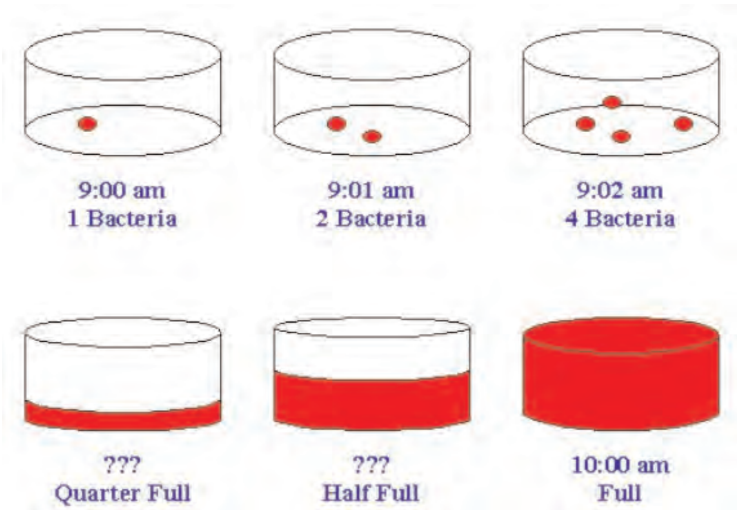
1. What circumstances might result in a high birth rate for a population? A low birth rate?
2. What circumstances might result in a high death rate for a population? A low death rate?
3. If both birth rates and death rates are declining worldwide, why is the world's population still increasing?
4. There are many factors that contribute to birth rates and death rates. Fertility rates and life expectancy are just two examples. Fertility rate is the average number of children born to women in a given population. How might the fertility rate affect the birth rate? How might it ultimately affect the population growth rate? How does life expectancy affect the death rate? How might it ultimately affect the population growth rate?
5. Can you think of any other factors that might affect the growth rate of a country?

Supplementary Classroom Activity 2

Impact of a Growing Population

The activity explores the mathematical and environmental aspects of population growth.

1. A scientist places one bacteria in a Petri dish at 9:00 a.m. Assume each bacteria is one cubic centimeter. The bacteria can reproduce at a rate that doubles its population every minute. The scientist observes that the container is completely full at 10:00 a.m.



   a. Estimate when the container was half full. Quarter full.
   b. What is the volume of the container?
   c. What volume will the bacteria population occupy at 10:02 am?
   d. In what ways is this example similar to human population growth?
   e. In what ways is this example different from human population growth?

2. What are the limiting factors in an environment that will control the growth of most populations of organisms?
3. What areas of the world are most populated? Why do you think these areas have so many people?
4. How does population size affect the resources used by a country? How does population size affect other environmental conditions? Are there other factors besides population size that can have an impact on resource consumption and environmental conditions in a country?

Notes

Unit 6

Risk, Exposure, and Health

Background

Introduction

Research indicates that each of us is exposed to a diverse and dynamic mixture of environmental hazards as a routine part of our lives. The effective management of human exposure to a variety of chemicals and biological agents present in various sectors of society has indeed become a very important public health policy issue. Using a risk assessment paradigm presents a systematic way to develop appropriate strategies in hazard identification, response assessment, exposure assessment, and risk characterization. Risk assessment generally serves as a tool that can be used to organize, structure, and compile scientific information in order to help identify existing hazardous situations or problems, anticipate potential problems, establish priorities, and provide a basis for regulatory controls and corrective actions.

Essential Questions

How do we know what contaminants are in our environment and how do they affect us?

What is risk assessment and how does it lead to an estimate of overall risk to the general population or target population?

What are the criteria for citing causal relationships between environmental threats and illness?

How and when do we communicate risk information to the public? Should the public be involved in the decision-making process?

Content

Soil, air, and water are ubiquitous. As more and more toxic chemicals find their way into these common mediums, concerns about environmental degradation become concerns about human health. Unit 6 points out that although single exposure to an environmental toxin is frequently studied, we must also look at the more common situation of differential exposure to mixtures of environmental agents, including biological, chemical, and physical stressors, which can further contribute to increased vulnerability of human populations and ecological systems.

Scientists study the relationship of exposure to health risk and risk management through a process called risk analysis. The Unit 6 text explains how risk analysis leads scientists through three basic phases: risk assessment, risk management, and risk communication. The unit concludes with a discussion of "risk perception."

The Unit 6 video presents two epidemiologic studies on environmentally induced health risks that demonstrate risk assessment, management, and communication to the public. Howard Hu and David Bellinger (Harvard School of Public Health) have followed the effects of children's exposure to metals from abandoned zinc mines in Tar Creek, Okalahoma. In 1983 the site was listed on the National Priorities List, making it one of the first Superfund Sites. This study focuses on aberrant neurodevelopmental problems as a result of differing degrees of exposure to the toxic mine tailings. The second case study takes viewers out of the rural setting and to an urban environment. Robin Whyatt, Columbia School of Public Health, is researching pesticide exposure (in utero and post-birth) in the inner city populations of New York City. Robin is studying the links to birth defects from indoor pesticide use. The goal of both case studies is to reinforce the need for improved assessment of exposure and better understanding of the biological mechanisms that determine toxicological interactions of single toxins or among mixture constituents.

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

  i. We are surrounded by both natural and man-made toxic substances; education on responsible care is the key to a healthy, productive environment.

  ii. The definition of "risk" is the probability of experiencing a hazard.

  iii. The degree of hazardous outcomes from chemical exposure depends on the toxicity of the substance, dose received, and the length of the exposure.

b. Skills

  i. To recognize science as an experimental process

  ii. To be aware of the importance of proper evaluation of scientific results and to realize that not all scientific results are conclusive.

  iii. To understand the importance of the exchange of information between the scientific community and the public

c. Dispositions

  i. Our economy has been built on a technological base. Technological processes produce chemicals that, if not managed carefully, can damage our entire ecosystem.

  ii. We need to develop an awareness of society's attempts to minimize risks of exposure from toxic substances through education, research, regulation of some industries for occupational and environmental health, and establishment of standards for food, air, and water quality.

Key Concepts

Case-control study
Cohort study
Contingent valuation
Delivered dose
Endocrine disrupter
Epidemiology
Hedonic valuation
No Observable Adverse Effects Level
Partition
Precautionary Principle
Reference concentration
Reference dose
Risk analysis
Risk assessment
Risk communication

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Risk, Exposure, and Health

Much controversy exists about the effects and risks that natural and synthetic pollutants have on the human population. Below is a list of some common misconceptions about risk and exposure to human health.

Many people believe that because adults are more mobile and work outside of their home for most of the day, they are more at risk for environmental exposures than children. But, in fact, children are more exposed to environmental threats. Children eat proportionately more food, drink more fluids, breathe more air, and play outside more than adults. This means that children may breathe in or ingest more pollutants per pound of body weight. For example, children absorb and retain a larger percentage of ingested lead than adults, which increases the toxic effects of the lead.

A common misconception is that lead poisoning is NOT a significant problem in the United States. However, despite a 94 percent decline in blood lead levels since 1976, caused principally by the removal of lead from gasoline, significant numbers of preschool children in the United States still have elevated blood lead levels (10 micrograms per deciliter or above) and suffer from lead toxicity. These children are at risk because they tend to live in poor quality housing, and many are of immigrant families that are not aware of the dangers of lead-based paint.

The scientifically unsound claim that the results of toxicity testing in animals have little relevance to human health is another important misconception. This claim is contradicted by the fact that every known human carcinogen has been shown to cause cancer in animal species. It is further supported by the close genetic similarity that has recently been demonstrated between humans and other species.

Another incorrect belief is that genetic inheritance and not air pollution is responsible for adolescent rates and degree of asthma attacks. Ambient air pollutants, especially ground-level ozone and fine particulates of automotive origin, appear to be important triggers of asthma. Asthma frequency declines when levels of these pollutants drop. Indoor air pollution, including insect dust, mites, molds, and environmental tobacco smoke is an additional trigger.

Finally, an everyday misconception is that if a product is on the shelf, it is safe. When we purchase a product, most of us assume that it has been tested and declared safe for the intended purpose. Many chemicals in products have not been tested or approved by any regulatory authority for their impacts on human health.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

Each person in the group should have 3 index cards. On the first card, participants should name a specific environmental hazard (biological, physical, or chemical) and describe its use or function and its health risk. On the second card, participants should write one question they have about environmental contaminants that pose a risk to human health. Finally, on the third card, they should describe a direct experience they have had with exposure to and/or health concern with contaminants in the environment. For example an individual might write:

Getting Ready

Methyl tertiary-butyl ether (MTBE), an additive to make gasoline burn cleaner and reduce emissions, causes cancer.

Is the toxicity of synthetic chemicals different from that of natural chemicals?

I feel bad that I live in a 200 year old farm house and there is still some lead based paint under the old paint.

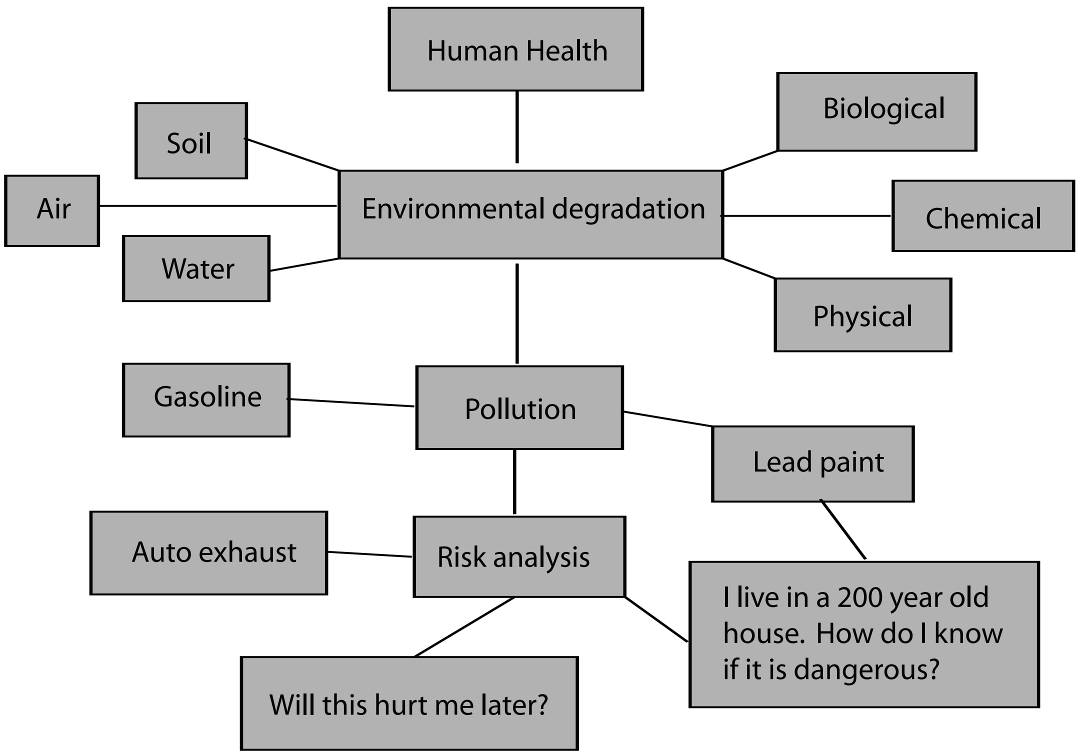


Figure 6.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Getting Ready

Activity Three: Who Gets the Vaccine?

FACILITATOR: The study group will need access to at least one computer that can access the Internet.

In this exercise the participants will play the role of CDC epidemiologists and they must use the Interactive Lab: Disease (www.learner.org/channel/courses/envsci/interactives/ disease) to help them decide "Who Gets the Vaccine."

Scenario Part 1

There is an immediate and dire situation occurring in two very different locations in the State of Alaska. It has come to the attention of the CDC in Atlanta that two towns are experiencing an outbreak of the Smoolichen Disease. Neither population has ever been exposed to this quite virulent disease. The only effective vaccine is a counter virus vaccine and specifically a slow counter virus and there are only 200 individual vaccine doses available at this time. The job of the CDC epidemiologist is to determine a course of action; let the disease run its course without using the vaccine or administer the vaccine to the population that will benefit the most..

PARTICIPANTS: Discuss the imaginary scenario up to this point and the proposed solution.

Scenario Part 2

The first outbreak has occurred in Shishmaref, which is located on a small barrier island off the coast of Alaska and is home to 600 Eskimos. These people live in small isolated groups around the island. They subsist through their fishing and harvesting from the sea. The degree of interaction between family groups is considered medium. The second outbreak has occurred in Point Lay, Alaska, population 213 people. About 85 percent of the population is American Indian. Point Lay is a very close knit community with high interaction from all parts of the community. Most of the population is either government workers or military personnel.

PARTICIPANTS: Run the Interactive Lab: Disease simulator for both populations in the virgin mode (tableau drop down menu). Do five to ten runs and then calculate the averages of both deaths and sick days per capita. Then run each population with a counter vaccine, C-slow virus. (The Smoolichen disease is similar in its etiology to the Red Death disease.) Again, all runs should be repeated five to ten times and averages calculated.

Using the data results and outcomes of the simulation, choose a course of action. The first option is to not give the vaccine to either group. The second option is to choose one of the two groups. The third is to give it to both groups. Be prepared to explain and defend your choice.

Video (45 minutes)

Activity Four: Watch the Video (30 minutes)

As you watch the video, think about the following focus questions.

1. What has happened in Pitcher, Oklahoma, to make it the largest Superfund site in the United States?
2. What are chat piles and how do they affect Tar Creek?
3. The people in the town of Pitcher have experienced high exposure to the lead in the mine tailing. How does exposure to lead lead to neurological problems?
4. Why were the children the primary targets for Howard Hu's study of exposure to metal from abandoned zinc and lead mines?
5. Hu's study also looks at the effects of multiple mixes of toxic metal exposure on people. What are the problems of doing exposure and risk assessments when more than one toxin is involved at the same time?
6. Robin Whyatt is researching links to birth defects from indoor pesticide use in New York City. What does she believe to be a common misconception about pesticides?
7. What are biomarkers and what biomarker(s) did Whyatt use in her pesticide exposure study? Did Hu use any biomarkers?
8. What did the public learn from both Hu's and Whyatt's exposure studies?

Activity Five: Discuss the Video (15 minutes)

Discuss the following questions about the video.

1. Summarize Howard Hu's study of children's exposures to metals from the abandoned Tar Creek mines. How will these results benefit you?
2. The unit text in Section D, Using Epidemiology in Risk Assessment, presented A.B. Hill's nine criteria for citing causal relationships. Using the nine criteria, determine if Hu's and Whyatt's study results satisfy all criteria in assessing the relationship between environmental threats and illnesses.
3. Do you see a need for any risk assessment and management assessments in your particular environment, such as work, school, home, fitness center, mall, restaurant, recreation area, etc.?
4. How do we discover what contaminants are in our environment and how do we know what impact they will have on us?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Toxic Dosage: Hazard or Not?

The hazard of chemicals in the environment is one that can be exaggerated or misinterpreted. Because we are exposed to many chemicals, both naturally occurring and synthetically produced, it makes sense to understand when to worry and when not to worry. The problem arises when people do not know the dose of a chemical required to cause an adverse effect. In many cases, people assume that any exposure to a chemical that can cause harm is harmful. In order for citizens to make good choices in their life styles, an understanding of dose and exposure is important.

To illustrate the above misconception, the American Council on Science and Health publishes a Holiday Dinner Menu each year. This menu is analyzed to determine exposure to natural chemicals known to cause adverse effects in rats. For example, people consume natural chemicals such as ethyl benzene in their coffee, hydrogen peroxide in their tomatoes, and furan in their sweet potatoes.

The bread in Thanksgiving stuffing contains furfural, a chemical that can cause cancer in rats when they are fed high doses of it. How many slices of bread would an average middle school student have to eat to consume an amount of furfural equal to the amount that increased the risk of cancer in rodents?

The facts

- White bread contains 167 micrograms of furfural/slice,
- The carcinogenic dose for rats is 197 milligrams per kilogram of body weight per day, fed every day of its life.
- A typical middle school student weighs 110 pounds (50 kilograms).

1. Calculate how many slices of bread a student would need to consume to reach a toxic dose. (Solution can be found after Unit 6: Between Sessions.)
2. Calculate how many slices of bread you would have to consume to reach a toxic dose.
3. What are some ways we can teach the public the differences between toxic and non-toxic dosages?

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 7 before the next session. In Unit 7, the emphasis is on the major environmental impact of agriculture and habitat loss associated with the expansion of lands devoted to human consumption of food and fiber. Environmental effects of this land conversion include: ecosystem stability (fragmentation of natural systems) and biodiversity loss.

Read for Next Session

For the next session be sure to read the Unit 7 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about agriculture. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to agriculture.

***Solution to Activity 6:** The carcinogenic dose for a student is 197,000 micrograms x 50 kilograms = 9,850,000 micrograms per day. If each slice has 167 micrograms of furfural, then she would need to eat 58,982 slices of bread to reach a toxic dose.*

Supplementary Classroom Activity 1

Hazardous Substance Exposure and Treatment Simulation

Objective

Students will be able to perform research on the exposure pathways, health effects, and treatment of patients exposed to hazardous substances.

Students will be able to work with a group to develop a script, action, and props for a simulated treatment of a patient or patients exposed to a hazardous substance.

Setting

Preview and show clips from any number of TV medical/hospital dramas of a treatment scenario, preferably one dealing with hazardous materials exposure.

Procedure

TV medical programs can be believable if people do enough research into the situation they are trying to create. Writers for these hospital dramas have access to real medical professionals as advisors. They also research their topics before trying to film them for an audience.

Supplementary Classroom Activity 1

Your task is to develop a scene—a mock response to a hazardous substance exposure event. The event must focus on the exposure itself, the health impacts of the exposure, and the medical treatment following the exposure.

The purpose of this exercise is to educate you and your classmates about the pathway, health effects, and treatment of a hazardous substance exposure. Your task is to develop a script and act it out in front of the class, or film it on location and show the tape to the class. The scene will deal with an exposure of a patient or patients to a hazardous substance, the patient's symptoms and health impacts as a result of the exposure, treatment, and prognosis for recovery.

Your cast of characters should include one or more patients, witnesses if appropriate, and medical professionals (doctors, nurses, paramedics, and ER staff). Your set, location, and costumes are up to you. You are required to hand in a complete script along with your performance. Remember that the goal is to educate your audience about the implications of exposure to the hazardous substance you choose.

Supplementary Classroom Activity 2

Develop a Fact Sheet

Materials

Access to computers, the computer lab, the library, and the Internet

Examples of Fact Sheets

Various art supplies (markers, colored pencils, construction paper, glue, tape, and scissors)

Copies of rubric

Objectives

Students will design a fact sheet intended to educate the public about the harmful health effects of hazardous substances.

Students will conduct research to support the information included in their fact sheet.

Procedure

List as many hazardous substances as you can. Pick one and write what you know about it. How does it affect human health? How did you learn about the health effects of this substance?

Discussion

Invite student to share answers.

Develop a consensus among the students by discussing what a hazardous substance is (a substance that could be harmful to people who come into contact with it).

Discuss the ways students have learned about hazardous substances.

Supplementary Classroom Activity 2

Show an example of a fact sheet. Have students seen one of these before? (Most likely they have in the form of anti-smoking or drug pamphlets.) Inform students that the purpose of a fact sheet is to inform the public about health issues and hazardous substances.

The students' task is to choose a hazardous substance and develop a fact sheet for it. Fact sheets should contain the following:

- Title
- An explanation of what the hazardous substance is
- An explanation of what happens when the substance enters the environment
- Description of how humans can be exposed
- Description of the health effects of the hazardous substance
- How to avoid exposure
- What to do if you are exposed
- Summary
- A section of references people can access for more information

Students are required to hand in a set of references to document the sources of their information.

Formatting

Traditionally, fact sheets are no longer than one page, filled front and back. Fact sheets can have simple or elaborate formats, as long as they effectively convey their message. The rationale behind a one-page document is that many people will not take the time to read a multi page document. Also, it is much easier to distribute a single page fact sheet to the public than multi-page documents. Provide examples of fact sheets for the students. Include a variety of formats (simple, columns, two and three fold pamphlets).

Evaluation

- Students will be required to peer review each other's fact sheets prior to handing them in, using the rubric.
- Rubrics should be used to evaluate the fact sheets. Students may develop their own or develop one in conjunction with the class, or use the rubric provided by the teacher.
- Encourage students to use the rubrics to assess their own work as they develop the fact sheets. You may want to practice using the rubric by allowing students to score sample fact sheets, matching their scores against yours.
- Students may be allowed class time to research and construct their fact sheets, or you may require that they work on their own, or both.

Closure

You may wish to have the students share their fact sheets, or even require them to present them in class. After evaluating the fact sheets, hang them in the hall, the library, the office, the nurse's office, or any place where they might be appropriate. You may even wish to submit them to your local health district for evaluation.

Unit 7
Agriculture

Background

Introduction

Will the Earth have enough agricultural resources to provide food for an ever-expanding human population? One key factor in determining our agricultural future is how food demand will change in relation to increasing population, higher incomes, and individual preferences. Another key factor will be competition of marginal land resources. Will the land be used for agriculture or urbanization? In light of global climate change, we must take into consideration that today's agricultural patterns may change in response to evolving precipitation, temperature, and weather patterns. Scientists and farmers are beginning to address the overuse and negative impacts of fertilizer and pesticide in ways that may lead to greater ecological sustainability. Economists are investigating the ability of farmers to maintain the sustainability of their commercial farm production. What will agriculture be like for future generations?

Essential Questions

What are the most productive forms of agriculture and how are we manipulating them to increase food production?

What are the benefits and drawbacks of fertilizer and pesticide use?

How can farmers change their agricultural practices for more sustainable food production and economic outcomes?

Content

Unit 7 focuses on the underlying principles of plant growth, Earth's resources, fertilizers, pesticides, and food production. The video for this unit describes agricultural practices related to rice production and sustainable economics for modern farmers. In the video you will learn how scientists such as Peter Kenmore from the United Nations Food and Agricultural Organization have been working with farmers to decrease the use of fertilizers and pesticides in rice production. We see the engagement of rice farmers in participatory and community-based scientific research that then informs their agricultural practices. This approach raises questions about the nature of science: who does it and when is it considered valid. The second part of the video describes how the perspective of today's farmers is changing to a conservation ethic and preservation of soil resources for future generations. Professor Pamela Matson studies the interactions of nitrogen in soil, water, and air resources in order to determine how to maintain ecosystems and farmers' standard of living.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. Agricultural production has kept pace with population increases primarily as a result of increased inputs.

ii. Earth has limited land resources for agriculture based on temperature, topography, climate, soil quality, and available technologies.

iii. The primary limiting factor for food production is the amount of water and nitrogen available for photosynthesis.

iv. Increased yields are a result of increased inputs.

v. The use of fertilizers and pesticides has ecological consequences.

vi. Recent technological innovations have influenced agricultural strategies.

b. Skills

i. Science is a process in which farmers and agricultural communities can participate.

ii. Science is an experimental process that includes verification of past studies.

iii. Science is a collaborative process.

c. Dispositions

i. Sustainability is essential to agricultural production for future generations.

Key Concepts

Photosynthesis	Irrigation	Radiometers
Increasing Yields	Fertilizers	Credit unions
Pests and disease	Pesticides	Photosynthesis
Livestock	Integrated pest management	Stomata
Biotechnology Agriculture and energy	Experimental design	Stomata
Sustainable agriculture	Peer review	Transpiration
Global climate change	Phytoplankton	Eutrophication
Harvest index	Green revolution	

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Agriculture

Agriculture is a declining industry and is less important because of its lower relative contribution to GNP and employment.

Agriculture is important because everybody eats food and lower income groups spend a large portion of their income on food. More nutritious food is a benefit to everyone.

Food production problems have been solved. Food prices are lower and there are surpluses.

In fact, new production technologies have raised new questions and created new ecological and economic issues. With more urbanization, increasing population, and rising income levels, world food demand is expected to increase significantly.

Agriculture can only be destructive/harmful to ecosystems and natural resources.

New approaches to agriculture, including integrated pest management and more sophisticated understanding of production techniques, can have positive impacts on natural systems.

Related Misconceptions about Ecology

Insects are harmful and eliminating them will benefit humans.

Many insects eat plants and can affect plant production. The elimination of some insect pests has disrupted natural predator-prey systems and resulted in decreased food production.

The addition of more nutrients automatically results in increased food production.

The careful and systematic use of fertilizers can result in increased production without increasing fertilizer application.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Each participant is given three index cards. On the first card, participants should indicate something they know about agriculture and agricultural procedures, such as the use of fertilizers and pesticides for control of insects. On the second card, they should write one question they have about either agriculture and food production. And on the third card, they should describe an experience they have had with agricultural concepts. Examples of comments and/or questions might be:

Agricultural practices in the world today are highly efficient.

Is the trade-off between food production and pesticide use worth it?

I met a person who argued that genetically modified foods are dangerous.

Getting Ready

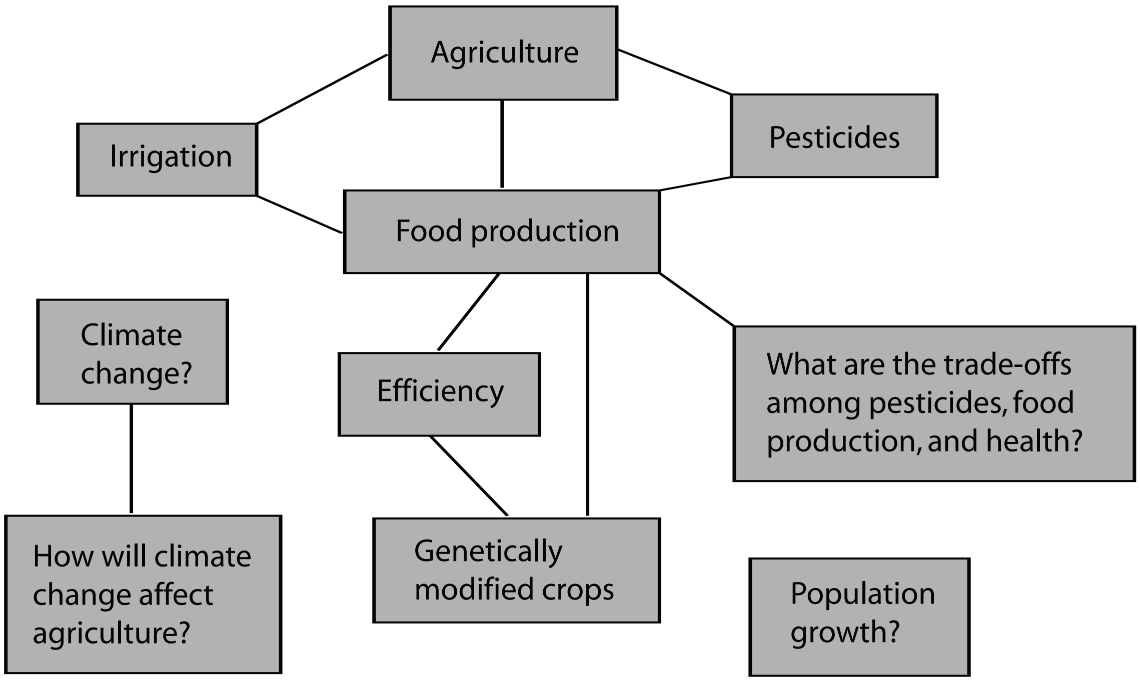


Figure 7.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: A Sustainable Agricultural Land-Use Scenario

In 1983, the World Commission on the Environment and Development, known as the Brundtland Commission, was established to assess the world's environmental problems and propose a global agenda for addressing these issues. The Commission identified a variety of environmental issues, such as living conditions, natural resources, population pressures, international trade, education, and health, and created a definition of sustainable development. According to the Brundtland Commission, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

This activity allows participants the opportunity to work through a potential sustainability scenario regarding the use of agricultural land and the application of chemical fertilizers, pesticides, and insecticides.

FACILITATOR: This activity will work best with at least three participants. If there are more, then groups of four work well.

Getting Ready

Materials

A large number of small objects of two different colors, such as small garden decorating stones, marbles, or candies.

Paper bags—one per group.

Setup

1. Divide the participants into groups of four.
2. Give each group a paper bag that contains 16 stones (or marbles) of one color. Each stone represents a hectare (2.5 acres) of usable agricultural land.
3. Give each group a handful of stones of a different color. These represent the fertilizers, pesticides, and insecticides.

Procedure

Participants draw one or more stones representing agricultural land from the paper bag. Each participant has to draw at least one stone in order to maintain an economically profitable level on his or her farm.

If participants do not draw a stone, then they lose their farm and are out.

Participants may take as many stones from the bag as they choose.

At the end of each round described below, the stones in the bag are counted, and an equal number of stones is added to the bag.

Activity

1. Round 1 and 2: First generation farmers. For each stone removed by a participant from the paper bag, one stone representing a fertilizer, pesticide, etc., is added to the paper bag immediately.
2. Round 3 and 4: Second generation farmers. For each stone a participant removes, three fertilizer stones are added to the bag immediately.
3. Round 5 and 6: Third generation farmers. For each stone removed from the bag, three fertilizer stones are added to the bag immediately.

Discussion

How did the action of the first generation farmers affect the third generation farmers?

During what round did the system collapse so that only polluted agricultural land remained? Explain what happened.

Were farmers able to sustain the agricultural resource? If so, how did they accomplish this?

Relate this scenario to the functional definition of sustainability presented by the Brundtland Commission.

How does this activity model the agricultural experiment shown in the video or described in the online text, especially as it relates to the future needs of generations of farmers?

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Are there advantages to growing rice in marginal environments?
2. What are the contradictory results from using pesticides to control insects in rice paddies?
3. Why is it important for farmers to conduct field experiments?
4. How does the study of nitrogen cycling illustrate a systems approach to understudying this issue?
5. How did the radiometer, the Green Seeker, illustrate how a technological breakthrough can add to an understanding to this fertilizer-environment issue?
6. What are the problems presented by the sugar cane borer and how has this been controlled?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. How will we feed the growing population and at what costs to the environment?
2. How do we meet the needs of people and decrease the use of pesticides and fertilizers?
3. How does natural selection play a role in the insect control dilemma?
4. Discuss the experimental design in the field for controlling insects.
7. Discuss the continuum of observation-discovery-new knowledge for managing the fields and the overall findings of this process.
8. Discuss the social and financial influence of credit unions on the fertilizer-environment issue.

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Bioaccumulation

Objective

Participants will develop an understanding of why some toxicants (such as pesticides) bioaccumulate. Most chemicals that bioaccumulate dissolve in lipids and therefore are not excreted but stay in body tissue.

Going Further

Materials

Oil
Red dye
5 100 ml beakers
2 400 ml beakers
Fishing pole
Red marker
Pipettes
Stirring rods
16 test tubes
1-liter beaker
Fish consumption advisories (one per participant)

Figure 7.2 Zooplankton

FACILITATOR: The following procedure is designed for a large group of participants. If you are working in a small group, each person could represent one part of the food chain, i.e., one person would represent all the zooplankton, one person all the little fish, etc.

Procedure

Review the food chain. Put an example on the board.

Explain that some chemicals accumulate in the fat of animals, like the pesticide DDT that was used to kill insects in order to protect crops.

With a group of 23 or 24, have 16 participants represent zooplankton. Give them each a test tube that contains 3 parts water and 1 part oil. These layers represent the fat and water in the organism. You can alter the number of zooplankton if necessary.

4 participants will be little fish. Give them each a 100 ml beaker.

2 participants will be big fish. Give them each a 400 ml beaker.

1 participant will be a fisherman/woman. Give this participant the fishing pole and a 1 liter beaker.

Make a solution using the red dye and oil and indicate to the group that this represents a fat soluble chemical like DDT.

Going Further

Activity

Read the following out loud to the class:

"While the zooplankton were feeding on algae, they digested 4 drops of pesticide. These 4 drops did not kill them or make them sick. However, more then 7 drops would have."

The zooplanktons should put 4 drops of the "pesticide" in their test tubes and stir them. They will notice the "pesticide" stays in the oil.

Read the following: "Each little fish will eat 4 zooplankton."

Each little fish should pour the contents of 4 zooplankton into their beaker. Have participants keep track of the amount of "pesticide" in each little fish.

Read the following: "Each big fish will eat 2 little fish."

Again have participants keep track of the amount of "pesticide" in the fish.

Discussion

The angler catches and eats two big fish. How many drops of "pesticide" are in the human? It takes 80 drops to kill or make the human sick. How many more infected fish could this human safely eat?

Why are pesticides are used in agriculture? Are there other ways to grow crops without using pesticides?

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 8 before the next session. Unit 8 describes how the world's water supply is allocated between major reserves such as oceans, ice caps, and groundwater. It then looks more closely at how groundwater behaves and how scientists analyze this critical resource. After noting which parts of the world are currently straining their available water supplies, or will do so in the next several decades, the unit text examines how humans are depleting freshwater supplies and the problems posed by salinization, pollution, and water-related diseases.

Between Sessions

Read for Next Session

For the next session be sure to read the Unit 8 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about water resources. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article, cartoon, or editorial related to water resources

Supplementary Classroom Activity 1

Transpiration Lab

Transpiration is the process through which water is lost from a plant by evaporation. Water is taken into a plant through roots and root hairs by osmosis, and it exits the plant through tiny openings on the underside of leaves known as stomata. While the stomata is open to let in carbon dioxide, water is lost. Transpiration is one of the main reasons water moves up the stem of a plant—water moves from a high water potential to a low water potential. In this experiment, four bean plants will be used to test transpiration rates under different environmental conditions. The conditions included a normal room setting (control) and exposure to a fan, heat lamp, and moist environment (plant misted and then covered with a plastic bag). Data will be obtained from each setting to determine if the various conditions affected the rate of water loss from leaves. Have students hypothesize which variable will cause the greatest rate of transpiration.

Materials

Graduated cylinder	Parafilm	Distilled water
Bean plants	Scalpel	Fan
Heat lamp	Spray bottle	Plastic bag to cover plant
Balance	1 cm x 1 cm graph paper	Scalpel

Procedure

1. Make a potometer by filling a graduated cylinder with water and covering it securely with parafilm. Poke a small hole in the parafilm. Remove the root from the plant and insert the plant into the parafilm hole so that the end of the stem is well below the water level in the graduated cylinder. Record the initial water level in the potometer. This plant will be your control. Repeat step number one but have a fan blowing on plant #2.
2. Repeat step number one but have a heat lamp on plant #3 .
3. Repeat step number one but mist plant #4 with water and then place a plastic bag over it.
4. Take readings of the potometer every 10 minutes after the initial reading for a total of 30 minutes. Record this data.

5. At the end of the 30 minutes, select one leaf of average size and trace that leaf on a piece of graph paper. Repeat for each condition.

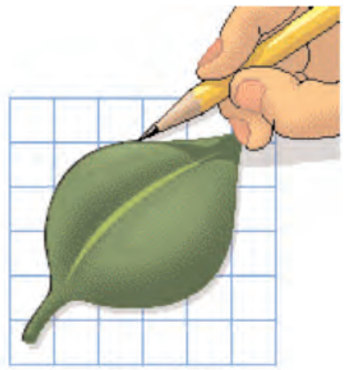


Figure 7.3 Tracing a leaf on graph paper.

6. Using the graph paper, calculate the area of the leaf.
7. Calculate the amount of water loss per square centimeter for each condition.
8. Graph the time versus water loss for each condition.
9. Calculate the rate of water loss for each condition by taking the total amount of water lost divided by 30 minutes.

Data

Condition	Water level At 0 min.	Water level At 10 min.	Water level At 20 min	Water level At 30 min	Water loss/cm^2	Rate of Water loss (ml water/min)
Room						
Fan						
Heat Lamp						
Mist						

Conclusion: Which condition had the greatest amount of water loss? Why? How does this affect agriculture?

Supplementary Classroom Activity 2

Eutrophication Lab

The purpose of this lab is to study the effects of fertilizer on pond water. Discuss with students what fertilizers are, why farmers need to use them, and how nitrogen is used in their bodies. Students should see that an increase in fertilizers causes an algal bloom that actually leads to a decrease in oxygen and a build up of sediment.

Materials

Pond water

400 ml beakers

Dissolved oxygen (DO) kit or meter

Fertilizer

Balance

Procedure

1. Measure the dissolved oxygen in the pond water.
2. Label beakers one through five and fill them with pond water.
3. Place the correct amount of fertilizer, according to the chart below, into each beaker.
4. Place the beakers in a sunny location.
5. Make observations for two weeks.
6. Measure the dissolved oxygen on the 7th and 14th days.

Beaker	Treatment
1	Control—no fertilizer
2	1 gram of fertilizer
3	2 grams of fertilizer
4	3 grams of fertilizer
5	4 grams of fertilizer

Data:

Day	**Observations**	**DO**
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		

Supplementary Classroom Activity 2

Conclusion

Discussion: What is an algal bloom?

Where did you see the greatest algal bloom?

Where did you see the lowest dissolved oxygen?

Where do these fertilizers come from? How do they get into a pond?

What are some alternatives to using fertilizers?

Unit 8

Water Resources

Background

Introduction

Water resources are under major stress around the world. Rivers, lakes, and underground aquifers supply water for drinking and sanitation, while the oceans provide habitat for a large share of the planet's food supply. Today, however, damming, diversion, over-use, and pollution threaten these irreplaceable resources in many parts of the globe and scientists widely predict that global climate change will have profound impacts on the hydrologic cycle.

Essential Questions

Can we meet the basic human and ecological needs for water, improve water quality, eliminate the overdraft of groundwater, and reduce the risks of political conflict over shared water?

Can we develop a model to understand a watershed system in order to manage water resources?

Content

Unit 8 describes how the world's water supply is allocated among major reserves such as oceans, ice caps, and groundwater. It then looks more closely at how groundwater behaves and how scientists analyze this critical resource. After noting which parts of the world are currently straining their available water supplies, or will do so in the next several decades, the unit examines how humans are depleting freshwater supplies and the problems posed by salinization, pollution, and water-related diseases.

The video illustrates how scientists go about collecting and verifying field data to address hypotheses. It also shows how individuals become involved in a specific research area in science based on their background and interests. The first part of the video addresses water use and management in Florida by reviewing the research of Dr. Wendy Graham, specifically in the central part of the state in the Suwanee River Watershed, and then describes resource management issues in the Everglades. The second part of the video focuses on watershed issues in Arizona with Dr. Tom Maddock and his study of groundwater flow. Both segments of the video address the importance of the managing a regional water resource supply and extend the model to state, national, and international levels.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. Water is a critical natural resource on Earth and is currently being stressed.

ii. The world's water is found in several major reserves, namely the oceans, groundwater, and glaciers and polar ice caps, and through the hydrological cycle, connects all of Earth's systems.

iii. Aquifers are important geological formations that serve as groundwater storage units and are being depleted faster than they can be recharged.

iv. Water resources are governed by political and economic systems.

b. Skills

i. It is more effective to study water-related issues at the watershed level.

ii. Science helps explain current events about global water issues.

iii. Scientists take a systems approach when studying watersheds and water issues.

c. Dispositions

i. Access to clean water for drinking and sanitation purposes is a basic human right.

ii. Water-related diseases need to be eradicated from developing countries.

iii. The Clean Water Act (1972) and Safe Drinking Water Act (1974) have generally protected public health and enforced standards of high water quality.

Key Concepts

Aquifer
Artesian
Capillary force
Catchment area
Discharge
Freshwater
Groundwater
Hydraulic head
Hydrological cycle
Hypoxia
Non-point source
Permeable
Point source
Pollution
Porous
Recharge
Salinization
Sorption
Total Maximum Daily Load
Valdose zone
Watershed
Wetlands

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Water Resources

Consider the following list of misconceptions as reported in the science and environmental education research literature.

- Many people believe that water originates from pipes, and not from watersheds, springs, and aquifers. There appears to be little understanding of the interconnections of the landscape and how water gets to a residence.
- It is a common misconception that wetlands are wastelands with no social or economic value to society. People tend to think of them as smelly and unproductive. Underlying basic ecological concepts of nutrients and productivity are little understood and the value of these transitional habitats is not recognized.
- Because people do not understand the interrelationships of the water cycle, they tend to believe that water flowing into the sea is wasted water. In fact this is an important connection in the hydrologic cycle.
- Because we seldom think about and never actually see groundwater, a number of misconceptions exist. Among them are:
  - Groundwater flows in underground rivers over great distances.
  - Groundwater is a non-renewable resource.
  - Groundwater is suitable for drinking without treatment.
- Seasonal changes in water resources and their ecological relationships are little understood. For example, many people believe that floods along rivers happen only after snow melts in the spring. (Recent news coverage of storm flooding may help correct related misconceptions.)
- A pervasive and interesting misconception is that all rivers flow "down" from north to south. This ignores the role of elevation and topography.
- Because the oceans are so vast, many people believe that oceans are a limitless resource. The also believe there are no political boundaries in the oceans. In fact, they are a limited and politically arbitrated natural resource.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Participants are given three index cards. On the first card, they should indicate something they know about watersheds or groundwater. On the second, they should write one question about either watersheds or groundwater. And finally on the third card, they should describe an experience they have had that relates to a watershed or groundwater. Examples of comments and questions might be:

- All drinking water is derived from surface water.
- What is the status of groundwater in our region or state?
- Are we vulnerable to a shortage of freshwater for drinking, bathing, etc.?

Getting Ready

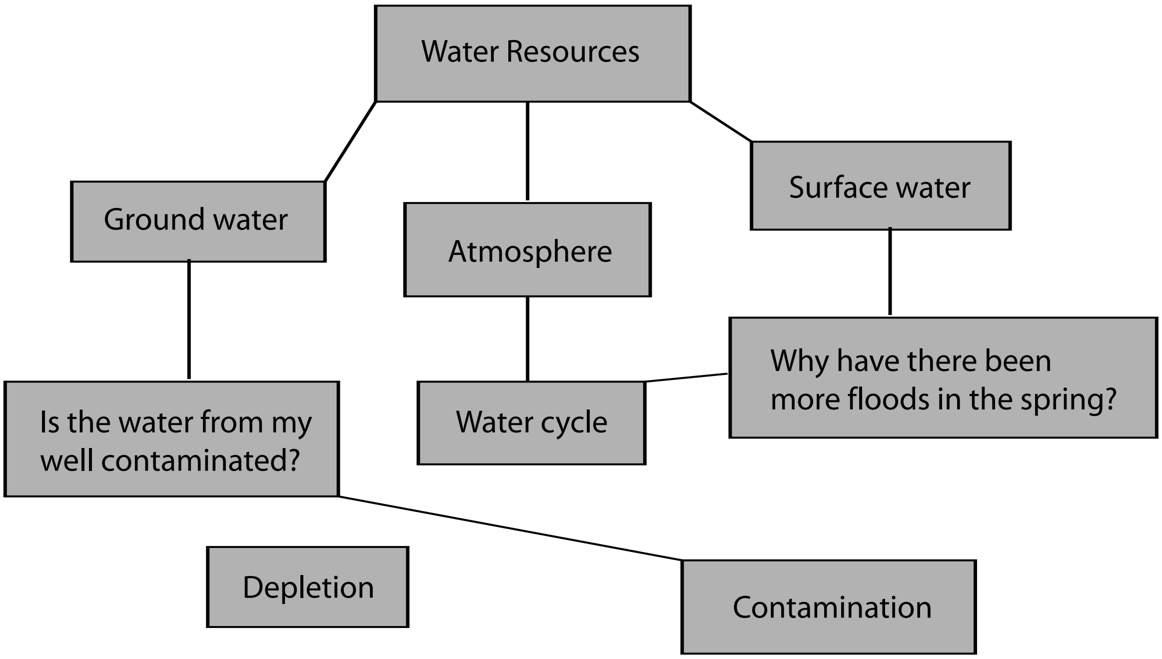


Figure 8.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: What is a Watershed?

In this activity, you will build a watershed model, then refer to a topographic map to note similarities between your model and the map to begin to understand the characteristics of a watershed.

Getting Ready

Part 1. Build Your Own Watershed

Materials

Stream table, children's pool, or large plastic container

Crumpled newspaper

Saran wrap

Spray bottle

Blue colored water

Clear acetate sheet for each participant

Erasable markers

Procedure

1. Build your watershed in a stream table, child's pool, or large plastic storage container.
2. Crumple some newspaper into a mountain-like form and tape to the bottom of container.
3. Using Saran wrap, cover the watershed/mountain structure, making sure to fit the wrap into the "nooks and crannies."
4. Using a spray bottle, squirt blue colored water over the watershed/mountain structure and make note where the water accumulates and runs down the watershed and makes streams and rivers to the base level.
5. Draw a diagram of your watershed and label the identified watershed components.

Part 2. Topographic Maps, Aerial Photographs, and Watersheds

1. Using a topographic map of the local area, identify the boundaries of the watershed in this area.
2. Place a clear, acetate sheet over a section of the topographic map and using an erasable marker, trace the boundary of the watershed, the path of the streams and rivers in the watershed, and any other important feature of the watershed.
3. Locate an aerial photo for this area using an appropriate Web site.

NOTE: There are many Web resources to locate watershed photos, topographic maps, etc. However we recommend using Google Earth since it is likely to be a common resource for most participants. Search for your own community and expand the Earth view to include all the water bodies associated with your watershed.

Discussion

1. What is the geographic area of your watershed and how does it compare to other watershed in your region?
2. Where are the main water bodies that store water for future use?
3. How does the population distribution of your community correspond to the distribution of water?
4. How are communities in your region connected by their watersheds?

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Describe the watershed systems studied by the principal researchers.
2. How does modeling play a role in understanding these watershed systems?
3. What do the scientists researching the various watersheds do with the hydrological models they develop?
4. Describe the importance of the riparian zone to the watershed as a whole.
5. Why is the process of evapotranspiration important to the understanding of the hydrological cycle in a region?
6. How do various chemicals identified as pollutants impact the overall aquifer?
7. Using the karst topography of central Florida as an example, describe the relationship of geology to the watershed.
8. How do you balance agricultural needs with human water use needs?

Activity Five: Discuss the Video

1. How far can you stress the watershed system before you cause ecological collapse?
2. Are there any examples in your watershed that are obvious stressors on the system?
3. What are some competing uses of water in your community?
4. Are there any current events that relate directly to the watershed you live in? Explain them and discuss public opinion regarding any problems or solutions.

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Community Water Resources

Have you considered where your water supply originates or where water goes after it is used? In this activity, you will research water resources in your local community. Sources of information can be your home water bill, if available; the United States Geological Survey (USGS website http://waterdata.usgs.gov); your town or city website; or your state department of environmental services or related agency.

FACILITATOR: If a computer with internet access is not available, print out data concerning local water use, supply, problems, etc., from the USGS water web site.

Going Further

Research answers to the following questions and share your answers with other members of the group.

1. In your community:
   a. What are the major sources of the water supply?
   b. How is water use divided among agricultural, industrial, power plant cooling, and public uses?
   c. Who are the biggest consumers of water?
   d. What has happened to water prices in the past 20 years?
   e. What water supply problems are projected?
   f. How is water being wasted?
2. Identify any floodplain areas in your community. Develop a map showing these areas and the types of activities found on these lands. Evaluate the management of such floodplains in your community and come up with suggestions for improvement.
3. In your community:
   a. What are principal non-point sources of contamination of surface water and groundwater?
   b. What is the source of drinking water?
   c. How is drinking water treated?
   d. Has pollution led to fishing bans or warnings not to eat fish from any lakes or streams in your region?
   e. Is groundwater contamination a problem? If so, what has been done about it?
   f. Is there a vulnerable aquifer or critical recharge zone that needs protection to ensure quality of groundwater?

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this unit. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 9 before the next session. In Unit 9, the decline of Earth's biological diversity will be considered. Subtopics will examine the gene pool, ecosystem structure, and endangered species.

Read for Next Session

For the next session be sure to read the Unit 9 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about biodiversity decline. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to biodiversity decline.

Supplementary Classroom Activity 1

A Long-term Watershed Study

This activity is a web-based study of one of the most influential, long-term watershed studies in the United States. The intent of this exercise is to introduce students to the nature of watershed and forest ecology research studies that provide data to understand the processes and mechanisms of watersheds and cycling of water through forests. The Hubbard Brook Experimental Forest (HBEF) is part of the White Mountain National Forest, located in central New Hampshire in the town of West Thornton. It is part of the Long Term Ecological Research program (LTER) funded by the National Science Foundation. The data from the Hubbard Brook Experimental Forest (HBEF) is now used in many environmental science, biology, and chemistry textbooks as a source for acid precipitation data, watershed dynamics, and nutrient and water cycling in forests, as well as an example of one of the longest forest ecology studies in the United States.

You can simulate these studies in local areas by using sampling protocols from watershed or aquatic sampling manuals and forest ecological methods references. The activities are designed to teach basic ecological principles and inquiry skills and to make students aware of the value of long-term research as a basis for conservation management and regional planning decisions.

Materials

Computer with Internet access and printer

Supplementary Classroom Activity 1

Procedures

Go to http://www.hubbardbrook.org

Click on the Students and Teachers button; then from the pull down menu click on the 6–12th Grade Educational Resources; and finally Teacher and Student Resources.

Once at the Teacher Resource page, you can access various activities, databases, and information that relate to the research at Hubbard Brook.

A series of activities can be downloaded and used in your schoolyard, laboratory, or classroom. These activities are related to the science and research conducted at the HBEF and contain actual data, protocols similar to those used at HBEF, and suggestions for research projects. Topics include an introduction, a watershed deforestation experiment, and forest ecology.

There are links in the left hand column to handouts for the virtual tour. These handouts are written at different levels of difficulty depending on the nature of the content covered and student abilities. National Science Education Standards can also be accessed and adapted to your specific state suggestions. Finally, a series of activities can be accessed from the Long Term Ecological Research link (Teacher's Manual of Classroom Activities).

Procedures and discussion questions are included with each activity in these sites.

Notes

Unit 9

Biodiversity Decline

Background

Introduction

In 1854, Chief Seattle said, "Man did not weave the web of life—he is merely a strand in it. Whatever he does to the web, he does to himself." Extinctions are occurring at an alarming rate due to human behavior. As humans expand their habitat and introduce invasive species, more native species are put at risk. Biodiversity is important for the stability of ecosystems. When one species is removed from an ecosystem, it is hard to predict what impact it will have on the rest of the organisms in the ecosystem. It is a difficult task, but scientists need to define and measure biodiversity to determine exactly what it is that we are at risk of losing. It is critical that we discuss how to protect biodiversity while we are still defining it.

Essential Questions

How is the health and stability of our ecosystem related to biodiversity?

What impact will biodiversity loss have on humans and other life?

How can we protect biodiversity?

Content

Unit 9 focuses on the importance of biodiversity to the health of ecosystems. Part One of the video is with Dr. Bill Laurance and Dr. Sue Laurance from the Smithsonian Tropical Research Institute. Their main focus is to determine how humans affect the tropical rainforest. We are losing 80 football fields of tropical rainforest per minute, ultimately leading to the extinction of thousands of species, many of which we've never even identified.

Part Two follows Professor Jeremy Jackson and his research studies of ocean ecology. His primary focus is on human impact on ocean ecosystems. He discusses how the shifting baseline syndrome makes it hard to know the entire impact over-fishing has had on the ecosystem. He has found that 90 percent of the big fish are gone compared with data from the 1950s. When the large fish are gone, seaweed overgrows and destroys the coral, demonstrating that removing just one species can lead to the collapse of an entire ecosystem.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

   i. Biodiversity encompasses genetic, species, and ecosystem diversity.

   ii. Fossil records help scientists understand biodiversity.

   iii. Threatened, endangered, and extinct species are indicators of general ecosystem health.

   iv. Humans are the cause of the sixth mass extinction.

   v. Biodiversity is threatened in many ways.

   vi. Habitat loss and invasive exotic species are the largest cause of biodiversity loss worldwide.

   vii. Pollution and over-harvesting threaten biodiversity.

b. Skills

   i. Science is a descriptive process.

   ii. Science is an experimental process.

   iii. Science helps explain current events.

c. Dispositions

   i. Communicate reasons why biodiversity is valuable and should be preserved.

   ii. Identify actions one can take to help preserve biodiversity.

Key Concepts

Biodiversity	Ecosystem
Carrying capacity	Species
Species richness	Genetic diversity
Gene pool	Natural selection
Threatened species	Endangered species
Vulnerable species	Extinct
Habitat	Generalist
Specialist	Habitat fragmentation
Exotic species	Invasive species
Baseline	Endangered species act (ESA)

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Biodiversity

Below are some misconceptions that people may have about biodiversity, as well as some clarifying information.

Not all species are important, so some have to be sacrificed.

> Often it is difficult to fully appreciate the complete impact a species has on an ecosystem. The complex interactions between species are often unknown. The loss of a single pollinator could have profound effects seen all the way up through the food chain.

If there is a lot of one species, then the ecosystem must be healthy. For example, if there are a lot of rock doves (pigeons) in the park, then the ecosystem is healthy.

> In fact, to have a healthy ecosystem you need diversity with populations that approach the carrying capacity of an ecosystem.

It is very common for people to think that large empty spaces that are unmanaged are wastelands. This can range from a vast expanse of desert to an abandoned city lot.

> However, we know that ecologically these spaces are very necessary to provide habitat for many species, thus protecting our biodiversity.

Biodiversity is not important to humans.

> It is a common misconception that humans are not part of the ecosystem, but we indeed are an important part in the web of life and so biodiversity is important for us.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about biodiversity. On the second, they should write one question they have about biodiversity. And on the third card, they should describe a direct experience that they have had that relates to biodiversity. For example an individual might write:

> There are two different types of squirrels that live in the park.
>
> How many types of plants and animals live in my community?
>
> I took a beautiful walk in the forest when I visited Mexico.

Getting Ready

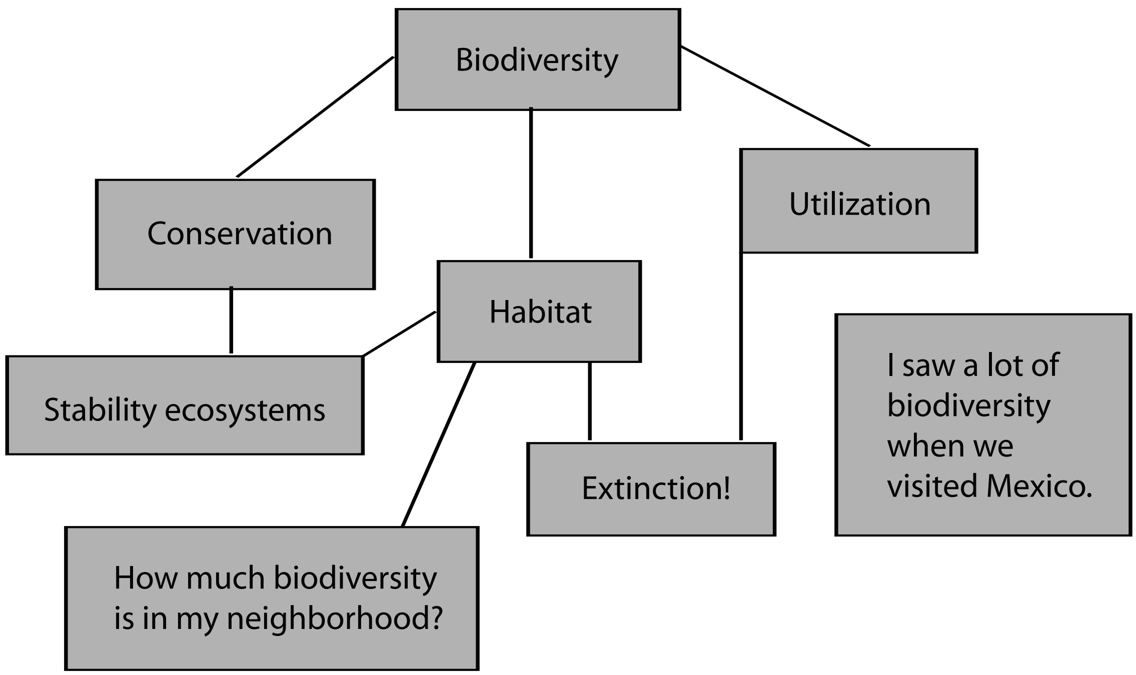


Figure 9.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found related to the week's topic. Everyone in the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Biodiversity Pre-Test

Another approach to testing prior knowledge is to conduct a pre-test. Participants should take the test below anonymously and then choose one of the following options.

1. The facilitator will analyze the results for misconceptions and discuss the results at the next meeting.
2. The facilitator leads a large group discussion of the correct answers directly after participants take the test.
3. Participants get in small groups and discuss their answers.

At the end of this unit, participants should take the test again to see what they have learned.

Getting Ready

Test Yourself: How Much Do You Know About Biodiversity?

Mark T in front of each statement you believe is true and mark F in front of each statement you believe is false. *Answers to the test below can be found after the Between Sessions section.*

______ 1. All species on Earth have already been discovered.

______ 2. More than one half of the world's species live in tropical forests.

______ 3. Just over 10 million species have been identified by scientists.

______ 4. Earth has more species than it needs.

______ 5. Most species do not benefit humans.

______ 6. All habitats have the same number of species.

______ 7. Biodiversity includes genetic diversity, species diversity, and ecosystem diversity.

______ 8. Biological diversity is more threatened now than at any time in the past 65 million years.

______ 9. The loss of forests, wetlands, grasslands, and other habitats contributes to loss of biodiversity.

______10. Many species become extinct without ever being identified.

______11. Large plants, birds, and mammals make up half the world's species.

______ 12. The countries with the most species of plants are located in Central and South America and in Southeast Asia.

______13. Coral reefs are as rich in biodiversity as tropical forests.

______14. Islands can be homes to species found nowhere else.

______15. Fewer than 100 species currently provide most of the world's food supply.

______16. Crop breeders need a diversity of crop varieties in order to breed new varieties that resist insect pests and diseases.

______17. Creating parks and zoos is the best way to preserve biodiversity.

______18. The biological resources of developing countries are a possible source of income.

______19. Two major causes of biodiversity loss are population growth and the increasing consumption of natural resources.

______20. Once a species becomes endangered, it will become extinct.

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. What is Dr. Bill Laurance studying? How does it relate to biodiversity?
2. What is forest fragmentation? Why are scientists concerned about forest fragmentation?
3. Why are tropical rainforests described as the lungs of the planet?
4. How are old-growth trees and birds affected by the increase of the forest edge, according to Dr. Sue Laurance?
5. What is Professor Jeremy Jackson studying? How does it relate to biodiversity?
6. What is the importance of coral reefs to the ecosystem.
7. Why is a baseline so important? Why can't you just look at how the world is now?

Activity Five: Discuss the Video

Discuss the following questions about the video and how it applies to your situation?

1. Describe the research being conducted in the tropical rainforest and in the coral reefs. Compare and contrast these investigations.
2. Will the land fragmentation lead to "islands of survival" or "islands of extinction"?
3. How have people changed the ocean ecosystem?
4. Construct a food web of the ocean ecosystem. What happens to this web when fish are removed? How does it relate to the loss of biodiversity?
5. Discuss the "Rise of Slime."
6. What can you do to address the problem of biodiversity loss?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Timber Harvesting Community Role Play

This is a group activity where participants will read a case study, role play, and, as a group, come to a consensus on how the issue can be resolved. The activity requires a minimum of 8 participants.

1. Before class, prepare the role cards. Participants are going to be in groups of eight. Determine how many groups of eight you will have and then number the cards accordingly. For example, if you have 24 participants, you will have three groups, so you should make three copies of the set of roles. Place a 1 on each role card in the first set, place a 2 on each role card in the second set, place a 3 on each role card in the third set, etc.

Going Further

2. Participants should read the case study.
3. The roles are as follows: facilitators, local citizens, land managers, conservation biologists, recreational housing developers, county commissioners, timber company representative, and land trust representatives.
4. Split the participants into 8 groups and assign a role to each group.
5. Give each group a copy of their role card. People in this group all have the same role. Give participants approximately 5 minutes to discuss their interests in the cases, possible actions, etc.
6. Have participants get in their new groups according to the number on their role card. In each group there should be one of each role. If you don't have a multiple of 8 then one participant may have to take on two roles. Each group must have a facilitator.
7. When participants are in their groups, the facilitator should have each member express his or her concerns. After everyone has had a chance to speak, then the group needs to come to a consensus. The facilitator should take notes, record the group's consensus, and have everyone sign the paper before it is turned in.
8. When every group has come to a consensus, the group facilitator should then share the results with the rest of the group.
9. After each group has made its presentation, discuss how biodiversity was at risk in this case study.
10. Just as we saw in the video, land fragmentation is an issue here as well. Discuss how and why this is a problem. Has anything like this happened in your community?

Case Study

A publicly traded timber company is feeling pressure to improve its bottom line. Due to increased international competition and a spike in the price of raw materials due to local over-harvesting, profits have plummeted and shareholders are demanding a turnaround. To make a quick profit, the company has decided to sell 250,000 acres of forested land to the highest bidder. Approximately one fourth of the land they intend to sell has river and lake frontage and thus will be sold at a premium. Because these particular tracts are more valuable, these parcels are sub-divided into the smallest plots zoning allows in order to maximize profit. The smallest lakeshore lot size the local government will allow is five acres. Other parcels will be divided into 10-, 20-, and 40-acre lots so they can be sold as quickly as possible.

Local government officials are in favor of this action because it will increase the local tax base, allowing residents' taxes to go down or remain stable while increasing the services (e.g., new or improved highways, social services, etc.) provided to the community.

However, these forested lands are unique, providing critical habitat to many species, particularly migratory songbirds that spend the summer here. Of the 56 species that time their migration to coincide with the abundance of insects to feed their young, 12 are threatened and 2 are on the brink of extinction. Because of the unique bird species found here, a national birding organization has named the area one of the five top "hot spots" for members to add to their species life lists. An activity not to be overlooked, bird-watching has become the most popular outdoor recreational activity and local motel owners have recently noticed an increase in the number of birders. To capitalize on this opportunity, the hospitality industry, the state tourism board, and birding organizations are proposing a birdwatchers' auto route through the area.

As the timber company places its land on the market, a local developer takes notice and proposes to buy the prime lake and riverfront properties in order to develop recreational housing on them. The developer's proposal calls for cabins and summer homes to be built on one acre lots. Since this plan would exceed the current zoning standard, the developer must ask for an exemption from the county planning and zoning office. A national land trust, recognizing the importance of this land for wildlife, has also begun negotiating with the timber company. Its goal is to preserve land for future generations, but it would be unable to do so if the county planning and zoning office approves the decreased lot size.

What should this community do?

Going Further

Case Study Role Cards

Local Citizen
You are concerned about how your family's quality of life will be changed by this development. Hunting and fishing have a long history in the area and are an annual tradition. These opportunities will be reduced as more land will be posted "Closed." With more houses and roads there will be an increase in storm water run-off, and water quality will decrease, affecting fishing in the remaining lakes and rivers. Competition for use of the remaining public lands will increase.

Conservation Biologist
Your job is to do research. You have studied the forest ecosystem that is being considered for development. You know that these woodlands are an important habitat for nesting songbirds that are threatened and endangered. In other areas you have seen their population decline dramatically after development. You also know that these birds are an indicator species; a decrease in their population tells you that the entire ecosystem is being affected.

County Commissioner
Your job is to oversee the functioning of the county government and pass resolutions affecting land use. You were elected by the people to represent their best interests. You would like to see development because it will increase the local tax base and that will mean a decrease, or a least no increase, in taxes from your constituents. Also, this development will increase employment opportunities. With a new election coming soon, you want to please your constituents.

Recreational Housing Developer
People need recreational homes to get away from the city and "revive" themselves. The local economy also needs this development, which will provide much needed employment opportunities.

Land Manager
Your job is to enforce how land is managed and cared for. You are an advisor to the county commissioner and you would like to see development minimized, especially around water. You will recommend that any housing developments are set back at least 200 feet from any body of water in order to decrease the rate of surface water run-off and the amount of nutrient loading. Too many nutrients in the water will decrease the habitat for fish and other aquatic species.

Timber Company Representative
You want to make as much money from the 250,000 acres as possible but are still willing to listen to the concerns from the community.

Facilitator
Your job is to make sure everyone at the table has a chance to speak and that they are heard. You should not share your personal opinions. You need to help the group come to a consensus on a plan. You should take notes and record the resolution that the group agrees upon. Once the group has agreed to the resolution, you should have each sign the document while also recording the role he or she played.

Land Trust Representative
Your organization would like to purchase this land to ensure that it remains undeveloped. You are very concerned about the loss of ecosystem diversity. However, your group cannot afford the same price as the housing developer. As a non-profit organization, your group does not have to pay property taxes. However, you are willing to pay the taxes in order to help maintain the tax base of the community.

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Next Week's Topic Overview

Read Unit 10 before the next session. In Unit 10, the emphasis is on energy—the types of energy we use and the impact it has on the environment. From industrial to household consumption of electricity and transportation, we are all dependent on energy. This unit discusses the environmental impact that results from of our use of non-renewable forms of energy and the types of renewable forms of energy that exist.

Read for Next Session

For the next session, be sure to read the Unit 10 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about energy. Consider discussing the topic with your friends or students and discussing common misconceptions.

Between Sessions

Current Events

Bring in a current event article or cartoon related to energy.

Answers to "How Much Do You Know About Biodiversity?"

1. *False*. Scientists discover new species daily and they estimate that there may be as many as 30 million species.
2. *True*. Over one half of the world's species live in tropical forests.
3. *False*. It is estimated that fewer than 1.4 million of the world's species have been named. Most of the unidentified species live in the tropics and in the ocean.
4. *False*. Species evolve to fill particular niches or habitats that exist on Earth. Many species depend on each other for survival. Destroying one species can lead to further extinction or changes.
5. *True or False*. We don't know. Scientists are often delighted to find a cure for a human disease in a mold or obscure plant. It seems foolish to destroy our genetic storehouse before we have even taken inventory. Also, extinction of a species can upset the balance of a complex ecosystem.
6. *False*. Some habitats, such as tropical forests, have many more species than others.
7. *True*. Biodiversity includes genetic, species, and ecosystem diversity.
8. True. Tropical deforestation is the main force behind this crisis. The destruction of wetlands, coral reefs, and temperate forests is also important.
9. *True*. As habitats are fragmented and destroyed, many species become extinct.
10. *True*. Habitats are destroyed without being studied.
11. *False*. Large, visible species of mammals, birds, and plants make up fewer than 5 percent of the world's species.
12. *True*. The world's rainforests are located in these countries.
13. *True*. Coral reefs are habitats with biotic richness.
14. *True*. Remote islands such as Hawaii have unique flora because evolution takes place there in isolation.
15. *True*. Fewer species are grown today than in the past. Genetic diversity is declining.
16. *True*. Monocultures dominate most forms of agriculture.
17. *False*. Zoos and parks are traditional strategies for protecting biodiversity and have helped preserve many species. However, newer strategies are needed to address the root causes of biodiversity loss.
18. *True*. The biologic beauty of these countries is an economic benefit as tourism increases.
19. *True*. Other root causes are lack of knowledge of species and ecosystems, poorly conceived policies (for example, those that favor deforestation), and the failure of economic systems to account for the value of biological resources.
20. *False*. Species can be protected by preserving habitat and by breeding programs in zoos and botanic gardens.

Supplementary Classroom Activity 1

BioBlitz

The BioBlitz is a chance for schools and communities to explore the biodiversity in their own backyards. By doing a BioBlitz you are able to determine what is living in a particular area at a particular point in time. To complete this activity you want to involve as many people as you can. The challenge is to document as many species as possible in a 24 hour period. The event can be as scientific as you want to make it and you can bring in professionals in your area to help you document as many species and taxonomic groups as possible. A BioBlitz gets people involved in their own communities and promotes a positive awareness of resources and local conservation. This is also a great opportunity for students and adults to experience first-hand how real science is put to work.

Prior to completing the BioBlitz you will want to select a site and collect several sets of field guides of all species (e.g., birds, fungi, lichens, mammals, plants, trees, insects, aquatic invertebrates). A kit should be made for each group of participants. These kits can be made with large plastic bags and should include: field guides, a first aid kit, map, binoculars, hand lens, snacks, and a data sheet.

Sample Data Sheet

Scientific Name	Common Name	Taxonomic Type	Site Found

If this becomes an annual activity, participants in the BioBlitz can discuss whether the biodiversity is changing and if so, why? This would also provide an opportunity to discuss the necessity of a baseline as was discussed in the video for this unit.

The following web links may be useful:

http://web.uconn.edu/mnh/bioblitz/

http://www.fieldmuseum.org/bioblitz/

http://www.pwrc.usgs.gov/blitz/

Supplementary Classroom Activity 2

Exotic Species

The introduction of exotic or invasive species is one of the main causes of loss of biodiversity. Students are split into groups of three. Each group researches one exotic or non-native species in its area to find out how it got there, what native species it is displacing, and what actions can be taken to prevent further spreading of this species. Each group should then share its findings with the rest of the class by creating an informational poster. The poster should include the following information:

- Picture
- Where the species is found
- Where it came from
- Whether it was introduced accidentally or deliberately
- What harm it does to the environment or economy
- What native species have been displaced
- What can be done to prevent further spreading

Removal of invasive plant species, such as spotted knapweed: After consulting local government and receiving permission and instructions, students could remove the invasive plant species in their area while keeping population data and location using a GPS.

Unit 10

Energy Challenges

Background

Introduction

We all rely on energy in our daily lives, from the foods that we eat to transportation to lighting and heating our homes. As our human population continues to grow exponentially, our consumption of coal, oil, and natural gas rises with it—along with global temperatures. The energy that we currently use comes from non-renewable sources, which produce the greenhouse gas carbon dioxide. This unit explores the consequences of our current energy consumption habits. It addresses renewable energy sources such as biomass, biofuels, solar, wind, and hydrogen technologies. Carbon sequestration is also discussed as a potential solution for removing carbon dioxide from the atmosphere and storing it in the ground.

Essential Questions

What forms of energy are available?

What are the benefits and drawbacks of current energy sources?

How can we provide the energy we need while maintaining ecological balance?

Content

Unit 10 focuses on resources that are used to produce energy. The Unit 10 text examines forms of non-renewable and renewable energy supplies for their benefits and limitations. Currently coal, oil, and natural gas supply the majority of our energy, while producing the greenhouse gas carbon dioxide and many other pollutants. The text looks at renewable forms of energy including nuclear power, biomass energy, hydropower, geothermal energy, wind power, solar energy, and hydrogen power.

Part One of the video discusses carbon capture and sequestration and the use of biofuels for transportation. You will meet scientist Dr. Neeraj Gupta, who is working on ways to purify carbon dioxide emissions from coal producing plants and then to store this CO_2 as a liquid deep underground. The video briefly describes the importance of solar energy and wind power in our need for clean renewable energy. Part Two of the video describes the research being done at the National Renewable Energy Laboratories (NREL) by scientists such as Andy Aden. A goal of NREL is to produce enough biofuels to meet one-third of the gasoline needs in the United States by the year 2030. A major concern with ethanol is that in its current production it uses corn kernels to produce fuel, which competes with people's need for food. Scientists at NREL are therefore trying to find an efficient way to use cellulosic material to avoid taking crops away from the food supply.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. Conservation is a necessary first step toward meeting today's energy needs.

ii. Current coal, oil, and natural gas deposits were formed over millions of years as a result of the accumulation of prehistoric plant and animal matter.

iii. A number of clean, productive renewable energy technologies are available and necessary to meet today's energy needs.

iv. Both non-renewable and renewable energies have limitations.

v. There are important benefits to using renewable energies.

b. Skills

i. Science is a descriptive process.

ii. Science is an experimental process.

c. Dispositions

i. Energy has a direct impact on social, economic, political, environmental, and economic systems.

ii. Science helps explain current events.

Key Concepts

Non-renewable energy

Renewable energy

Fossil fuels

Nuclear power

Biomass

Biofuels

Carbon sequestration

Hydropower

Geothermal energy

Wind energy

Solar energy

Photovoltaic

Hydrogen power

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Misconceptions about Energy

Renewable energy is a second rate form of energy.
Renewable energy is non-polluting and produces energy of the same quality as that from non-renewable sources.

Renewable energy systems are too expensive.
While scientists agree that there is a financial cost associated with renewable energy, people need to consider the environmental cost when they use non-renewable sources of energy.

Background

Wind turbines are noisy.

Modern wind turbines produce very little noise. The turbine blades produce a whooshing sound as they encounter turbulence in the air, but the noise tends to be masked by the background noise of the blowing wind. An operating modern wind farm at a distance of 750 to 1000 feet is no noisier then a kitchen refrigerator.

Solar energy only works well in warm, sunny climates.

Solar technologies can work efficiently anywhere as long as they're placed correctly. Photovoltaic cells (solar panels) actually become more efficient at colder temperatures. Solar thermal collectors for hot water can make adequate amounts of hot water, even at subzero temperatures. Passive solar heating works well in any climate as long as the building is well insulated.

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences (20 minutes)

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about energy production. On the second, they should write one question they have about energy production. And on the third card, they describe a direct experience that they have had that relates to energy use. For example an individual might write:

Gasoline is burned in cars to produce energy for them to run.

How does solar energy work?

Last summer, when it was really hot, we didn't have any electricity.

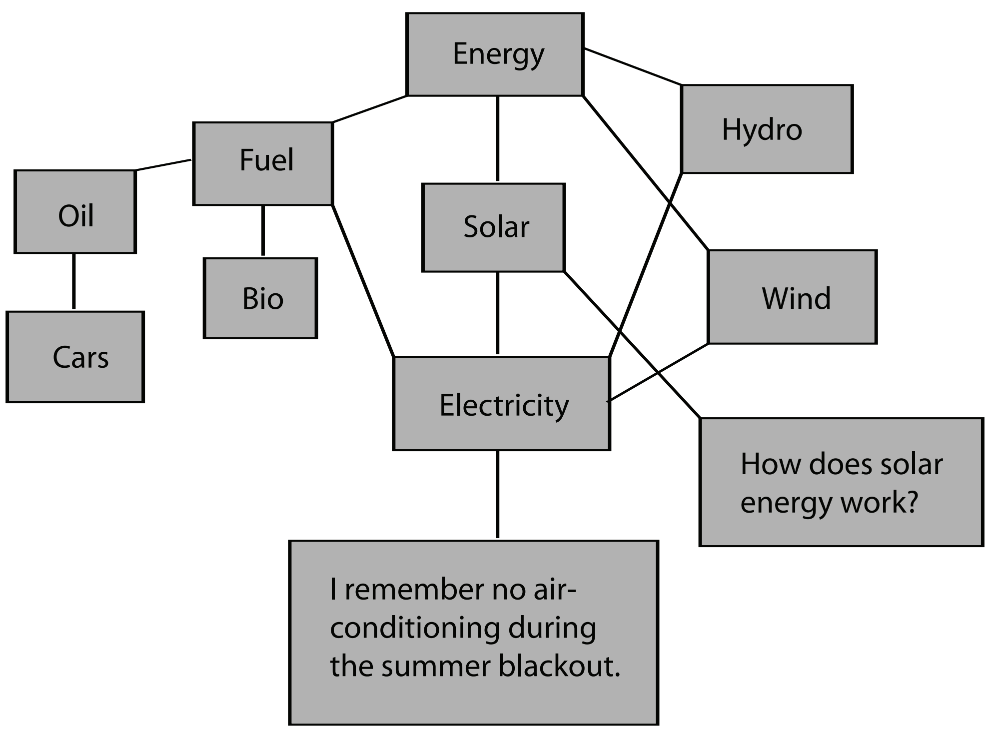


Figure 10.1 The study groups idea collection with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other group members and the unit content.

Background

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Home Energy Quiz

Each participant should complete the following quiz. After participants have calculated their energy score, the facilitator should combine the results for each question and find the mean number of points for each question. In a large group, discuss where the greatest amounts of energy are used. Then break into smaller groups and ask participants to discuss ways to make their homes more energy efficient. After approximately 10 minutes, have each group share their ideas.

Background

Home Energy Quiz

How much insulation do you have in your attic?
- 6 inches or less (2 points)
- 7 to 11 inches (4 points)
- 12 inches or more (6 points)

How often were your furnace filters cleaned or changed in the last year?
- Not at all (0 points)
- 1 to 3 times (2 points)
- 4 or more times (4 points)

How many compact fluorescent light bulbs do you have in high-use areas of your house?
- No compact fluorescent bulbs (0 points)
- 1 to 4 compact fluorescent bulbs (2 points)
- 5 or more compact fluorescent bulbs (4 points)

What is the temperature on your thermostat in winter and summer?
- Winter
  - 74ºF or higher (2 points)
  - 71ºF to 73oF (4 points)
  - 70ºF or lower (6 points)
- Summer
  - 74ºF or lower (2 points)
  - 75ºF to 77ºF (4 points)
  - 78ºF or higher (6 points)

What is the size of your home?
- Small—less than 1000 ft^2 (6 points)
- Average—1000 ft2 to 2500 ft^2 (4 points)
- Large—2500 ft^2 or larger (2 points)

What type of vehicle does your family drive?
- Small compact car (6 points)
- Full size car (4 points)
- Van (2 points)
- SUV or truck (0 points)

When traveling in your vehicle, are you:
- Usually alone (0 points)
- Sometimes with someone else (2 points)
- Usually with someone else (4 points)
- Always with someone else (6 points)

Do you recycle?
- Always (6 points)
- Usually (4 points)
- Seldom (2 points)
- Never (0 points)

Add up your score and see where you fit in.
8–21: There are a lot of ways to improve the energy efficiency of your home that will help same energy, money, and the environment.
22–36: Your house could be more energy efficient and comfortable.
37–50: Congratulations! You are well on your way to becoming an energy super-star!

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Why is burning oil, natural gas, and coal of concern to us?
2. What is the goal of carbon sequestration and how do scientists at Batelle Memorial plan to meet this goal?
3. Why do the holes for carbon sequestration have to be so deep?
4. What does the term "renewable" mean?
5. What are the benefits or using biofuels as energy for transportation?
6. What are the concerns about using biofuels as energy for transportation?
7. What is cellulosic material and why are scientists at the National Renewable Energy Laboratories researching it?
8. What are other possible energy sources for transportation?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. Discuss how scientists at Batelle Memorial and the National Renewable Energy Laboratories conduct their research. How does this reflect the nature of science?
2. What is the relationship between carbon sequestration and global climate change?
3. What are the advantages and disadvantages of using biofuels? Can you propose an alternative to fossil fuels and biofuels for transportation?
4. Based on what you learned from the video, discuss an energy plan for your school that minimizes the amount of carbon dioxide put into the atmosphere.

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Online Energy Interactive Lab: Part 1

FACILITATOR: Participants will need access to the Internet and should be directed to http//:www.learner.org/channel/courses/envsci/interactives/energy.

Overview

In the world today, with populations and economies booming, the demand for energy is rising. A portfolio of different energy sources is used to meet this demand. In this lab, the challenge is to try to meet the world's projected energy demand by choosing from the available energy sources, while keeping atmospheric CO_2 under control and also avoiding the particular limits and pitfalls associated with each energy source.

Simulation 1

Before the industrial revolution, the world's atmospheric CO_2 levels were below 280 parts per million (ppm). Levels have now risen to ~380 ppm. In order to limit the worst effects of climate change, many scientists believe we must keep peak atmospheric CO_2 to no more than double the pre-industrial concentration, or about 550 ppm.

The goal of this lesson is to try to keep total atmospheric CO_2 under 550 ppm limit while staying within the tolerances defined for each specific fuel source. If you approach a limit on a particular fuel, you will be given a warning. The slider bar will change color and indicate that you cannot use more of that particular fuel. If you hit a hard limit, depleting the entire world's reserves of that fuel or power source, you will not be allowed to increase the use of that power source.

You should use the following chart to graph the changes in energy per year and the atmospheric carbon dioxide while also recording the changes you made.

Year	Changes Made	% Oil	% Coal	% Gas	% Biofuel	% Nuclear	% Hydro	% Solar	% Wind
2000									
2010									
2020									
2030									
2040									

Were you able to keep atmospheric CO_2 under 550 ppm from the year 2000 to 2100? What needs be done to help you meet this goal?

Going Further

Simulation 2

If people start conserving energy and if our technology becomes more energy efficient, less CO_2 will be emitted. In this simulation you can introduce improvements in energy efficiency by using the "advanced options" tab. When you click on this tab, you can decrease energy demand, increase energy efficiency, and increase carbon capture and storage. The goal again is to keep atmospheric CO_2 under 550 ppm or even lower by the end of the century.

Graph the changes in energy per year and the atmospheric carbon dioxide while also recording the changes you make in the following chart.

Year	Changes Made	% Oil	% Coal	% Gas	% Biofuel	% Nuclear	% Hydro	% Solar	% Wind
2000									
2010									
2020									
2030									
2040									
2050									
2060									
2070									
2080									
2090									
2100									

Were you able to keep atmospheric carbon below 550 ppm. If so, what made the difference this time?

Conclusion

The problem of meeting the world's energy needs while limiting dangerous atmospheric CO_2 concentrations is neither easily solved nor insurmountable. As you've seen in this lab, no energy source is a magic bullet. Energy efficiency will be key as well, because energy that isn't expended is the cleanest energy of all. There may also be technologies on the horizon that will help with some of our fuel sources.

Going Further

Activity Six: Online Energy Interactive Lab: Part 2

What are the advantages and disadvantages of our energy sources? In this activity, participants will use the information from Unit 10 to fill out the following table.

Energy Source	Renewable?	CO_2 emissions	Advantages	Disadvantages
Coal				
Oil				
Natural Gas				
Nuclear Power				
Biofuel				
Hydropower				
Geothermal				
Wind Energy				
Solar Energy				
Hydrogen				

Going Further

Discussion

With a partner, compare your results.

In a large group, discuss similarities and differences of the energy sources and respond to the following questions.

1. What energy sources are being used currently where you live?
2. What energy sources will be best for your future?
3. How do we get there from here?

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Next Week's Topic Overview

Read Unit 11 before the next session. In Unit 11, the emphasis is on atmospheric pollution. When fossil fuels are burned, CO_2 is not the only pollutant that is a concern. Mercury, nitrogen dioxide, and sulfur dioxide are also emitted. This unit will examine: surface air pollution, ozone depletion, green house gases, acid rain, and mercury pollution.

Read for Next Session

For the next session be sure to read the Unit 11 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about atmospheric pollution. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to atmospheric pollution.

Supplementary Classroom Activity 1

Renewable Energy Project

In this project students will investigate and present information on one form of renewable energy. The teacher should divide students into groups of four and assign (or let them choose) a form of renewable energy. The types of renewable energies to choose from are: solar, geothermal, wind, hydroelectric, hydrogen, biofuels, and methane. If you allow students to choose, be sure there is at least one group for each energy source so students will learn about all seven energy sources.

Student Handout

You may work with a team of up to four people to complete this task. Each person on the team will take on one of the following expert roles and have the responsibilities that go along with that role:

The Research

SCIENTIST: You are concerned with understanding and explaining how this energy source works. Here are some questions you will want to consider for your presentation.

1. What is the source of power or raw materials for this energy source?
2. How does the system harness and transfer energy?
3. What are the by-products from this energy source?
4. Is it possible to use this energy source in our area of the country?

ENVIRONMENTALIST: You are concerned with the effects of this technology on nature. You want to explain how this new project could impact the natural surroundings. You would ideally want to see technology that will not produce greenhouse gases and that will not consume natural resources in such a way that would adversely affect future generations of both humans and other species. Here are some questions you will want to consider for your presentation.

1. Are there any harmful wastes produced by this technology?
2. Will natural habitats be adversely affected by this technology?
3. Are there any concerns to public health and safety?
4. How will using these energy resources contribute to global warming?

ECONOMIST: You are concerned about how much the technologies will cost. You want an energy source that is both efficient and cost effective, something that will give a return on the initial investment to put the technology in place.

1. How does the cost of this energy source compare to the current cost of fossil fuels in this area?
2. How much money will it cost to start to use this technology?
3. How much money will be saved by using this technology over the long term?
4. Does this technology create any extra employment opportunities?

HISTORIAN/SOCIOLOGIST: You are concerned with how this energy source has been used around the world. Humans have always used energy to improve their quality of life. Many different types of energy have been used in different regions and at different times in history. Here are some questions you will have to answer in your presentation.

Supplementary Classroom Activity 1

1. When was this energy source first discovered or invented?
2. Where in the United States or other countries is this energy source currently used?
3. How easily do you think our community would accept using this new energy source?
4. How much energy is currently produced using this technology?
5. How has this technology affected the lives of the people who use it?

The Presentation

After completing your research, you will present your information to the group. Your presentation should include:

- An oral presentation with 2 to 3 minutes of information from each of your team member experts.
- A poster, PowerPoint presentation, or portfolio that includes pictures that show how your energy source is used.
- A written report with information from each of your team member experts. Each team member should prepare 2 to 3 pages typed, double-spaced. It should include a bibliography of all references used.
- A scale model or demonstration that will help the audience visualize how the energy source works.

Supplementary Classroom Activity 2

Electrolysis of Water

Note: It is recommended that the teacher try this activity before doing it with students.

Introduction

Hydrogen is a renewable source of energy as long as it is not harvested from fossil fuels. Hydrogen is non-polluting because when it burns it combines with oxygen in the air to produce water. In this lab students will see how hydrogen can be separated from water through the process of electrolysis, using electricity to separate the molecules. They will then see the amount of energy contained in a small amount of hydrogen when they burn it to form water.

Pre-Activity Discussion Questions

How is hydrogen produced?

What happens when hydrogen is burned?

Why is hydrogen considered a non-polluting, renewable energy resource?

Materials

electrodes, sodium hydroxide, 400 ml beaker, water, DC power supply, alligator clips, test tubes, graduated cylinder, stir rods, wood splints, matches, safety glasses

Set up

Students should work in pairs.

Supplementary Classroom Activity 2

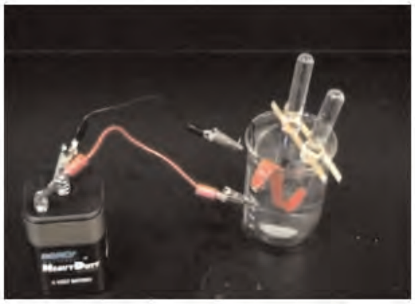


Figure 10.2 Experimental Set-Up

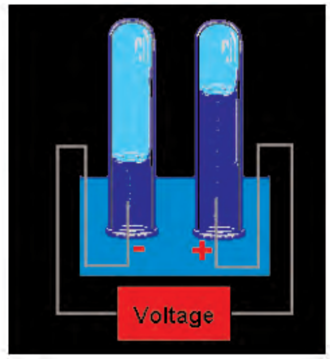


Figure 10.3 Experimental Results

Procedure

1. Wear safety glasses throughout the experiment.
2. Fill the beaker half full with water.
3. Fill each test tube with water so there is no air in the test tube. Using a small piece of plastic or cardboard, cover the test tube and invert it into the water in the beaker. There should be NO air bubbles in the test tubes.
4. Add 0.5 grams of sodium hydroxide to the water. Stir. The sodium hydroxide acts as a catalyst to speed up the reaction. The reaction would occur without this catalyst but at a much slower rate.
5. Place the electrodes as shown above. A section of the metal portion of the electrode should be outside of the test tube.
6. Attach the electrodes to the DC power supply. Observe.
7. When one of the beakers is filled with gas, disconnect the electrodes.
8. Using a rubber band, mark the test tube that is not completely full so you can measure the amount of gas collected later.
9. Carefully remove both test tubes from the beaker. DO NOT invert the test tube or you will lose the gases you've collected.
10. Place a flaming wood splint into the mouth of the test tube that was completely filled with gas (the test tube should still be upside down). Observe.
11. Insert a glowing splint up past the rubber band of the test tube that was half full (the test tube should still be upside down). Observe.
12. Measure the amount of gas collected in both test tubes.

Supplementary Classroom Activity 2

Data

Make observations while the test tubes are filling with gas. Record anything interesting that you notice.

Record the volume of gas in each test tube.

Write the chemical equation for electrolysis of water: (2H2O ------> $2H_2$ + O2)

Write the chemical equation for the burning of hydrogen: ($2H_2$ + O2 -------> $2H_2O$)

Conclusion

What gas was in each test tube? How did you determine this? Why is hydrogen a good source of energy?

Discussion

Through this activity students will see that hydrogen can be produced by the electrolysis of water. Twice as much hydrogen gas will be produced as oxygen gas. When hydrogen is burned, the only byproduct is water. Currently, the problem is finding an energy source that will carry out the electrolysis of water in order to produce the hydrogen renewably and efficiently. Discuss with participants ways that hydrogen could be produced from water without using fossil fuels.

Unit 11
Atmospheric Pollution

Background

Introduction

The increase in world population and the growth of industry have resulted in an increase in atmospheric pollution. This pollution is the cause of many deaths and serious health problems. To further understand atmospheric pollution, we must study where pollutants come from, how they behave, and how they are globally transported. Then it will be possible to make changes in our society that will allow us to live longer, healthier lives.

Essential Questions

Over the course of industrial history, what have we learned about atmospheric pollution?

How does today's increased population and industrial use impact the atmosphere?

What does the future hold in terms of prevention of atmospheric pollution?

Content

Unit 11 begins with the health risks associated with atmospheric pollution and the four types of processes that affect air pollution levels: emissions, chemistry, transport, and deposition. This creates the context for the unit, which then provides a detailed description of the identification of primary and secondary pollutants, where they come from, and how they interact with each other.

In Part One of the video for Unit 11, you will be introduced to Charles Kolb and his mobile laboratory, a vehicle equipped with atmospheric pollutant measuring devices. This vehicle has been employed by several cities in the United States to conduct studies of atmospheric pollution. In Part Two of the video you will meet Luisa Molina, who is a lead scientist in the Megacity Initiative Local and Global Research Observation (MILAGRO) project taking place in Mexico City. Over 450 scientists from 50 academic research associations in Europe, Mexico, and the United States have developed instruments to collect and record data that will allow the largest study of its kind to be a model for other megacities around the world.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

i. Atmospheric pollution is affected by emissions, chemistry, transport, and deposition, at a global and local level.

ii. Atmospheric pollutants can be primary or secondary.

iii. Atmospheric pollution has drastic effects on the health and well-being of people, plants, and animals on Earth.

b. Skills

i. Atmospheric pollution requires interdisciplinary study because of its complex interactions with other Earth systems.

ii. When studying atmospheric pollution, a spatial approach is important because of the dynamic nature of Earth.

c. Dispositions

i. Pollution in the atmosphere affects all life on Earth.

ii. Ongoing research and study can provide new knowledge that would decrease atmospheric pollution, improving life and enhancing our ability to be stewards of Earth.

Key Concepts

Acid rain	Mercury	Primary pollutant
Aerosol/particulate matter	Methane	Radical
Ambient	Montreal Protocol	Secondary pollutant
Anion	National ambient air Quality standards	Smog (industrial/photochemical)
Carbon monoxide	Nitrogen oxides	Sulfur dioxide
Cation	Non-attainment areas	Volatile organic compounds/hydrocarbons
Chlorofluorocarbon	Ozone	
Hydroxyl radical	Photodissociation	

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions and Atmospheric Pollution

Many people mistakenly associate the creation of ozone as a positive thing. They may think that because there is an ozone hole, creation of ozone would be beneficial. However, ground-level ozone, which is different from Earth's stratospheric ozone layer, is the most important secondary air pollutant.

Another common misconception is that climate change and the loss of the ozone layer are pretty much the same thing. In fact, climate change and the loss of the ozone layer are two different problems that are not very closely connected. The largest contributor to global warming is carbon dioxide gas released when coal, oil, and natural gas are burned. Chlorofluorocarbons (CFCs), gases that cause stratospheric ozone depletion, play only a minor role in climate change. The depletion of the stratospheric ozone layer, including the ozone hole, is a serious environmental problem because it causes an increase in ultraviolet radiation, which can harm people, animals, and plants. This is a different problem from climate change.

The recent emphasis on ozone and aerosol cans has led to the belief that aerosol spray cans are a major contributor to climate change. However, we know that using aerosol spray cans has almost no effect on climate change. In the past, aerosol spray cans contained CFCs, which contributed to the depletion of the ozone layer (not the same as global warming). Under U.S. law, aerosol spray cans no longer contain CFCs.

Educational research tells us that most people believe that general pollution and toxic chemicals are major contributors to climate change. Scientific research tells us that most forms of pollution play little or no role in climate change. The invisible carbon dioxide released when coal, oil, and gas are burned is the single most important contributor to climate change. The burning of fossil fuels, such as coal and oil, to produce energy for electricity, heat, and transportation is the primary source of carbon dioxide, which is the most important contributor to global warming. Carbon dioxide does not contribute to general air pollution.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about air pollution. On the second, they should write one question they have about atmospheric pollution. And on the third card, they should describe a direct experience that they have had that relates to atmospheric pollution. For example, an individual might write:

> Atmospheric pollution affects everyone.
>
> How does air pollution happen?
>
> It's hard to breathe when the atmosphere is polluted.

Getting Ready

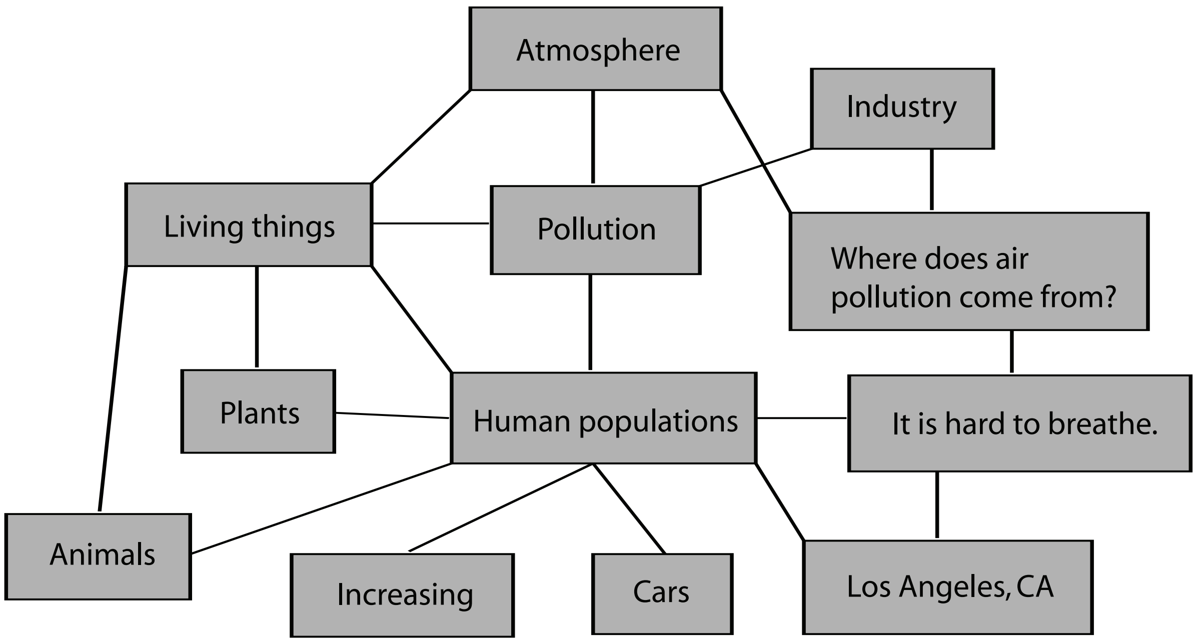


Figure 11.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Tree Leaf Symmetry

This activity creates appreciation for our natural resources by demonstrating to participants one aspect of the biosphere that is affected by atmospheric pollution. It is important to note that this activity is not meant to create understanding for the participant but to assist in the learning process.

FACILITATOR: You need to collect a good selection of representative sample leaves from a variety of locations. Keep them organized and bring them to the group meeting.

Materials

Topographic map of local area of study, areas marked

Leaves

Getting Ready

Setup

1. Facilitator will collect leaves from a predetermined area and mark a map with the location of the area selected.
2. Facilitator will explain to participants that a normal healthy tree leaf will be bilaterally symmetrical, and that slight variations that occur in the right and left symmetry are usually caused by errors during the development of the tree or leaf. As the stress on the environment increases, so does the asymmetry.

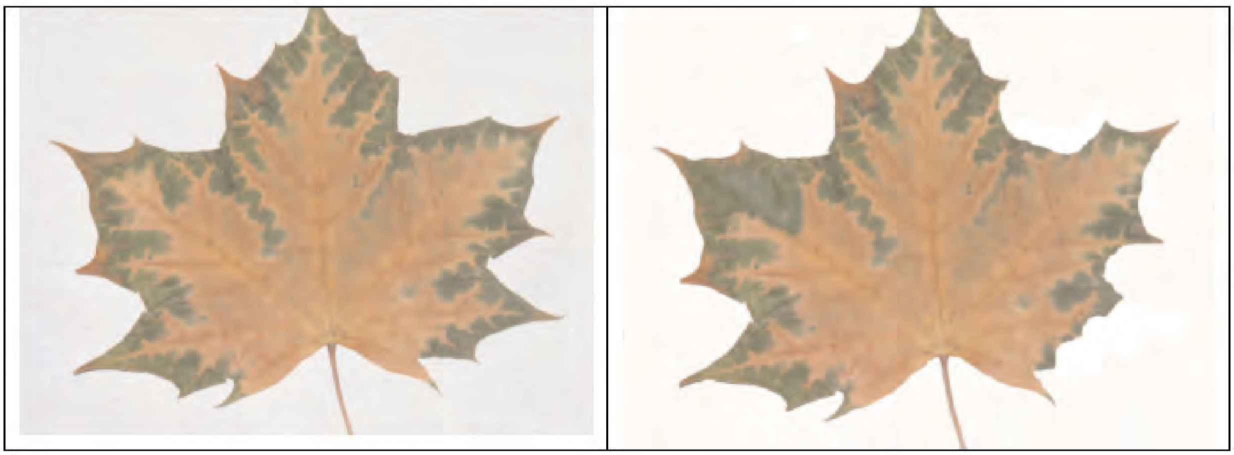


Figure 11.2a and 11.2b Photos of the different types of asymmetry seen in tree leaves

Procedure

1. Trace an outline of each leaf and label.
2. Fold outline in half to compare the symmetry of each leaf.
3. Rank each leaf tracing in order from most to least symmetrical.
4. Assess the quality of the environment by asymmetry of the leaves that they examine.

Discussion

1. What type of pollution causes one leaf's symmetry to be so radically different from the normal symmetrical leaf pattern?
2. What type of pollution was in the area where these leaves were collected?
3. Is the asymmetry of leaves found in other polluted areas different or similar?

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions:

1. Why is it important to study the atmosphere in relation to air pollution?
2. How do primary and secondary pollutants form?
3. What are the names and chemical formulas for three of the most studied pollutants (primary or secondary)?
4. What is MILAGRO?
5. Why is it important that we study Mexico City?
6. What is important about Aerodyne's mobile laboratory?
7. How are atmospheric pollutants measured?
8. What are some of the health risks associated with atmospheric pollution?
9. How long does it take for the global air to circulate once around the world?
10. What are some regional and global effects of atmospheric pollution?

Activity Five: Discuss the Video (15 minutes)

Discuss the following questions about the video.

1. What implications does Aerodyne's mobile laboratory have for emissions monitoring and control of automobiles?
2. How does the temperature of each of the atmospheric layers affect the behavior or pollution?
3. Why is the creation of ground ozone harmful?
4. What can be done to decrease the air pollution that will be produced by an increasing world population?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Discussion of Local and National Air Quality

This activity encourages participants to apply their knowledge from reading the text and watching the video to answer questions related to specific situations and geographical areas. The EPA website located at http://www.epa.gov/air/data/geosel.html has various options for generating air quality reports that are region- or state-specific.

Going Further

Part 1

Generate a report for air quality in cities in the United States. Print out the report found at the EPA Web site for the United States, Air Quality Index Report, Metropolitan Statistical Area (MSA) summary type, for the year of 2006 (or later, if available).

The report includes data on 303 cities throughout the United States. Among the data, the group will find the air quality index, status of air quality, and levels of various pollutants such as carbon monoxide, sulfur dioxide, and ozone. Participants can compare and contrast the various cities. For example, they can compare the number of days the air quality was good, moderate, or unhealthy.

Discussion

1. To what extent does the population of a city affect the number of days of satisfactory air quality?
2. What is satisfactory air quality?
3. To what extent does the geography of a city affect the number of days of satisfactory air quality?
4. Compare the local air quality conditions to other sites throughout the United States.

Part 2

Go to the EPA website above and generate reports for the specific location of the group. At the web site:

Select the geographic area for the report.

Select the maps and reports you want for the group.

Select the types of measurements you want to consider.

Participants should examine the reports about their local area and then discuss what contributes to the status of air quality in their community.

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Next Week's Topic Overview

In Unit 12, the emphasis is on global warming and climate change. You will read about Earth's past climate as well as the impact of human activities on our climate today.

Read for Next Session

Read the Unit 12 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about global warming. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to global warming.

Supplementary Classroom Activity 1

Collecting Atmospheric Particles

Introduction

This activity allows students to discover how many particles are in the air. This activity can be used to measure the amount of particles in the air at different locations. Examining the particles under a microscope can extend this activity.

Materials

Circular paper filters

Vaseline

Procedure

1. Apply a very thin layer of Vaseline on the paper filter.
2. Leave the paper filter in an area undisturbed for a pre-determined amount of time.
3. Examine the paper filter after the time has passed and draw conclusions about the quality of the air based on their findings.

Results

Students can present their findings to the class or, as mentioned above, use a microscope to examine the particles and continue to do research about air pollution.

Supplementary Classroom Activity 2

pH and Plant Growth

Students will test plant growth with different pH levels, and, understanding that the pH scale is exponential, draw conclusions about acid rain's effect on plant life.

Materials

Wisconsin fast plant seeds, or other fast-growing plant seed

Vinegar or lemon juice

Bicarbonate, such as baking soda

Film canisters with hole drilled in bottom

Shallow plastic pan

Re-usable kitchen wipes

Pre-cut "wicks" from kitchen wipe

pH test kit

Soil

Setup

1. Prepare solution samples of varying acidic pH levels based on research about acid rain.
2. Place the wick through the hole in the bottom of the film canister, then plant the seeds approximately _ to _ inch below the surface of the moist soil.

Procedure

1. Place the film canisters on a moist kitchen wipe that is laid in the bottom of a shallow pan. It is important to place all film canisters that will be watered with the same type of pH water in the same shallow pan; keeping a small amount of water in the shallow pan will water the plants.
2. Keep the plants under growing lights that are on a timer that closely resembles the natural daylight cycle, or keep them in the window to get natural light.
3. Water each group of plants with the designated water. Testing the pH of the water every couple of days would be advantageous.

Results

Teacher and students should decide together on the format for reporting to the rest of the class. For example, they could create a lab report or present a poster that describes the experiment.

Notes

Unit 12
Earth's Changing Climate

Background

Introduction

Earth has been undergoing one of the most extensive experiments in the history of civilization. Today the planet is warmer than it has been for thousands of years. Climate changes can be caused both by natural forces and by human activities. Ancient records of climate, held in glacial ice formations, offer some clues about a warming world. Global climate change could result in rising sea levels, changes to patterns of precipitation, increased variability in the weather, and a variety of other consequences. These changes threaten our health, agriculture, water resources, forests, wildlife, and coastal areas.

Essential Questions

What do we know about global climate changes over the course of Earth's history?

What are the effects of global climate change on today's world?

What does the future hold in terms of global climate change?

Content

Unit 12 focuses on how present warming trends over the entire planet are caused by human activities, how past changes have been investigated, and what future warming scenarios might hold for natural and human ecology. The Unit 12 text introduces basic science concepts and focuses on Earth as a complex system that constantly changes. The global climate system is explained in terms of geological, hydrological, biological, and sociological interactions, which all affect global climate. Unit 12's content builds from Unit 2, Atmosphere, and leads to interesting projections of near-term impacts and the major laws and treaties that will affect future generations.

In the Unit 12 video you will be introduced to the idea that future changes might be predicted by knowledge of the past. In Part One, Dr. Lonnie Thompson and his work using ice cores from tropical glaciers to investigate past climate change provide an interesting insight into ecological field sciences and past environmental conditions. Dr. Thompson's studies indicate clearly that recent climate change is a result of human activities. However we are not sure what the future holds for ecosystems. In Part Two we meet Dr. Chris Field, whose Jasper Ridge Global Change Experiment uses various climate change scenarios to attempt to predict 50 to 75 years in the future. The results of these studies will help us to better understand, predict, and cope with global climate change.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following:

a. Knowledge
   i. Atmospheric changes take place over time.
   ii. World-wide data has been collected on climate change.
   iii. The rate of change has increased in recent history.
   iv. Atmospheric change results in plant growth changes.
   v. Climate change has direct ecological consequences.
   vi. Ecological consequences cannot necessarily be predicted.

b. Skills
   i. Science is a descriptive process.
   ii. Science is an experimental process.
   iii. Science helps explain past, present, and future events.

c. Dispositions
   i. Global climate change has a direct impact on social, economic, political, and economic systems.
   ii. Science helps inform us about ecological effects of changing systems.

Key Concepts

Earth's atmosphere

Greenhouse effect

Greenhouse gases

Aerosols

Climate change

Global warming

Carbon cycle

Recent history

Industrial age

Impacts

Human society

Natural ecosystems

Laws and treaties

Feedback systems

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions and Climate Change

With the increasing public awareness and media focus on ecological conditions, it is clear that educators must address the common misconceptions people hold about climate change. The causes of misunderstandings related to climate changes come from applying ideas drawn from other ecological problems such as pollution and ozone depletion, confusing concepts of climate and weather, and intuitive observations of the existing environment.

A common misconception is that the greenhouse gases responsible for climate change are forms of air pollution. We know that pollution is made up of artificial chemicals or substances that are toxic to life. Automobiles and industry are the principal sources of these toxic chemicals. Confusing air pollution with climate change leads to misconceptions about the health effects attributed to bad chemicals and thus climate change. The pollution model of climate change ignores the influences of farming, deforestation, and efficient energy use in global climate change.

If climate change results in deforestation, it is possible that animals will use more oxygen than plants produce and will not be able to breathe. Most people know that plants (trees) take in carbon dioxide and give off oxygen. We also know that deforestation is contributing to raising the level of atmospheric carbon dioxide. Therefore, in some peoples' minds, because there are fewer trees, animals may eventually use up all the oxygen in the atmosphere and be unable to breathe.

Misconceptions about weather and climate are very common. People consider human activity to be a major factor in weather change. In addition, people believe that they have already witnessed the effects of global climate change on local weather conditions. The popularization of global climate change has provided a conceptual framework for people to interpret their personal observations. The correct interpretation is that global climate change includes changes in weather patterns, more violent tropical storms, rising sea levels, and shifts in ocean currents that could cause regional climate changes shifts in ecological zones and alterations in patterns of plant growth and development.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about climate change. On the second, they should write one question they have about climate change. And on the third card, they should describe a direct experience that they have had that relates to climate change. For example an individual might write:

Climate change is occurring faster than ever.

What causes climate change?

It seems the winters are warmer with less snow.

Getting Ready

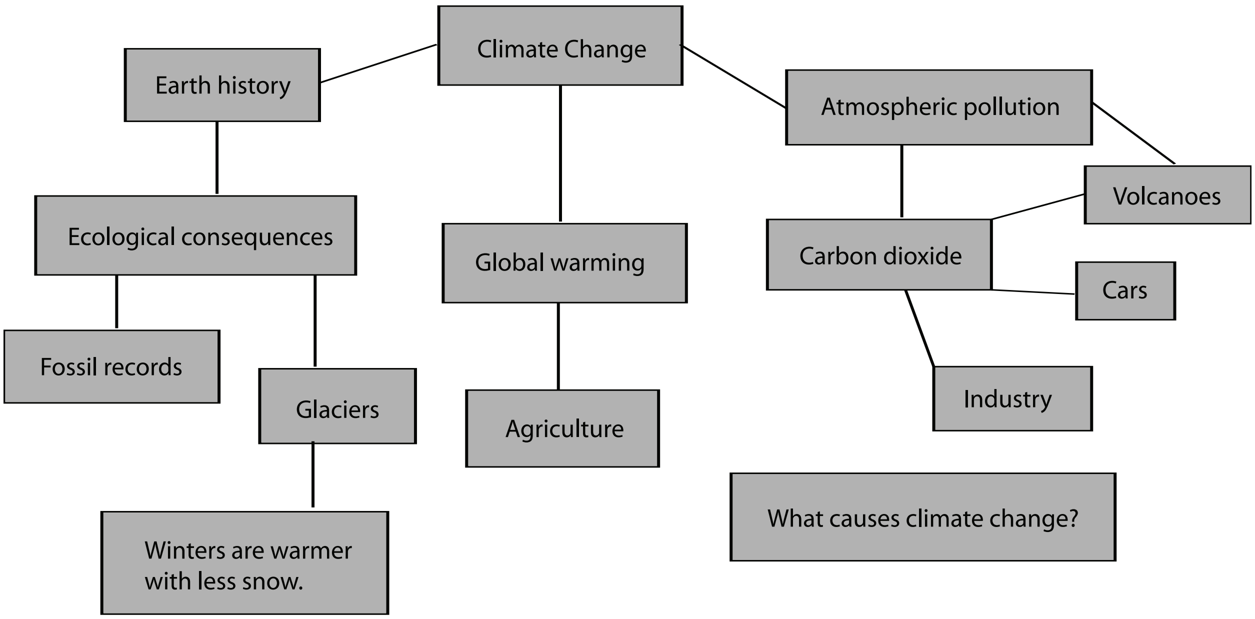


Figure 12.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Greenhouse Demonstration

The demonstration can be used during the first half of this study session to illustrate or investigate global climate change. The materials and apparatus should be set up before the workshop begins.

Materials

2 identical containers	Vinegar
2 covers	Baking soda
clock	2 shallow dishes
light source	2 thermometers
Matches	Setup

The containers should be placed side-by-side with 5–10 cm between them. Place a thin layer of black sand on the bottom of both containers. Put one thermometer inside each tank. The thermometers should be located and oriented so that they can be easily read when the experiment is underway. Place one dish, face-up, in the center of each tank. The dishes should be broad and shallow. Mount the light above the containers. The light should have at least a 150 watt bulb. Measure 5 ml of vinegar for 1 ml (~1 g) of baking soda for one container.

Procedure

The demonstration should begin with the containers at room temperature and with the light source off. Add the vinegar slowly to one container so that the dish does not overflow. At the start of the demonstration, note the temperatures in the two containers. Repeat these measurements at regular intervals every 30 seconds, until the temperatures in both tanks begin to plateau.

NOTE: It is important to begin this experiment with the containers near room temperature and to allow a minute or so between turning the light source on and taking the first temperature measurement. One complicating factor in this demonstration is that the vinegar-baking soda-CO_2 producing reaction is endothermic. During the reaction itself, the temperature in the experimental tank may go down. Give the containers time to adjust to the temperature changes.

Discussion

1. Which container heats faster and to a higher temperature?
2. Why is there a difference between the containers?
3. How is this demonstration similar to the greenhouse effect?
4. What conclusions can you draw about climate change?

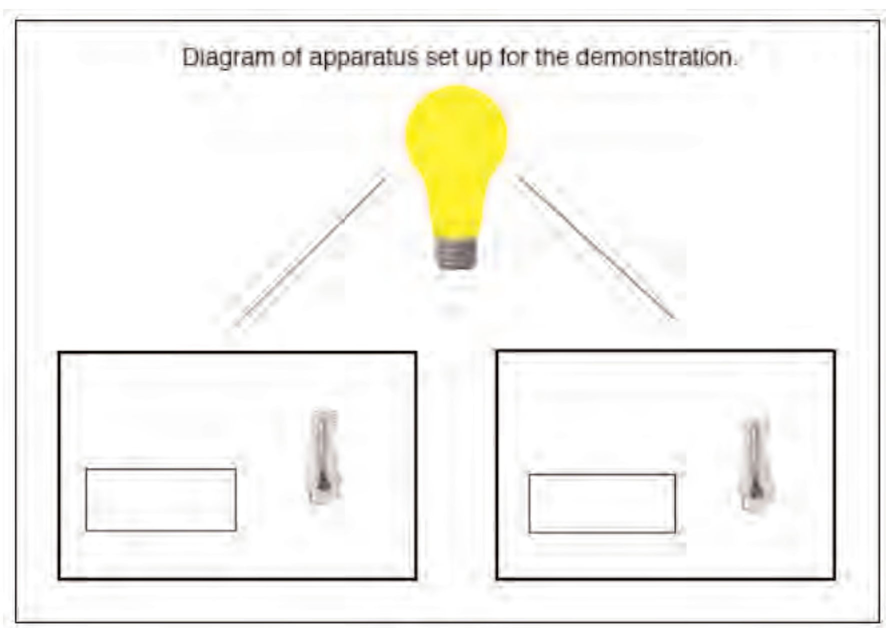


Figure 12.2 Activity 3 Set-up

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. What can we learn about recent climate change from studying ice cores?
2. Is climate change a naturally occurring event/process?
3. How and why is studying the tropics important to climate science?
4. What is preserved in ice cores that reveals climate history?
5. What is the current status of glaciers and their distribution on Earth and how rapidly are they changing?
6. How can plant communities be used to build predictive models of climate change?
7. Does carbon dioxide play a role in the negative feedback system of climate change? How?
8. What are the research findings for the Jasper Ridge Experiment?

Activity Five: Discuss the Video (15 minutes)

Discuss the following questions about the video.

1. What is the combined effect of different factors (CO_2 levels, water levels, nutrients, temperature, species diversity) on an ecosystem?
2. What evidence do we have for global warming or climate change?
3. How do scientists study global climate change in the past and how can we predict the future?
4. How does the past inform the future?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Historical Climate Statistics

This group activity focuses on the analysis and discussion of the historical temperature records from central England from 900 AD to 1900 AD. The objective is to demonstrate the concept of climate change at a specific place over time. We know from the video that scientists have evidence that global climate has changed in the past and is subject to natural changes over time. From the historical and geologic records we know that global temperature change has been both dramatic and gradual. We also know that natural events such as volcanic eruptions can have an effect on local and global temperature.

Materials

Graph paper

Going Further

The information in the following table shows the average winter temperature in central England from 900–1900 AD.

Year	**900**	**950**	**1000**	**1050**	**1100**	**1150**	**1200**	**1250**	**1300**	**1350**
Temp (° C)	3.45	3.55	3.62	3.69	3.58	3.69	4.12	4.09	4.05	3.81

Year	**1400**	**1450**	**1500**	**1550**	**1600**	**1650**	**1700**	**1750**	**1800**	**1850**	**1900**
Temp (° C)	3.63	3.46	3.65	3.5	3.21	3.18	3.38	3.55	3.47	3.66	3.97

Plot on graph paper, time on the x axis and temperature on the y axis.

Discussion Part 1

1. What conclusions can you make, in general, from the whole plot?
2. When are temperatures the highest and the lowest?

Look at the period from 1550 to 1700. This is often referred to as the Little Ice Age, a period of particularly harsh climate conditions across most parts of the world. A combination of decreased solar activity and numerous large volcanic eruptions cooled Earth's climate. Cooling caused glaciers to advance and stunted tree growth. Livestock died, harvests failed, and humans suffered from increased famine and disease. Other examples of climate change due to natural forces exist, including the "year without a summer," which followed the 1815 eruption of Tambora, in Indonesia. At an earlier time, Europe experienced a warm period that may have helped the Vikings to settle Greenland. In order to understand the current climate change debate, one must understand that natural events and cycles play an important role in determining climate on Earth.

Discussion Part 2

In the graph below you can see the percent of volcanic particles suspended in the atmosphere and the dates at which specific events occurred. Discuss the following questions.

1. How do you think volcanic particles get into the atmosphere?
2. What effect would these particles have on the amount of sunlight reaching Earth?
3. What is the correlation of the temperature graph to the volcanic particles graph?
4. What other historical events might be associated with change in annual temperature?

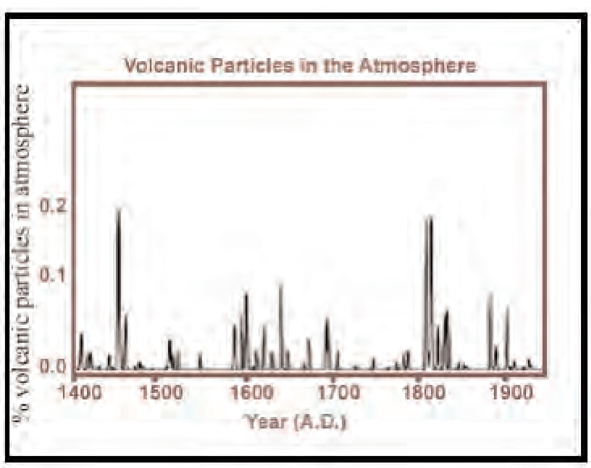


Figure 12.3 Graph of Volcanic Particles in Atmosphere from 1400 to 2000

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Bring to Next Session

Keep a record for one entire day of all of the food you eat and where each product comes from. (You can usually find where a product was made on the label.) Please bring this record to the next session where you will do an activity that examines the amount of energy used to bring food to your table.

Next Week's Topic Overview

Read Unit 13 before the next session. In Unit 13, the emphasis is on the environment's response to humans. Sub-topics will each examine a different area of concern, and examples are given. All of the sub-topics are linked to projections of the future, and the uncertainties with predicting the future will be a key part of the discussion.

Read for Next Session

Read the Unit13 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about possible solutions to environmental challenges. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article, cartoon, or editorial related to solutions to today's environmental challenges.

Supplementary Classroom Activity 1

Plant Growth and Nutrient Availability

This activity demonstrates why most soils are deficient in essential plant nutrients.

Setup

Collect various types of soils, enough of each for testing with test kits (clay, sand, artificial soils such as growing media and vermiculite). All samples should be air dried before initial testing. Enough of each type of soil should be set aside so that initial tests for nutrient content may be established (N, P, K, and pH). Data should be recorded on data sheets as well as in a central location. This will be your beginning fertility data.

Procedure

Mix a commercial fertilizer with soil in a 1:1 ratio. Soil tests should be performed again after fertilization. (Air-dry soils completely if a liquid fertilizer is used.) Flower pots with drainage holes should be filled with each type of soil/fertilizer mix, one type of soil per pot.

Thoroughly water each pot (approximately 200 mL of water per pot). After watering, pots should be allowed to drain and dry for 3 days. Place the pots in a sunny location to facilitate drying.

Repeat the watering of pots two more times. Allow to dry thoroughly, then remove each soil sample from its pot to ensure complete drying before re-testing. Collect a composite from each type for testing. Complete the tests for pH N, P, and K.

Analysis

Compile all data and compare to initial soil tests. Conclusions should be drawn as to each soil type's nutrient holding capacity. This activity demonstrates why most soils are deficient in nutrients. Point out that nutrient withdrawal by plants is not the main factor that determines the soil's inherent nutrient holding capacity. Draw conclusions about other factors that affect nutrient holding capacity (soil type, organic matter content, organic vs. inorganic origin, water holding capacity, etc.).

Supplementary Classroom Activity 2

Investigating Ice Cores

Materials

Plastic graduated cylinders

Food coloring

Particles (ash or pollen)

pH test kit

Dissolved oxygen kit

Nitrogen and/or phosphate kit

Supplementary Classroom Activity 2

Preparation

Before class, the teacher should prepare one ice core per pair or triad of students. The plastic graduated cylinders should be able to stand up inside of your freezer. Over a period of a week, add different layers of water to the cylinder, allowing the water to freeze before adding the next layer. Make the various layers of ice different from each other by varying the color, suspended particles, pH, oxygen, nitrogen, or other physical factors. Be sure to correlate one chemical factor (pH) with one physical factor (ash particles).

Bring the core samples to class (packing them in ice and dishtowels in a cooler assists greatly in the preservation of the ice cores). The class will investigate the physical and chemical characteristics of each layer. They can remove the cores from the cylinder by slowly pouring warm water over the cylinder until it melts enough for the core to slip out. Students should measure, draw, and label the thickness of the different layers of ice and graph the data over imaginary time. Students then take samples from sections of the core and test for particulates, pH, or oxygen. Finally, students will draw and graph the results.

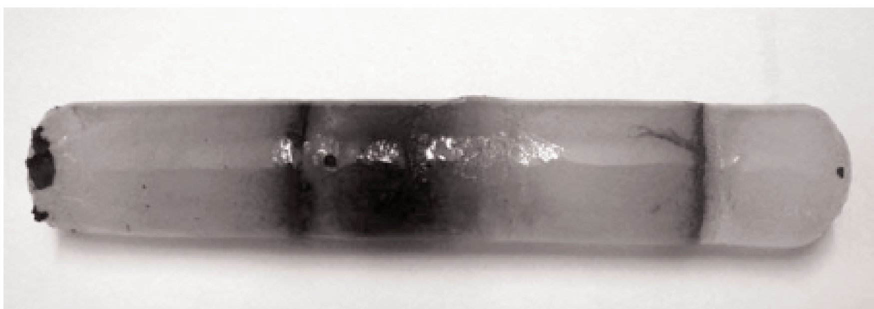


Figure 12.5 Ice Core Sample

Introduction

Conduct a general class discussion about what students know about air pollution and how they would go about finding evidence of air pollution, perhaps from a volcano. Some general open-ended questions that would be appropriate to elicit relevant student knowledge would be:

Has anyone ever seen air pollution? Where? When?

What did it look like? How does that compare to another student's description of air pollution?

How was the air pollution formed? When?

How did the air pollution get in the snow?

Procedure

Give each small group one ice core.

Ask students to do the following.

- Predict if there is evidence of air pollution in their ice core.
- Identify layers of ice and measure and diagram the layers.
- Separate the layers by cutting or breaking the ice.
- Measure the mass of the sample. Record results.
- Measure the volume of the sample using a graduated cylinder and melting the water.

Supplementary Classroom Activity 2

Discuss this aspect of the measurements with students. Density can be calculated at this time, as well.

Ask students to continue.

- Melt each of the layers and measure the pH.
- Predict the presence of air pollution in their samples based on the observation of sedimentation in each of their melted layers, and by taking a measurement of the pH level.
- Carefully extract the ash or boil away the melted ice water and mass the ash.

On the board, a large piece of paper, or an overhead, have all the groups report their results. Construct a class data table and have the students:

- Compare their predictions to their results
- Look for trends in the data, high and low pH vs. presence of air pollution
- Compare their group data to the overall class data
- Try to determine if pH does help them predict the presence or absence of air pollution in an ice core

Layer	Mass (g)	Volume (ml)	pH	Prediction	Mass of particles (g)
A	20	20	7	None	0
B	26	25	5	Some	1.0
C	19.5	18	4	Many	1.5
D	19.5	19	6	Few	.5

Discuss methods that scientists use in predicting the presence of air pollution.

Since there is bound to be some anomalous data, discuss with the class the sources of error and how the process of science includes aspects of non-confirming data.

Notes

Unit 13

Looking Forward: Our Global Experiment

Background

Introduction

Unit 13 is a synthesis of the Habitable Planet course that addresses the effect of humans on planet Earth. The content focuses on solutions to some of our environmental challenges. The emphasis is on how environmental science can help us make informed choices and how these choices can lead to various outcomes. The growing awareness of global environmental issues is considered a positive indication of a developing global ethic that is necessary to prevent major catastrophe. Three themes are discussed in detail: ways to measure and reduce the human footprint, multiple stresses on interconnected Earth systems, and strategies for confronting the climate-energy challenge.

Essential Questions

How can we increase the quality of human life, encourage economic development, and still protect the environment as human appropriation of the natural world becomes larger?

To what extent do we understand that environmental problems on planet Earth are interconnected and that when we affect one part of the system, we affect other parts as well?

Do we recognize that climate change has the potential to make other environmental challenges much more difficult to solve because of the global scale of its impacts?

Content

Unit 13 focuses on Earth as a system—how human impact has affected this system and how environmental science can help provide solutions to many of our global environmental problems. The unit considers Earth's limited capacity in terms of how the dramatic increase in human population over the past several decades has increased demands on natural resources. This trend has affected biological diversity in tropical rain forests and coral reefs. Both the text and video address these issues in detail.

This unit develops the concept of human society's ecological or environmental footprint and asks how we can calculate the footprint for resources such as water and land use, energy consumption, pollution, etc. We present the difficulty in determining society's footprint for the decline in biodiversity and climate change as an example of the difficulty in determining humans' overall impact on Earth's natural resources.

Background

The video features interviews with a wide array of scientists, including excerpts by some who appeared in previous videos and some who helped develop the online text. These experts make the point that we do not understand Earth systems well enough to know what will happen if we continue to stress these systems. We have no real way of predicting the eventual effect on agriculture, spread of human diseases, increase in sea level, loss of species diversity, and overall habitability of planet Earth. They conclude that environmental science can help clarify the consequences of our choices and, we hope, guide society to make better choices in taking care of our habitable planet.

Learning Goals

During this session, you will have an opportunity to build your understanding of the following.

a. Knowledge

   i. Earth as a system functions as an interconnected set of structures and processes that involve the geosphere, hydrosphere, atmosphere, biosphere, and cryosphere.

   ii. Technological advances in the sciences and engineering will increase our understanding of Earth as a system.

   iii. Human population growth and economic development have had a profound impact on our habitable Earth by creating major environmental problems.

   iv. Understanding the components of the coral reef ecosystem allows us to develop models for an interconnected system.

   v. Climate change and human energy demands are interconnected and have an impact on Earth as a system.

b. Skills

   i. Scientists use quantitative, qualitative, experimental, and other methods to understand Earth as a system.

   ii. Calculating our human ecological footprint is one method of considering the effect of humans on the habitable Earth.

c. Dispositions

   i. Awareness of environmental problems and identifying the choices we have in developing solutions for these problems is critical.

   ii. There is a need to develop an environmental ethic to help in recognizing and participating in the solution to environmental problems.

   iii. Environmental science knowledge and skills are subject to change.

Key concepts

Earth System	Ecological footprint
Coral-zooxanthallae	Carbon sequestration
Carbon capture and storage	

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions

Throughout the Habitable Planet course, we have focused part of each unit on related misconceptions. Any one of these misconceptions can relate to the overall theme of Unit 13 in some way. In this final unit on our ecological future, two specific common misconceptions should be considered. First, most people believe that there will be technological fixes that will deal specifically with environmental problems. Although there is some truth to this, technological fixes alone will not solve problems such as global climate change or depletion of marine fisheries. Technological advances will contribute to a myriad of approaches to sustain the habitable planet. Technology is an important part of the mix, but it is not the exclusive answer. We must also address everyday consumptive practices and natural resource management and conservation strategies.

Second, there is a commonly held belief that the human race is not subject to catastrophic consequences such as extinction. Young people in particular think that the human race could not become extinct. While the thought of human extinction seems far-fetched, we know that the consequences of environmental degradation and, specifically, ecological tipping points are not predictable. We should not discount our fallibility. Under the direst circumstances, it is possible for any species to become extinct on planet Earth.

The combined collection on common misunderstandings found in the Professional Development Guide to the Habitable Planet course is one of the most complete and comprehensive treatments of ecological misconceptions in environmental science education literature. Educators who take these prior understandings into consideration when teaching ecology or environmental science will find that their students will be forced to reconcile their existing knowledge with recent science information about our planet and its future. This will lead to more meaningful learning and, we hope, changes in behavior.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

Each person in the group should have three index cards. On the first card, participants should name a single ecological problem. On the second card, participants should write one question they have about that problem. Finally, on the third card, they should describe a direct experience they have had that relates to the problem. For example, an individual might write:

> Wild fires are increasing each year in the Rocky Mountains.
>
> What is the cause of all these fires?
>
> The air quality in my city has been terrible because of the nearby wildfires.

Getting Ready

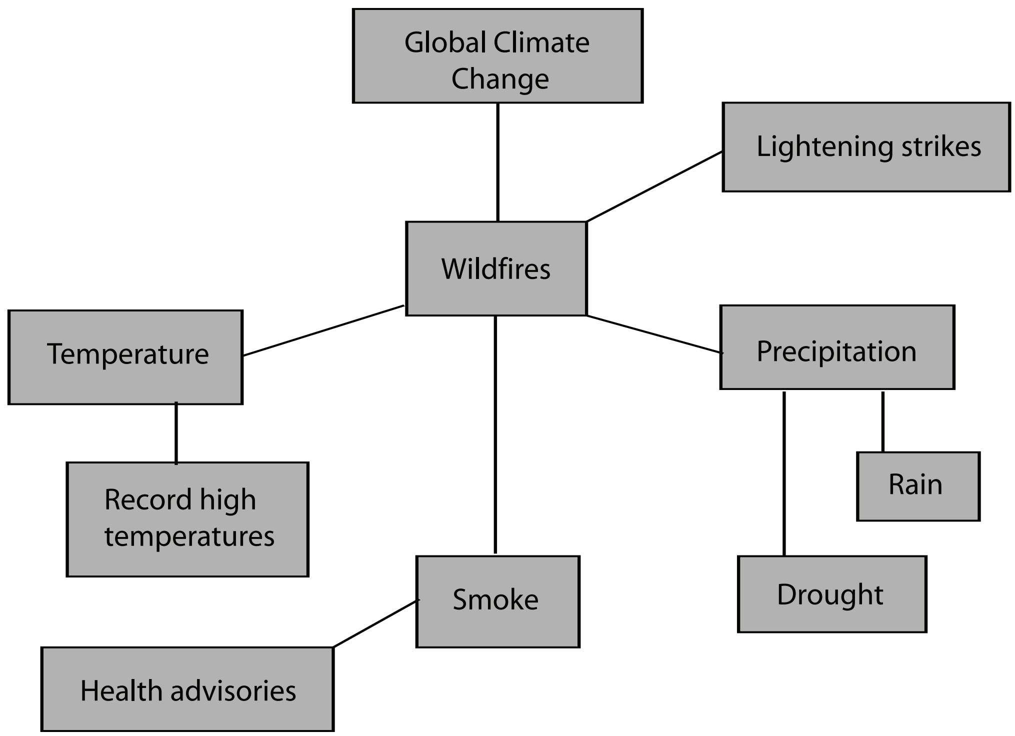


Figure 13.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Your Ecological Footprint

The ecological footprint measures the amount of renewable and nonrenewable resources that humans use. Earth's resources are needed to support everything that we eat or use, and Earth absorbs the wastes we create. Given the current world population, there are 4.7 biologically productive acres available per person, and this does not include the needs of all the plants and animals.

The ecological footprint calculator calculates the number of acres a person uses given his or her lifestyle. It also calculates how many "Earths" would be required if everyone had the same type of lifestyle. For example, the average person in the United States uses 24 acres; if every person in the world used this much, we would need five planets!

Getting Ready

Facilitator

1. Explain the ecological footprint to participants including what the 4.7 acres per person means.
2. Give participants some examples of ecological footprints:
   a. Pakistan: Less than 2 acres
   b. Italy: 9 acres
   c. Canada: 22 acres
   d. United States: 24 acres

Procedure

1. Predict your ecological footprint.
2. Using the instructions below, calculate your ecological footprint. Start by filling in only the My Score column.
3. After everyone has filled out the form, share your grand totals and find the group's average ecological footprint.
4. What activities scored the highest number of points? Why?
5. What changes can you make to reduce your ecological footprint?
6. Go back to your ecological footprint calculator and fill in the "points I could save" column with the goal of saving "one Earth."
7. Share the changes you made with the rest of the group.

Note: There are also many ecological footprint calculators online that can save time in making final calculations. A simple web search (key words: calculate, environmental, and footprint) will reveal many links to appropriate Web sites.

Ecological Footprint Calculator

Complete each category for a typical day in your home. After completing a category, add your points for a subtotal and transfer this subtotal to the summary chart. After completing all of the categories, add your subtotals together to calculate your ecological footprint.

Water Use			
Question	Answer/Points	My Score	Points I Could Save
My shower (or bath) is:	No shower/bath (0) Short shower 3–4 times a week (25) Short shower once a day (50) Long shower once a day (70) More than one shower per day (90)		
I flush the toilet:	Every time I use it (40) Sometimes (20)		
When I brush my teeth:	I let the water run (40) I don't let the water run (0)		
We use water-saving toilets	Yes (-20) No (0)		
We use low-flow showerheads	Yes (-20) No (0)		
	Water Use Subtotal:		

Getting Ready

Food Use			
Typically, I eat:	Meat more than once per day (600) Meat once per day (400) Meat a couple of times a week (300) Vegetarian (200) Vegan (150)		
All of my food is grown locally or is organic.	Yes (-20) No (0)		
I compost.	Yes (-20) No (0)		
Most of my food is processed.	Yes (20) No (-20)		
Little of my food has packaging.	Yes (-20) No (0)		
On a typical day I waste:	None of my food (0) One-fourth of my food (25) One-third of my food (50) Half of my food (100)		
	Food Subtotal:		

Transportation Use			
On a typical day, I travel by:	Foot or bike (0) Public transit/school bus (30) Private vehicle: 2 or more people (100) Private vehicle: 1 person (200)		
My vehicle's fuel efficiency is:	More than 30 miles/gallon (-50) 24–30 miles/ gallon (50) 17–23 miles/gallon (100) Less than 17 miles/gallon (200)		
The time I spend in vehicles on a typical day is:	No time (0) Less than half an hour (40) Half an hour to 1 hour (100) More than 1 hour (200)		
The car in which I travel on a typical day is:	No car (-20) Small (50) Medium (100) Large (200)		
Number of cars for my household:	No car (-20) Less than 1 car per driver (0) One car per driver (50) More than 1 car per driver (100) More than 2 cars per driver (200)		
Number of flights I take per year:	0 (0) 1 to 2 (50) More than 2 (100)		
	Transportation Subtotal:		

Getting Ready

Shelter Use			
My house is:	Single house on large lot (50) Single house on small city lot (0) Townhouse/attached house (0) Apartment (-50) Green-design house (-100)		
Divide the number of rooms in your home (not including bathrooms) by the number of people living in your home.	1 room or fewer per person (-50) 1–2 rooms per person (0) 2–3 rooms per person (100) More than 3 rooms per person (200)		
I own a second, or vacation home.	Yes (200) No (0)		
	Shelter Subtotal:		

Energy Use			
In cold months, my house temperature is:	Under 59°F (15°C) (-20) 59 to 64°F (15 to 18°C) (50) 65 to 71°F (19 to 22°C) (100) 72°F (23°C) or more (150)		
I dry clothes outdoors or on an indoor rack.	Always (-50) Usually (0) Sometimes (20) Never (60)		
I use an energy-efficient refrigerator.	Yes (-50) No (50)		
I have a second refrigerator or freezer.	Yes (100) No (0)		
I use 5 or more compact fluorescent light bulbs.	Yes (-50) No (100)		
I turn off lights, computers, and televisions when they're not in use.	Yes (0) No (50)		
For cooling I use:	Air conditioning in car (50) Air condition in home (100) Electric fan (-10) Nothing (-50)		
My clothes washer is a:	Top load (100) Front load (50) Laundromat (25)		
	Energy Use Subtotal:		

Clothing Use			
I place my clothes in the dirty laundry everyday.	Yes (80) No (0)		
One-fourth (or more) of my clothes are handmade or secondhand.	Yes (-20) No (0)		
Most of my clothes are purchased new each year.	Yes (200) No (0)		
I sell or give away clothes I no longer wear.	Yes (-50) No (100)		
I buy ____ new pairs of shoes each year.	0–1 (0) 2–3 (20) 4–6 (60) 7 or more (90)		
	Clothing Subtotal:		

Getting Ready

Stuff I Use			
All my garbage on an average day could fit into a:	Shoebox (20) Small garbage can (60) Large garbage can (200) Box smaller than a shoebox (0)		
I recycle everything possible.	Yes (-100) No (0)		
I reuse or repair items instead of throwing them away.	Yes (-30) No (0)		
I try not to use disposable items as often as possible.	Yes (-50) No (60)		
I use rechargeable batteries.	Yes (-30) No (0)		
My house has___electronics (computer, TV, Stereo, etc.).	0 (0) 1–5 (25) 6–10 (75) 11–15 (100) More than 15 (200)		
For outdoor recreating I use ___ equipment. (A lot = boat, snowmobiles, dirt bikes, etc. Very little = soccer, bicycling, etc.)	None (0) Very little (20) Some (60) A lot (80)		
	Stuff Subtotal:		

Summary

Transfer your subtotals from each section to the table below and add them together to calculate your ecological foot print.

Water Use	
Food Use	
Transportation Use	
Shelter Use	
Energy Use	
Clothing Use	
Stuff I Use	
Grand Total	

Grand total __________ ÷ 350 = __________ Earths

_________ Earths X 4.7 acres/Earth = ___________ acres

If everyone lived the way I do, we would need _______ Earths for all the people in the world.

Video (45 minutes)

Activity Four: Watch the Video (30 minutes)

As you watch the video, think about the following focus questions.

1. What is the argument for preserving all remaining ecosystems? Where should we pay particular attention and why?
2. How do terrestrial, aquatic, and marine conservation efforts compare? What are the consequences of these efforts.
3. What is an ecological "tipping point" and why is it critical?

Activity Five: Discuss the Video (15 minutes)

Discuss the following questions about the video.

1. "When all else fails men turn to reason." What does this statement mean in the context of your local community?
2. What do you think are the key ecological issues that the public is aware of in relation to environmental degradation. Why is the public aware of these issues and not others?
3. What do you think are the best and worst case scenarios for our human/ecological condition? Why?
4. What are the ecological consequences of human population growth?
5. Why is genetic evolution so important and how do we convince all human beings of its critical aspects?
6. What part do marine environments play in our ecological future?
7. How does the human spirit depend on our ecological condition?
8. Why do scientists believe that climate is the critical ecological factor for the habitable planet?
9. What is the only solution to climate change? What is the economic consequence?
10. What is the most important approach to future environmental quality? Why?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: What did you eat today and where did it come from?

The future habitability of Earth depends on producing enough food and getting it to people. According to the unit 13 video, rising human population, biodiversity loss, and climate change are issues of primary environmental concern. How do these issues influence your thinking about your daily diet and the source of your life-sustaining nutrients?

In most developed countries, food travels all over the world to make it to grocery stores and subsequently to dinner plates. Most people do not consider the fact that the further your food travels, the more fossil fuels are consumed and the more greenhouse gases created. According to researchers at the University of Michigan's Center for Sustainable Agriculture, an average of over 7 calories of fossil fuel is burned up for every calorie of energy we get from our food. This means that in a 400 calorie breakfast, a person will, in effect, have "consumed" 2,800 calories of fossil-fuel energy. Highly packaged food also consumes more fossil fuels then fresh produce. Meat uses more fossil fuels than plant protein. The production of 1 calorie of animal protein requires more than ten times more fossil fuels than plant protein. In this activity, participants will explore how far their food has traveled for one day and create a "foodshed."

FACILITATOR: Make sure participants have the food record they were asked to prepare for homework. The record should list all food that was eaten and where it came from for one entire day. Participants will need to estimate the distance traveled for each food product.

1. Have the group make two columns and list packaged foods in one and unpackaged foods in the other. Total the distance traveled for packaged versus non-packaged items. Compare the differences in distance traveled and energy consumed. Have each person in the group do the same and compare individual to group results.
2. Have the group make two columns and list all the meat and non-meat products consumed by the group in one day. Total the distance traveled for meat versus non-meat products. Compare the distance and energy consumed. Have each person in the group do the same and compare individual to group results.
3. On a single world map, mark where all the participants' food originated. Use the points of food origin to create a line surrounding the entire area encompassed by the food the group ate in one day. The enclosed area is the group "foodshed." Do the same for each individual in the group and compare the individual to group "foodsheds." Identify the major ecosystems and biomes in which your food originates.

Discussion Questions

1. How does your individual daily food consumption compare to that of the entire study group? Why do you think it is different for different members of the group?
2. The unit 13 video identifies rising human population, biodiversity loss, and climate change as issues of primary environmental concern. How does your daily food consumption affect each of these global issues?
3. How can we reduce the amount of fossil fuels burned when we choose the foods we eat? How can we help reduce the amount of chemicals used to produce our food? How can we reduce the amount of carbon emissions associated with our food production?
4. Given that, according to the video, we are adding a billion people to the Earth every 12–15 years, what can people in your community do to ensure adequate food production and supply?

Going Further

5. In an increasingly affluent society, people have the financial resources to buy better and better products, including food. How does increasing affluence affect diet and food consumption? What are the production, supply, and energy consequences? How might this affect global biodiversity?
6. Many scientists in the Unit 13 video believe fossil fuel impacts are the most critical concern facing people and Earth. How can your daily diet influence fossil fuel impacts?

At the beginning of the video we saw the claim, "When all else fails, men turn to reason." What if our global food production and supply infrastructure were to fail? How will "men turn to reason?" What can be done now to prevent this catastrophic state? Do you have faith that people will use good sense and have the desire to prevent this outcome? Why?

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to the supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Supplementary Classroom Activity

Taking Eco-Action

There are five steps to addressing an environmental issue. These are selecting an issue, defining the problem, researching possible solutions, evaluating the options, and taking action. The purpose of this activity is not simply to take action or to have students take action, but to enable students to become rational, thinking human beings who want to see the "big picture" and who are willing to act to benefit everyone. Issues raised by environmental education are often highly emotional and complex, and passionate discussion ensues.

Part 1: Environmental Issues, Problems, and Solutions

Setting the Stage for Action

Educators must create a positive context with students before beginning environmental action activities. Many of the related readings and activities in the Habitable Planet course can be used to develop a context for environmental action. A quick review of the various units in this Professional Development Guide will provide a number of activities that develop understanding, skills, and positive dispositions in relation to a variety of ecological topics. Among the key concepts are biodiversity, population, and climate change. Local newspapers can provide relevant topics for study. Some of the Habitable Planet videos can be used with students to stimulate discussion and elicit relevant thinking and values. No matter what educational materials you are using with your students, what is critical is that you open the students' minds to various perspectives and possibilities regarding environmental issues and actions that might address existing problems.

Step 1: Choosing the Issue. The teacher will lead a discussion to generate ideas with students. Ways to do this include eliciting ideas from the students themselves and taking a field trip to a designated area, such as a wetland, to spark ideas. Students may have their own concerns about a particular area where they have noticed changes due to an increase in use or fluctuations in local climate. Students may choose to interview their friends and family to generate more ideas.

Step 2: Defining the Problem. Students may want to skip this step, as they will be focused on a solution, but this step is the most crucial. Students must actually define a problem to be addressed. They need experience and knowledge to complete this step. An example of a defined problem could be that students have noticed an excess of trash being dumped in a wetland area. To complete this step, they should be able to identify the groups that have an interest in wetlands, know the groups' philosophies, social interests, and values, and identify their own concerns and listen to other points of view with an open mind.

Step 3: Searching for Solutions/Researching Further. In this step, students seek solutions. This may involve going back to step 2, reviewing one or two units in the Habitable Planet online textbook, or using additional resources. Logic activities are useful, as the more students are encouraged to look at things in different ways, the more likely they are to apply this type of thinking to the wetlands issue at hand. Once students understand the design behind the preservation of a wetland area or the concept of land use that was intended when rights to that area were established, they can confidently move on to Part 2 of this classroom activity.

Supplementary Classroom Activity

Part 2: Options and Action

After researching the topic and searching for solutions in Part One, students should now be able to proceed to the fourth step, which involves examining the consequences that will result from the various options that can be taken, and step five, which is taking action.

Step 4: Evaluating the Options. This step is the most crucial for the teacher to facilitate. Environmental education does not simply ask a student to get emotional about an issue and then take action. The students must understand the "big picture" and make decisions that will benefit all involved in the community, region, country, and world. Following the adage "Think Globally, Act Locally" is a good rule of thumb. Questions that can be asked of students include:

What are the values and interests served by this solution?

What outcomes will result from this solution?

What will stand in the way of achieving this solution?

Who wins from this solution? Who loses?

Does this solution actually solve our defined problem?

In the case of a polluted watershed, students may realize that a proposed solution could be to ask a land area's caretakers to post signs discouraging others from dumping their trash or to coordinate a class clean-up day. Such solutions could produce a win-win solution.

Step 5: Taking Action. The class members must decide if they are able to make a meaningful contribution to the solution and what resources will be required of them. (Make sure to indicate that time is considered a resource.) It is important for the teacher to create a context of action for the students. It would be damaging to the students' experience of environmental education and activism as well as their morale if they expect a far greater outcome than they achieve. It is up to the teacher to pave the way for the students so that this is a successful venture for all involved. For example, if students expect the watershed area to stay clean after they have spent one day cleaning it and are not taught that sustainability of a project and continual maintenance of the project is expected, they could be disheartened and discouraged.

Creating opportunities for students to take action, share what they learn, and plan for the next venture is all part of this step. It is important that the teacher encourage students not to let their efforts end with just this project. Supporting the students in other projects, such as volunteering with other organizations or directing their own action projects, is very important and lets the students know that they have power in a situation, their community, their environment, and elsewhere.

Conclusion

These five steps—evaluating an issue found in activities one and two, exploring options, seeing the big picture, evaluating the options and consequences, and taking action—can be implemented anywhere, with any project, with any chapter in this text.

Notes

Further Reading

Unit 1

University of California Museum of Paleontology, Web Geological Time Machine, http://www.ucmp.berkeley.edu/help/timeform.html.
An era-by-era guide through geologic time using stratigraphic and fossil records.

Science Education Resource Center, Carleton College, "Microbial Life in Extreme Environments," http://serc.carleton.edu/microbelife/extreme/index.html.
An online compendium of information about extreme environments and the microbes that live in them.

James Shreve, "Human Journey, Human Origins," National Geographic, March 2006, http://www7.nationalgeographic.com/ngm/0603/feature2/index.html?fs=www3.nationalgeographic.com&fs=plasma.nationalgeographic.com.
An overview of what DNA evidence tells us about human migration out of Africa, with additional online resources.

Unit 2

National Aeronautics and Space Administration, "The Importance of Understanding Clouds," NASA Facts, FS-2005-0-073-GSFC, http://www.nasa.gov/pdf/135641main_clouds_trifold21.pdf.

Unit 3

National Academy of Sciences, Office on Public Understanding of Science, "El Niño and La Niña: Tracing the Dance of Ocean and Atmosphere," March 2000, http://www7.nationalacademies.org/opus/elnino.html.
A summary showing how atmospheric and oceanographic research have improved our capability to predict climate fluctuations.

National Weather Service Climate Prediction Center,http://www.cpc.ncep.noaa.gov/.
Assessments, weather forecasts, graphics, and information on climate cycles including El Niño/La Niña, NAO, PDO, and others.

Woods Hole Oceanographic Institute, "Ocean Instruments: How they work, what they do, and why they do it," http://www.whoi.edu/science/instruments/.
A guide to gravity corers, seismometers, and other ocean research tools.

Unit 4

Paul A. Colinvaux, Why Big Fierce Animals Are Rare: An Ecologist's Perspective (Princeton, NJ: Princeton University Press, 1979).
A survey of major questions in ecology, including why every species has its own niche.

Chris Reiter and Gina C. Gould, "Thirteen Ways of Looking at a Hedgehog," Natural History, July/August 1998.
Hedgehogs' spines are unique adaptations, but they have thrived in many regions for millions of years because they are generalists in terms of climate zones and diet.

ReefQuest Centre for Shark Research, "Catch As Catch Can," http://www.elasmo-research.org/education/topics/b_catch.htm.
Contrary to their popular image as mindless eating machines, great white sharks' foraging strategies are selective and efficient.

Further Reading

Unit 5

Jeffrey Sachs, The End of Poverty: Economic Possibilities For Our Time (New York: Penguin, 2006).
Economist Jeffrey Sachs offers a plan to eliminate extreme poverty around the world by 2025, focusing on actions to improve the lives of the world's one billion poorest citizens.

John Bongaarts, "How Long Will We Live?" Population and Development Review, vol. 32, no. 4 (December 2006), pp. 605–628.
A look at the factors that have increased life expectancy in high-income countries since 1800 and at prospects for continued gains.

Joel E. Cohen, "Human Population Grows Up," Scientific American, September 2005, pp. 48–55.
In the next 50 years, Earth's human population will be larger, slower-growing, more urban, and older than in the 20th century, with significant implications for sustainability.

"The Economics of Demographics," (whole issue) Finance & Development, vol. 43, no. 3, September 2006.
A detailed look at policy adjustments that can help world leaders cope with demographic change.

Mike Davis, "Slum Ecology," Orion, March/April 2006.
Living conditions in urban slums invert the principles of good urban planning: houses stand on unstable slopes, people live next to polluted and toxic sites, and open space is scarce or lacking.

Malcolm Gladwell, "The Risk Pool," New Yorker, August 28, 2006.
Population age structures and dependency ratios explain Ireland's recent economic boom and the woes of many U.S. corporate pension plans.

Paul Harrison and Fred Pearce, AAAS Atlas of Population and the Environment (Berkeley: American Association for the Advancement of Science and University of California Press, 2000), http://atlas.aaas.org/index.php?sub=intro.
An online source of information on the relationships between human population and the environment, with text, maps, and diagrams.

Unit 6

European Commission , Environment Directorate, "REACH," http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm.
An overview of the REACH regulation, including information on benefits and costs.

Dennis Paustenbach, ed., Human and Ecological Risk Assessment: Theory and Practice (New York: Wiley, 2002).
A comprehensive textbook, including risks involving air, water, food, occupational exposures, and consumer products.

National Research Council, Science and Judgment in Risk Assessment (Washington, DC: National Academy Press, 1994).
An exploration of how risk analysts make assumptions and deal with uncertainty, written to help the EPA make risk assessments more valid and credible by using scientific data more fully and making the limits of knowledge clear.

U.S. National Institutes of Health, National Library of Medicine, "Tox Town," http://toxtown.nlm.nih.gov/.
An animated online guide to connections between chemicals, the environment, and public health, including common exposure locations, non-technical descriptions of chemicals, and links to scientific and health resources.

Unit 7

Evans, L.T., Feeding the Ten Billion: Plants and Population Growth (Cambridge, UK: Cambridge University Press, 1998).

Halweil, Brian, "Can Organic Farming Feed Us All?" Worldwatch, May/June 2006.

King, John, Reaching for the Sun: How Plants Work (Cambridge, UK: Cambridge University Press, 1997).

Leigh, G.J., The World's Greatest Fix: A History of Nitrogen and Agriculture (Oxford, UK: Oxford University Press, 2004).

Pew Initiative on Food and Biotechnology, http://pewagbiotech.org/.
Research and recommendations from a now-complete project on issues arising from advances in agricultural biotechnology.

Jennifer Thomson, Seeds For the Future: The Impact of Genetically Modified Crops on the Environment (Ithaca, NY: Cornell University Press, 2007).

Further Reading

Unit 8

Peter H. Gleick, The World's Water 2006-2007: The Biennial Report on Freshwater Resources (Washington, DC: Island Press, 2006).
Current information on water needs, trends, and policies worldwide.

John McPhee, "Atchafalaya," in The Control of Nature (New York: Farrar Strauss Giroux, 1989).
A renowned journalist describes the technical challenges and environmental impacts of human efforts to manage the flow of the Mississippi River.

Sandra Postel, Liquid Assets: The Critical Need to Safeguard Freshwater Ecosystems, Worldwatch Paper 170 (Washington, DC: Worldwatch Institute, July 2005).
An overview of the valuable functions performed by freshwater ecosystems and policy options for protecting them.

Unit 9

Annenberg Media, Rediscovering Biology: Molecular to Global Perspectives, Units 4 ("Microbial Diversity") and 12 ("Biodiversity"), http://www.learner.org/channel/courses/biology/index.html.
Two units from a professional development course for high school biology teachers, including video, online text, and supporting materials.

Center for Biological Diversity, "The Road to Recovery: 100 Success Stories for Endangered Species Day 2006," http://www.esasuccess.org/reports/.
Profiles of species that have increased their populations under the U.S. Endangered Species Act.

Cornell Laboratory of Ornithology, The Search for the Ivory-Billed Woodpecker, http://www.birds.cornell.edu/ivory.
News, evidence, and updates from the researchers who claimed to have found an ivory-bill in 2004.

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