# TEACHER BACKGROUND INFORMATION

# CLIMATE CHANGE AND ECOSYSTEM RESPONSE

Global warming is, quite literally, a hot topic. Though the mechanism of global warming may not be big news, the projected impact often makes headlines. Recent documentary films on the topic have focused even more attention on the potentially disastrous effects of even a few degree temperature rise. Whole island countries could disappear into the ocean as polar ice melts and sea level rises. Hurricanes and tropical storms may intensify. And ecological interactions could change in unpredictable ways. For example, a recent news story reports that melting sea ice may be forcing some polar bears into cannibalism now that fewer seal hunting opportunities are available. Increasingly, it seems, global warming shows up on the front page of the newspaper — but the evolutionary implications of global warming often remain hidden.

Global warming is certainly a climatic and environmental issue — but it is also an evolutionary one. Over the past 20 years, biologists have uncovered several cases of evolution right under our noses — evolution caused by global warming. One of the key mechanisms of evolution, **natural selection**, causes organisms to evolve in response to a changing environment. Imagine a population with several different variants in it: some individuals happen to be better able to survive and reproduce at higher temperatures than other individuals. Clearly, if the temperature increases, those heat tolerant individuals will have an advantage and will leave more offspring — and those offspring will also carry the genes for heat tolerance. Over many generations, this process produces a population with adaptations well-suited for the hotter environment. So long as the population has different genetic variants in it, some better able to survive and reproduce in particular situations than others, the population has the capacity to evolve when faced with a changing environment.

Over the past 25 years, global surface temperatures have increased about .5°F. That might not sound like much, but it turns out to be more than enough to change the ecology and evolution of life on Earth. In many cases, these changes are simply non-evolutionary examples of **phenotypic plasticity,** where an organism expresses different traits depending on environmental conditions. For example, many organisms respond to warmer weather by reproducing earlier and taking advantage of an earlier spring — but this early reproduction is not caused by genetic changes in the population and so is not an example of evolutionary change. Similarly, many species have shifted their ranges in response to this tiny temperature difference, spreading towards the poles, as those habitats warm — but this change in range cannot be traced to a genetic shift in the population and so is not an example of evolution. And still other species simply seem to be on the path to endangerment or extinction as their habitats (like coral reefs) are degraded and their population sizes drop.

However, in a few cases, we know that species have actually evolved — experienced a change in gene frequency in the population — in response to global warming. Interestingly, in those cases, the species are not necessarily becoming more heat tolerant, but are adapting to changes in seasonal timing:

- **Canadian squirrels** are evolving to take advantage of an earlier spring and are breeding sooner, which allows them to hoard more pinecones for winter survival and next year's reproduction. Squirrels with genes for earlier breeding are more successful than squirrels with genes for later breeding.

- **European great tits** (a type of bird) are also evolving different breeding times. Birds that are able to adjust egg-laying to earlier in the spring can time hatching so that it coincides with greater food (caterpillar) abundance — and with recent climatic changes, the caterpillars have been maturing earlier in the spring. Birds with genes for more flexible egg-laying times are more successful than birds with less flexibility in their egg-laying.

- One **North American mosquito** species has evolved to take advantage of longer summers to gather resources while the weather is good. Mosquitoes with genes that allow them to wait longer before going dormant for the winter are more successful than mosquitoes that go dormant earlier.

In a sense, these populations are the lucky ones. Small animals (like the birds, squirrels and mosquitoes described above) tend to have large population sizes and short generation times — and that bodes well for their ability to evolve along with a changing environment. Large population size means that the species is more likely to have the genetic variation necessary for evolution, and having a short generation time means that their rate of evolutionary change may be able to keep pace with environmental change. However, other species may not be so lucky: larger animals tend to have longer generation times and so evolve more slowly — and larger animals also tend to have smaller population sizes, which means that their populations are simply less likely to contain the gene versions that would allow the population to adapt to warmer climates. If global warming continues, such species may come face to face with extinction, as the environments to which they have been adapted over the course of thousands or millions of years change right out from underneath them in the course of a few decades.

**TEACHER BACKGROUND INFORMATION #2**

**IMPORTANT TERMS:** Biological diversity, species abundance, fossil pollen, ecosystem. Food

web, adaptation;

Answers to **ANALYSIS AND CONCLUSION** questions:

1. After 6600 years the precipitation falls to 51 cm; oaks are gone and duckweed is disappearing.

2. After 9200 years precipitation falls to 38 cm; Duckweed, ducks and wolves are gone; grass is disappearing;

    - After 10,000 years precipitation falls to 34 cm; Grass is replaced by mesquite; Mice and snakes move in; Grasshoppers and jack rabbits are the only organisms common to both the initial and the final food webs;

3. Lack of Mesquite;

4. Number of ducks;

5. A decrease in precipitation id solely responsible for the other changes.

6. Maximum and minimum levels would be more realistic.

**ALIGNMENT TO NATIONAL SCIENCE STANDARDS:**

- ✓ Unifying Concepts and Processes (K-12)
    - Consistency, change, and measure
- ✓ Science as Inquiry, Content Standard A (9-12):
    - Abilities necessary to do scientific inquiry
    - Understandings about scientific inquiry
- ✓ Life Science, Content Standard C (9-12):
    - Interdependence of organisms
    - Matter, energy, and organization in living systems
    - Behavior of organisms
- ✓ Earth and Space Science, Content Standard D (9-12):
    - Energy in the earth system
- ✓ Science in Personal and Social Perspective, Content Standard F (9-12):
    - Personal and community health
    - Environmental quality
    - Science and technology in local, national, and global changes

# INSTRUCTIONAL ACTIVITY
# WARMING TO EVOLUTION

**BACKGROUND:** Scientists are still investigating and learning about the relationship between climate change and biological diversity in natural systems. They have identified many factors which are known to determine the growth and distribution of plants and animals within these systems: temperature, precipitation, carbon dioxide concentration, light, available food, chemical components and disturbances such as disease, severe storms, wildfires, and human land use or any combination of these factors. For example, trees have "moved" thousands of miles over the course of Earth's history in response to global temperature changes of about 5 degrees Celsius occurring over thousands of years. If the rate of change is a degree or so over a thousand years, species seem able to move and "keep up" with the changing climate. However, extensive studies of fossil pollen from lakes around North America tell scientists that intact forest and animal ecosystems do not simply move north as temperatures change. Animal and plant species changed in abundance and in effect changed the entire "look" of the ecosystem. It is this kind of change over time and space that has ecologists most concerned.

**OBJECTIVES:**

Students will:

- Trace the effects if a gradual climate change on a model ecosystem which is simplified from a real situation.
- Explain ways in which environmental factors interact to set limits on geographic ranges.

**MATERIALS: DATA TABLE:CLIMATE CHANGE FACTORS AND ECOSYSTEM REPSONSE, CLIMATE CHANGE INFORMATION SHEET**, paper/pencil, butcher paper, markers, glue/tape;

**PROCEDURE:**

1. Read the **CLIMATE CHANGE INFORMATION SHEET**: **PART I**.

2. With a partner diagram the food web in the ecosystem described in **Part I** on a large sheet of butcher paper using the drawing provided on the illustration sheets.

3. Read **Information Sheet: Part II**.
   - Fill in the columns in the **DATA TABLE: CLIMATE CHANGE FACTORS AND ECOSYSTEM RESPONSES** using the information from the second reading selection.

4. After filling out the chart, diagram a new food web on butcher paper for the same ecosystem at the end of 10,000 years.

5. Prepare a written summary of the climatic changes that occurred in the ecosystem under study over the 10,000 year period.

6. Respond to the questions in the **Analysis and Conclusions** section and be prepared to discuss and defend your answers in an open discussion with the class.

## ANALYSIS AND CONCLUSIONS:

1. When did the first changes in the ecosystem occur?

2. What were the changes that took place?

3. What subsequent changes occurred and in which years?

4. What similarities and differences are there between the initial and the final food webs?

5. What is a barrier to dispersal for the Merriam pocket mouse?

6. What limited the Red wolves population size?

7. What climatic factors are responsible for the other changes?

8. Why could the use of annual average values for temperature and precipitation make tis model artificial?

## DATA TABLE : CLIMATE CHANGE FACTORS AND ECOSYSTEM RESPONSES

| ROUND | YEARS | AVERAGE ANNUAL PRECIPITATION | AVERAGE ANNUAL TEMPERATURE | CHANGES IN ORGANISMS |
|---|---|---|---|---|
| 1 | 200 | | | |
| 2 | 400 | | | |
| 3 | 600 | | | |
| 4 | 800 | | | |
| 5 | 1000 | | | |
| 6 | 1200 | | | |
| 7 | 1400 | | | |
| 8 | 1600 | | | |
| 9 | 1800 | | | |
| 10 | 2000 | | | |
| 11 | 2200 | | | |
| 12 | 2400 | | | |
| 13 | 2600 | | | |
| 14 | 2800 | | | |
| 15 | 3000 | | | |
| 16 | 3200 | | | |
| 17 | 3400 | | | |
| 18 | 3600 | | | |
| 19 | 3800 | | | |
| 20 | 4000 | | | |
| 21 | 4200 | | | |

| | | | | |
|---|---|---|---|---|
| 22 | 4400 | | | |
| 23 | 4600 | | | |
| 24 | 4800 | | | |
| 25 | 5000 | | | |
| 26 | 5200 | | | |
| 27 | 5400 | | | |
| 28 | 5600 | | | |
| 29 | 5800 | | | |
| 30 | 6000 | | | |
| 31 | 6200 | | | |
| 32 | 6400 | | | |
| 33 | 6600 | | | |
| 34 | 6800 | | | |
| 35 | 7000 | | | |
| 36 | 7200 | | | |
| 37 | 7400 | | | |
| 38 | 7600 | | | |
| 39 | 7800 | | | |
| 40 | 8000 | | | |
| 41 | 8200 | | | |
| 42 | 8400 | | | |
| 43 | 8600 | | | |
| 44 | 8800 | | | |
| 45 | 9000 | | | |

| | | | | |
|---|---|---|---|---|
| 46 | 9200 | | | |
| 47 | 9400 | | | |
| 48 | 9600 | | | |
| 49 | 9800 | | | |
| 50 | 10000 | | | |

# CLIMATE CHANGE INFORMATION SHEET

## PART I

An oak tree grows next to a shallow stream in a grassy area. There are no shrubs here. Grasshoppers and Black-tail jack rabbits feed on Little bluestem grass. Duckweed grows in the water, providing food for wood ducks. These birds also feed on grasshoppers, acorns and grass. The ducks are a major food source for the Red wolves.

## PART II

To the west of the grassy area there is a desert. There, Glossy snakes eat Merriam pocket mice. These mice can burrow under shrubs and cacti to hide from the snakes. The mice cannot live in a grassy area. In the desert they burrow under mesquite shrubs and eat seeds. Grasshoppers and jack rabbits eat the mesquite leaves.

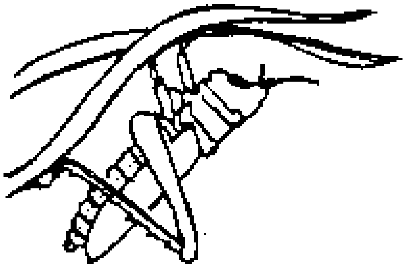
The climate is changing in the grassy area. For the next 10,000 years the average precipitation will decrease by 1.25 cm every 200 years. The average temperature will increase by 0.3 ° C every 200 years.

An average annual temperature of more than 22 °C or an annual average precipitation of less than 51 cm will cause the stream to start drying up and the oak trees to die.

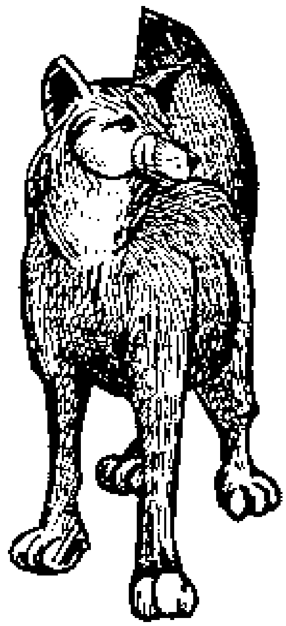
If the average annual temperature reaches 31 °C or the average annual precipitation is less than 34 cm, the water table will be too low for grass to grow.

**NOTE: When filling out the data table, assume that organisms in the desert area are trying to disperse to the grassy area at all times and that they will invade it whenever the conditions allow it.**

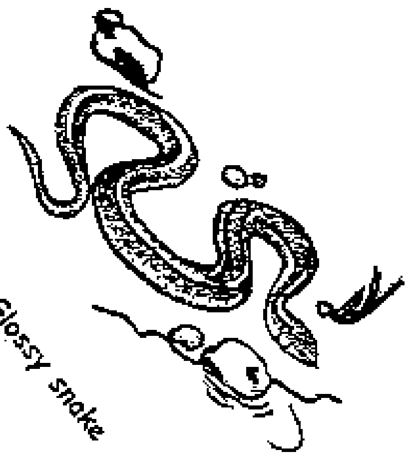
# FOOD WEB ILLUSTRATION #1



Grasshopper



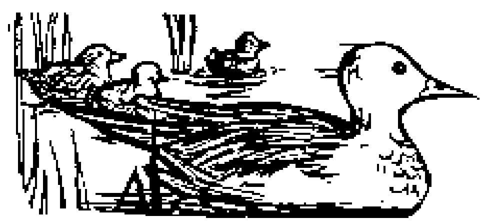
Red wolf



Glossy snake

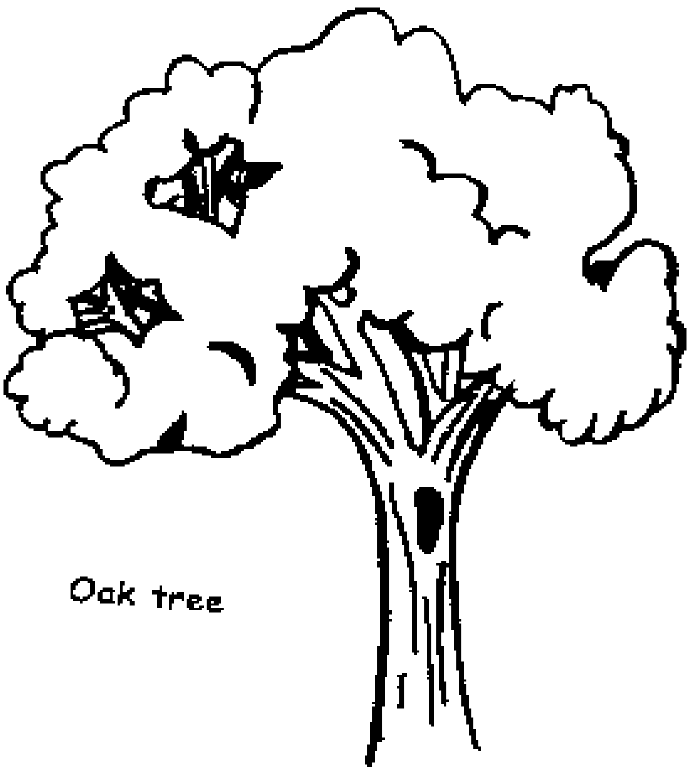
Black-tailed Jackrabbit

Merriam pocket mouse



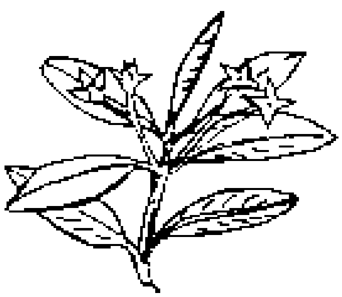
Wood Duck

# FOOD WEB ILLUSTRATION #2

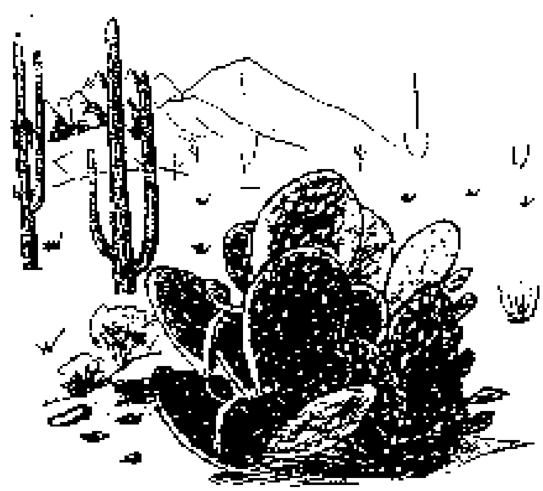


Oak tree

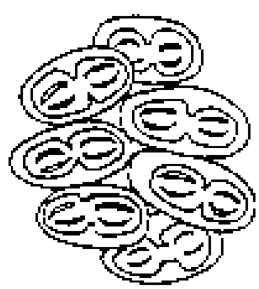
Bluestem grass



Mesquite bush



Cactus



Duckweed