

OZONE BIOMONITORING GARDEN STUDY



THEME: Ozone Garden and the Effects of Air Pollution

GRADE: Seventh

BEST TIME TO PLAN TRIP: Early Fall

UNIT RATIONALE

Scientists have noticed that ground level ozone levels tend to be worse at higher elevations, especially at night. Because of this, it is important to monitor ozone levels at various elevations. Purchase Knob is a high elevation site within the park. One of the methods we use to monitor the effects of ozone pollution is to periodically check how certain sensitive species of plants are reacting to ozone exposure. During the study students will be able to understand what ground level ozone is and how it affects plants and animals and assist in collecting data from a specific plant in the ozone biomonitoring garden.

SCIENCE 7TH GRADE NORTH CAROLINA STANDARDS

NATURE OF SCIENCE

Students are involved with science as a human endeavor that relies on reasoning, insight, skill and creativity as they participate in on-going research projects at the Great Smoky Mountains National Park. Students are exposed to science's universal laws through a systematic study of the rules, patterns and cycles in nature.

SCIENCE AS INQUIRY

Students are involved in scientific investigation that involves the collecting of relevant evidence, the use of logical reasoning and the application of imagination to devise hypotheses and explanations to make sense of collected evidence. Students use tools of investigation to collect data and mathematics to gather, organize and present data.

PERSONAL AND SOCIAL PERSPECTIVES

Students make personal and societal connections to the issues facing the Great Smoky Mountains National Park. Specifically, they will be exposed to the form and function of interacting systems.

Competency Goal 1: The learner will design and conduct investigations to demonstrate an understanding of scientific inquiry.

- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations.
- 1.03 Apply safety procedures in the laboratory and in field studies:
- 1.04 Analyze variables in scientific investigations.
- 1.05 Analyze evidence.
- 1.06 Use mathematics to gather, organize, and present quantitative data resulting from scientific investigations.
- 1.08 Use oral and written language.

Competency Goal 3: The learner will conduct investigations and utilize appropriate technologies and information systems to build an understanding of the atmosphere.

- 3.01 Explain the composition, properties and structure of the atmosphere.
- 3.02 Describe properties that can be observed and measured to predict air quality.
- 3.03 Conclude that the good health of environments and organisms requires.
- 3.04 Evaluate how humans impact air quality.
- 3.06 Assess the use of technology in studying atmospheric phenomena and weather hazards.





Competency Goal 4: The learner will conduct investigations, use models, simulations, and appropriate technologies and information systems to build an understanding of the complementary nature of the human body system.

4.07 Explain the effects of environmental influences on human health.

4.08 Explain how understanding human body systems can help make informed decisions regarding health.

LANGUAGE ARTS 7TH GRADE NORTH CAROLINA STANDARDS

Competency Goal 1 The learner will use language to express individual perspectives in response to personal, social, cultural, and historical issues.

1.01 Narrate an expressive account.

1.02 Respond to expressive materials that are read, heard, and/or viewed.

1.03 Interact in group settings.

1.04 Reflect on learning experiences.

MATH 7TH GRADE NORTH CAROLINA STANDARDS

Competency Goal 1: The learner will understand and compute with rational numbers.

1.01 Develop and use ratios, proportions, and percents to solve problems.

1.02 Develop fluency in addition, subtraction, multiplication, and division of rational numbers.



CORRELATION TO THE NATIONAL SCIENCE EDUCATION STANDARDS CONTENT STANDARDS GRADES 5-8

CONTENT STANDARD A

Science as Inquiry: All students will develop abilities necessary to do scientific inquiry and an understanding of scientific inquiry. This includes:

- answering questions through scientific investigation,
- conducting a scientific investigation,
- using appropriate tools and materials to gather, analyze and interpret data,
- thinking critically to make relationships between evidence and explanations,
- recognizing and analyzing alternative explanations and predictions
- communicating scientific procedures and explanations
- using mathematics in all aspects of scientific inquiry
- using technology to gather data and analyze

CONTENT STANDARD C

Life Science: All students will develop an understanding of structure and function in living systems, regulation and behavior, populations and ecosystems and diversity and adaptations of organisms. Specifically students will understand:

- The structure and function of whole organisms and their ecosystems
- All organisms must be able to obtain and use resources, grow, reproduce and maintain stable internal conditions while living in a constantly changing external environment.
- An organism's behavior evolves through adaptation to its environment.

CONTENT STANDARD D

Science and Technology: All students should develop abilities of technological design and an understanding about science and technology. This includes:

- designing a solution or product
- implementing a proposed design
- evaluating completed products
- communicating the process

CONTENT STANDARD E

Science in Personal and Social Perspectives: All students should develop an understanding of personal health, populations, resources and environments, natural hazards, risks and benefits and science and technology in society.

CONTENT STANDARD F

History and Nature of Science: All students should develop understanding of science as a human endeavor and the nature of history and science.





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PLANNING A SUCCESSFUL TRIP

SCHEDULE FOR A DAY OF ACTIVITIES IN GREAT SMOKY MOUNTAINS NATIONAL PARK AT PURCHASE KNOB

- Meet park ranger at Purchase Knob
- Use rest rooms
- Large group introduction
- Break into two groups
- Participate in activities
- Lunch
- Switch groups
- Large group conclusion

- Check the weather before you go. Lunch will be eaten outside.
- School buses can park at the program site.
- The pre-visit activities included in this packet are specific to the theme of your program and should be presented prior to your scheduled visit. The post-visit activities are designed to reinforce and build upon the park experience.
- A map to the Appalachian Highlands Science Learning Center Purchase Knob can be found on page 7
- All students, teachers, and chaperones will meet the Park Rangers at the Appalachian Highlands Science Learning Center at Purchase Knob.
- The maximum number of students for this trip is 60. We require an adult or teacher for every ten students to create a positive and rewarding experience. The on-site instruction is conducted by a park ranger. However, your assistance is needed with discussion and discipline. Please feel free to contact the park at (828) 926-6251 if you have any further questions.

•Dressing for the Weather

Please remind your students to wear appropriate footwear and clothing for an extended outdoor program. Short pants, flip flops, or sandals are not recommended. Temperatures in the mountains can be 10-15 degrees colder than at your school. You may wish to alter portions of the program should inclement weather appear.

•Restrooms and Water

Restrooms and water fountains will be available at the program site.

•Lunch

Lunches will be eaten picnic style on the grounds of the Learning Center. Lunches should be put in a box for storage and kept on the bus until needed. Lunches, snacks, and drinks should be provided by the students. There are no concessions at Purchase Knob.

•Safety

Purchase Knob is a remote location, far from any medical facilities. Students will spend most of their time away from buildings, so please bring a cellular phone. Notify the park ranger of any special concerns or medical conditions including students with allergies, asthma or other medical conditions.

•Cancellation

Should anything unforeseen occur preventing you from keeping your appointment, please contact the park at (828) 926-6251 to notify us of your late arrival or cancellation.





BACKGROUND INFORMATION

Park Description:

The National Park Service is charged with the management and preservation of the nation's most precious natural and cultural resources. These resources are woven into our natural heritage, and they provide opportunities for recreation, appreciation of beauty, historical reflection, cultural enrichment, and education.

Great Smoky Mountains National Park is one of the largest protected land areas east of the Rocky Mountains. With over 500,000 acres (800 square miles) of forest, the Smokies contain an enormous variety of plants and animals. In terms of biological diversity, a walk from a mountain's foot to its peak is comparable to the 2,000 mile hike on the Appalachian Trail from Georgia to Maine.

Because the National Park Service is charged with protecting resources and natural systems, the park engages in comprehensive research programs, such as air quality monitoring, to foster an understanding of park resources and to show how they are affected by local, regional, and global influences. Since the Smokies are so biologically diverse, the park is designated as an International Biosphere Reserve by the United Nations. The international system contains over 320 reserves in over 80 countries with the primary objectives of conserving genetic diversity and coordinating environmental education, research, and monitoring.

The Smokies also have a rich cultural history. Native Americans have lived in this area for thousands of years, and permanent white settlement began around 1800. The coming of commercial logging around 1900 stripped trees from two-thirds of what is now park land. Established in 1934, the park was created from more than 6,000 tracts of private and commercial land that was bought mostly with money raised and privately donated. Centrally located within a two-day's drive for half of the nation's population, Great Smoky Mountains National Park has the highest visitation of all the national parks in the country.

Purchase Knob Description:

The Purchase Knob property, over 530 acres in size, was donated to Great Smoky Mountains National Park by Katherine McNeil and Voit Gilmore in January 2001. Situated at an elevation of over 5,000 feet, the area contains old-growth forests, mountain meadows and high elevation wetlands. It also rests on geological formations that aren't found anywhere else in the park, lending to a unique and diverse habitat for the study of plants and animals. The house is the location of the Appalachian Highlands Science Learning Center, whose mission is to provide a space for researchers to perform biological inventory and monitoring while offering education programs for students and teachers on these same subjects.



PRE-SITE ACTIVITY

OZONE GARDEN BIOMONITORING INFORMATION



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Applying, Analyzing, Connecting, Contrasting, Demonstrating, Gathering information, Measuring, Reporting, Summarizing

Vocabulary:

•**Bioindicator:** vascular or non-vascular plant exhibiting a typical and verifiable response when exposed to a plant stress such as ozone.

•**Chlorosis:** yellowing of leaf caused by the loss of chlorophyll needed for photosynthesis.

•**Epidermis:** surface layer of cells in a leaf.

•**Ground-level Ozone:** an air pollutant that is a result from a chemical reaction between nitrogen oxides and VOCs in the presence of sunlight.

•**Necrosis:** localized death of a living tissue.

•**Nitrogen Oxides (NO_x):** produced from burning fuels, including gasoline and coal. Nitrogen oxides react with volatile organic compounds (VOCs) to form smog and ground level ozone. Nitrogen oxides are also major components of acid rain.

•**Ozone:** form of oxygen with three atoms of oxygen; a colorless, highly reactive gas that exists from the Earth's surface miles up into the atmosphere.

•**Photosynthesis:** the process by which green plants containing chlorophyll use the energy of sunlight to produce carbohydrate (sugars).

•**Purpling (or Stippling):** most common symptom of ozone damage on specific species of broad leaf plants; discrete and very fine purple colored spots that are seen on the upper side of the leaf's surface.

•**Sulfur Dioxide (SO_x):** a gas produced by burning coal, most notably in power plant and the production of paper. Sulfur dioxide plays an important role in the production of acid rain and haze.

•**Stomata:** tiny openings in a leaf surface through which gaseous interchange takes place.

•**Temperature Inversion:** a weather condition in which a layer of warm air settles over a layer of cold air that lies near the ground.

•**VOCs:** Volatile Organic Compounds - VOCs are released from burning fuel (gasoline, oil, wood, coal, natural gas, etc.), solvents, paints glues and other products used at work or at home. Cars are an important source of VOCs. VOCs combine with nitrogen to form Ozone. Trees naturally give off VOCs; 85% of the VOCs in North Carolina are from natural (or biogenic) sources.

Materials:

- Vocabulary
- Computer(s) with internet accessibility to view website(s)
- Student activity sheet (page 10)

Objectives:

- 1) be able to estimate the percentage of injury on the leaves of various plant species
- 2) become familiar with the vocabulary associated with estimating ozone symptoms on plants (stippling, chlorosis, necrosis)
- 3) become familiar with the natural threats to Spruce Fir Forests.
- 4) learn ways to help reduce air pollution

Background:

A website (<http://www.nature.nps.gov/air/edu/O3Training/index.cfm>) has been created by the national park service as a practice for those who will be going out into the field to monitor the effects of ozone pollution on plants. This activity is vital for students to practice to ensure their field activities are both meaningful to them and to the park as valid data.

Relate to the students that during their field trip to Purchase Knob they will be assisting in a research project by collecting data on the amount of visible symptoms they see on plants as a result of ozone exposure. To do this, they will need to practice their estimating skills. While on the field trip, students will be estimating the amount of brownish dots they see on plant leaves (called stippling), the amount of chlorosis (yellowing) and the amount of necrosis (death). When practicing, students should estimate





the percentage of leaf that appears as back dots.

Additionally students can practice estimating in the Lesson: Ozone Damage Data Collection

Procedure:

Students should work in pairs at computers or view from a large screen as a class. The teacher should first walk the students through an example reading the instructions on the “Leaf Game” activity sheet. Students should record their answers on the activity sheet.

Collect trial results from each student group pair and compare with actual percentages. Which percentage groups did the class as a whole have the most difficulty with? Which were the easiest? It has been studied that most people do the best job with the outer extremes; did that hold true with the class?

To view the Spruce Fir podcast video go to

<http://www.thegreatsmokymountains.org/eft/10modules.html> Turn the microscope knob that is viewed on the computer to Section 2, A Connected Web. Click “Watch Video” and view video.

To play the Clearing the Air game go to

<http://www.thegreatsmokymountains.org/eft/10modules.html> and turn the microscope knob that appears on the computer screen to Section 6 Protecting Biodiversity. Click “Play Game” and follow instructions.



THE LEAF GAME

- Open the address <http://www.nature.nps.gov/air/edu/O3Training/index.cfm>
- Change the number of practice leaves to “10,” click “select.”
- Next, click one of the images to practice. Common Milkweed is a good one since it is in color.
- Rate the percent of black dots covering the entire leaf surface. Even though ozone damage does not cross over veins, veins count in the overall percentage of the leaf. Write an “x” in the percentage category that you think is the correct answer.
- Click “OK” after you have selected a percentage and see the answer. Record an “o” in the percentage category of the correct answer.
- Click “next image” to continue the training.

1. Which species did you use? _____

Trial 1

2. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 2

3. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 3

4. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 4

5. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 5

6. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 6

2. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 7

3. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 8

4. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 9

5. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

Trial 10

6. ___ 0% ___ 1%-6% ___ 7%- 25% ___ 26%-50% ___ 51% - 75% ___ 76% - 100%

7. Overall, did you underestimate or overestimate the amount of ozone damage?



PRE-SITE LESSON

OZONE DAMAGE DATA COLLECTION



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 30 minutes

Setting: Classroom

Skills: Gathering information through observing; Analyzing information; Drawing conclusions.

Vocabulary:

- **Biomonitoring:** Over time, looking at a plant or animal that lives in a natural environment to check the quality of the ecosystem.
- **Chlorophyll:** Green pigment found in most plants that absorbs light plants use to make food.
- **Chlorosis:** a condition where plants produce insufficient chlorophyll and become discolored. Leaves often become pale yellow.
- **Ecosystem:** combined physical and biological components of an environment.
- **Ground level Ozone:** an air pollutant created by the interaction of nitrogen and VOC's in the presence of sunlight.
- **VOC's:** Volatile Organic Compounds. Highly reactive compounds in the air that can be either natural or man-made.

Materials:

- Color copies or projected images of leaves
- Data Sheet

Objectives:

- 1) explain how ground level ozone can injure plants
- 2) describe a biomonitoring project

Background:

An Ozone Biomonitoring Garden is a way schools can take part in an important study to determine the effects of ozone on plant populations.

The study will help to understand the relationship between foliar ozone injury and the growth of plants. The results of the study may be used to inform decision makers so adequate protective measures can be developed to improve the quality of the air we breathe. Results can be compared by tracking one leaf over the growing season and comparing a plant's growth over several years. Ozone is formed when nitrogen oxides (NOx) combine with volatile organic carbons (VOCs) in the presence of sunlight to form an unstable gas that harms humans, plants and animals. Humans suffer through lung ailments leading to permanent lung damage and reduced immune system function. Plants show foliar damage and slowed growth. This adversely impacts the agriculture and forestry industries as well as plants in nature. Impacts to animals and aquatic systems have not yet been adequately studied. Much can be done to reduce tropospheric (ground level) ozone by reducing energy use. Switching to more energy efficient appliances, using alternative, cleaner fuels when available, riding a bike

or walking instead of driving, driving the most fuel efficient vehicle possible, and using mass transportation are all ways to reduce energy consumption. Working with local, regional and national decision makers to develop the best possible standards to protect air quality for the benefit of public health and the environment is another important way to reduce ozone and improve air quality.

Monitoring

Ozone produces a type of injury on plant leaves that is unique and easy to diagnose. Typical symptoms:

- Appear after late June (except in high elevations areas which have shown symptoms in late May)
- Are found on most mature leaves first (so if you see what appears to be symptoms only on the newest leaves near the top of the plant, what you are seeing isn't ozone related).
- Are seen on the upper leaf surface, if you turn it over and it goes through, it is probably insect or Lesson: Ozone Damage Data Collection Monitoring Life in Great Smoky Mountains National Park Great Smoky Mountains National Park other damage.
- Appear as purplish-black spots (called stippling or purpling) that DOES NOT cross leaf veins. If spots do cross veins, it is damage likely caused by insects.

Procedure:

Explain to the students that they will collect data on photographs of leaves from one plant growing in Great Smoky Mountains National Park. In the field, data is only collected on the 8 lowest leaves and is done weekly.





1: Have students practice their estimation skills on 5 leaves by visiting the website <http://www.nature.nps.gov/air/edu/O3Training/index.cfm>. It is suggested that you train on Common Milkweed since it is in color. Ozone damage appears on the leaf as brownish-red stippling (dots).

2: Hand each student or groups of students one of the data sheets.

3: Either project images of each leaf, starting with the lowest leaf, or make color copies of the plant page for each student.

4: Have students estimate the percentage of ozone damage on each leaf. The plant they are collecting data on is Cut-leaf Coneflower (*Rudbeckia laciniata*).

Wrap Up:

Have each group compare their answers. Did they all estimate the same percentages of ozone damage?

Probably not. When data is collected in Great Smoky Mountains National Park throughout the summer, we are left with a trend for the entire growing season. Even if one set of data collectors make mistakes, we will still get an overall trend that shows the plants health. You can track a real plant through the growing season by going to the Hands on the Land website http://www.handsontheland.org/monitoring/projects/ozone/ozone_bio_search.cfm

Under “Report, Graphs and Maps”, use the drop down list next to “Animate a plant’s foliar injury over time” to select “Purchase Knob”. Next click the

“Graph” button.

This next page will allow you to animate one plant over the entire growing season. To view a plant, select a “Plant ID” from the drop down list. CB0209 is the Crown beard plant 02 from the year 2009.

Drag the scroll bar under the drawing of the plant to see it change over the growing season. A red color indicates that a leaf is missing. Black indicates that the leaf is still there but is completely dead. Purple indicates ozone damage, yellow indicates chlorosis and green indicates a healthy leaf.

You will notice errors in the data since a plant can’t recover from ozone damage, chlorosis or dead tissue. You will also notice that even with errors, you can still see the trend of ozone damage through the season.

Ask students why they think it is important to monitor plants for ozone damage? *The damage impacts the plants ability to photosynthesize as chlorophyll is lost. This also impacts the nutritional value of the plant if it is eaten by animals. Research has shown that plants with ozone damage are not as able to protect themselves against insect infestations or diseases.*

Assessment:

Students can be graded on both the practice described in procedure 1 and the accuracy of their final data.

Answer Key:

Leaf 1: 76 - 100%

Leaf 2: 51 - 76% (high end)

Leaf 3: 51- 76% (low end)

Leaf 4: 26 - 50% (high end)

Leaf 5: 7-25%

Leaf 6: 1 - 6%

Leaf 7: 1 - 6%

Leaf 8: 0%

Extensions:

Monitor sensitive plants in your area either by planting them in your schoolyard or out in the wild. Go to <http://www.nature.nps.gov/air/edu/O3Training/index.cfm> for a list of sensitive species.

Resources:

Ozone Biomonitoring Study on Hands on the Land <http://www.nature.nps.gov/air/edu/O3Training/index.cfm>



MONITORING LIFE IN GREAT SMOKY MOUNTAINS NATIONAL PARK OZONE DAMAGE DATA SHEET



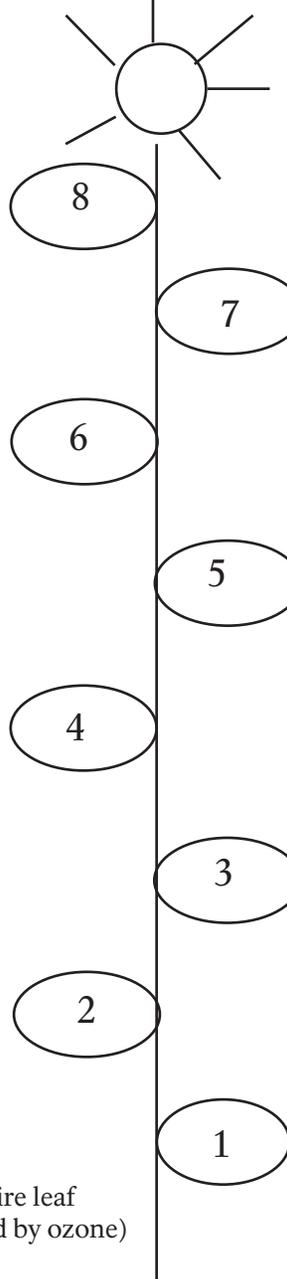
Group Name: _____

Date: _____

Plant Species: _____

Plant ID#: _____

TOP OF PLANT



Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Leaf present				Leaf Missing		
P	0%	1-6%	7-25%	26-50%	51-75%	76-100%

Observations: _____

Rate the % of ozone symptoms covering the entire leaf
 P = purpling (reddish-purple injury spots caused by ozone)

BOTTOM OF PLANT



MONITORING LIFE IN GREAT SMOKY MOUNTAINS
NATIONAL PARK
CUT-LEAF CONEFLOWER (PLANT ID CC0409)



Leaf 1



Leaf 2



Leaf 3



Leaf 4



Leaf 5



Leaf 6



Leaf 7



Leaf 8

PRE-SITE ACTIVITY

OZZY OZONE



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Analyzing, Classifying, Comparing, Connecting, Applying, Assessing, Contrasting, Estimating, Evaluating, Generalizing, Hypothesizing, Interpreting, Predicting, Summarizing

Materials:

- pdf worksheet found on http://www.handsontheland.org/teachers/data/O3_Skills_Center_Student_Worksheet.pdf
- Pencils
- Computer with internet connection to view Ozzy Ozone website <http://www.handsontheland.org/ozzone-inquiry>

Learner Objectives:

- 1) recognize what chlorosis, necrosis, and purpling/stippling look like
- 2) learn what chlorosis, necrosis, and purpling/stippling means for the plant
- 3) learn how we know that the purpling/stippling symptoms are from ozone
- 4) practice estimating ozone damage and other symptoms on selected plants

Procedure:

Have students go to the Ozzy Ozone website and choose a date and start looking for ozone-related injury. They can test themselves using the fields listed on the top of the webpage.

ON-SITE ACTIVITY

OZONE GARDEN BIOMONITORING STUDY



Grade Level: Seventh grade

Subject Area: Science

Activity time: 75 minutes

Setting: Outside in the park

Skills: Analyzing, Applying, Assessing, Calculating, Charting, Classifying, Collecting information, Comparing, Describing, Estimating, Gathering information, Hypothesizing, Identifying cause and effect, Interpreting, Recording data, Summarizing

Materials:

- Clipboard
- Data sheets
- Pencils
- Meter sticks

Objectives:

- 1) describe two characteristics of ozone damage on plants
- 2) relate which type of chemical pollutant relates to ozone formation
- 3) describe how plants can be monitored for ozone symptoms over time
- 4) explain why plants should be monitored

Background:

One of the types of pollution we research is ground level ozone. For years, scientists have noticed that ozone levels tend to be worse at higher elevations, especially at night. Because of this, it is important to monitor ozone levels at various elevations.

One of the methods we use to monitor the effects of ozone pollution is to periodically check how certain sensitive species of plants are reacting to ozone exposure. A team of researchers, some of whom have been working in this park since 1988, have developed a way to monitor plants for visible effects of ozone pollution. During the study the students will assist the rangers in collecting some of this data.

Procedure:

Everyone will work with a partner to monitor their plant. It is important not to make any assumptions as to why they see something but just to rate what they see on the plant. Students will be estimating the percent of stippling or purpling on the leaf, the percent of yellowing or chlorosis, and the percent of death or necrosis. The students will start collecting data from the base of the plant and note leaves that are missing. The students will collect the data on the data sheets.



POST-SITE ACTIVITY

EFFECTS OF HIGH OZONE LEVELS ON PLANTS



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Analyzing, Classifying, Comparing, Connecting, Applying, Assessing, Charting, Contrasting, Evaluating, Generalizing, Hypothesizing, Interpreting, Predicting, Summarizing

Materials:

- High Ozone Levels worksheet (pages 13-14)
- Pen/pencil
- Computer with internet connection

Objectives:

- 1) analyze previously recorded data
- 2) determine the appropriate type of graph to use to illustrate the data
- 3) draw conclusions based on analysis of the graph and the table
- 4) understand what the term “Stewardship” means
- 5) how students can become a steward in their school and their community.

Background:

The Ozone Biomonitoring Garden section of the Hands on the Land website allows students to compare their data with previously recorded daily ozone levels at Purchase Knob. This enables the park rangers and thus the students to draw conclusions from the recorded data.

Procedure:

The students should create a graph using data listed on the data sheet. Students should be able to determine which type of graph (line, bar, pie chart...) will best illustrate the story the data tells. Students should draw conclusions based on the data from the graph and Table 1.1.

Have students share their graphs and final conclusions with the entire class. As a group, determine if there are any other conclusions that can be drawn from the analysis. If not, what additional information would you like to have? How can you get that information?

To view the Stewardship podcast video go to <http://www.thegreatsmokymountains.org/eft/10modules.html> Turn the microscope knob that appears on the computer screen to Section 7, Backyard Stewardship. Click “Watch Video” and view video. Ask students how they can become stewards within their own school and community.



EFFECTS OF HIGH OZONE LEVELS ON PLANTS

GRAPHING EXERCISE



1. **Graphing Exercise:** Listed below are the following 8 days of 1 hour Ozone averages over a 14 day period. Use an appropriate graph to graph the data (Line, x-axis = date, y-axis = 1 hour ozone average) to the right of the data

Date	1 Hour Ozone Average (parts per billion)
7/10/08	40 ppb
7/13/08	54 ppb
7/14/08	61 ppb
7/15/08	69 ppb
7/18/08	87 ppb
7/20/08	98 ppb
7/22/08	58 ppb
7/23/08	62 ppb

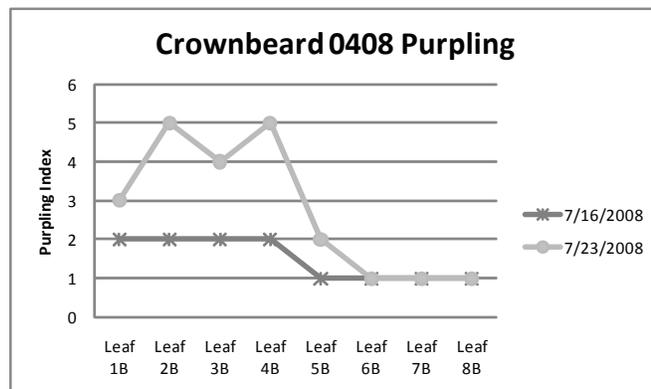
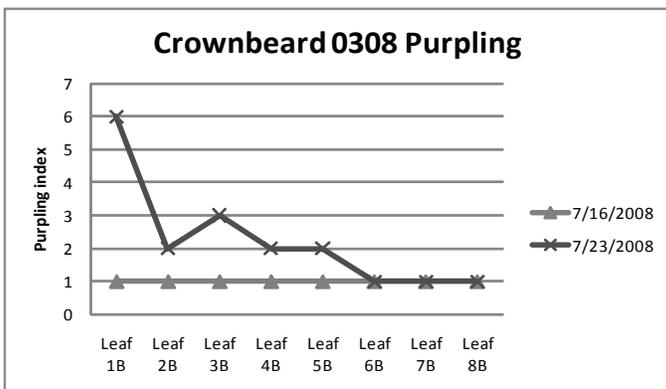


2. Listed below are the purpling (stippling) foliar injury of three Crownbeard plants and the graphs for each corresponding plant. Using the graph you created above, the information in Table 1.1, and the corresponding graphs describe the relationship between 1 hour ozone levels and Crownbeard purpling. Analyze what happens to leaves 1-8 on two plants. State your findings in the area below the graphs.

Table 1.1: Effects of High Ozone Level Days on Crownbeard Plants

Purpling Foliar Area Injury (measured in percentages): 1 = 0, 2 = 1-6, 3 = 7-25, 4 = 26-50, 5 = 51-75, 6 = 76-100 (NPS scale)

	Crownbeard 0308		Crownbeard 0408	
	7/16/08	7/23/08	7/16/08	7/23/08
Leaf 1B	1	6	2	3
Leaf 2B	1	2	2	5
Leaf 3B	1	3	2	4
Leaf 4B	1	2	2	5
Leaf 5B	1	2	1	2
Leaf 6B	1	1	1	1
Leaf 7B	1	1	1	1
Leaf 8B	1	1	1	1



EFFECTS OF HIGH OZONE LEVELS ON PLANTS

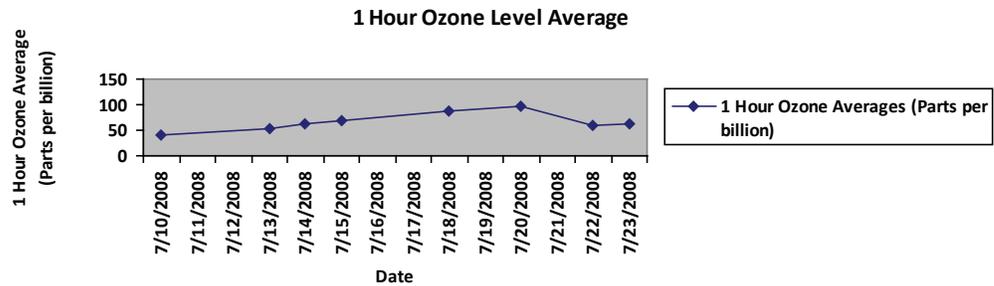
GRAPHING EXERCISE ANSWER KEY



1. Graphing Exercise

Listed below are the following 8 days of 1 hour Ozone averages over a 14 day period. Use an appropriate graph to graph the data (Line, x-axis = date, y-axis = 1 hour ozone average) to the right of the data

Date	1 Hour Ozone Average (in parts per billion)
7/10/08	40 ppb
7/13/08	54 ppb
7/14/08	61 ppb
7/15/08	69 ppb
7/18/08	87 ppb
7/20/08	98 ppb
7/22/08	58 ppb
7/23/08	62 ppb



2. Using the graph you created and the information in Table 1.1, describe the relationship between 1 hour ozone levels and Crownbeard purpling. Analyze what happens to leaves 1-8 on the two plants. State your findings in the area below.

The greater the amount of ozone air pollution present, the more foliar injury that will likely be observed on ozone sensitive plants such as Crownbeard. The amount of foliar (leaf) injury is likely to increase shortly after days with high levels of ozone air pollution. During the days of 7/18/08 and 7/20/08 ozone increased. Crownbeard leaves that had had light (category 1-2) purpling (stippling) on the 16th were damaged, and we can see the effects on the 23rd, 3 days later.

POST-SITE ACTIVITY

STEWARDSHIP



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 30 minutes

Setting: Classroom

Skills: Communicating, Connecting, Applying

Vocabulary:

•Stewardship: Our responsibility to care for our natural resources - land, air, wildlife and water - sustainably, so future generations can enjoy them.

Materials:

- Computer with Internet connection

Objectives:

- 1) understand what the term “Stewardship” means
- 2) how the students can become a steward in their school and their community

Procedure:

To view the Stewardship podcast video go to <http://www.thegreatsmokymountains.org/eft/10modules.html> Turn the microscope knob that appears on the computer screen to Section 7, Backyard Stewardship. Click “Watch Video” and view video. Ask students how they can become stewards within their own school and community.



PARENT/CHAPERONE LETTER

Greetings Parents/Chaperones:

Park rangers are pleased to be presenting an educational program to the students in Great Smoky Mountains National Park. In order to achieve the goals for a successful program, the park rangers will need your assistance in the following ways:

(These points will help to ensure that park rangers and teachers will be able effectively conduct the lessons and activities throughout the trip.)

- The program will be conducted outside and there will be some hiking throughout the trip. Prepare your student with appropriate footwear, long pants, layers, and rain gear.
- If your child is bringing a lunch from home, we recommend that students bring water to drink and a lunch with minimal packaging. Soft drinks are usually left unfinished by students, and remaining sugary drinks cannot be poured out on the ground. (Minimally packaged lunches lead to less trash being left behind or scattered by the wind. Additionally, this reduces the accumulated trash to be disposed).

If you are a chaperone attending the field trip:

- Please be an active part of the lessons. Keep up with the group and listen to the information being given in the case that you may be called upon to assist (handing out materials, sub-dividing groups etc.).
- Please do not hold conversations with other chaperones or use a cellular phone while the rangers are teaching the students.
- Refrain from smoking during the trip. If you must smoke, please alert a ranger or teacher and remove yourself from the group.
- Please be aware that the program will be conducted outside and that there will be some hiking throughout the trip. Prepare yourself with appropriate footwear, long pants, layers, and rain gear.
- We recommend that parents and students bring a small towel in their backpacks to sit on at lunch (there are no picnic tables at the program site).

Thank you for your needed assistance. We look forward to meeting you on the program!

Sincerely,

The Education Staff at Great Smoky Mountains National Park

