

LICHENS



THEME: Lichens and Air Quality

GRADE LEVEL: Seventh

BEST TIME TO PLAN TRIP: Fall or Spring

UNIT RATIONALE

There are many species of algae and fungi, but when certain species of fungi join with certain species of algae in a symbiotic relationship, they become a unique organism called a lichen. This unit is on lichens and how they are used as bioindicators of poor air quality. It is important to monitor our lichen composition so we can see if we are losing biodiversity, with the less tolerant species dying out and being replaced by the more tolerant species. During this study students will observe and identify the growth form of the lichens on the assigned tree and determine the percentage of lichen coverage of each growth form. Students will better understand different lichen growth forms, their unique symbiotic relationship, and their use as bioindicators.

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 including.





3.06 Assess the use of technology in studying atmospheric phenomena and weather hazards.

Competency Goal 4: The learner will conduct investigations and 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

AT PURCHASE KNOB

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

- Meet park ranger at Purchase Knob
- Use restrooms
- 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 picnic style on the grounds outside of the Learning Center..

•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.

•Restrooms and Water

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

•Lunch

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.

AT CLINGMANS DOME

SCHEDULE FOR A DAY OF ACTIVITIES IN GREAT SMOKY MOUNTAINS NATIONAL PARK AT CLINGMANS DOME

- Meet park ranger at Oconaluftee Visitors Center (OVC)
- Use restrooms at OVC
- Travel to Clingmans Dome in bus
- 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.

• All students, teachers, and chaperones will meet the park rangers at the Oconaluftee Visitors Center

•The maximum number of students for this trip is 50. 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)497-1942 if you have any further questions.

•Restrooms and Water

Restrooms only available at Oconaluftee Visitor center and a limited number at Clingmans Dome. There are seasonal water fountains located at Oconaluftee Visitor center but there are no water fountains available at Clingmans Dome. Groups should bring their own drinks.



SAFETY CONSIDERATIONS AND OTHER IMPORTANT INFORMATION



- Great Smoky Mountains National Park is a federally protected public use area. Please help the rangers keep all of the plants and animals protected in the park by not picking the plants or taking anything from the park.
- Please remind your students to wear appropriate footwear and clothing for this extended outdoor experience. Flip flops, slip-on shoes, or sandals are not appropriate for the program.
- Temperatures in some parts of the park can be 10-15 degrees colder than at your school. Long pants and layers are suggested for the program. Pants are the best precaution against cool temperatures, bee stings, ticks, and poison ivy.
- Within the park, cell phones are not always reliable. Rangers will follow the on-site agenda. If an unexpected problem occurs, rangers do carry park radios to make contact with the park dispatch office. For non-emergencies, call the Park Ranger dispatch at 865-436-1230 or contact a park employee.

Animals and Plants of Concern in the park

- All animals in the park are wild and their behaviors are unpredictable. Treat all animals with caution.
- Venomous snakes - Two species of venomous snakes live in the Smokies, the copperhead and timber rattlesnake. Students should be cautious where they place their hands and feet.
- Insects - Yellow jacket wasps are the insects of greatest concern. They build nests in the ground along trails and streams and are aggressive when disturbed. Stings cause local swelling and can lead to severe allergic reactions in sensitive individuals. Such persons should carry epinephrine kits.
- Poison Ivy - Poison ivy is a three-leaved plant which can grow on the ground as well as on “hairy” vines up trees. To avoid chances of an allergic reaction wear long pants, stay on trails, and avoid direct contact with vegetation. If contact occurs or is a concern, wash affected parts in cold soapy water immediately.
- It is extremely helpful to rangers leading the program for students to wear clearly labeled name tags with first names only.
- Pets are not allowed on most park trails. Please do not bring them on the field trip.
- For more information about the park (Things to Know Before You Come) please visit the park’s website: <http://www.nps.gov/grsm/planyourvisit/things2know.htm>





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.

Clingmans Dome Description:

Clingmans Dome, towering 6,642 feet above sea level is the highest peak in the Smokies. The peak was once called Smoky Dome, but was renamed Clingmans Dome in honor of U.S. Senator and Confederate brigadier general, Thomas Clingman. The seven-mile spur road to Clingmans Dome follows the border between TN and NC. The road leads to a parking area some 332 feet below the summit. From there it is a steep half-mile walk on a paved trail to the peak. Along the way the path climbs through a spruce-fir forest. This type of forest, rarely found in the southern Appalachians, is a remnant of the ice age. The walk and organized activities will give students the opportunity to learn about this forest community, its inhabitants, and the dangers this fragile forest community faces. At the peak a 375 foot ramp spirals upward to a 45 foot observation tower, allowing a view above the trees. This is the third highest mountain east of the Mississippi river. Mt. Mitchell and Mt. Craig, 70 miles west in Yancey County, North Carolina, are both slightly higher.



PRE-SITE ACTIVITY

LICHEN INFORMATION



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 60 minutes

Setting: Classroom

Skills: Analyzing, Applying, Categorizing, Comparing, Describing, Discussing

Vocabulary:

- **Algae:** a photosynthetic organism that lacks the complex reproductive structures of mosses, liverworts, and vascular plants.
- **Crustose:** crust-like lichen growth form with the lower surface growing on and among the particles of its substrate (rocks, bark...). Crustose lichen cannot be removed from the substrate in one piece.
- **Foliose:** leaf-like lichen growth form with a flattened body and distinguished upper and lower surfaces.
- **Fruticose:** shrubby or hair-like lichen growth form with no distinguishable upper and lower surface. Fruticose lichen either stands erect or hangs down from its substrate.
- **Fungus:** an organism that lacks chlorophyll and reproduces by spores.
- **Lichen:** a mini-ecosystem consisting of at least two organisms: a fungus and a photosynthetic partner (algae or cyanobacteria).

- **Moss:** members of the plant kingdom that have tiny green “leaves” composed of cells that contain chloroplasts. Mosses are generally grassy green.

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

- **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.

- **Symbiosis:** the living together of unlike organisms; it may or may not be for mutual benefit.

- **Thallus:** the vegetative body of a lichen consisting of both algal (or cyanobacteria) and fungal components.

Materials:

- Vocabulary and Definitions worksheet (listed above and on the left)
- Lichen information worksheet (page 11)
- “Lichen Growth Forms” worksheet (page 12)
- Computer with internet connection

Objectives:

- 1) be introduced to vocabulary and definitions relating to lichens
- 2) gain an overall view of the importance of lichens
- 3) be introduced to the three main lichen growth forms
- 4) understand the biodiversity of

the Great Smoky Mountains National Park.

Background:

Present the lichen story to the class: Once there was a fine carpenter named Freddy Fungus, and he could build a home using any material. But Freddy was helpless when it came to feeding himself, because he couldn’t cook. Then along came chef Alice Algae, who could whip up fabulous food right out of thin air. But alas, Alice needed a home. When Freddy and Alice met they took an immediate lichen to each other. And although their marriage was sometimes on the rocks and out on a limb, they lived symbiotically ever after. Freddy and Alice’s tale is a classic way of describing the symbiotic partnership within lichens, unique “dual organisms” composed of fungus and algae.

This lesson will introduce lichens and their characteristics. Students should read individually the vocabulary and definitions worksheet. Answer any questions that may come up after the vocabulary is read.

Procedure:

Divide the students in the classroom into four groups. Give each group one of the four subject areas: “What is a Lichen,” “What Role do Lichens Serve?,” “Why Should I Care About Lichens or Why Like Lichens?,” and “How Are Lichens Used in Biological Monitoring?” Have the students read and explain the section to the other three groups. Additionally, students should be able to identify the three



PRE-SITE ACTIVITY

LICHEN INFORMATION CONTINUED



main lichen growth forms by sight after viewing the “Lichen Growth Forms” worksheet. After seeing and reading about the three main forms of lichens, students can (individually or in groups) use adjectives and similes/metaphors to describe the three varieties of lichens. Then students can quiz each other to see if they can figure out each lichen based on their description. Allow students to share with the class their most unique or interesting adjectives and similes/metaphors.

View the following videos as a class to prepare for the Lichen field trip.

To view the Lichen Science Friday video go to
<http://www.sciencefriday.com/program/archives/201011124>

To view the Biodiversity podcast video go to
<http://www.thegreatsmokymountains.org/eft/10modules.html> Turn the microscope knob that appears on the computer screen to Section 1, Understanding Biodiversity. Click “Watch Video” and view video.





What is a Lichen?

There are many species of algae and fungi, but when certain species of fungi join with certain species of algae, they become a unique organism called a lichen. Scientists can identify each different combination by the characters of its thallus (the point where the algae and fungus join). The alga and fungus work so closely together, each union has its own lichen species name.

What role do Lichens serve?

Lichens can grow in places where most other organisms can't. They can attach themselves to bare rock, bark, sand, animal bones and soil, growing on surfaces that would be inhospitable for most other forms of life. They have a special survival technique that allows them to shut down when conditions are too harsh such as extreme heat, cold or drought. Thus, lichens are the stepping stone, slowly beginning the process of creating a soil and organic matter foundation for other things to grow upon by processing nutrients from the air and providing a place for plants to sink their roots.

Most lichens grow very, very slowly, often less than a millimeter per year. Some lichens are thought to be the oldest living things on Earth. Lichens are also very diverse, with over 3,000 species found in North America. Lichen diversity tends to be at its highest in ecosystems that have had the least amount of disturbance. Because of this, lichen diversity can tell scientists a story of how pristine (undisturbed) a particular area is.

Why Should I Care About Lichens or Why Like Lichens?

Lichens are important in many ways:

- ◆ Drug companies make antibiotics from lichen substances.
- ◆ Lichens are home to many different types of spiders, mites and insects.
- ◆ Lichens have been used as a natural dye to color wool and wood since the 16th century.
- ◆ Many lichens are edible, it is said that George Washington's troops at Valley Forge ate a protein soup made from lichens during the harsh winter.

How Are Lichens Used in Biological Monitoring?

A biological indicator (or bioindicator) is a living organism that reflects the quality of the environment. Biological monitoring (or biomonitoring) describes the use of bioindicators to evaluate various environmental conditions. Lichens have been found to be bioindicators for the general atmospheric conditions since they absorb water and nutrients from the air (including pollution) over their entire surface. The effect of air pollution on lichens includes:

- ◆ bleaching (the loss of chlorophyll in the algal cells)
- ◆ development of a red coloration
- ◆ blackening
- ◆ stunted growth or a decline in growth rate
- ◆ development of tiny lobes along margins
- ◆ failure to produce fruiting bodies
- ◆ loss of sensitive species with a possible replacement by tolerant species

Lichen Growth Forms

(overall shape and configuration of the lichen body)

- **FOLIOSE (leaf-like)**
 - flattened body
 - distinguished upper and lower surfaces
- **FRUTICOSE (shrubby or hair-like)**
 - grow erect or hang straight down
 - no distinguishable upper and lower surfaces
- **CRUSTOSE (crust-like)**
 - lower surface grows on and among the particles of the substrate
 - cannot be removed from the substrate in one piece



Great Smoky Mountains National Park



ON-SITE ACTIVITY LICHEN STUDY

Grade Level: Seventh Grade

Subject Area: Science

Activity time: 75 minutes

Setting: Outside in the park

Skills: Analyzing, Applying, Categorizing, Collecting information, Comparing, Contrasting, Discussing, Hypothesizing, Inferring, Measuring, Summarizing

Materials:

- Data sheets
- Compasses
- Grid transparency
- Lichen guide
- Forest measuring tape
- String

Objectives:

- 1) describe the three main growth forms of lichens
- 2) explain why lichens should be monitored
- 3) gather baseline data by determining the percent of lichen coverage on selected tree species
- 4) determine if there is any change in lichen coverage over time (long-term)
- 5) attempt to correlate any changes in lichen coverage to environmental factors such as air quality/atmospheric pollution (sulfur dioxide, ground level ozone, acid rain)

Background:

A bioindicator is a species that reacts so strongly to a pollutant or a change in its environment that it can be used to determine the effects of that pollutant. Biomonitoring is when you check the health of the indicator species over time to see a longer term effect from exposure. Lichens have been used to directly measure the results of an excess of sulfur dioxide in the air.

In the Smokies, though we have been studying air quality since 1988, we are really just starting to use biomonitoring of lichens. To do this, it is important to know what we have (baseline data) in order to understand how it is being affected by air pollution.

Procedure:

Each group will be assigned a tree; it is your job to identify the tree species, use the guides provided to identify the types of lichens you observe and then use the grid to determine the percentage of each lichen type.

Not all lichens respond to air pollution in the same way. One type of lichen actually thrives in polluted areas. It is important to monitor our lichen composition so we can see if we are losing biodiversity with the less tolerant species dying out and being replaced by the more tolerant species.



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.



POST-SITE ACTIVITY

LICHEN SENSITIVITY IN THE UNITED STATES



Grade Level: Seventh Grade

Subject Area: Science

Activity time: 30 minutes

Setting: Classroom

Skills: Analyzing, Applying, Calculating, Comparing, Connecting, Contrasting, Hypothesizing, Inferring, Summarizing

Materials:

- “Lichen Sensitivity Activity” (pages 16 ,17, and 18)
- Pen/pencil

Objectives:

- 1) compare SO_x and NO_x emission sources in the Northwestern United States versus the Southeastern United States
- 2) review the primary sources of sulfur, nitrogen, and VOC's.

Background:

Lichens vary in sensitivity to both nitrogen and sulfur dioxide. This activity is to help students understand the differences between emission sources in the Northwestern United States and the Southeastern United States.

Procedure:

The students should complete the “Lichen Sensitivity Activity” worksheets. Once the class has completed the activity individually, compare answers as a group. Answer any remaining questions.

Resources:

- 1) “United States Forest Service: National Lichens & Air Quality Database and Clearinghouse” <http://gis.nacse.org/lichenair/>
- 2) SAMI Final Report_0802.pdf





LICHEN SENSITIVITY WORKSHEET

1. Analyze Table 1. Determine the VOC percentages for each of the VOC emission sources.

Table 1: State Emissions Summary for the eight SAMI southeastern states (VOC emission in thousand tons per year).

Emissions Source	1990 VOC	% of Total VOC	2010 VOC	% of Total VOC	Difference
Utilities	6	_____	10	_____	_____
Industrial Point	689	_____	668	_____	_____
Highway Vehicles	1,183	_____	798	_____	_____
Nonroad	355	_____	296	_____	_____
Area	1,417	_____	1,443	_____	_____
Total	3,651	100	3,216	100	_____

2. What is the primary source for VOC emissions in the southern United States?

3. What emissions source will have the largest projected reduction in VOC emissions by 2010 due to the Clean Air Act?

4. Analyze Table 2. Determine the NOx percentages for each of the NOx emission sources.

Table 2: State Emissions Summary for the eight SAMI southeastern states (NOx emission in thousand tons per year).

Emissions Source	1990 NOx	% of Total NOx	2010 NOx	% of Total NOx	Difference
Utilities	1,585	_____	977	_____	_____
Industrial Point	550	_____	556	_____	_____
Highway Vehicles	1,285	_____	792	_____	_____
Nonroad	497	_____	490	_____	_____
Area	383	_____	450	_____	_____
Total	4,300	100	3,265	100	_____

5. What is the primary source for NOx emissions in the southern United States?

6. What emissions source will have the largest projected reduction in NOx emissions by 2010 due to the Clean Air Act?





LICHEN SENSITIVITY CONTINUED

7. Analyze Table 3. Determine the NO_x percentages for each of the NO_x emission sources.

Table 3: State Emissions Summary for Washington and Oregon in 2002 (NO_x emission in thousand tons per year).

Emissions Source	N-NO _x	% of Total N Emissions
Utilities	22	_____
Industrial Point	4	_____
Highway Vehicles	93	_____
Nonroad	62	_____
Area	7	_____
Total	188	100

8. What is the primary source for NO_x emissions in Oregon and Washington?

9. How are the NO_x emission sources percentages different in the Northwestern United States versus the Southeastern United States?

10. Why are decreases of nitrogen-containing pollutants harder to achieve than sulfur dioxide pollutants?

11. Analyze Table 5. Determine the SO_x percentages for each of the SO_x emission sources.

Table 5: State Emissions Summary for the eight SAMI southeastern states (SO_x emission in thousand tons per year).

Emissions Source	1990 SO _x	% of Total SO _x	2010 SO _x	% of Total SO _x	Difference
Utilities	4,710	_____	3,270	_____	_____
Industrial Point	671	_____	662	_____	_____
Highway Vehicles	33	_____	29	_____	_____
Nonroad	121	_____	157	_____	_____
Area	464	_____	524	_____	_____
Total	5,998	100	4,641	100	

12. What is the primary source for SO_x emissions in the southern United States?

13. What emissions source will have the largest projected reduction in SO_x emissions by 2010 due to the Clean Air Act?





LICHEN SENSITIVITY CONTINUED

14. Analyze Table 6. Determine the SO_x percentages for each of the SO_x emission sources.

Table 6. Summary of Oregon and Washington sulfur emissions in 2002. (SO_x emission in thousand tons per year).

Emissions Source	S-SO ₂ (tons/y)	% of Total S Emissions
Utilities	31	45
Industrial Point	6	9
Highway Vehicles	5	7
Nonroad	20	29
Area	7	10
Total	69	100

15. What is the primary source for SO_x emissions in Oregon and Washington?

16. How are the SO_x emission sources percentages different in the Northwestern United States versus the Southeastern United States?



LICHEN SENSITIVITY WORKSHEET

ANSWER KEY



1. Analyze Table 1. Determine the VOC percentages for each of the VOC emission sources.

Table 1: State Emissions Summary for the eight SAMI southeastern states (VOC emission in thousand tons per year).

Emissions Source	1990 VOC	% of Total VOC	2010 VOC	% of Total VOC	Difference
Utilities	6	<u>0.2</u>	10	<u>0.003</u>	<u>+4</u>
Industrial Point	689	<u>19</u>	668	<u>21</u>	<u>-21</u>
Highway Vehicles	1,183	<u>32</u>	798	<u>25</u>	<u>-385</u>
Nonroad	355	<u>10</u>	296	<u>9</u>	<u>-59</u>
Area	1,417	<u>39</u>	1,443	<u>45</u>	<u>+26</u>
Total	3,651	100	3,216	100	

2. What is the primary source for VOC emissions in the southern United States?

Area.

3. What emissions source will have the largest projected reduction in VOC emissions by 2010 due to the Clean Air Act?

Highway Vehicles.

4. Analyze Table 2. Determine the NOx percentages for each of the NOx emission sources.

Table 2: State Emissions Summary for the eight SAMI southeastern states (NOx emission in thousand tons per year).

Emissions Source	1990 NOx	% of Total NOx	2010 NOx	% of Total NOx	Difference
Utilities	1,585	<u>37</u>	977	<u>30</u>	<u>-608</u>
Industrial Point	550	<u>13</u>	556	<u>17</u>	<u>+6</u>
Highway Vehicles	1,285	<u>30</u>	792	<u>24</u>	<u>-493</u>
Nonroad	497	<u>12</u>	490	<u>15</u>	<u>-7</u>
Area	383	<u>9</u>	450	<u>14</u>	<u>+67</u>
Total	4,300	100	3,265	100	

5. What is the primary source for NOx emissions in the southern United States?

Utilities.

6. What emissions source will have the largest projected reduction in NOx emissions by 2010 due to the Clean Air Act?

Utilities.



LICHEN SENSITIVITY WORKSHEET

ANSWER KEY CONTINUED



7. Analyze Table 3. Determine the NO_x percentages for each of the NO_x emission sources.

Table 3: State Emissions Summary for Washington and Oregon in 2002 (NO_x emission in thousand tons per year).

Emissions Source	N-NO _x	% of Total N Emissions
Utilities	22	12
Industrial Point	4	2
Highway Vehicles	93	49
Nonroad	62	32
Area	7	4
Total	188	100

8. What is the primary source for NO_x emissions in Oregon and Washington?

Highway vehicles.

9. How are the NO_x emission sources percentages different in the Northwestern United States versus the Southeastern United States?

In the Southeastern United States the highest NO_x emission source was utility while in the Northwestern United States the highest NO_x emission source is highway vehicles and nonroad.

10. Why are decreases of Nitrogen-containing pollutants harder to achieve than sulfur dioxide pollutants?

While utility is an important source of NO_x especially in the Southeast, highway vehicle and non-road sources account for the majority of emissions in the Northwest. Therefore, compared to sulfur dioxide, decreases of N-containing pollutants are harder to achieve because they are more directly tied to population size (amount of fossil fuel burned per person).

11. Analyze Table 5. Determine the SO_x percentages for each of the SO_x emission sources.

Table 5: State Emissions Summary for the eight SAMI southeastern states (SO_x emission in thousand tons per year).

Emissions Source	1990 SO _x	% of Total SO _x	2010 SO _x	% of Total SO _x	Difference
Utilities	4,710	<u>79</u>	3,270	<u>70</u>	<u>-1440</u>
Industrial Point	671	<u>11</u>	662	<u>14</u>	<u>-9</u>
Highway Vehicles	33	<u>0.5</u>	29	<u>0.6</u>	<u>-4</u>
Nonroad	121	<u>2</u>	157	<u>3</u>	<u>+36</u>
Area	464	<u>8</u>	524	<u>11</u>	<u>+60</u>
Total	5,998	100	4,641	100	



LICHEN SENSITIVITY WORKSHEET

ANSWER KEY CONTINUED



12. What is the primary source for SO_x emissions in the southern United States?

Utilities.

13. What emissions source will have the largest projected reduction in SO_x emissions by 2010 due to the Clean Air Act?

Utilities.

14. Analyze Table 6. Determine the SO_x percentages for each of the SO_x emission sources.

Table 6. Summary of Oregon and Washington sulfur emissions in 2002. (SO_x emission in thousand tons per year).

Emissions Source	S-SO ₂ (tons/y)	% of Total S Emissions
Utilities	31	45
Industrial Point	6	9
Highway Vehicles	5	7
Nonroad	20	29
Area	7	10
Total	69	100

15. What is the primary source for SO_x emissions in Oregon and Washington?

Utilities. Currently the region's two coal-fired electric utilities are the largest remaining regional point sources. Sulfur dioxide (SO₂) has declined substantially in the Pacific Northwest states and elsewhere in the U.S. since implementation of the federal Clean Air Act. Emission controls on point sources have been very effective in reducing regional SO₂ emissions.

16. How are the SO_x emission sources percentages different in the Northwestern United States versus the Southeastern United States?

Both in the Southeastern United States and in the Northwestern United States the highest NO_x emission source were utilities.

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

