Plants on Pollution Patrol
Grade 4, Science

Georgia Performance Standards:
S4L1. Students will describe the roles of organisms and the flow of energy within an ecosystem.
      c. Predict how changes in the environment would affect a community (ecosystem) of organisms.
      d. Predict effects on a population if some of the plants or animals in the community are scarce or if there are too many.

Total Duration: 3 hours

Focus: In this life science lesson from The Clean Air Campaign, fourth grade students will learn about interdependence of plants and animals in an ecosystem through guided research; explore the concept of sensitive plant species that are indicators of pollution; conduct actual field studies to assess the impact of air pollution on local plants; and predict how a community would change if air pollution killed the most sensitive plants, leaving only pollution-tolerant plants behind.

Materials:
For each student:
- 1 copy Student Handout, including Worksheet and Biomonitoring Field Study Report
- 1 computer with Internet access
- 1 clipboard
- 1 calculator
- 1 hand lens or other portable magnifier
- 1 index card for use in photos

For the class:
- 1 camera (or multiple disposables) and film or digital media for 2-3 photos per student
- 1 pack wide-tipped markers to mark index cards for photo identification

Procedures:
Step 1: Teacher Preparation
Scout and select locations for the bio-monitoring project (Step 3). Identify milkweed plants at the site OR select another pollution-sensitive species to

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monitor. Among suitable alternatives are choke cherry or black cherry, tulip poplar, sycamore, dogbane, coneflower, flowering dogwood, and blackberry. Preview the directions contained in Trackstar Track #377405 for help recognizing plant species and learning bio-monitoring procedures. For more in-depth information on bio-monitoring or to register your project for data-sharing with other schools, see "Using Indicator Plants as Bio-indicators of Ozone." Consider creating a classroom garden of "air cleaning plants," as described in Trackstar Frame #14, to reinforce lesson concepts.

Timing is everything. Ozone is a secondary pollutant that forms seasonally. It has highest concentrations late in the day on summer evenings. The later it is in summer, the more pronounced the pollution damage. For best results, conduct the bio-monitoring field studies (Step 3) in August or September. If it is difficult for the class to access indicator plants growing in their natural habitats, consider planting an "ozone garden" from seed or cuttings. Milkweed is a long-lived perennial that will provide a learning lab for ozone pollution and monarch butterflies, year after year.

Acquire or assemble materials needed for bio-monitoring. Make copies of the student handout. Arrange for students to have access to individual, Internet-connected computers for research at Step 2. Note that the final research Web site in Step 2 offers only five minutes of free access to a particular interactive simulation per day, from each email address. As an alternative, teachers may register for a 30 day unlimited free trial including student access at ExploreLearning. (No credit card or financial information requested).

Step 2: Introduction and Guided Research
Duration: 1 ½ hours
Background Knowledge: Before students begin the Internet research assignment, they should be familiar with the roles of organisms and flow of energy in an ecosystem. Review this info or, if students are totally unfamiliar with the subject, this slide presentation on energy flow and/or this video about an ecosystem. (Note: The Web site is free but requires registration).

Guided Research: Distribute student worksheets and tell the class they will go on a Webquest to search for answers to the worksheet questions. Situate students at Internet-connected computers and direct them to the Trackstar Web site, where they should enter 377405 in the box labeled: "View track number" and click "Go." Tell students they should then click "View in

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Frames" and *read the notes at the top of each page for directions* (scrolling down as necessary) before viewing Web page content.

In the first frame, students will view the Wisconsin Department of Natural Resources Web site to learn about bio-monitoring and how certain plants and animals can warn us about pollution. Next, they will learn how air pollution affects plants and animals from the EasyBreathers Web site and specifically about ground level ozone from the Pathfinder Science Web site at University of Kansas. The National Parks Conservation Association will show students how air pollution is harming plants and animals in our parks.

After viewing a short slide presentation from EasyBreathers on how to monitor milkweed plants for signs of ozone pollution damage, students will check out this slide show from Wisconsin DNR to learn how to distinguish between ozone pollution damage and other leaf injuries. At the Monarchs Across Georgia Web site, students will learn how to recognize the main types of milkweed in their area and then find out who eats milkweed at the MonarchWatch Web site. From the Journey North Web site they will learn who eats the monarch butterflies who, in turn, eat milkweed. Then, students will look at images of ozone damage in other species of plants at NASA's AURA Web site before going to the interactive National Park Service Web site to practice estimating percentage of leaf damage.

Next, students will watch a slide show from Oldham School about lichens as a bio-indicator of sulfur dioxide air pollution and study slides of pollution-tolerant vs. pollution-sensitive lichens from the British Lichens Society. Then, students will discover some pollution-tolerant plants that do not decline when exposed to air pollutants, but actually improve air quality by removing toxins! Finally, students will play a simulation game from ExploreLearning to predict changes in an ecosystem due to air pollution. After completing the research, students will answer a synthesis question that compels them to use information learned to predict how air pollution will affect an ecosystem over time.

Step 3: Biomonitoring Field Studies
Duration: 1 hour (repeat as desired to observe changes in conditions)

Distribute a copy of the Field Studies Report and an index card to each student. Have students use wide-tipped markers to write their names on the index cards, which will be placed in the vicinity of plants or leaves being

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photographed to identify the researcher. Make sure students have pencils, clipboards, and hand lenses or other magnifiers before taking the class outside to the bio-monitoring area or ozone garden. Remind students to note the location of a specific leaf on the report form and take a photograph (or request that a photo be taken) before disturbing the plant. Spread students throughout the area and assign each child to a specific plant (or allow students to find their own plants and to request approval before proceeding). Do not allow removal of more than two leaves from the same plant. Lower leaves are older and thus usually show more damage. Encourage students to complete their research and complete their reports in the field. Remember to have photos developed and distribute to students to attach to their reports. If it is unclear whether leaf damage is due to ozone exposure, even after viewing the information in Trackstar about how to distinguish ozone damage, a photo may be submitted to NASA for analysis. Press collected leaves between pages in old phone books with weight on top, for one week – ten days.

Step 4:   Effects of Air Pollution on an Ecosystem
Duration: 20 minutes

Display field study reports with corresponding photos and pressed leaves, so students can compare their results and get an overall picture of the health of milkweed plants in the ecosystem. Encourage students to generalize from their research and field work to draw conclusions about these questions: Is our air polluted? (answer will vary depending on location and season) How do you know? (ozone data map from research, milkweed monitoring results) What are the first effects of ozone pollution on an ecosystem? (sensitive plants may show damage before other components of ecosystem) What effects cascade from the damage done to plants? (scarcity of a plant limits the population of animals that depend on that plant for food and affects every other organism connected in a food web, in some way) How could animals be affected by ozone pollution? (indirectly, as a result of damage to plants on which they depend, and directly, in terms of their own respiratory health) What are some ways that plants respond to pollution in an ecosystem? (pollution-tolerant species may out-compete the pollution-sensitive species and become dominant in the area). What are some ways that animals may respond to pollution in an ecosystem? (migration, change in diet, increased competition with others for limited resources, starvation/decline in population)

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Step 5: Debriefing: The Big Ideas
Duration: 10 minutes

Engage students in a conversation about what they learned from their research and field studies, using the student worksheet Answer Key as a guide. Expand on student input to make sure all of the following concepts are included:

- Air pollution is a type of environmental change that affects entire ecosystems.
- Ground-level ozone is formed when pollutants from vehicle tailpipes react with vapors and fumes in the air on hot, sunny days.
- Ozone pollution hurts certain plants, including milkweed and many others.
- Ozone-damaged plants are an indicator that pollution levels are also high enough to affect humans, animals, and ecosystems.
- All organisms in an ecosystem are inter-connected
- Air pollution can change an ecosystem by forcing organisms to adapt or die.
- If a plant cannot adapt quickly enough, it will die and be replaced by more pollution-tolerant species.
- Changes in the types of plants in a community will result in changes in the types of animals in the community, because plants provide shelter and food for the animals.
- If there are too few healthy milkweed plants and too many hungry monarch larvae (who only eat milkweed), the populations of both species will decline.
- Ozone pollution levels can be lowered by reducing tailpipe emissions (i.e. more fuel-efficient vehicles, fewer miles driven, more carpooling, bus and bike riding, less time letting engines idle, etc.); reducing power plant emissions (by conserving energy and thus reducing demand for coal-fired electricity, cleaning smokestack emissions, etc.); and reducing release of vapors from volatile organic compounds (by patronizing "green" dry cleaners, fueling cars in the dark when gas fumes are less likely to evaporate, using low VOC paints, etc.).

Assessment

An Answer Key for the student worksheet and a Scoring Rubric for student research and field studies are provided to assess mastery of lesson activities and key concepts.

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Follow-Up:
After you have taught this lesson plan, please tell the Clean Air Schools program about your efforts in a brief, 60-second online survey at CleanAirCampaign.org. The information you provide is invaluable in helping this non-profit education program direct its resources to improving these lesson plans and creating new materials for your students. Thanks!

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**Plants on Pollution Patrol
Student Worksheet**

For use with Track # 377405 at http://trackstar.4teachers.org
Note: Each blank correctly filled in is worth 3 points.

Frame 1: Biomonitoring
List three bio-indicator species and the conditions they warn us about

Frame 2: How Air Pollution Hurt Plants, Animals and People
a. List one way air pollution can harm a plant.
    _____

b. List one way air pollution can harm an animal.
    _____

c. List one way air pollution can harm a person.
    _____

Frame 3: What is Ozone and What Are Its Effects?
What is the difference in "good ozone" and "bad ozone"? (Hint: where is each formed?)
_____

Identify the three steps in making ground-level ozone:
1. _____
2. _____
3. _____

Who is responsible for making ozone pollution?
_____

Frame 4: How is Air Pollution Affecting Our National Parks?
Name of national park you read about: _____

Identify a pollutant and its effects on plants, animals, or non-living things

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Frame 5: How Can I Monitor Milkweed for Signs or Pollution?
What is the main way you can tell that a milkweed plant has been harmed by ground level ozone?
_____

Frame 6: How Can I Tell Pollution Damage from Other Leaf Injuries
What is one sign that dots on a milkweed leaf do NOT indicate air pollution?
_____

Frame 7: How Do I Recognize Milkweed?
Write the names of two types of milkweed that you might expect to grow in your particular area.
1. _____
2. _____

Frame 8: Who Eats Milkweed?
a. What animal eats milkweed exclusively? _____

b. If all the milkweed plants in your area died of air pollution, what sort of plants would take their place? (State characteristics, not species)
   _____

c. What would happen to the animals that ate milkweed? _____

Frame 9: Who eats Monarchs?
a. What animals eat monarch larvae or butterflies? _____

b. What would happen to animals that eat monarchs, if there were no monarch larvae or adults? _____

Frame 10: What Other Sensitive Plants Could I Monitor for Air Pollution?
Identify an air pollution-sensitive plant species you have seen (or think you could find) in your area: _____

Frame 11: How Do I Estimate the Extent of Pollution Damage to a Leaf?
What species will your class monitor? (Ask your teacher if you do not know)
_____

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Train to estimate percentage of leaf damage for that species, to accuracy of 80% or better. Print score sheet to show to teacher. Select "1" when asked number of leaves. Do not use Back button in browser or score will be lost. Keep trying until you master this skill at 80%.

Note: After mastering ozone leaf-damage assessment for one species, view the remaining Trackstar frames and complete the rest of the worksheet. If time remains, you may return to this frame and train in a different species, for extra credit.

Frame 12: What Do Lichens Tell Us about Air Pollution?
a. If you saw Usnea subfloridana thriving, what could you deduce about air quality?
_____

b. What could you tell about air quality if you saw Lecanora flourishing and no other lichens in the area?
_____

Frame 13: Which Lichens Flourish (Or Die) in Polluted Air?
a. Which of the lichens can stand to live where the air is high in sulfur?
_____

b. If you found a flourishing lichen of the Xanthoria family and no other lichens living in the area, what pollutant is likely to the in the air?
_____

c. If an Usnea cornuta lichens was found in the woods near your home, what could you conclude about the air quality nearby?
_____

Frame 14: Which Plants are Air Pollution Heroes?
Pick your three favourite houseplants that have the power to purify air:
1) For benzene: _____
2) For formaldehyde: _____
3) For trichloroethelyne: _____

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Frame 15: How Can I Predict Changes in an Ecosystem Due to Air Pollution?

a. How long did it take for the first community to stabilize?

_____

b. What are the effects when some grass is diseased (simulating ozone-damaged milkweed)?

_____

c. What do you think would happen if all the grass were removed from this food chain?

_____

Synthesis Question: Tell what you think would happen to an ecosystem (both plants and animals) if one species of plant was tolerant of ozone and all the other species of plants in the area were not.

_____
_____
_____

Extra Credit: After completing the worksheet, feel free to return to Frame 12 to train in another species for extra credit. List additional species here: _____ Print score sheet.

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Field Study Report

Identify plant species being studied: _____

Describe location where plant was found: _____

Position of leaf on plant:
Row _____ (# of row, counting down from top) of _____ (total # rows)

Observations

Describe general condition, coloring, damage to leaf: _____ _____ Any black or purple dots? □yes □no Any dots on veins?* □yes □no Any dots under leaf?* □yes □no Any leaf yellowing (chlorosis)? □yes □no Is leaf wilted? □yes □no Is leaf dead (necrosis)? □yes □no Was leaf collected? (Attach.) □yes □no Was leaf photographed? □yes □no photo ref # , if any: _____	Draw or trace leaf here (or indicate that drawing is on back, if leaf too large for this space). Show any damage, stippling, discoloration, holes, etc. using colored pencils.

*Note: If there are any dots under the leaf or on the veins, the damage is not caused by ozone.

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Data

Approximately what percentage of the leaf is affected by ozone stippling, if any? _____

Conclusions

Has ozone air pollution affected this community of organisms (ecosystem)?
□yes   □no
What evidence supports your conclusion?

_____

Predictions

Predict how increased ozone levels might affect this ecosystem in the future.

_____

_____

Predict what would happen to other plants and animals if milkweed became scarce or disappeared.

_____

_____

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Answer Key for Plants on Pollution Patrol
for use with Trackstar Track # 377405 at http://trackstar.4teachers.org

Frame 1: What is Biomonitoring?

List three bio-indicator species and the conditions they warn us about

List three bio-indicator species	and the conditions they warn us about
Canary	Methane or carbon monoxide in coal mines
Eagle	Pesticides
Milkweed	Ozone pollution

Frame 2: How Does Air Pollution Hurt Plants, Animals and People?
It is not required for students to name the specific pollutants that cause the effects listed.
List one way air pollution can harm a plant. (Accept any one of the following)
1. Ozone can interfere with a plant's ability to make and store food, making it susceptible to disease, insects, weather, or other damage.
2. Ozone can kill or damage leaves by attacking photosynthetic cells (and causing spots).
3. Carbon monoxide can discolor leaves and disrupt photosynthesis.
4. Nitrogen compounds, with sulfur dioxide and ozone, can cause acid rain which damages plants
5. Sulfur dioxide can cause leaf bleaching and tissue death.
6. Particle pollution (particulate matter) can cover leaves and block photosynthesis.

List one way air pollution can harm an animal. (Accept any one of the following)
1. Toxins in air pollution can enter an organism if eaten, breathed or absorbed.
2. Ground level ozone can hurt the ability of people or animals to breathe.
3. Particle pollution (particulates) can not only make it hard to breathe, but can also cause dangerous metals to enter the body and accumulate.
4. Acid rain can contaminate drinking water and kill trees (which provide animals shelter and food).
5. Global warming can affect migration, habitat location, diet. Students who clicked on related links may know that polar bears, pika, turtles, birds, and corals are at risk.

List one way air pollution can harm a person. (Accept any one of the following)
1. compromise immune system
2. reduce oxygen intake
3. irritate eyes, nose and throat
4. reduce ability to exercise outdoors
5. trigger asthma
6. aggravate chronic lung disease
7. reduce lung function loing-term

Frame 3: What is Ozone and What Are Its Effects?
What is the difference in "good ozone" and "bad ozone"?
Ozone that is formed in the upper atmosphere protects the earth from UV rays.
Ozone formed at ground-level is harmful to breathe.

Identify the three steps in making ground level ozone.
1. Organic compounds (VOCs) are released from evaporating gasoline, paints and solvents.
2. Cars, power stations, and factories burn fossil fuels that release nitrogen oxide gases.
3. Heat and sunlight trigger chemical reactions between nitrogen oxides and organic compounds, forming ozone.

Who makes ozone pollution? (Accept any of the following)
Industries and power companies produce ozone, but so do ordinary people by driving cars, boats, and other vehicles; using paints and certain cleaning products that release vapors, and by creating demand for electricity and products that polluting industries make.

Frame 4: How Is Air Pollution Affecting Our National Parks?
Name of national park you read about: _____
Answers will vary, but should include one pollutant and its effects:

Park	Pollutants	Effects
Great Smoky Mountains	Ozone Sulphur and nitrogen Acid rain	30 species incl. 90% black cherries have damage High deposition (contamination) levels Damage to high elevation red spruce
Mammoth Cave	Mercury	Contaminated endangered Indiana bats (neurological and reproductive effects)
Joshua Tree	Warming (due to greenhouse gases)	Trees will be edged out and replaced with more heat-tolerant invasive grasses
Rocky Mountain	Nitrogen deposition	Contaminated soils and waters affect plants and animals

Frame 5: How Can I Monitor Milkweed for Signs of Pollution?
What is the main indication (how can you tell) milkweed is harmed by ground level ozone?
Stipples (dots) appear on the leaves of milkweed plants that are damaged by ozone.

Frame 6: How Can I Tell Pollution Damage from Other Leaf Injuries?
What is one sure sign that black dots on a milkweed leaf do NOT indicate air pollution?
If the stipples (dots) are on the leaf veins, they are not indicative of ozone damage.

Frame 7: How Do I Recognize Milkweed?
Write the names of two types of milkweed plants that you might expect to grow in your area.
Answers will vary but might include Curley, Walter, Fragrant, Mexican, Poke, Blood Flower, Barrens, Red, Longleaf, Swamp, Michaux's, Green, Aquatic, Purple, Four-leafed, Common, Butterfly, White, Whorled-leaf, Green Comet, or Green Antelope Horn Milkweed, depending on your location; or any Asclepias sp.

Frame 8: Who Eats Milkweed?
What animals eat milkweed? Monarch butterfly larvae, milkweed beetles, tussock moths, and aphids.

What would happen if all the milkweed plants in your area died of air pollution? Monarch larvae, which eat only milkweed leaves, might starve to death, be forced to migrate, or have to eat other plants~ including species that are not poisonous and therefore do not make monarchs undesirable to predators.

What sort of plants would take the milkweeds' place? If milkweed plants die out because of pollution sensitivity, it is likely that more pollution-tolerant plants would take their place. This group of plants would offer different opportunities for shelter and food than milkweed does.

Frame 9: Who eats Monarchs?
 What animals eat monarch larvae or butterflies?
Spiders and ants eat monarch larvae. Birds and wasps prey on mature monarch butterflies. Viruses, bacteria, mites and nematodes are parasitic.

What would happen to those animals that eat monarchs, if there were no more monarch larvae or butterflies? The monarch's predators, the black-beaked orioles and black-headed grosbeaks, as well as its parasites: wasps, ants, and spiders, would have to compete for other food, migrate, or die.

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Frame 10: What Other Sensitive Plants Can I Monitor for Signs of Air Pollution?
Identify an air pollution-sensitive plant species you have seen (or think you could find) in your area, other than milkweed. Answers will vary, but could include: dogbane, aster, primrose, tree-of-heaven, redbud, white ash, sycamore, aspen, elder, elderberry, thimbleberry, black cherry, choke cherry, aspen, dogwood, snowberry, fox grape or other species.

Frame 11: How Do I Estimate the Extent of Pollution Damage to a Leaf?
Attach score sheet showing mastery at 80% level or above. List species: _____

Frame 12: What Do Lichens Tell Us About Air Pollution?
If you saw Usnea subfloridana thriving, what could you deduce about air quality?
Since Usnea sp, is pollution-sensitive, if it is thriving the air quality must be very good.

What would you think about air quality if you saw Lecanora lichens flourishing and no other lichens in the area? Since Lecanora is pollution-tolerant, it can live both in polluted or unpolluted areas. However, the absence of any pollution-sensitive species and the presence of this pollution-tolerant species probably means the air is polluted.

Frame 13: Which Lichens Flourish (Or Die) in Polluted Air?
Which of the lichens can stand to live where the air is high in sulfur? Hypogymnia physode

If you found a flourishing lichen of the Xanthoria family and no other lichens living in the area, what pollutant is likely to the in the air? Since Xanthoria is not just pollution-tolerant but pollution-loving, the air is probably polluted with Nitrogen oxides of some sort.

If an Usnea cornuta lichens was found in abundance in the woods near your home, what could you conclude about the air quality nearby? The air is probably unpolluted if sensitive Usnea sp. is nearby.

Frame 14: Which Plants Are Air Pollution Heroes? (Accept any one from each column)

Benzene Toxins	Formaldehyde Toxins	Trichloroethelyne toxins
Chinese Evergreens Chrysanthemum Dragon tree English Ivy Gerbera Daisy Janet Craig Dracaena Peace Lily Striped Dracaena	Bamboo palm Corn stalk plant Devils Ivy Ficus trees Philodendrons Snake plant Spider plants	Dracaena marginata Gerbera Daisy Peace Lily Potted flowering Mums Ribbon plant

Frame 15: How Can I Predict Changes in an Ecosystem Due to Air Pollution?
How long does it take for the community to stabilize? It is stabilized from the beginning, in this scenario.

What are the effects when grass is diseased (simulating ozone-damaged milkweed)? First, the grass population declines, followed by the rabbits, the snakes, and then the hawks. But when almost all of the diseased grass has died and there are less than 1% of rabbits left to graze on the grass, suddenly grass re-populates the area, the rabbit population grows after its food source increases, and the snake population grows after there are more rabbits to eat. The hawk population never recovers because it was down to 0 individuals.

What do you think would happen if you removed all the grass from this food chain?
If the grass completely disappeared, the rabbit population would start to decline soon after, followed by the snake population, and finally the hawks.

Synthesis Question: Tell what you think would happen to an ecosystem (both plants and animals) if one species of plant was tolerant of ozone pollution and all the other species of plants in the area were not.
A pollution-tolerant plant would likely take over an area previously occupied by pollution-sensitive plants, if the sensitive plants did not survive. This change in dominant plant species would affect the types of animals that could live in the area, since animals depend on plants for food and shelter.

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Trackstar Track #377405: Plants on Pollution Patrol

(The following content is available online at [Trackstar](#) Web site: enter Track #377405)

What could be more exciting than watching grass grow? Monitoring plants for signs of air pollution! Certain plants serve as "bio-indicators." Like canaries in a coal mine, sensitive plant species warn us of conditions that could harm plants, animals, and even people. These are the plants that look like they have a rash or wither at the first sign of dirty air.

Some other plants are pollution-tolerant. If you find them in abundance in an area where there are no pollution-sensitive plants, it's a sure bet the air is dirty. Some of these amazing plants even remove toxins and improve air quality!

View these tracks to learn more about bioindicators, find out how to conduct field studies, and save the earth from pollution while there is still time! Read the questions in the annotations and find the answers in each track.

For a copy of the lesson, Student Worksheet, Field Study Report and assessment rubric that accompany this track, go to The Clean Air Campaign Web site (http://www.cleanaircampaign.com/Kids-Schools/Lesson-Plans) and click "Plants on Pollution Patrol."

1. What is Biomonitoring?
http://dnr.wi.gov/org/caer/ce/eek/earth/field/biomon.htm
Find out how plants and animals warn us about pollution before we even notice anything is wrong.   Write the names of three indicator species and the conditions each one warns us about.

2. How Does Air Pollution Hurt Plants, Animals, and People?
http://www.easybreathers.org/explore/airpollution/impactsIntro.html
Read about how plants, animals and people are affected by different types of air pollution. List some of these effects on your worksheet. (Note: Click on the words: "plants," "animals," and "people" at the very bottom of this web page to get key information. Use the back button to return to the original page between clicks).

3. What is Ozone and What are its Effects?
http://pathfinderscience.net/ozone/index.cfm
Have you ever wondered what is the difference between so-called "good ozone" and "bad ozone"? Find out where ozone is harmful~ in the upper atmosphere or at ground level. Identify the three steps in making ground-level ozone. Click on the map to see today's ozone levels across the country. Discover who is responsible for making ground level ozone. For more info on ozone damage to plants, click "Background" under the "Creating a Context" heading.

4. How is Air Pollution Hurting our National Parks?
http://www.npca.org/turningpoint/
Check out this report on air pollution in national parks. Click the word "Habitat" on the right side of the web page. Choose one of the four parks and read its story. Identify at least one pollutant and tell how it has affected specific plants, animals or non-living things in the park. Acrobat Reader is required to open this report.

5. How Can I Monitor Milkweed for Signs of Pollution?
http://www.easybreathers.org/engage/ppt/milkweed.ppt
View this slide presentation to learn how to look for signs of pollution damage on milkweed plants. What is the main indication that milkweed has been damaged by ground-level ozone in the air? PowerPoint (or PowerPoint Viewer) is required to view this Web site.

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6. How Can I Tell Air Pollution Damage from Other Leaf Injuries?
http://dnr.wi.gov/org/caer/ce/eek/earth/field/milkweed/slideshowindex.htm
View this slideshow to learn how to tell the difference between ozone pollution damage and other leaf problems. What is one sure sign that purplish-black dots on a milkweed leaf do NOT indicate air pollution?

7. How Do I Recognize Milkweed Plants?
http://www.monarchsacrossga.org/MAGmilkweed_in_ga.php
Can you identify milkweed plants? Check out this field guide to milkweeds that grow in Georgia. Write the names of two types of milkweed plant that you might expect to grow in your geographic area.

8. Who Eats Milkweed?
http://www.monarchwatch.org/milkweed/damage.html
What animals eat milkweed? What would happen to them if all the milkweed plants in the area died of air pollution leaf damage? What sort of plants would take the milkweeds' place?

9. Who Eats Monarchs?
http://www.learner.org/jnorth/tm/monarch/sl/4/1.html
Who eats monarch larvae or butterflies? Watch this slideshow to find out. How would these predators be affected if there were no monarchs to eat . . . . .because the monarchs had no milkweed to eat?

10. What Other Plants Can I Monitor for Signs of Pollution?
http://aura.gsfc.nasa.gov/outreach/garden_gallery.html
No milkweed plants in your area? Try one of these other species. All are sensitive to air pollution and show damage easily. Click Bioindicator Species in paragraph 3 for a list of additional plants with links to photos and descriptions. Identify one species you have seen or think you could find in your area.

Ask your teacher which species your class will be monitoring when you conduct field studies on ozone damage.

11. How Do I Estimate the Extent of Pollution Damage to a Leaf?
http://www.nature.nps.gov/air/edu/O3Training/index.cfm
Practice estimating the percentage of a leaf that shows ozone damage, using this interactive training program. First set the number of leaves you want to review at some number between 5 and 20. Then click on the species your class is going to monitor and estimate the damage for a set of leaves. Remember that ozone stippling does not occur on leaf veins, which make up a large percentage of leaf area. Repeat the activity until you reach 80% accuracy or better. **Print the scoresheet**. Come back *after finishing the rest of the frames*, and try another species for extra credit. (Note that black cherry, crownbeard, and coneflower are only in black and white).

12. What Do Lichens Tell Us about Air Pollution?
http://www.saddleworth.oldham.sch.uk/science/biology_revision/indicator_species.pps
Check out this slide presentation about lichens. When a type of lichens *intolerant* of a certain kind of pollutant (meaning it is *sensitive* to that pollutant) it is likely to sicken and die when exposed to dirty air. So, if you saw Usnea subfloridana thriving on a tree, what could you deduce about air quality? What would you think if you saw Lecanora lichens flourishing and no other lichens in the area?

13. Which Lichens Flourish (or Die) in Polluted Air?
http://www.thebls.org.uk/content/projects/pixs.doc
Which of the lichens pictured can stand to live where the air is high in sulfur (polluted)? If you found flourishing lichens of the Xanthoria family and no other lichens living in the area, what pollutant is likely to

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the in the air? If an Usnea cornuta lichens was found in abundance in the woods near your home, what could you conclude about the air quality nearby?

14. [Which Plants Are Air Pollution Heroes?](http://www.denverplants.com/foliage/html/CleanAir3.htm)
http://www.denverplants.com/foliage/html/CleanAir3.htm
Some pollution-tolerant plants do not decline when exposed to air pollutants, but actually improve air quality by removing toxins! Find out which species have proven effective as "air cleaners" in tests conducted by NASA. Click on the names of specific plants to see photos and descriptions. Pick three plants you would like to grow in your home (one from each category of toxins removed). Click on Clean Air Report (on the right side of the screen under "Houseplant Articles") to learn more about how plants remove pollutants from the air.

15. [How Can I Predict Changes Air Pollution Will Make in an Ecosystem?](http://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=381)
http://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=381
WARNING: The interactive "gizmo" at this web site times out after one 5-minute session. READ THESE DIRECTIONS COMPLETELY BEFORE STARTING.

Launch the Food Chain Gizmo. Click the Bar Graph tab and then Show Numerical Values. Press the Play arrow (next to the word "Controls") and watch how the populations of grass, rabbits, snakes and hawks change. How many time-units (time counter at bottom right) does it take before the population levels stabilize and stay the same? Click Reset (curved arrow); then click the Healthy button next to Grass and change the setting to Diseased, to simulate the effect of ozone-damaged plants on an ecosystem. Watch the effects for at least 100 time units. What happened?

What do you think would happen if you removed all the grass from the food web? Reset, click the Grass minus button until it reaches 0, and play again. Why do you think the result was different?

If you get locked out after 5 minutes, click Browse Gizmos at the top of the web page, select Life Science, and then play any other Ecology gizmo.

Plants on Pollution Patrol
Scoring Rubric

Proficiency Level and Activities	4 Caped Crusader	3 Earth Saver	2 Pollution Buster	1 Only Human
Researched bio-indicator plants and air pollution using Trackstar track #377405	. **Exceeds standard** Viewed all Trackstar frames	. **Meets standard** Viewed most Trackstar frames	. **Partially meets standard** Viewed frames	**Does not meet standard** Did not participate
Completed worksheet based on research	Accurately completed 80% of worksheet or more	Accurately completed 50 – 79% of worksheet	Attempted worksheet	Did not participate
Trained in recognizing ozone leaf damage in preparation for biomonitoring	Practiced until mastery (80% accuracy or better on any one species)	Practiced until competent (60% accuracy or better on any one species)	Practiced and improved skills	Did not participate
Conducted bio-monitoring activities in the field	Participated			Did not participate
Completed Field Study Report including predictions on effects of change	Observed, recorded data AND drew or traced leaf AND drew conclusions	Observed, recorded data OR drew or traced leaf AND drew conclusions	Observed leaf AND worked on field study report	Did not participate
Extra credit Completed online training for a second species, after mastering one species at 80% accuracy or better				

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