THE OZONE INDICATOR IN FOREST HEALTH MONITORING

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A typical biomonitoring site in eastern forests.

OVERVIEW OF THE OZONE INDICATOR

The Forest Health Monitoring Program (FHM) is a cooperative program with State and Federal partners designed to monitor, assess, and report on the health of the Nation's forests. Ozone pollution is one stress factor that affects forest health and growth and, for many species, causes direct foliar injury. The visible foliar response of ozone sensitive trees and shrubs can be used to detect and monitor ozone stress in the forest environment. This approach is known as biomonitoring and the plant species used are known as bioindicators.

In FHM, ozone bioindicator plants serve as an early warning system for changes in forest health that may be associated with poor air quality. The FHM bioindicator data is not used to quantitatively assess air quality or to make definitive statements about forest health. It *is* used to provide critical evidence of when periods of high ozone concentration, during the growing season, have potential biological significance.

Assessment Questions

The assessment questions for the ozone indicator in FHM are outlined below. Answers to the first 3 questions provide a direct assessment of air quality or ozone stress across the landscape. Answers to questions 4 and 5 address questions of impact.

1. **Are phytotoxic concentrations of ozone present in the forest ecosystem?**
2. **Is regional air quality (e.g., ozone pollution) changing over time?**
3. **If so, is it improving or deteriorating?**
4. **In what percentage of a region or forest type is there an indication of ozone air quality impacts on scenic beauty (e.g., measurable changes in leaf color, leaf size, or leaf number)?**
5. **In what percentage of a region or forest type is there an indication of ozone air quality impacts on biodiversity, growth increment, crown condition, or damage?**

Summary of Field Procedures

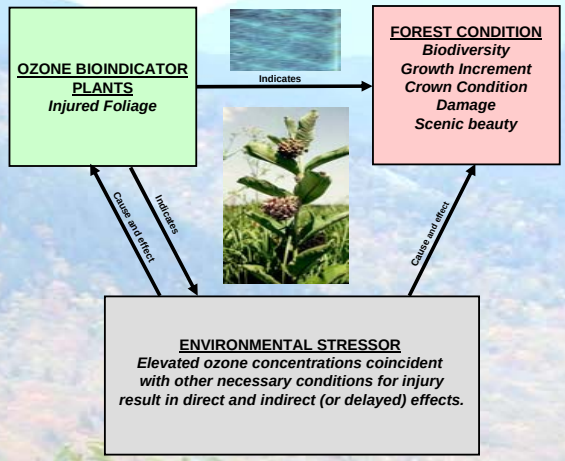
Step 1: **The field crew selects a suitable site for biomonitoring close to the FHM ground plot. The best sites are large open areas with more than 3 bioindicator species. These sites are mapped for repeat visits.**

Step 2: **The field crew selects 30 individual plants of each species on the site for injury identification and scoring. Each plant with ozone injury is rated for the percent of the plant that is injured and the average severity of injury. A plant with no injury is tallied with zeros for these measurements.**

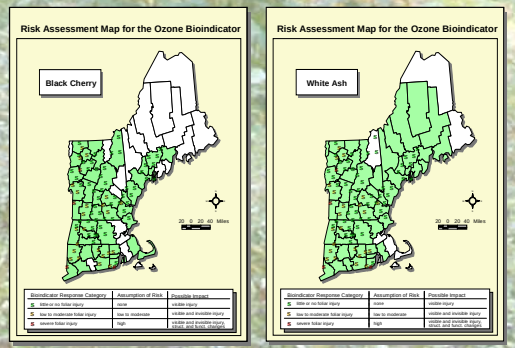
Step 3: **The field crew collects a voucher sample of 3 leaves for each injured species on the site. Each leaf or branch sample is mailed to a regional expert for validation of the ozone injury symptom.**

Step 4: **A plot-level index is formulated from the amount and severity ratings and the numbers of plants and species evaluated at each site. Additional summary statistics are also calculated. This data is used to assess gradations of response to ozone at the regional level.**

The Conceptual Model for the Ozone Bioindicator Plants Indicator

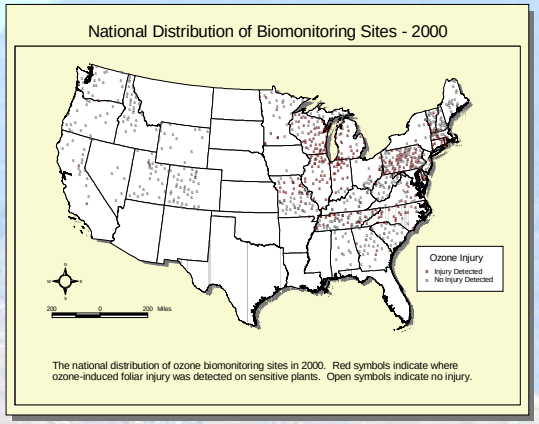


Spreading dogbane *Blackberry* *Sassafras*



Note: **Using the ozone indicator data to assess risk is done by mapping the overlay between areas of low, moderate, and severe biological response and the natural range of certain ozone sensitive species. This work is preliminary.**

The 2000 National Map for the Ozone Bioindicator Plants Indicator



The national distribution of ozone biomonitoring sites in 2000. Red symbols indicate where ozone-induced foliar injury was detected on sensitive plants. Open symbols indicate no injury.

The National Map - General Approach

The primary objective of the field crew procedures is to establish an ozone biomonitoring site at every forested ground plot associated with the national FHM grid. Sites are mapped and evaluated wherever crews are able to find a sufficient number of the ozone sensitive species in close proximity to the ground plot. Additional sites may be added off-plot, independent of the FHM grid, in high ozone areas within each state.

In the Northeast and North Central states, field crews and state cooperators have spent several years developing a permanent network of ozone sites that are sampled every year. In the South and West the network of ozone biomonitoring sites is still under development. The sites mapped for 2000 represent only a portion of the available plots.

The National Map - Summary Findings

Most of the eastern United States experiences high ambient ozone levels across the landscape for most of the growing season. Generally, the highest concentration of plus ozone sites and the highest injury ratings are found in areas with the poorest air quality. This relationship is less apparent in very dry years, e.g., 1999.

In contrast, much of the western landscape is assumed to be relatively clean with only occasional intrusions of above background concentrations of ozone in the ambient air. The FHM plot network provides a valuable biological record of ozone air quality that has been missing from the area as a whole. The biomonitoring effort is focused on establishing a baseline of ozone air quality for the more remote forested areas and on establishing off-plot sites downwind of the more populated areas, where concern about ozone air quality is high or growing.

Species - East and West

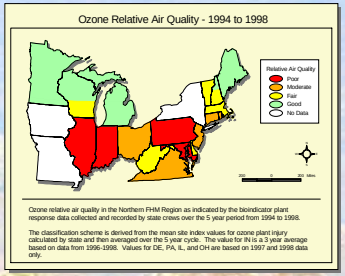
The most useful and most often symptomatic bioindicator species in the East include blackberry, black cherry, common milkweed, white ash, yellow poplar, and spreading dogbane. QA procedures include field audits and leaf vouchers for validation of the ozone injury symptom.

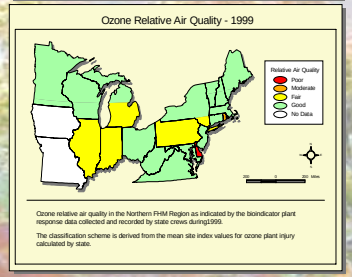
In the West, ozone injury has been detected by the field crews on ponderosa pine, Jeffrey pine, red elderberry, and blue elderberry in CA, WA, and UT. Recent fumigation trials using ambient exposure levels have confirmed the usefulness of additional species including Scouler's willow, red alder, pacific ninebark, mugwort, mountain snowberry, and skunkbush.

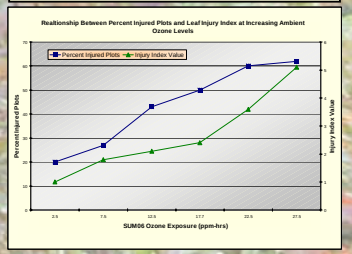
Regional Maps and the Biological Ozone Index

During the 1999 field season ambient ozone concentrations across much of the Northeast reached a 10 year high. However, the potential impact of the 1999 ozone season on vegetation was considerably reduced by severe drought. Drought stressed plants are effectively protected from ozone injury as stomates close and prevent uptake and subsequent injury.

The regional map (*see below*) showing the injury index values averaged over a 5 year period, that included both wet and dry years and variable ozone levels, provides a more representative view of regional air quality than the single year index shown in the 1999 map.





***Graph of Ozone vs. Injury*: The relationship between ambient ozone and injury suggests that numbers of injured sites and severity of injury will increase with increasing ozone levels across the forested landscape.**

This analysis was completed by Teague Prichard of the Wisconsin DNR, a Cooperator with the FHM Biomonitoring Program.