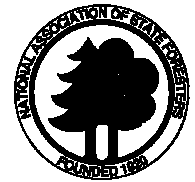




Forest Inventory and Analysis Ozone Indicator



FIA Fact Sheet Series

The Ozone Indicator is one of the forest health variables measured by the FIA program. It is designed to detect and monitor ozone stress in the forest environment. Ozone-induced foliar injury data is collected from field sites on a nation-wide grid of ozone biomonitoring plots. Sampling intensity varies across the landscape according to differing air quality regimes and perceived risk to ozone sensitive forest types.

Why is the Ozone Indicator Important?

Air pollutants, such as ground-level ozone, are known to interact with forest ecosystems. Ozone pollution has been shown to reduce tree growth, alter species composition, and predispose trees to insect and disease attack. Ozone also causes direct foliar injury to many plant species. Affected leaves are often marked with discoloration and lesions, and they age more rapidly than normal leaves. This approach is known as biomonitoring and the plant species used are known as bioindicators.

Information about ozone bioindicator plants can be used to answer the following questions about the effects of air quality on forested ecosystems:

- Is regional air quality (specifically ozone pollution) changing over time? If so, is it improving or deteriorating?
- In what percentage of a region or forest type are ozone bioindicator plants indicating the possibility of air pollution impacts on forest health (e.g., biodiversity, growth increment, crown condition, or damage)?

The ozone foliar injury response is not intended to be used alone when making statements about forest health.

However, once the presence of ozone injury is established, these indicator data can be considered in association with other FIA indicators and non-FIA exposure data to assess the impact of ozone stress on long-term forest condition.

Ozone bioindicator plant information contributes to the investigation of several key forest ecosystem characteristics. As an indicator of stress, ozone sensitive plants provide a mechanism to detect and monitor biologically significant changes in air quality. They also indicate forest condition by providing a visible link between ozone exposure and the effects of that exposure on productivity, biodiversity, and aesthetics. These relationships are summarized in the conceptual model shown in Figure 1.

What Species are Good Bioindicator Plants?

The essential characteristic of a good bioindicator species is that it responds to ambient levels of ozone pollution with distinct visible foliar injury symptoms that are easy to diagnose. The bioindicator species used in eastern FIA regions have been used repeatedly in ozone field studies. The list includes blackberry, black cherry, common milkweed, yellow poplar, white ash, sassafras and sweetgum. Less familiar species include big-leaf aster and spreading dogbane. The bioindicator species list for western FIA regions includes ponderosa pine, quaking aspen, Scouler's willow, red alder, ninebark, elderberry, and seven additional shrub and herb species. The FIA fieldwork contributes significantly to the much needed field tests of western bioindicator species under natural conditions of ozone exposure.

How are Ozone Bioindicator Plants Measured?

Field Personnel collecting ozone bioindicator data are thoroughly trained and tested prior to the beginning of each field season. Crew procedures include site selection, species identification, and symptom identification and scoring. Each plant is evaluated for amount and severity of injury. At each field site, the field crews evaluate up to 30 individual plants of 3 or more bioindicator species. If ozone injury is recorded, leaf samples are collected for validation of the ozone injury symptom by an ozone specialist. Errors are further minimized by audits of the field personnel and by complementary quality assurance studies.

Where and When are Ozone Bioindicator Plants Measured?

Suitable sites for biomonitoring are open areas in which the ozone-sensitive species are found and where the trained observer is reasonably certain that soil and site conditions are stable and free of chemical contaminants. The best sites are easy to get to, larger than 3 acres, with low drought potential and high plant counts. A small number of biomonitoring plots in each FIA region are located close to weather and air quality monitoring stations to improve the interpretation of bioindicator data.

FIA field personnel select sites for ozone biomonitoring during the normal field season. The foliar injury data is collected during an abbreviated evaluation window that is different for each FIA Region.

Are There any Special Concerns When Making Measurements?

The incidence and severity of ozone injury on vegetation increases during the summer months in eastern FIA regions. By late July, symptoms have developed distinctly, are easier to measure and are very stable. Therefore, quantifying ozone injury by FIA field personnel is limited to a three-week period during late July to mid-August. The field personnel receive a refresher training course in ozone symptom identification and voucher handling immediately before the evaluation period.

In western FIA regions, due to differences in growing season, topography, target species, and other regional factors that influence plant response to ozone, the identification of an optimum evaluation window for this indicator is problematic. Nevertheless, to maintain national consistency and improve crew logistics, the western regions use a mid-season, five-week window for foliar injury evaluations.

Other physical or biological foliar injury symptoms may mimic ozone symptoms. Since the bioindicator species selected for this indicator were selected because of their sensitivity to ozone and their distinct ozone injury symptoms, this potential problem can be adequately covered during training.

How is Ozone Data Analyzed?

The primary goal of this indicator in FIA is to provide a biological index of ozone stress in the forest environment using a consistent protocol on a nationwide system of biomonitoring plots. Results are used to quantify regional trends in ozone stress in terms of significant changes in the number and distribution of biomonitoring plots with ozone injury and increases or

decreases in the injury severity index. Figure 2 shows an example of how ozone bioindicator plant data may be displayed to show the annual distribution of plots with ozone symptoms on sensitive bioindicator species. These results are compared to corresponding information on ozone levels in the air as well as other information such as rainfall amounts and soil moisture conditions. This additional information provides the context in which the ozone bioindicator data are analyzed.

A plot-level index is formulated from injury amount and severity ratings recorded for each plant and the numbers of plants and species evaluated at each site. This, in turn, is used to monitor yearly fluctuations in the severity of the bioindicator response by region or forest type. For trend analyses, FIA intends to use consecutive 5-year periods with variable ozone levels, weather, wind flow, and precipitation patterns to examine regional trends in ozone air quality over the long-term. Kriging techniques are applied to the 5-year biosite averages to generate a surface of biological response data across the landscape. As illustrated in Figure 3, this interpolated surface may be used to identify areas of probable ozone injury to plants and

to identify where ozone effects on sensitive tree species require a more intensive evaluation of injury and growth response. Results may be linked analytically to forest health data collected on the FIA Phase 2 and Phase 3 plots.

Are Related Data Sets Used?

Yes, air quality data sets are used in the ozone bioindicator plants analyses. These data are obtained through the National Air Data Branch of the US EPA. Climate data are obtained from the nearest National Oceanic and Atmospheric Administration weather stations, the National Trade Data Bank, and published scientific literature.

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For more information about the ozone indicator:

- Visit our ozone indicator website: <http://fiaozone.net>

For more information about the FIA Program:

- Visit our national FIA website: <http://www.fia.fs.fed.us>
- See our "FIA Contacts" Fact Sheet

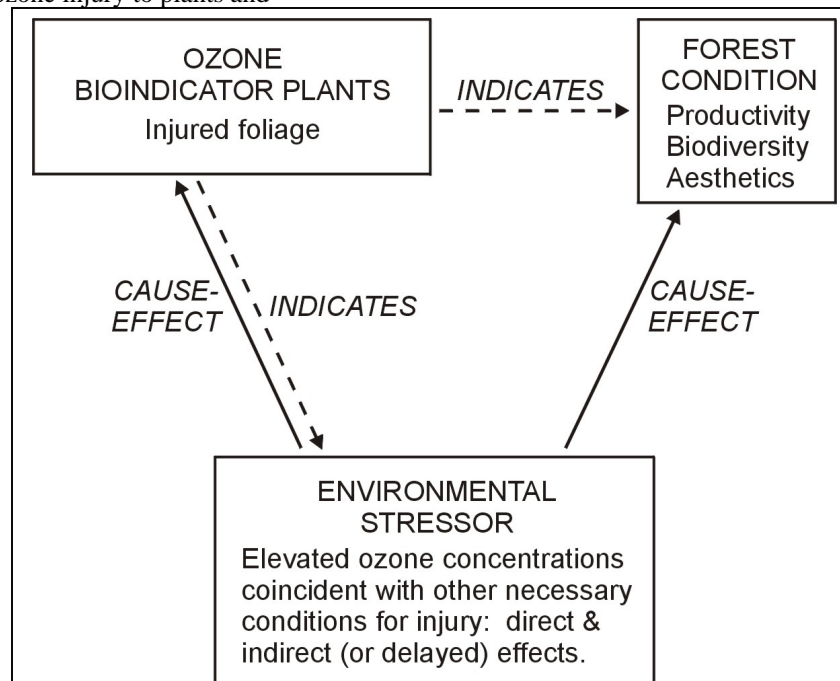


Figure 1. Conceptual Model for the Ozone Bioindicator Indicator



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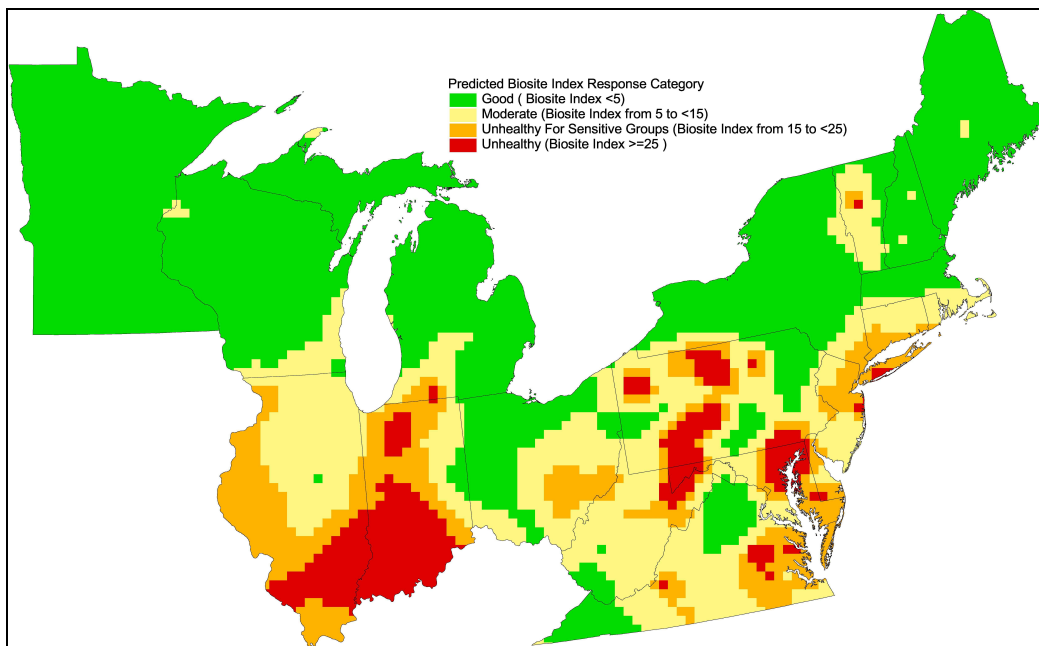


Figure 3: Biosite Index Estimates and Risk in Northeastern States. Probable ozone injury and risk in the Northeast FIA region as determined by plot-level injury values (biosite index) averaged over a six-year period (1994-1999) and then categorized into four levels of risk (none, low, moderate, and high) defined in terms of the relative risk of tree or ecosystem-level disturbance to the forest resource from ambient ozone exposure.

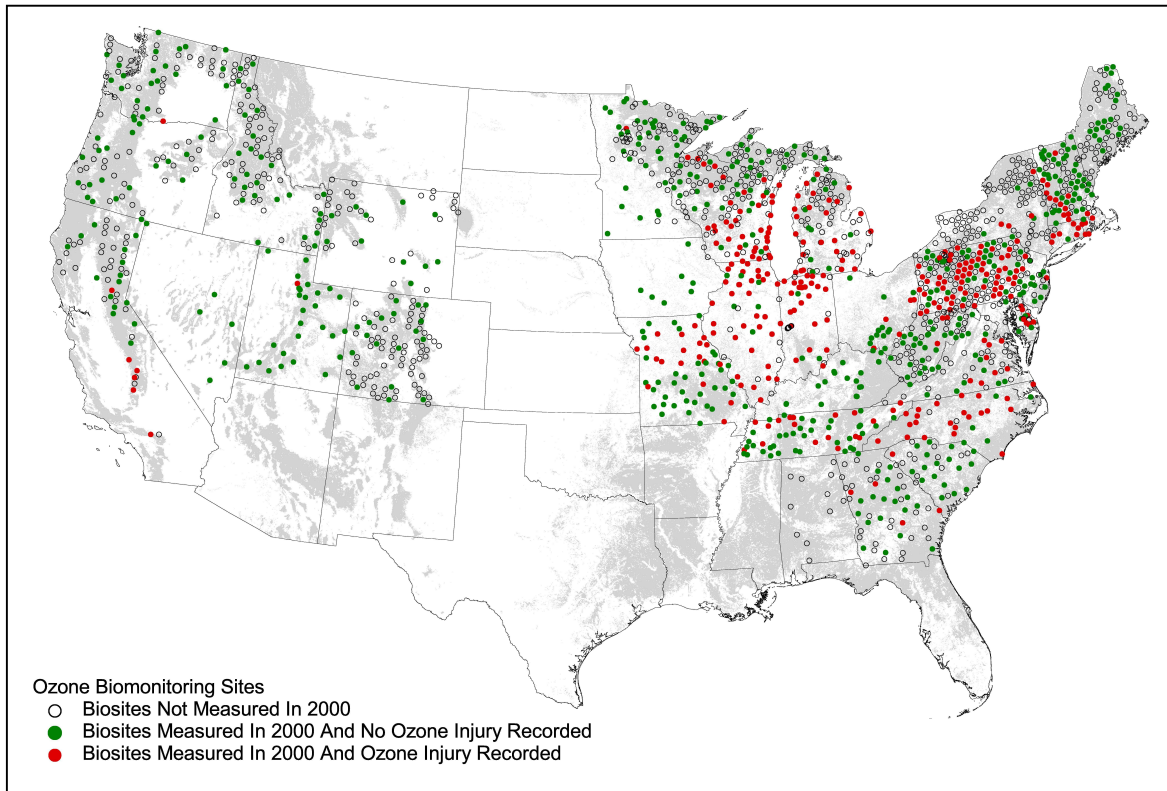


Figure 2. FIA Ozone Biomonitoring Sites, 2000.