Section 9. Ozone Bioindicator Plants (East)

9.0 QUICK REFERENCE FOR THE OZONE INDICATOR

9.0.1 QUICK REFERENCE ON FIELD PROCEDURES FOR UNTRAINED FIELD CREWS

There are certain procedures for the ozone indicator that may be performed by individuals that have not attended the ozone training and been certified to collect ozone data. These procedures still require some explanation and oversight by the certified crew member. Untrained personnel may assist in the selection and mapping of the ozone biomonitoring site and in the location and identification of bioindicator species on the selected site. It may also be helpful for the untrained crew person to act as the data recorder for the certified crew member, thus speeding up the data collection process.

9.0.2 QUICK REFERENCE ON PDR SCREENS

Ozone indicator data are recorded on portable data recorders (PDR's) including Paravant, Husky, Handspring and Palm. Each of the tables below corresponds to a PDR data screen or portion of a screen that includes ozone measurement variables. The tables serve as a quick reference for the PDR application screens by indexing the Subsections in this chapter where the variables on each screen are defined. An "x" in one of these tables means that the variable is prompted for on the FIA Ozone Grid, and the field crew is required to complete that field. For a written summary of the data entry procedures, definitions, and codes for the ozone measurement variables refer to subsections 9.1.3 and 9.2 through 9.5. There is a PDR Field Manual and a User's Guide for the Palm that provide a self-guided tour of the data entry screens for the ozone indicator.

Table 9-1. Bioindicator Plot Identification Screen (Subsection 9.2 and 9.6)

Measurement Variables	PDR Prompt	SAMPLE KIND 1,2, and 3	FG Subsection
STATE	State	X	9.2.1
COUNTY	Cnty	X	9.2.2
OZONE HEXAGON NUMBER	Hex Num	X	9.2.3
PLOT NUMBER	PlotNum	x	9.2.4
QA STATUS	QA Stat	X	9.2.5
CREW TYPE	CrewTyp	Default=1	9.2.6
OZONE SAMPLE KIND	O3SmpKn	X	9.2.7
MONTH	Month	X	9.2.8.1
DAY	Day	X	9.2.8.2
YEAR	Year	Set to current year	9.2.8.3
OZONE GRID DENSITY	GridDen	X	9.2.9
PLOT SIZE	PlotSiz	X	9.2.10
ELEVATION	Elev	X	9.3.4
ASPECT	Aspct	X	9.2.11
TERRAIN POSITION	TerrPos	X	9.2.12
SOIL DEPTH	SoilDep	X	9.2.13
SOIL DRAINAGE	SoilDrn	X	9.2.14
PLOT WETNESS	PlotWet	X	9.2.15
DISTURBANCE	Distrb	X	9.2.16
INJURY CHECK	InjChk	X	9.2.17

Table 9-2. Plot Notes Screen (Subsection 9.5.1 and 9.6)

Measurement Variables	PDR Prompt	SAMPLE KIND 1,2, and 3	FG Subsection
REMARKS1	Rem1	X	9.5.1
REMARKS2	Rem2	X	9.5.1

Table 9-3. Bio Species Screen (Symptom Scoring, Subsection 9.4, 9.6.4 and 9.6.6)

Measurement Variables	PDR Prompt	SAMPLE KIND 1,2, and 3	FG Subsection
SPECIES	Species	X	9.4.1 and 9.6.4
AMOUNT	Amount	X	9.4.2 and 9.6.6
NUMBER OF PLANTS	NbrPlnt	X	9.4.3
SEVERITY	Severity	x	9.4.4 and 9.6.6

9.1 OVERVIEW

Air pollutants, such as ground-level ozone, are known to interact with forest ecosystems. Ozone is the only regional gaseous air pollutant that is frequently measured at known phytotoxic levels (Cleveland and Graedel 1979; Lefohn and Pinkerton 1988). Ozone pollution has been shown to have an adverse effect on tree growth and alter tree succession, species composition, and pest interactions (Forest Health and Ozone 1987; Miller and Millecan 1971; Smith 1974). In addition, we know that ozone causes direct foliar injury to many species (Skelly and others 1987; Treshow and Stewart 1973). We can use this visible injury response 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 (Manning and Feder 1980). In the enhanced FIA Program, ozone bioindicator plants are used to monitor changes in air quality across a region, and to assess the relationship between ozone air quality and Phase 2 and Phase 3 indicators of forest condition (e.g., growth increment and dieback).

A useful bioindicator plant may be a tree, a woody shrub, or a nonwoody herb species. The essential characteristic is that the species respond to ambient levels of ozone pollution with distinct visible foliar symptoms that are easy to diagnose. Field studies and/or fumigation experiments have identified ozone sensitive species and characterized the ozone specific foliar response for both eastern (Davis and Umbach 1981; Duchelle and Skelly 1981; Krupa and Manning 1988) and western (Richards and others 1968; Mavity and others 1995; Brace 1996) bioindicators. Foliar injury symptoms include distinct patterns of coloration, often associated with accelerated senescence.

This section describes procedures to select field sites for ozone biomonitoring using the FIA ozone grid, and to evaluate ozone injury on the foliage of sensitive plant species. Additional ozone sites, on an intensified ozone grid, may also be established by State and federal cooperators to improve the interpretive value of this indicator. This intensified sampling is done using the same methodology as the regular grid activities and is just as important.

9.1.1 SCOPE AND APPLICATION

The scope of this indicator is national, but procedures are amended regionally as needed, particularly with regard to suitable sites and target species. Other variables, such as number of species, number of plants, and methods of scoring are standardized nationally. The procedures, reporting, and assessment goals were developed with the following considerations:

1. Ozone plot distribution across the landscape covers both the more remote and expansive forests away from population centers and the more fragmented forests located in close proximity to urban areas;

2. Ozone plot stratification nation-wide reflects regional differences in air quality regimes and perceived risks to different forest types;

3. Sampling intensity in different regions is designed to allow links between ozone biomonitoring data and other FIA indicators;

4. Estimated errors for the ozone indicator measurements are kept below 10%; and

5. Seasonal variability in ozone injury is addressed. We know that ozone injury must reach an undefined threshold within a leaf before the injury becomes visible to the human eye, and then tends to be cumulative over the growing season until fall senescence masks the symptoms.

NOTE: There are certain regions of the country where ambient ozone concentrations, during the growing season, routinely exceed levels that are known to injure sensitive plants. Other regions have relatively clean air. In regions with poor air quality, the crew data underscore the extent and severity of ozone pollution in our nation’s forests. In cleaner regions, the emphasis must be on establishing a baseline for the ozone indicator. In this regard, field crews collecting mostly zeros for the ozone injury variables are making a significant contribution to the national FIA database.

9.1.2 SUMMARY OF METHOD

Crew procedures include the selection of a suitable site for symptom evaluation, identification of two or more known ozone-sensitive species at the site, and identification of ozone injury on the foliage of up to 30 plants of each species. Each plant is evaluated for the percentage of injured area and severity of injury on a five-point scale. Field crews record information on the location and size of the opening used for biomonitoring and record injury amount and severity ratings for each plant.

In the East, to eliminate problems with seasonal variability in ozone response, all foliar evaluations are conducted during a four-week window towards the end of the growing season. In the West, 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 or six-week window for foliar injury evaluations.

In some States with a particular interest in air quality, foliar injury data are also collected from ozone sites on an intensified ozone grid. These supplementary ozone sites are standardized for certain site characteristics that influence ozone uptake by sensitive plants (Heck 1968; Krupa and Manning 1988), and are often co-located with physical air quality monitors. They are intended to improve the regional responsiveness of the ozone indicator.

Voucher specimens (pressed leaves with symptoms) are collected for each species for proper symptom identification. For each voucher, injury type and location codes are recorded to fully describe the injury observed in the field. Additional quality control measures include field audits and remeasurement of 10% of the biomonitoring sites.

The implementation of an ozone grid independent of the traditional FIA plot system allows greater flexibility in plot location on the ground and greater sampling intensity in areas believed to be at high risk for ozone impact. In addition, plots are deliberately chosen for ease of access and for optimal size, species, and plant counts, thus maximizing data quality. Ozone is a regional pollutant, understood to have regional effects on vegetation. Therefore, data collected on the ozone grid will have direct application to the FIA P2 and P3 plots within the same region

No specialized safety precautions are necessary to complete the fieldwork for the ozone indicator.

9.1.3 SUMMARY OF TALLY PROCEDURES, DEFINITIONS, AND CODES

All of the ozone bioindicator data are entered under Option 07 on the Tally main menu. For each biomonitoring site, you must select Option 07 from the Tally main menu and complete the three data entry screens for ozone data. The Bioindicator Plot Identification Screen (Table 9-1) includes a record of plot status and detail on site characteristics that influence ozone injury expression. The Plot Notes Screen (Table 9-2) prompts crews to add additional information that will help interpret the injury results and/or assist

subsequent crews collecting data at the same location. The Bio Species Screen (Table 9-3 prompts crews for injury amount and severity codes on a plant by plant basis. This screen includes a pop-up menu, which keeps a running total of numbers of plants and species evaluated by the field crews. Help screens may be accessed for any variable, from any of the 3 screens presented under the Tally, Bioindicator Plants Option 07.

Ozone applications other than Tally also use three data entry screens as described above.

9.1.4 EQUIPMENT AND SUPPLIES

- A large diameter, 10X hand lens for close examination of plant leaves for ozone injury.
- Reference photographs and laminated leaf samples to aid in symptom identification.
- A small plant press with cardboard inserts to store leaf vouchers collected in the field.
- Stamped, addressed envelopes for mailing the leaf vouchers to the National Ozone Advisor.
- Stiff paper or cardboard for protecting the leaf vouchers in the mailing envelopes.
- Flagging: for temporary marking of sites or sample plants.
- Three field data sheets: (1) For documenting Foliar Injury Data in the event of a PDR failure; (2) For preparing the plot location map; and (3) For recording Voucher Leaf Samples Data for QA. (see Appendix 9.B).

9.1.5 TRAINING AND QUALITY ASSURANCE

Each field crew member is trained and tested for familiarity with the site selection, species selection, and data collection procedures, and their ability to recognize ozone injury and discriminate against mimicking symptoms. Although field crews are certified during the regular preseason training session, they must also participate in a refresher session held just prior to the beginning of the evaluation window for this indicator.

The National Ozone Advisor and one or more individuals in each region assume quality control responsibilities for the field season. Regional Advisors meet during a preseason session to refine methods and establish a unified approach to training, audits, and debriefing. Their responsibilities include: (1) training and certifying the State trainers and/or field crews as needed for their region, (2) documenting hot audits of the field crews, (3) overseeing the field crew refresher session held just prior to the evaluation window for this indicator, (4) assisting in the field with remeasurement procedures for symptom quantification, and (5) conducting a debriefing session for the indicator.

A field audit crew remeasures a subsample of the ozone ground plots in each region. Auditing procedures cover species selection, symptom identification, and quantification of injury, as well as foliar sample collection, preservation and shipment. Field crew supervisors audit the field crews and assist Regional Advisors and QA staff with remeasurement activities as needed.

Results of the field audits and remeasurement activities are used to determine if the measurement quality objectives are being met. Regional Advisors and Field Supervisors who are certified for the ozone indicator have the authority to implement whatever corrective action is needed in the field (e.g., retraining and retesting).

9.1.5.1 VOUCHER SPECIMENS

Leaf samples are collected by field crews, cooperators, and all QA staff. They are to be placed in a small plant press immediately after removal from the selected plant. This is to preserve the integrity of the leaf sample and the injury symptoms until they can be validated by the National Indicator Advisor. A data sheet identifying the field crew and plot location is to be filled out and mailed with each sample.

Field crews, cooperators, and all QA staff collect leaf samples on the ozone biomonitoring sites according to procedures outlined in Subsection 9.6.7. These voucher specimens are pressed and mailed to the National Indicator Advisor for validation of the ozone symptom. If QA staff and regular field crews happen to be evaluating the same site at the same time, they collect and mail separate vouchers.

9.1.6 COMMUNICATIONS

Any questions arising during the field season that cannot be answered by the Field Supervisor or State Coordinator, should be directed to the Regional Advisor for the ozone indicator. If any field crew or cooperator is uncertain about whom to call for information, or if a Regional Advisor is not indicated, they should contact the National Ozone Advisor. Keep in mind that Advisors may be in the field and, therefore, unavailable for phone calls during normal workday hours. Messages left on answering machines should clearly identify who you are and when, where, and how to return your call. Field crews should be aware of differences in time zones and use email, if possible.

National Advisor (East and West) and Regional Advisor for the Northeast and Mid-Atlantic States:

Gretchen Smith Phone: (413) 545-1680
Holdsworth Hall (978) 544-7186 (before 7am; after 7pm)
University of Massachusetts
Department of Forestry and Wildlife Management
Amherst, MA 01003-0130
e-mail: gcsmith@forwild.umass.edu

Regional Advisor for the South:

Dan Stratton Phone: (828) 257-4352
USDA Forest Service
P.O. Box 2680
Asheville, NC 28802
e-mail: dstratton@fs.fed.us

9.2 PLOT LEVEL DATA

Ozone plots vary in size and do not have set boundaries. When describing plot-level characteristics, use the predominant characteristics where most of the plant species are located. If conditions vary markedly across the site, or by species, then describe this in the plot notes or on the site map. Specify the elevation, aspect, terrain position, soil depth, soil drainage, and disturbance for the highest priority species (Subsection 9.6.4) found on the site. For a complete explanation of the procedures associated with these measurement codes, refer to Subsection 9.6.

9.2.1 STATE (State)

Record the unique FIPS code identifying the State where the plot center is located.

When collected: All plots
Field width: 2 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: See Appendix 1

9.2.2 COUNTY (Cnty)

Record the unique FIPS code identifying the county where the plot center is located.

When collected: All plots
Field width: 3 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: See Appendix 1

9.2.3 OZONE HEXAGON NUMBER (Hex Num)

Record the unique code assigned to each ozone hexagon. In some cases this will be a former FHM or P3 hexagon.

When collected: All plots
Field width: 7 digits
Tolerance: No errors
MQO: At least 99% of the time
Values:

9.2.4 PLOT NUMBER (PlotNum)

Record the plot number that describes whether an ozone plot consists of one or two locations. If two locations are selected, they must be within 3 miles of each other. Two locations are selected as needed to obtain optimal species and plant counts for each ozone plot. The hexagon number is the same for both locations.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 2

1 The ozone plot consists of a single location or, this is the first location for an ozone plot that has been split between two locations.
2 The ozone plot is split between two locations. This code identifies the second location added by the field crew to increase species and plant counts for a single hexagon number.

9.2.5 QA STATUS (QA Stat)

Record the code to indicate the type of plot data collected.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 7

1 Standard ozone plot
2 Cold check
3 Not used
4 Training/practice plot (off grid)
5 Botched plot file
6 Blind check
7 Production plot (hot check)

9.2.6 CREW TYPE (CrewTyp) [Default set to “1”]

Record the code to specify what type of crew is measuring the plot.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 2

1 Standard field crew
2 QA crew (any crew collecting remeasurement data)

9.2.7 OZONE SAMPLE KIND (O3SmpKn)

Record the code that describes the kind of plot being visited.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 3

1 Initial plot establishment.
2 Remeasurement of a previously established plot.
3 Replacement of a previously established plot that was replaced because the original plot could not be relocated or because it no longer met ozone plot measurement criteria.

9.2.8 CURRENT DATE

Record the MONTH (2-digits), DAY (2 digits), and YEAR (4-digits) that the current plot was completed.

9.2.8.1 MONTH (Month)

Record the month that the plot was completed.

When collected: All plots
Field width: 2 digits
Tolerance: No errors
MQO: At least 99% of the time

Values:

January	01	May	05	September	09
February	02	June	06	October	10
March	03	July	07	November	11
April	04	August	08	December	12

9.2.8.2 DAY (Day)

Record the day of the month that the plot was completed.

When collected: All plots
Field width: 2 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: 01 to 31

9.2.8.3 YEAR (Year) [Default set to 2002]

Record the year that the plot was completed.

When collected: All plots
Field width: 4 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: Beginning with 1998, constant for a given year

9.2.9 OZONE GRID DENSITY (GrdDen)

Record the code that identifies whether the plot is on the base ozone grid or on an intensified ozone grid.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 2

1 Unique ozone plot within a polygon. (1 site:1polygon)
2 One of two or more ozone plots within the same polygon.

9.2.10 PLOT SIZE (PlotSiz)

Record the code that indicates the size of the opening used for biomonitoring.

When collected: All plots
Field width: 1 digit
Tolerance:
MQO: Repeatable estimate
Values: 1 to 3

1 Greater than three acres.
2 Greater than one acre, but less than three acres.
3 Not used
4 Not used

9.2.11 ASPECT (Aspct)

Record the code that identifies the direction of slope for land surfaces with at least 5 percent slope as measured with a hand compass to the nearest degree.

When collected: All plots
Field width: 3 digits
Tolerance: +/- 30°
MQO: At least 99% of the time
Values: 0 to 360°

9.2.12 TERRAIN POSITION (TerrPos)

Record the code that identifies the position of the plot in relation to the surrounding topography.

When collected: All plots
Field width: 1 digit
Tolerance: Repeatable estimate
MQO: At least 99% of the time
Values: 1 to 5

1 Ridge top or upper slope
2 Bench or level area along a slope
3 Lower slope
4 Flat land unrelated to slope
5 Bottom land with occasional flooding

9.2.13 SOIL DEPTH (SoilDep)

Record the code that indicates the depth of the soil where most of the bioindicator species are growing.

When collected: All plots
Field width: 1 digit
Tolerance: Repeatable estimate
MQO: At least 99% of the time
Values: 1 to 2

1 Bedrock is not exposed.
2 Bedrock is exposed; Soil is generally shallow.

9.2.14 SOIL DRAINAGE (SoilDrn)

Record the code that identifies the soil drainage conditions where most of the bioindicator species are growing.

When collected: All plots
Field width: 1 digit
Tolerance: Repeatable estimate
MQO: At least 99% of the time
Values: 1 to 3

1 Soil is well drained
2 Soil is generally wet
3 Soil is excessively dry

9.2.16 DISTURBANCE (Distrb)

Record the code that identifies the presence and kind of disturbance where most of the bioindicator plants are growing. The area affected by any human caused or natural disturbance must be clearly visible and recent enough to influence plant health and condition. Disturbance that results in significant soil compaction is especially significant.

When collected: All plots
Field width: 1 digit
Tolerance: Repeatable estimate
MQO: At least 99% of the time
Values: 0 to 2

0 No recent or significant disturbance.
1 Evidence of overuse; Human activity causing obvious soil compaction or erosion.
2 Evidence of natural disturbance including fire, wind, flooding, grazing, pests, etc.

9.2.17 INJURY CHECK (InjChk)

Record the code that indicates whether ozone injury was observed on non-tallied plants or species. This variable allows a plot to be identified as impacted by ozone even though there is no quantitative data on injury severity for trend analyses. A leaf voucher must be collected to validate the injury.

When collected: All plots
Field width: 1 digit
Tolerance: No error
MQO: At least 99% of the time
Values: 0 to 1

0 No injury was observed on non-tallied plants or species.
1 Ozone injury was observed on non-tallied plants or species and a leaf voucher collected.

9.3 GPS COORDINATES

Use a global positioning system (GPS) unit to determine the plot coordinates and elevation of all ozone plot locations. GPS readings are collected according to procedures outlined in the FIA National Core Field Guide for Phase 2 & 3 Plots, Version 1.6. The ozone data entry applications accept GPS readings obtained using a geographic coordinate system (not UTM). If you are using UTM, record readings on the field data sheet for mapping and on the PDR Plot Notes screen. If GPS coordinates cannot be collected, elevation and plot coordinates are obtained from USGS topographic maps, generally the 7½ minute series quadrangle. Record elevation on the Plot ID screen and approximate latitude and longitude on the Plot Notes screen.

NOTE: For several of the following GPS variables, the term plot center is used. There may be no obvious center to the ozone plots. Coordinates are collected as close as possible to a central location or marker that clearly locates the plot for returning crews. Explanatory notes are added to the plot map and Plot Notes screen as needed.

9.3.1 GPS UNIT (GPSType)

Record the kind of GPS unit used to collect coordinates. If coordinates cannot be obtained, record 0.

When collected: All plots
Field width: 1 digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 0 to 4

0 GPS coordinates not collected
1 Rockwell Precision Lightweight GPS Receiver (PLGR)
2 Other brand capable of field averaging
3 Trimble GeoExplorer or Pathfinder Pro
4 Recreational GPS (Garmin, Magellan, etc.)

9.3.2 GPS SERIAL NUMBER (GPS_Nbr)

Record the last six digits of the serial number on the GPS unit used.

When collected: When GPS UNIT >0
Field width: 6 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: 000001 to 999999

9.3.3 GPS LATITUDE (GPS_Lat)

Record the latitude of the plot center to the nearest hundredth second, as determined by GPS.

When collected: When GPS UNIT = 1, 2, 3 or 4
Field width: 8 digits
Tolerance: +/- 140 ft
MQO: At least 99% of the time
Values:

9.3.4 GPS LONGITUDE (GPS_Long)

Record the longitude of the plot center to the nearest hundredth second, as determined by GPS.

When collected: When GPS UNIT = 1, 2, 3 or 4
Field width: 9 digits
Tolerance: +/- 140 ft
MQO: At least 99% of the time
Values:

9.3.5 GPS ELEVATION (GPS_Elev)

Record the elevation above mean sea level of the plot center, in feet, as determined by GPS.
If no GPS Unit is available, record elevation from the appropriate USGS topographic map.

When collected: When GPS UNIT = 0,1, 2 or 4
Field width: 6 digits
Tolerance:
MQO: At least 99% of the time
Values: -00100 to 20000

9.3.6 GPS ERROR (GPSEr)

Record the error as shown on the GPS unit to the nearest foot.

When collected: When GPS UNIT = 1 or 2
Field width: 3 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: 0 to 70 if possible; 71 to 999 if an error of less than 70 cannot be obtained

9.3.7 NUMBER OF GPS READINGS (#Read)

Record a 3-digit code indicating how many readings were averaged by the GPS unit to calculate the plot coordinates. Collect at least 180 readings if possible.

When collected: When GPS UNIT = 1 or 2
Field width: 3 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 999

9.4 FOLIAR INJURY DATA

All measurement codes for the BioSpecies screen (e.g., foliar injury data) are defined below. The codes and definitions are the same whether the crew is entering data on a PDR or personal data assistant (Palm). Plants selected for ozone injury evaluations are rated for the percent of injured area and the severity of injury on a scale of 0 to 5 (see Subsection 9.6.6). If a plant does not have injury, it is tallied with zeros for these measurements. A pop-up menu keeps track of plant counts by species. The plot is complete only after you have tallied 30 plants of at least 3 species, or when no additional plants can be found on the plot. Ozone plots vary in size and do not have set boundaries. Time and safety concerns should dictate how much ground area to cover to complete the foliar injury evaluation procedures.

9.4.1 SPECIES (Species)

Record the three-digit code that identifies each species on the plot. Codes for the bioindicator species are listed on the help screen for this variable. Species codes may be entered in the order they are encountered as you walk through the plot evaluating plants. A pop-up menu keeps a running total of numbers of plants and species evaluated.

When collected: All plots
Field width: 3 digits
Tolerance: No error
MQO: At least 90% of the time
Values:

9.4.2 AMOUNT (Amount)

Record the code that identifies the percentage of leaves on the plant with ozone injury symptoms relative to the total number of leaves on the plant. The percent scale code and definitions are fully described in Subsection 9.6.6.

When collected: All plots
Field width: 1 digit
Tolerance: +/- 1 class
MQO: At least 90% of the time
Values: 5 classes

0 No injury; The evaluated plant does not have any leaves with ozone symptoms.
1 1 to 6 percent of the leaves have ozone symptoms
2 7 to 25 percent of the leaves are injured.
3 26 to 50 percent of the leaves are injured.
4 51 to 75 percent of the leaves are injured.
5 Greater than 75 percent of the leaves have ozone symptoms.

9.4.3 NUMBER OF PLANTS (NbrPlnt)

Record the number of plants you have tallied so far with no injury. When 0 is entered for AMOUNT, the PDR prompts you for the NUMBER OF PLANTS with no injury. When a number greater than zero is entered for AMOUNT, the PDR prompts you for the associated SEVERITY value. You can enter zero and non-zero

values for any species as they are encountered on the plot. The pop-up menu keeps track of plant counts by species so that you do not have to.

When collected: When AMOUNT = 0
Field width: 2 digits
Tolerance: No error
MQO: At least 90% of the time
Values: 1 to 30

9.4.4 SEVERITY (Severity)

Record the code that identifies the mean severity of symptoms on injured foliage. The percent scale code and definitions are fully described in Subsection 9.6.6.

When collected: When AMOUNT > 0
Field width: 1 digit
Tolerance: +/- 1 class
MQO: At least 90% of the time
Values: 5 classes

0 No injury. The evaluated plant does not have any leaves with ozone symptoms.
1 On average, 1 to 6 percent of the leaf area of injured leaves has ozone symptoms.
2 On average, 7 to 25 percent of the leaf area of injured leaves has ozone symptoms.
3 On average, 26 to 50 percent of the leaf area of injured leaves has ozone symptoms.
4 On average, 51 to 75 percent of the leaf area of injured leaves has ozone symptoms.
5 On average, greater than 75 percent of the leaf area of injured leaves has ozone symptoms.

9.5 PLOT NOTES

Use these fields to record notes pertaining to the entire plot. If the notes apply to a specific aspect of the plot, then make that clear in the notes. Record the location where GPS coordinates were collected, and GPS file name, as needed. If no GPS Unit was available, record the geographic coordinates (i.e., latitude and longitude) of the plot center in Degrees, Minutes, and Seconds using USGS topographic maps, generally the 7½ minute series quadrangle.

9.5.1 Plot Notes (Rem1 and Rem2)

Record any information on site characteristics, safety, plant location, injury patterns, or recent rainfall amounts that will assist subsequent crews visiting the site or help interpret the results.

When collected: All plots
Field width: Unlimited alphanumeric character field
Tolerance: N/A
MQO: N/A
Values: English language words, phrases and numbers

9.6 OZONE BIOMONITORING PROCEDURES

NOTE: In the following discussion the words site, biosite, and plot are used interchangeably to refer to the open area used for the ozone biomonitoring evaluations. Some plots or biosites will be new, established for the first time in 2002 on the new FIA ozone grid. Other plots have been established for many years as part of the FIA-P3 or FHM plot system. Both old and new plots have equal importance to the FIA program and are part of the national database for ozone biomonitoring.

The **primary objective** of the field crew procedures for the ozone indicator is to establish an ozone **biomonitoring site within each polygon on the FIA 2002 ozone grid**. These sites are used to detect and monitor trends in ozone air pollution injury on sensitive species. Procedures include the selection of a suitable site for symptom evaluation, identification of **three known ozone-sensitive species** at the site, symptom identification and scoring on the foliage of **30 plants of each** of three species, and the collection of voucher leaf samples. Each individual plant with ozone injury is scored for **amount and severity** of injury. Plants used for the selection of **leaf vouchers** are also evaluated for injury location and type. If a plant does not have ozone injury, it is still tallied with zeros for the amount and severity measurements. A hardcopy **map,** providing directions, plot coordinates, and key characteristics of the bioindicator site, is prepared for each plot.

All **foliar evaluations** are conducted during the latter half of the field season. This is necessary to eliminate differences between plots that are caused by timing. During the evaluation window, **all ozone sites on the ozone grid are evaluated for ozone injury.** The same sites are evaluated **every year**.

Site selection procedures depend on whether crews are establishing new ozone sites or revisiting established plots. However, procedures for species and plant selection, symptom identification and scoring, and collection of leaf samples for verification of the ozone symptom are the same for all crews.

9.6.1 EVALUATION WINDOW

Quantifying ozone injury on the FIA ozone plots is limited to an evaluation window from **late-July to mid-August**. The evaluation window for crews in the Northern Region (NO) begins 29 July and extends through 23 August. In the Southern Region (SO), the window is open from 22 July through 23 August.

All established biomonitoring sites are evaluated each year. The ozone injury evaluations are generally completed over a 5 to 20 day period during the window depending on the size of the State and the number of crews dedicated to the ozone survey. If possible, crews should adjust the timing of their evaluations so that more southern States use the earlier dates of the window while more northern States delay until the mid to later dates. Similarly, within each State, the more southern biomonitoring sites should be evaluated first, the more northern sites last.

9.6.2 SITE SELECTION PROCEDURES

Site selection procedures begin with an in-office review of the ozone grid for each State. Candidate sites must be easily accessible open areas greater than one acre in size that are more than 100 feet (30 m) from a busy (paved) road. A site must contain at least thirty individuals of at least two bioindicator species to be evaluated for ozone injury. It is preferable that all sites have three or more species. The following table may be used as a decision guide for site selection:

Decision Table	First Choice = **Best Site**	Second Choice
Access:	Easy	Easy
Size of opening:	>3 acres (1.2h); wide open area <50% crown closure	Between 1-3 acres; long narrow or irregularly sized opening
Plant Numbers:	More than 30 plants of more than 3 species	More than 30 plants of 2 or 3 species
Soil/site conditions:	Low drought potential; good fertility; No recent disturbance or obvous soil compaction.	Moderately dry area with little or no disturbance.

States in the Northern (NO) and Southern (SO) Regions, that are establishing ozone sites for the first time, complete the site selection procedures described below and map the best site that can be found within the confines of each grid polygon visited by the crews during the field season. The subsequent procedures for species and plant selection, and symptom quantification are completed only if the evaluation window is open at the time of site selection and establishment.

The best ozone sites are often associated with wildlife preserves on public land. Other examples of suitable openings include old logging sites and abandoned pasture or farmland where you are reasonably certain that soil/site conditions are stable and free of chemical contaminants. Private landowners are often eager to participate in the ozone program. State and county parks and wildlife openings also provide good ozone sites. Avoid open areas where plants are obviously stressed by some other factor that could mimic the ozone response. Do not select a site under a high-tension power line or on or near an active or reclaimed landfill. No more than **one half day** should be spent locating a new bioindicator evaluation site.

FIA crews and State Cooperators that have an established network of ozone sites are strongly encouraged to select and map new sites as needed throughout the field season, but the focus of the field activities should be on symptom quantification during the late season evaluation period. Once the evaluation window opens, crews complete the bioindicator measurements on all ozone sites on the grid. The logistics of completing the bioindicator measurements may vary from State to State depending on the numbers of plots and crews. In most States, the ozone measurements may be completed over a 5 to 20 day period, at any point during the window. Crews must provide **geographic coordinates (i.e., latitude and longitude)** for all newly established ozone sites.

9.6.3 SITE MAPPING

Once a bioindicator site is selected, the field crew records the estimated size of the site opening and other key site characteristics identified on the PDR or data sheet. The crew then **maps the location of the site** relative to some obvious and permanent marker such as a telephone pole, building, or property marker. Directions to the site, including road names and distances, are added to the map. Crews also **mark the starting point for plant selection** (see Subsection 9.6.5) **and approximate location of plant groupings** used for evaluation (see Subsection 9.6.6) on the site map. If available, a GPS unit is used to determine plot coordinates and elevation. Otherwise, this information is obtained from a USGS topographic map, generally the 7½ minute series quadrangle.

Ozone site maps are used by audit and regular crews in subsequent visits to the plot (see Figure 9-1). This bioindicator site map must be kept with the appropriate state or federal cooperator so that it is readily available to whoever needs it.

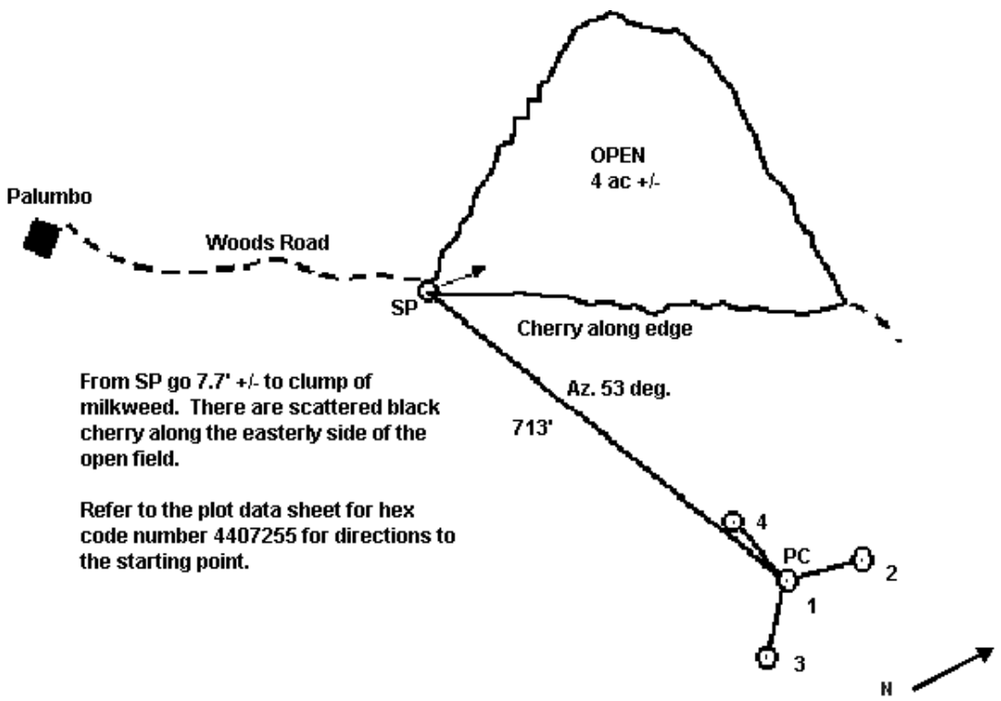

Figure 9-1. Example of a well-drawn map showing the location of the biosite and the approximate location of the bioindicator species and other key landmarks. Road names and north arrow are also included.

9.6.4 SPECIES SELECTION

At the selected bioindicator site, the crew evaluates **30 individuals of three or more bioindicator species**. If three species cannot be found at the site, then two species are still evaluated. Crews may combine species and plant counts from neighboring locations to obtain the required plant counts for each site. If 30 plants of two or more species cannot be found at the site, then a new site or additional location must be selected. A

prioritized list of species is provided to the field crews for each region. The top three species in each list are the most common throughout the sampling region. Therefore, crews are encouraged to select from the top of the list down when more than three species are found at the same site. However, species with 30 or more individual plants should be a first priority for choice of species. Key identifying characteristics of each species are provided in the Appendix 9.A.

Field crews record the species code number for each selected species in the PDR or on the data sheet. The target species and codes for the North and South Regions are:

Code	Definition – Bioindicator Species	Scientific Names
915	Blackberry	*Rubus allegheniensis* (second year canes only)
762	Black Cherry	*Prunus serotina*
365	Common and Tall Milkweed	*Asclepias spp.*
621	Yellow Poplar	*Liriodendron tulipifera*
541	White Ash	*Fraxinus americana*
931	Sassafras	*Sassafras albidum*
366	Spreading Dogbane	*Apocynum androsaemifolium*
364	Big Leaf Aster	*Aster macrophylum*
611	Sweetgum	*Liquidambar styraciflua*
761	Pin Cherry	*Prunus pensylvanica*

9.6.5 PLANT SELECTION

After site and species selection, the next task is to contiguously sample 30 individual plants of each species. **Thirty plants of a target species must be sampled**, if they are available on site. In fact, crews are strongly encouraged to **evaluate 150 plants at each site** (30 plants of five species), if possible. The value of the bioindicator data increases significantly with increased numbers of plants evaluated. This is true even if the crew records 30 consecutive zeros on three different species.

NOTE: The borders of some biomonitoring sites are difficult to determine and crews may be uncertain how much ground area to cover to complete the plant selection procedures. Specific guidelines are not set because the constraints on crew time and resources vary considerably from one State to the next. Time and safety concerns should take priority. Each crew must make every effort to maximize the number of plants and species evaluated for ozone injury at each plot location. Generally, crews are expected to complete 3 ozone sites in a ten hour work day.

The following procedures help crews to collect the bioindicator data in as systematic or unbiased a way as possible.

1. Identify a **starting point** at the edge of the opening. This point is **mapped** on the plot data sheet so that audit and regular crews evaluate roughly the same population of plants in subsequent visits to the plot.

2. Move away from the starting point, towards the center of the opening.

3. Begin locating individuals in a **sweeping pattern**, selecting plants that are growing under the same or similar growing (microhabitat) conditions. Do not skip plants with little or no injury.

4. Select the more exposed plants (**high sunlight exposure**) and avoid suppressed and shaded individuals. Plants along the edge of an opening may be used if, in your judgement, they receive direct sunlight for three to four hours each day.

5. **Avoid** plants under 12 inches in height or so tall that you cannot see or touch at least half of the crown area.

6. Evaluate the foliage that you can see and touch on **30 plants of each species** in the opening.

7. **Record** the amount and severity of injury for each plant evaluated (with or without symptoms) on the PDR, personal data assistant, or data sheet.

NOTE: A **pop-up menu** keeps track of the plant counts by species. You can tabulate more than three species and a limited sample number of 30 plants per species. Stop when the pop-up display indicates you have tabulated 30 plants of at least 3 species, or when no additional plants can be found on site.

NOTE: **Milkweed and blackberry** spread vegetatively. This means that neighboring plants are often genetically identical. To avoid repeat sampling of **clonal** material, take several steps between each plant selected for evaluation. Use a systematic approach to select individual plants. For example, select the plant closest to your left side then take two steps and select the plant closest to your right side and repeat. (A comparable systematic approach should be applied to all evaluated species to minimize bias in the plant selection process.) With blackberry, it is often difficult to distinguish individual plants or stems. In this case, use an approximate 2-foot square area to represent a single plant.

9.6.6 SYMPTOM IDENTIFICATION AND SCORING

The bioindicator species selected for each region are those that have been determined through field and laboratory studies to be highly sensitive to ozone air pollution. However, within a species, differences in genetics between individuals result in differential sensitivities to ozone. This means that you often find an individual of a species with severe air pollution injury growing immediately adjacent to another individual of the same species with few or no symptoms.

In addition to genetics, the age of the leaves (position on the stem, branch, or rosette) affects a plant's susceptibility to ozone air pollution. In general, leaves at 75% full expansion are the most sensitive and tend to show symptoms most definitively toward the center of the leaf. Older leaves show symptoms more widespread over the leaf surface, while younger leaves show symptoms more commonly near the leaf tip. If leaves on one

branch are affected, then leaves at a similar leaf position on another branch should be affected, especially for branches on the same side of the plant under similar environmental conditions (sun or shade leaves).

When scoring foliar symptoms on bioindicator plants check for the following characteristics of ozone injury.

- Symptoms are more severe on **mid-aged and older** leaves. New leaves will have no or very little injury.
- Symptoms are most likely confined to the **upper leaf surface**, and are typically visible as tiny **purple-red to black spots** (stippling).
- Check leaves covering each other. **Overlapped leaves** will have no injury on the bottom leaf.
- There will be some **uniformity** to size and shape of the lesions (stippling) on a leaf.
- Later in the growing season, stippling may be associated with leaf yellowing or **premature senescence**. Check the ground for fallen leaves.

Each plant with ozone injury is evaluated for the percent of the plant that is injured and the average severity of injury. For each plant located, the percentage of injured area and the severity of injury are both rated on a scale of 0 to 5 (see below). Both amount and severity estimates are confined to the exposed portion of the plant. If a plant does not have injury, it is still tallied with zeros for these measurements.

Percent Scale for Injury Amount: Estimate and record the percentage of leaves on the plant with ozone injury symptoms relative to the total number of leaves on the plant.

CODE	DEFINITION
0	No injury; the plant does not have any leaves with ozone symptoms.
1	1 to 6 percent of the leaves have ozone symptoms.
2	7 to 25 percent of the leaves are injured.
3	26 to 50 percent of the leaves are injured.
4	51 to 75 percent of the leaves are injured.
5	>75 percent of the leaves have ozone symptoms.

Percent Scale for Severity of Injury: Estimate and record the mean severity of symptoms on injured foliage.

CODE	DEFINITION
0	No injury; the plant does not have any leaves with ozone symptoms.
1	On average, 1 to 6 percent of the leaf area of injured leaves have ozone symptoms.
2	On average, 7 to 25 percent of the leaf area of injured leaves have ozone symptoms.
3	On average, 26 to 50 percent of the leaf area of injured leaves have ozone symptoms.
4	On average, 51 to 75 percent of the leaf area of injured leaves have ozone symptoms.
5	On average, >75 percent of the leaf area of injured leaves have ozone symptoms.

NOTE: **Blackberry and white ash** have compound leaves. Use the **whole leaf**, not each leaflet, to estimate injury amount and severity. A typical clump of blackberry plants will have both current year (vegetative) and second year (flower and fruit bearing) canes available for evaluation. The amount and severity measurements are confined to the foliage on the **second year canes**. The foliage on the current year canes is naturally resistant to ozone injury. Do not use blackberry if you can find only current year canes.

Proceed as follows:

1. **Record** the injury amount and the injury severity ratings for each plant on the PDR or data sheet.

2. Use the **notes** section on the PDR or data sheet to add other information that will help interpret the results (e.g., below average rainfall for the area).

3. **Collect** a voucher leaf sample (three leaves of each injured species evaluated at each location) and mail them to the National Advisor using the guidelines presented in Subsection 9.6.7.

NOTE: Do not take measurements in steady rain. Foliar symptoms are easiest to see under overcast skies. Bright sun will make it difficult to see the ozone stipple. Stand so that you reduce the glare on the leaf surface. Long periods without rain will inhibit symptom development even on the most sensitive plants. If you are experiencing **below average rainfall** for your area, please note this in the PDR or on the data sheet.

9.6.7 COLLECTION OF LEAF SAMPLES

The voucher leaf samples are a critical aspect of the data collection procedures as they provide the necessary validation of the ozone injury symptom observed in the field by the field crews. Crew data that do not include a voucher leaf sample are removed from the FIA database. During the evaluation window, a voucher leaf sample must be collected for each injured species evaluated on the bioindicator site. For example, if a field crew records ozone injury on blackberry, black cherry, and milkweed then a minimum of **one voucher (3 leaves) from each of the three species (9 leaves in all)** is collected and mailed to the National Indicator Advisor.

Note: If **QA** staff and regular field crews happen to be evaluating the same site at the same time, they collect and mail separate vouchers.

Note: The recognition of ozone injury symptoms in the field is not an exact science, and many other foliar injury symptoms can be mistaken for ozone injury. Crews are encouraged to collect and mail in voucher specimens of both known and suspected ozone injury for verification by the National Advisor.

9.6.7.1 FIELD COLLECTION

For each injured species, the voucher consists of **three leaves** that clearly show the ozone injury symptom. Ideally, these are three leaves with high amounts of foliar injury symptoms. If this is not possible, send whatever leaf sample is available even if it is only one leaf with faint symptoms. Cut the leaf at the petiole with hand clippers or a sharp knife.

If the leaves are wet when you cut them, shake off any excess moisture and **pat dry**. Place the samples into the plant press you were provided at training. Each leaf is **placed in the press** so that it does not overlap another leaf. Ozone symptoms become indistinguishable on leaves that overlap each other in the press and the voucher becomes, therefore, worthless. Include a **label** with each leaf sample you place into the plant press that identifies which plot the sample came from and the date. Labels are provided for this purpose. Record the information on the labels with indelible ink and then wrap them around the petiole of one leaf per sample so that the backsides stick together and will not slip off the leaf. If you forget to take the plant press with you into the field, then place the leaves and accompanying label between pages of a notebook, or otherwise keep as flat as possible.

NOTE: **Blackberry and white ash** have compound leaves. Select the whole leaf (not individual leaflets) when preparing a voucher sample.

9.6.7.2 DATA COLLECTION

The plants from which the leaf vouchers are selected must be evaluated by the field crews for **injury location and injury type**. This information, together with the visible injury symptoms on the leaf samples, will be used to validate the ozone injury data observed and recorded in the field by the field crews. Injury location and type are representative codes of the sampled population. The injury location and type codes are recorded on the upper half of the voucher data sheet as follows:

Injury Location: Specify the leaf age or position of the leaves with ozone injury.

CODE	DEFINTION
1	>50% of the injured leaves are younger leaves. Younger leaves are usually located towards the branch tip (e.g., blackberry, black cherry, yellow poplar, white ash, sassafras, sweetgum, pin cherry, and spreading dogbane) or top of the plant (e.g., milkweed and big-leaf aster).
2	>50% of the injured leaves are mid-aged or older leaves. Mid-aged and older leaves are located halfway along the branch (e.g., blackberry, black cherry, yellow poplar, white ash, sassafras, sweetgum, pin cherry, and spreading dogbane), or main stem of the plant (e.g., milkweed and big-leaf aster), or more towards the base of the branch or stem.
3	Injured leaves are not concentrated in any one location, leaf age or position. Injury may be spread more or less evenly over the plant or is, otherwise, difficult to describe.

***Injury Type**:* Specify the visible injury symptom.

CODE	DEFINITION
1	The injury on >50% of the injured leaves is best described as upper-leaf-surface stipple, i.e., tiny purple-red to black spots occurring between the veins. Stippling may be associated with leaf yellowing and leaf drop late in the evaluation window; When injury is severe, stipples may coalesce and appear as uniform discoloration of the leaf surface.
2	The injury on >50% of the injured leaves is something other than upper-leaf-surface stipple. For example, small white to tan flecks occurring between the veins, or injury that is clearly visible on both leaf surfaces, or a general discoloration of the leaf that resembles early fall coloration.
3	The visible injury is varied or, otherwise, difficult to describe.

NOTE: Not all location and type codes are indicative of ozone injury. Certain combinations of location and type codes, considered with a questionable leaf voucher, may invalidate the injury data. Other combinations provide quality assurance for the injury assessment. Crews should describe any unusual or questionable symptoms on the upper half of the voucher data sheet.

9.6.7.3 MAILING PROCEDURES

Vouchers are **mailed** in bulk at the end of the evaluation window, or earlier, depending on your work schedule. It is very important to mail only **dry, pressed leaf samples**. Before mailing, make sure you have filled out the upper half of the **voucher data sheet**. This sheet is filled out on the same day the sample is collected even if the sample is not mailed on that day. Please **comment** on the weather or general plot conditions that might help interpret the injury data. For example, *"It's been 14 days now without rain," "Every plant showed the same response and it was very obvious," or "This was a highly disturbed site."* Avoid noting whether you think the leaf sample shows ozone injury or a mimicking symptom or referring to your amount and severity ratings so as not to influence the validation process.

The lower half of the voucher data sheet is filled out by the National Ozone Advisor to whom you are sending the sample. Place the voucher data sheet and the leaf sample between two pieces of stiff paper or cardboard before placing into a mailing envelope addressed to the National Advisor. Manila folders and newspaper may also be used for voucher mailings. Do not tape the leaves to the folders, paper or cardboard. Taped samples often break apart when they are handled, making evaluation difficult. Include as many samples as fit easily into each mailing envelope. There must be a unique voucher data sheet for each sample or species, unless you are using the form for multi-species.

9.6.8 CREW MEMBER RESPONSIBILITIES

1. Although one or two crew partners may be trained for this indicator, one person typically takes the lead responsibility for site selection, plant selection, and ozone injury evaluations. All procedures can be successfully completed by one person. Two person crews are recommended for safety reasons.

2. All members of the field crew may assist each other in the site selection process. Once a site is selected, one crew member is responsible for mapping the site and the location of bioindicator species on the field data sheet.

3. Only the crew member trained and certified in ozone injury evaluations may collect the amount and severity data and the leaf voucher. Other crew members may assist by recording the injury scores on the PDR or data sheet and by getting the plant press supplies ready.

4. The crew member that evaluates the plants for injury is responsible for collecting and mailing the voucher sample with air pollution symptoms.

9.6.9 SITE INTENSIFICATION

In addition to the unique ozone plots that are identified by the base ozone grid, some Cooperators have established additional biomonitoring sites to represent the local plant populations and environmental conditions. This is not an auxiliary effort, but an integral part of the monitoring activities for this indicator. In some States, additional biomonitoring sites are limited in number and are deliberately located close to weather and air quality monitoring stations. In other States, the ozone grid is intensified to allow for an unbiased allocation of additional biomonitoring sites. It is recommended that additional sites, whether few or many in number, be located on public land to facilitate the annual measurement activities.

Ozone biomonitoring sites added to the base grid typically possess attributes of an ideal site for evaluating ozone injury on sensitive species. They are larger than three acres, contain the maximum number of indicator species, and have soil/site conditions with low drought potential and adequate fertility. They are evaluated for ozone injury using the same methods and during the same time frame as described above. Voucher leaf samples must be collected, according to procedures described in Subsection 9.6.7 and mailed to the National Indicator Advisor.

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Appendix 9.A Key Identifying Characteristics of the Ozone Bioindicator Species

1. ***Blackberry*** is an upright or arching shrub; greenish to greenish-red stems are ridged with stout prickles. Alternate leaves have 3-7, mostly 5, leaflets, sparingly pubescent above, velvety beneath, green on both sides. Flowers white, May-July. Fruits black, July-September. Dewberry is very similar to common blackberry, but it is a vine with prickly stems trailing over the ground. Raspberry has smaller leaves and rounded stems covered with a whitish bloom. Blackberry is found in dry fields, clearings, and sunny thickets.

2. ***Black Cherry*** is a small to large tree. Twigs have a bitter-almond smell and taste. The alternate leaves are narrow, shiny, 2-6 in long, and blunt-toothed, with the midrib prominently fringed beneath with white to brown hair. Leaves of choke cherry, a similar species, have a hairless midrib beneath and are sharp toothed. Leaves of pin cherry are longer and narrower with finely serrated margins. Black cherry is found on a variety of forest soils, deep and moist to dry and gravelly, and along the edges of disturbed areas.

3. ***Common Milkweed*** is recognized by a solitary, simple stem 1-6 feet tall that may or may not be covered with hair. The opposite or whorled leaves are twice as long (2 to 12 in) as they are wide, have smooth margins, and stems with milky juice. The surface of the leaf is hairy below and smooth above. The petioles are short and thick. Flowers are borne in large clusters on stalks in the upper nodes. They appear rose or greenish-white, from June to August. You may see developmental stages of the Monarch butterfly or feeding injury on the plants. Milkweed is common along roadsides, in fields and meadows.

4. ***Yellow Poplar*** is a tall, straight, forest tree found on good sites with many hardwoods and loblolly pine in the South. Leaves are 4 to 6 in in diameter, squarish at base, mostly 4-lobed, with smooth margins. Twigs stout, bitter to taste, with diaphragmed pith. Bud shaped like a duck's bill.

5. ***White ash*** is characterized by opposite, compound leaves; leaflets 5-9, stalked, green above and white or pale beneath, usually with smooth margins, slightly toothed near the leaf tips. Buds are inset in the leaf scar. Twigs are round, shiny, and mostly hairless. White ash is difficult to distinguish from green ash; Green ash leaves tend to be narrower, with more teeth, and hairy beneath; buds are set above the leaf scar and branch stems are usually hairy. Ash is sometimes confused with hickory, but can be readily distinguished by its opposite leaves and buds.

6. ***Sassafras*** has a characteristic odor and taste, spicy. Leaves are simple, narrowly lobed (mitten shaped) or entire. Twigs are green. Found from southwestern Maine, south to Florida, north to central Michigan, and west.

7. ***Sweetgum*** has star shaped leaves, deeply 5-7 lobed, margin finely serrate, bright green above, hairy in the axils of the leaf veins below. Twigs shiny and green to yellowish brown, somewhat fragrant when crushed. Fruit a spiny ball, often hanging. Common on bottomland soils and old fields from southern Connecticut, south to Florida and west.

8. ***Pin Cherry*** is a small, shrubby tree often found on cut over, burned, or abandoned sites. Leaves are long, narrow, finely serrate, and yellow-green; less shiny than those of black cherry. Pin cherry leaves may look like black cherry leaves, but they have no hair beneath. Maine to northern Georgia and west.

9. ***Spreading Dogbane*** is a perennial herb characterized by its opposite leaves with smooth margins and red stems with milky juice. The simple leaves are oblong or egg-shaped, dark green above and pale beneath; 2-3 in long. The plant grows 1-4 feet high and has wide-spreading branches that give the plant an awkward appearance. It flowers throughout the summer; pinkish with a pink stripe in the center. Pods are long and narrow, in pairs. Young milkweed may be confused with dogbane, but differs in having larger, thicker leaves, hairy on the under surface. If evident, milkweed flowers are showy and the pods are large. Dogbane prefers the edges of dry woods from Canada to Mexico, but is also found in dry fields and thickets.

10. ***Bigleaf Aster*** is a perennial wild flower commonly found as an understory plant in dry woods. The leaves of this aster are heart shaped, 3 or more in wide, with unevenly toothed margins, and have a stem nearly as long as the length of the leaf. Near the flat-topped flower cluster, the leaves become smaller and the stems are margined by a wavy leaf portion called a wing. Flowers may be violet, lavender, or light blue; evident in August and September. The plant grows 1-4 feet high and is native over eastern U.S. and south to North Carolina, west to Illinois.

OZONE BIOINDICATOR PLANTS
Site Characteristics - 2002

This sheet must be completed only if you have *not* entered this same information on the Bioindicator Plot ID screen.

To be filled out by the FIELD CREW or Cooperator: Refer to Field Guide 1.6 for code definitions.

State	County	Ozone Hexagon Number	Plot Number[1]	Month	Day	Crew ID	Crew Type
							regular QA

[1]Plot Number refers to the number of locations (1 or 2) used for each hexagon number. A separate sheet should be used for each location.

√ Please put a check mark beside the correct information. Please complete all data fields.

Ozone Sample Kind:	
	Initial plot establishment on the 2002 FIA ozone grid.
	Remeasurement of a previously established plot.
	Replacement of a previously established plot that was replaced to meet new site selection guidelines (or lost site).

Ozone Grid Density: (Is the grid intensified, or not?)	
	This hex number identifies a unique ozone plot within a polygon (1 site:1 polygon)
	One of two or more ozone plots within the same polygon, each with their own hexagon number.

Plot size:		Terrain position:	
	> 1.2 hectares (3.0 acres)		Ridge top or upper slope
	0.2 – 1.2 hectares (1/2 to 3 acres)		Bench or level area along a slope
	Other: please describe		Lower slope
			Flat land unrelated to slope
			Bottom land with occasional flooding

Aspect: 000° = no aspect; 360° = N aspect	Elevation: record estimate in feet or meters	
Record to nearest degree =	Feet =	Meters =

Soil Drainage:		Soil Depth:	
	Well-drained		Bedrock not exposed
	Wet		Bedrock exposed
	Excessively dry		

Disturbance: Disturbance on the site or in localized areas where the bioindicator plants are growing.	
	No recent or significant disturbance; Do not count disturbance >3 years old.
	Evidence of overuse; Human activity causing obvious soil compaction or erosion.
	Evidence of natural disturbance including fire, wind, flooding, grazing, pests, etc.

Fill in below all that apply. Check here if geographic coordinates were obtained from a topographic map:

GPS Type:	GPS Serial Number:
Latitude =	GPS Error =
Longitude =	Number of Readings =
Elevation =	GPS File Name =

[1]If no GPS Unit is available, please use a map and record estimated latitude, longitude, and elevation for each plot location.

Comments: Include information on additional species in the area, safety, directions, or additional site characteristics that may be useful.

File this completed data sheet with the sheet used for mapping the Bioindicator Site Location and then store it in the appropriate Ozone Plot Folder for your State or Region.

OZONE BIOINDICATOR PLANTS - 2002

Foliar Injury Data – Use this sheet *only* if no PDR is available for data entry!

State	Cty	Hexagon No. or Site ID	Month	Day	Measurement Type (check one):
					___ Regular crew ___ QA crew

Record species code number from list below (choose up to 3; use additional sheets for >3 species at one site):
915 Blackberry **762** Black cherry **365** Milkweed **621** Yellow Poplar **541** White ash **931** Sassafras
611 Sweetgum **761** Pin cherry **366** Dogbane **364** Big leaf aster
Then use the codes from the percent injury scale to record the percent of the leaves injured relative to the total leaf number (amount) and the average severity of symptoms on the injured leaves (severity). Add notes to the back.
0 = No injury; **1** = 1-6%; **2** = 7-25%; **3** = 26-50%; **4** = 51-75%; **5** = >75%

	Species Code		Species Code		Species Code	
Plant	amount	Severity	amount	severity	Amount	Severity
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

OZONE BIOINDICATOR PLANTS

Data Sheet for Mapping the Bioindicator Site Location

To be filled out by the FIELD CREW or Cooperator: Refer to Field Guide 1.6 for code definitions.

State	County	Ozone Hexagon Number	Plot Number[1]	Month	Day	Year	Crew ID

[1]Plot Number refers to the number of locations (1 or 2) used for each hexagon number. A separate sheet should be used for each location.

Include the following information on the map:

(1) Location of the site relative to some obvious and permanent marker.
(2) Road names and distances as needed.
(3) North arrow.
(4) Species codes and approximate location of plant groupings used for the ozone injury evaluations.

Return the original of this map to the corresponding Plot Folder so that it can be used by audit and regular crews in subsequent visits to the plot. Mail a copy to the National Indicator Advisor the year that the site is established.

Geographic coordinates:	
GPS Latitude =	GPS Longitude =
Latitude estimated from a topographic map =	
Longitude estimated from a topographic map =	

OZONE BIOINDICATOR PLANTS

Summary Sheet on Field Methods

The following table may be used as a decision guide for site selection:

Decision Table	First Choice = ***Best Site***	Second Choice
Access:	Easy	Easy
Size of opening:	Greater than 3 acres	1 to 3 acres
Plant Numbers:	More than 30 plants of more than 3 species	Close to 30 plants of 2 or 3 species
Soil/site conditions:	Low drought potential; Adequate fertility; No disturbance or obvious soil compaction.	Moderately dry area with little or no disturbance.

The following procedures help crews to collect the bioindicator data in as systematic or unbiased a way as possible.

1. Identify a starting point at the edge of the opening and map it.
2. Move away from the starting point, towards the center of the opening, locating individuals in a sweeping pattern and selecting plants that are growing under similar growing conditions.
3. Select the more exposed plants and avoid suppressed and shaded individuals. Do not skip plants with little or no injury.
4. Evaluate the foliage on each plant for the amount and severity of injury. Record it electronically.
5. Collect a leaf voucher (3 leaves) showing ozone injury on each species. Store it in a leaf press.

When scoring foliar symptoms on bioindicator plants check for the following characteristics of ozone injury.

1. Symptoms are usually more severe on mid-aged and older leaves.
2. New leaves will have no or very little injury.
3. Symptoms are most likely confined to the upper leaf surface as tiny purple-red to black spots.
4. Check leaves covering each other. Overlapped leaves will have no injury on the bottom leaf.
5. There will be some uniformity to size and shape of the lesions (stippling) on a leaf.
6. Stippling may be associated with leaf yellowing or premature senescence.

Percent Scale for Injury Amount: Estimate and record the percentage of leaves on the plant with ozone injury symptoms relative to the total number of leaves on the plant.

CODE	DEFINITION
0	No injury; the plant does not have any leaves with ozone symptoms.
1	1 to 6 percent of the leaves have ozone symptoms.
2	7 to 25 percent of the leaves are injured.
3	26 to 50 percent of the leaves are injured.
4	51 to 75 percent of the leaves are injured.
5	>75 percent of the leaves have ozone symptoms.

Percent Scale for Severity of Injury: Estimate and record the mean severity of symptoms on injured foliage.

CODE	DEFINITION
0	No injury; the plant does not have any leaves with ozone symptoms.
1	On average, 1 to 6 percent of the leaf area of injured leaves have ozone symptoms.
2	On average, 7 to 25 percent of the leaf area of injured leaves have ozone symptoms.
3	On average, 26 to 50 percent of the leaf area of injured leaves have ozone symptoms.
4	On average, 51 to 75 percent of the leaf area of injured leaves have ozone symptoms.
5	On average, >75 percent of the leaf area of injured leaves have ozone symptoms.

Species codes: 915 Blackberry 762 Black cherry 365 Milkweed 621 Yellow poplar 541 White ash 931 Sassafras 366 Spreading dogbane 364 Bigleaf aster 611 Sweetgum 761 Pin cherry.
Note: The best sites are large open areas with 3, 4, or 5 species and close to 30 plants of each species.

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OZONE BIOINDICATOR PLANTS
Data Sheet for the Voucher Leaf Samples - 2002

To be filled out by the FIELD CREW or Cooperator: Refer to Field Guide 1.6 for code definitions.

State	County	Ozone Hexagon Number	Plot Number[1]	Month	Day	Crew ID	Crew Type
							regular QA

[1]Plot Number refers to the number of locations (1 or 2) used for each hexagon number. A separate sheet should be used for each location.

To be filled out by the Cooperator (only needed when the hex number and tally numbers are not known).

Ozone plot name or identification number	Name and e-mail address of data collector

Fill in the required codes. Code definitions are in the Field Guide. For quick reference, see below.

Bioindicator Species	Injury Location	Injury Type	Is the leaf sample injury close to 100% ozone stipple, or is some other upper-leaf-surface injury also present?
			Close to 100% _____ Estimated percent other _____

Notes: Add notes on the leaf samples, plot conditions, safety, and weather as needed.

Species codes: 915 Blackberry 762 Black cherry 365 Milkweed 621 Yellow poplar 541 White ash 931 Sassafras 611 Sweetgum 761 Pin cherry 366 Spreading dogbane 364 Bigleaf aster.
Injury Location codes: 1 = greater than 50% of the injured leaves are younger leaves; 2 = greater than 50% of the injured leaves are mid-aged or older; 3 = injured leaves are all ages.
Injury type codes: 1 = greater than 50% of the injury is upper-leaf-surface stipple; 2 = greater than 50% is not stipple (tan flecks, bifacial or general discoloration); 3 = injury is varied or difficult to describe.

Questions? Call your Regional Advisor. Northeast: Gretchen Smith (413) 545-1680 [gcsmith@forwild.umass.edu] North Central: Ed Jepsen (608) 266-3538; South: Dan Stratton (828) 257-4352; West: Sally Campbell (503) 808-2034 or (703) 605-4191.

Mail this sheet with the leaf samples to :
[Note: One sheet for each species.]

Gretchen Smith
Department of Natural Resources Conservation
160 Holdsworth Way
University of Massachusetts
Amherst, MA 01003

QA/QC PERSON: To be filled out by the ozone advisor or regional expert.

Positive for ozone	Negative for ozone	Date validated	Date rechecked	Sample condition

Notes: Explanation of symptoms or questions for the data collector.