

**OZONE SENSITIVE PLANT SPECIES ON NATIONAL PARK SERVICE AND
U.S. FISH AND WILDLIFE SERVICE LANDS
June 2003, Baltimore, Maryland
Workshop Report**

SUMMARY: The National Park Service (NPS) convened a workshop in June 2003 to review and update lists used by the NPS and the U.S. Fish and Wildlife Service (FWS) to identify ozone sensitive plant species. At the workshop, ozone effects scientists made recommendations for the lists; subsequent to the workshop, an additional group of reviewers provided comments to the lists. The results are presented in the following report.

BACKGROUND: The NPS and FWS, both Department of Interior agencies, are responsible for identifying and protecting air quality related values (AQRVs) on their lands. AQRVs include resources that may be affected by air pollution and include vegetation, wildlife, water, soils, and visibility. One of the most widespread air pollutants is ozone, which harms vegetation as well as human health. Ozone is not emitted directly from smokestacks or vehicles, but is formed when other pollutants, primarily nitrogen oxides and volatile organic compounds, react in the atmosphere in the presence of sunlight, usually during the warm summer months. Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems. The Environmental Protection Agency has established an ozone standard to protect human health; however, EPA has not set a standard to protect vegetation and there is much evidence to suggest that the human health-based standard is not protective of sensitive vegetation.

Ozone enters plants through leaf stomata and oxidizes plant tissue, causing changes in biochemical and physiological processes. Both visible foliar injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss, reduced photosynthesis, and reduced leaf, root, and total dry weights) can occur in sensitive plant species. In a natural ecosystem, many other factors can ameliorate or magnify the extent of ozone injury at various times and places such as soil moisture, presence of other air pollutants, insects or diseases, and other environmental stresses. Ozone effects to natural vegetation have been documented throughout the country, particularly in many areas of the East and in California. A relatively small number of national parks and national wildlife refuges have been surveyed for ozone injury. As a result, injury has been documented in Great Smoky Mountains, Shenandoah, Lassen Volcanic, Sequoia/Kings Canyon, and Yosemite National Parks, and Edwin B. Forsythe, Cape Romain, Moosehorn, Seney, and Mingo National Wildlife Refuges.

WORKSHOP GOALS AND RESULTS: In the 1990s, NPS and FWS developed lists of ozone sensitive plant species for many parks and refuges and in 2000 published these lists in the Federal Land Managers' Air Quality Related Values Workgroup (FLAG) report. As new information has become available, NPS and FWS recognized a need to review, revise, and update the lists of sensitive plant species. In June 2003, the National Park Service (NPS) sponsored a workshop in Baltimore, Maryland, for this purpose.

Workshop participants (Appendix A) had extensive experience in ozone field surveys and ozone fumigation experiments conducted with species that occur on NPS and FWS lands. Participants reviewed the existing NPS and FWS lists of sensitive species and, using expert judgment based on knowledge of scientific literature, fumigation experiments, and field experience, revised and updated the lists, sorting ozone-sensitive species into two lists:

- 1) **Sensitive** species: species that typically exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar injury symptoms in the field have been documented by more than one expert observer
- 2) **Bioindicator** species (subset of sensitive species): sensitive species that exhibit foliar symptoms in the field at ambient ozone concentrations that can be easily recognized as ozone injury by subject matter experts; species whose ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers; species that are widely distributed regionally; and, species that are easily identified in the field

Both lists are limited in number of species because, to date, relatively few species from natural ecosystems have been fumigated in chambers or examined in the field for ozone symptoms. Because of these limitations, the lists also include a small number of exotic species, e.g., *Ailanthus altissima*. Although *A. altissima* is undesirable in parks and refuges, it serves as an indicator of possible ozone injury to native species and can therefore be useful to resource managers. Continuing fumigations and field surveys will likely identify many other ozone sensitive species and the lists will be revised accordingly. In addition, the lists include only species that display foliar injury in response to ozone. Other species may be sensitive to ozone, but respond with growth and reproduction effects, which are very difficult to document under field conditions.

The list of sensitive species will enable parks and refuges to identify their AQRVs that are sensitive to ozone. Bioindicator species, because of the attributes described above, are recommended for use in field surveys in parks and refuges where the risk for ozone injury to plants is considered moderate or high. The workshop participants cautioned that field diagnoses of injury on any plants, including bioindicator plants, should only be attempted by trained observers because other agents, including insects and disease, produce foliar symptoms.

A third list was developed for species suspected to be sensitive to ozone. For these suspect species, there is some evidence of sensitivity; however, the suspect species do not meet the criteria listed above for bioindicator or sensitive species. For example, suspect species may have shown foliar injury in fumigations at unrealistically high ozone concentrations or in very limited field observations, or they may be species for which evidence from different observers is conflicting. Suspect species should not be included on park or refuge lists of ozone sensitive species. However, researchers may want to consider suspect species as potential candidates for future investigation.

After the Baltimore meeting, the three lists were distributed for review by an additional group of ozone researchers (Appendix B). Their comments were incorporated into the three final lists for bioindicator, sensitive, and suspect species (Appendix C). The NPS is using the lists of sensitive species (which includes bioindicator species) in a risk assessment for approximately 270 parks in the NPS Inventory and Monitoring Program. Risk assessments for individual parks consider 1) presence of sensitive species, 2) ozone concentrations and cumulative doses, and 3) soil moisture status (as indicated by the Palmer Z Index). The results from these assessments will assist park managers in determining the need for future ozone monitoring and vegetation surveys.

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PLANT SPECIES IN NPS/FWS UNITS SENSITIVE* TO OZONE

*Species considered “sensitive” are those that typically exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar injury symptoms in the field have been documented by more than one observer.

Scientific Name	Common Name	
<i>Aesculus octandra</i>	Yellow buckeye	Sensitive
<i>Ailanthus altissima</i>	Tree-of-heaven	Sensitive
<i>Alnus rubra</i>	Red alder	Sensitive
<i>Alnus rugosa</i>	Speckled alder	Sensitive
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	Sensitive
<i>Apios americana</i>	Groundnut	Sensitive
<i>Apocynum androsaemifolium</i>	Spreading dogbane	Sensitive
<i>Apocynum cannabinum</i>	Dogbane, Indian hemp	Sensitive
<i>Artemisia douglasiana</i>	Mugwort	Sensitive
<i>Artemisia ludoviciana</i>	Silver wormwood	Sensitive
<i>Asclepias exaltata</i>	Tall milkweed	Sensitive
<i>Asclepias incarnata</i>	Swamp milkweed	Sensitive
<i>Asclepias syriaca</i>	Common milkweed	Sensitive
<i>Aster acuminatus</i>	Whorled aster	Sensitive
<i>Aster macrophyllus</i>	Big-leaf aster	Sensitive
<i>Cercis canadensis</i>	Redbud	Sensitive
<i>Clematis virginiana</i>	Virgin's bower	Sensitive
<i>Corylus americana</i>	American hazelnut	Sensitive
<i>Eupatorium rugosum</i>	White snakeroot	Sensitive
<i>Fraxinus americana</i>	White ash	Sensitive
<i>Fraxinus pennsylvanica</i>	Green ash	Sensitive
<i>Gaylussacia baccata</i>	Black huckleberry	Sensitive
<i>Krigia montana</i>	Mountain dandelion	Sensitive
<i>Liquidambar styraciflua</i>	Sweetgum	Sensitive
<i>Liriodendron tulipifera</i>	Yellow-poplar	Sensitive
<i>Lyonia ligustrina</i>	Maleberry	Sensitive
<i>Oenothera elata</i>	Evening primrose	Sensitive
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Sensitive
<i>Philadelphus coronarius</i>	Sweet mock orange	Sensitive

<i>Physocarpus capitatus</i>	Ninebark	Sensitive
<i>Physocarpus malvaceus</i>	Pacific ninebark	Sensitive
<i>Pinus banksiana</i>	Jack pine	Sensitive
<i>Pinus jeffreyi</i> **	Jeffrey pine	Sensitive
<i>Pinus ponderosa</i> ***	Ponderosa pine	Sensitive
<i>Pinus pungens</i>	Table-mountain pine	Sensitive
<i>Pinus radiata</i>	Monterey pine	Sensitive
<i>Pinus rigida</i>	Pitch pine	Sensitive
<i>Pinus taeda</i>	Loblolly pine	Sensitive
<i>Pinus virginiana</i>	Virginia pine	Sensitive
<i>Platanus occidentalis</i>	American sycamore	Sensitive
<i>Populus tremuloides</i>	Quaking aspen	Sensitive
<i>Prunus serotina</i>	Black cherry	Sensitive
<i>Prunus virginiana</i>	Choke cherry	Sensitive
<i>Quercus kelloggii</i>	California black oak	Sensitive
<i>Robinia pseudoacacia</i>	Black locust	Sensitive
<i>Rhus copallina</i>	Winged sumac	Sensitive
<i>Rhus trilobata</i>	Skunkbush	Sensitive
<i>Rubus allegheniensis</i>	Allegheny blackberry	Sensitive
<i>Rubus canadensis</i>	Thornless blackberry	Sensitive
<i>Rubus cuneifolius</i>	Sand blackberry	Sensitive
<i>Rubus parviflorus</i>	Thimbleberry	Sensitive
<i>Rudbeckia laciniata</i>	Cutleaf coneflower	Sensitive
<i>Salix gooddingii</i>	Gooding's willow	Sensitive
<i>Salix scouleriana</i>	Scouler's willow	Sensitive
<i>Sambucus canadensis</i>	American elder	Sensitive
<i>Sambucus mexicana</i>	Blue elderberry	Sensitive
<i>Sambucus racemosa</i>	Red elderberry	Sensitive
<i>Sapium sebiferum</i>	Chinese tallowtree	Sensitive
<i>Sassafras albidum</i>	Sassafras	Sensitive
<i>Solidago altissima</i>	Goldenrod	Sensitive
<i>Spartina alterniflora</i>	Smooth cordgrass	Sensitive
<i>Symphoricarpos albus</i>	Common snowberry	Sensitive
<i>Vaccinium membranaceum</i>	Huckleberry	Sensitive
<i>Verbesina occidentalis</i>	Crownbeard	Sensitive

Vitis labrusca	Northern fox grape	Sensitive
Vitis vinifera	European wine grape	Sensitive

** *P. jeffreyi* and *P. ponderosa* may hybridize, making identification difficult.

*** *P. ponderosa* var. *ponderosa* is the more sensitive variety; *P. ponderosa* var. *scopulorum* is not as sensitive.

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**PLANT SPECIES FOUND IN NPS/FWS UNITS AND CONSIDERED GOOD
FIELD BIOINDICATORS* FOR OZONE INJURY SURVEYS**

- *Bioindicator species for ozone injury meet all or most of the following criteria:
- species exhibit foliar symptoms in the field at ambient ozone concentrations that can be easily recognized as ozone injury by subject matter experts
 - species' ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers
 - species are widely distributed regionally
 - species are easily identified in the field

Scientific Name	Common Name	
<i>Ailanthus altissima</i>	Tree-of-heaven	Bioindicator
<i>Alnus rubra</i>	Red alder	Bioindicator
<i>Alnus rugosa</i>	Speckled alder	Bioindicator
<i>Apios americana</i>	Groundnut	Bioindicator
<i>Apocynum androsaemifolium</i>	Spreading dogbane	Bioindicator
<i>Artemisia douglasiana</i>	Mugwort	Bioindicator
<i>Artemisia ludoviciana</i>	Silver wormwood	Bioindicator
<i>Asclepias exaltata</i>	Tall milkweed	Bioindicator
<i>Asclepias syriaca</i>	Common milkweed	Bioindicator
<i>Aster acuminatus</i>	Whorled aster	Bioindicator
<i>Aster macrophyllus</i>	Big-leaf aster	Bioindicator
<i>Cercis canadensis</i>	Redbud	Bioindicator
<i>Corylus americana</i>	American hazelnut	Bioindicator
<i>Eupatorium rugosum</i>	White snakeroot	Bioindicator
<i>Fraxinus americana</i>	White ash	Bioindicator
<i>Gaylussacia baccata</i>	Black huckleberry	Bioindicator
<i>Liriodendron tulipifera</i>	Yellow-poplar	Bioindicator
<i>Lyonia ligustrina</i>	Maleberry	Bioindicator
<i>Oenothera elata</i>	Evening primrose	Bioindicator
<i>Physocarpus capitatus</i>	Ninebark	Bioindicator
<i>Physocarpus malvaceum</i>	Pacific ninebark	Bioindicator
<i>Pinus jeffreyi</i> **	Jeffrey pine	Bioindicator
<i>Pinus ponderosa</i> ***	Ponderosa pine	Bioindicator
<i>Platanus occidentalis</i>	American sycamore	Bioindicator
<i>Populus tremuloides</i>	Quaking aspen	Bioindicator
<i>Prunus serotina</i>	Black cherry	Bioindicator

Rhus trilobata	Skunkbush	Bioindicator
Rubus allegheniensis	Allegheny blackberry	Bioindicator
Rubus canadensis	Thornless blackberry	Bioindicator
Rudbeckia laciniata	Cutleaf coneflower	Bioindicator
Salix scouleriana	Scouler's willow	Bioindicator
Sambucus canadensis	American elder	Bioindicator
Sambucus mexicana	Blue elderberry	Bioindicator
Sambucus racemosa	Red elderberry	Bioindicator
Sapium sebiferum	Chinese tallowtree	Bioindicator
Symphoricarpos albus	Common snowberry	Bioindicator
Vaccinium membranaceum****	Huckleberry	Bioindicator
Verbesina occidentalis	Crownbeard	Bioindicator
Vitis labrusca	Northern fox grape	Bioindicator
Vitis vinifera	European wine grape	Bioindicator

** *Pinus jeffreyi* and *P. ponderosa* may hybridize, making identification difficult.

*** *P. ponderosa* var. *ponderosa* is the more sensitive variety; *P. ponderosa* var. *scopulorum* is not as sensitive.

****Sensitivity of *Vaccinium membranaceum* has been demonstrated in chambers, but not in the field, possibly because of low ozone levels throughout its range.

10272003

**PLANT SPECIES IN NPS/FWS UNITS SUSPECTED* OF BEING SENSITIVE
TO OZONE**

*Species suspected of being sensitive to ozone are species for which there is some evidence of sensitivity, but species does not meet criteria for sensitive species (i.e., sensitive species typically exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar injury symptoms in the field have been documented by more than one observer). Suspect species are also those species for which evidence from different observers is conflicting. NOTE: THIS LIST SHOULD NOT BE USED TO IDENTIFY OZONE-SENSITIVE SPECIES IN PARKS. IT CAN BE USED TO IDENTIFY SPECIES OF INTEREST FOR FUTURE RESEARCH.

**GRSM – injury noted in Great Smoky Mountains NP.

Scientific Name	Common Name	
<i>Acer macrophyllum</i>	Bigleaf maple	Suspect
<i>Acer negundo</i>	Boxelder	Suspect
<i>Acer rubrum</i>	Red maple	Suspect
<i>Acer saccharinum</i>	Silver maple	Suspect
<i>Aconitum uncinatum</i>	Wild monkshood	Suspect (GRSM**)
<i>Aesculus glabra</i>	Ohio buckeye	Suspect
<i>Amelanchier laevis</i>	Allegheny serviceberry	Suspect (GRSM)
<i>Anemone quinquefolia</i>	Wood anemone	Suspect (GRSM)
<i>Anemone virginiana</i>	Thimbleweed	Suspect (GRSM)
<i>Aristolochia durior</i>	Dutchman's pipe	Suspect (GRSM)
<i>Asclepias quadrifolia</i>	Four-leaved milkweed	Suspect
<i>Aster curtisii</i>	Curtis's aster	Suspect (GRSM)
<i>Aster divaricatus</i>	White-wood aster	Suspect (GRSM)
<i>Aster engelmannii</i>	Engelmann's aster	Suspect
<i>Aster infirmus</i>	Entire-leaved aster	Suspect (GRSM)
<i>Aster puniceus</i>	Purple-stemmed aster	Suspect
<i>Aster umbellatus</i>	Flat-topped aster	Suspect
<i>Betula alleghaniensis</i>	Yellow birch	Suspect
<i>Betula populifolia</i>	Gray birch	Suspect
<i>Bidens frondosa</i>	Beggar-ticks	Suspect (GRSM)
<i>Bromus tectorum</i>	Cheatgrass	Suspect
<i>Calycanthus floridus</i>	Sweet-shrub	Suspect (GRSM)
<i>Campsis radicans</i>	Trumpet creeper	Suspect
<i>Cephalanthus occidentalis</i>	Buttonbrush	Suspect (GRSM)

<i>Cladrastis lutea</i>	Yellowwood	Suspect
<i>Clitoria mariana</i>	Butterfly pea	Suspect (GRSM)
<i>Cornus florida</i>	Flowering dogwood	Suspect
<i>Diervilla sessilifolia</i>	Bush-honeysuckle	Suspect (GRSM)
<i>Gaylussacia ursina</i>	Bear huckleberry	Suspect (GRSM)
<i>Gentiana amarella</i>	Northern gentian	Suspect
<i>Geum radiatum</i>	Mountain avens	Suspect (GRSM)
<i>Gillenia trifoliata</i>	Bowman's-root	Suspect (GRSM)
<i>Glyceria nubigena</i>	Manna grass	Suspect
<i>Hamamelis virginiana</i>	Witch-hazel	Suspect (GRSM)
<i>Helianthus divaricatus</i>	Woodland sunflower	Suspect
<i>Helianthus glaucophyllus</i>	White-leaf sunflower	Suspect (GRSM)
<i>Helianthus microcephalus</i>	Small wood sunflower	Suspect (GRSM)
<i>Helianthus strumosus</i>	Paleleaf woodland sunflower	Suspect
<i>Hexastylis arifolia</i>	Heartleaf	Suspect (GRSM)
<i>Hieracium paniculatum</i>	Panicled hawkweed	Suspect (GRSM)
<i>Impatiens capensis</i>	Spotted touch-me-not	Suspect (GRSM)
<i>Larix decidua</i>	European larch	Suspect
<i>Larix leptolepis</i>	Japanese larch	Suspect
<i>Lindera benzoin</i>	Spicebush	Suspect
<i>Menziesia pilosa</i>	Minnie-bush	Suspect (GRSM)
<i>Oxydendrum arboreum</i>	Sourwood	Suspect (GRSM)
<i>Pinus nigra</i>	Austrian pine	Suspect
<i>Pinus strobus</i>	Eastern white pine	Suspect
<i>Prenanthes altissima</i>	Rattlesnake root	Suspect (GRSM)
<i>Prunus americana</i>	Wild plum	Suspect
<i>Rhamnus alnifolia</i>	Alder-leaved buckthorn	Suspect (GRSM)
<i>Rhododendron bakeri</i>	Cumberland azalea	Suspect (GRSM)
<i>Rhododendron calendulaceum</i>	Flame azalea	Suspect (GRSM)
<i>Rhododendron catawbiense</i>	Catawba rhododendron	Suspect (GRSM)
<i>Rhus glabra</i>	Smooth sumac	Suspect
<i>Rhus typhina</i>	Staghorn sumac	Suspect
<i>Rubus argutus</i>	Highbush blackberry	Suspect
<i>Rubus idaeus</i>	Red raspberry	Suspect
<i>Rudbeckia hirta</i>	Black-eyed susan	Suspect

<i>Rugelia nudicaulis</i>	Rugel's ragwort	Suspect
<i>Saxifraga arguta</i>	Saxifrage	Suspect
<i>Senecio serra</i>	Tall butterweed	Suspect
<i>Silphium asteriscus</i>	Rosin-weed	Suspect (GRSM)
<i>Smilax glauca</i>	Glaucous catbrier	Suspect (GRSM)
<i>Smilax rotundifolia</i>	Greenbrier	Suspect (GRSM)
<i>Solidago roanensis</i>	Roan's goldenrod	Suspect (GRSM)
<i>Spiraea x vanhouttei</i>	Vanhoutte spirea	Suspect
<i>Stachys clingmanii</i>	Clingman's hedge-nettle	Suspect (GRSM)
<i>Stewartia ovata</i>	Mountain stewartia	Suspect (GRSM)
<i>Syringa x chinensis</i>	Chinese lilac	Suspect
<i>Syringa vulgaris</i>	Common lilac	Suspect
<i>Tilia americana</i>	American basswood	Suspect
<i>Tilia euchlora</i>	Crimean linden	Suspect
<i>Tilia heterophylla</i>	White basswood	Suspect (GRSM)
<i>Tilia platyphyllos</i>	Bigleaf linden	Suspect
<i>Toxicodendron radicans</i>	Poison-ivy	Suspect
<i>Trautvetteria caroliniensis</i>	Tassel-rue; False bugbane	Suspect (GRSM)
<i>Vitis aestivalis</i>	Summer grape	Suspect (GRSM)
<i>Vitis riparia</i>	Riverbank grape	Suspect
<i>Vitis vulpina</i>	Frost grape	Suspect (GRSM)

10272003