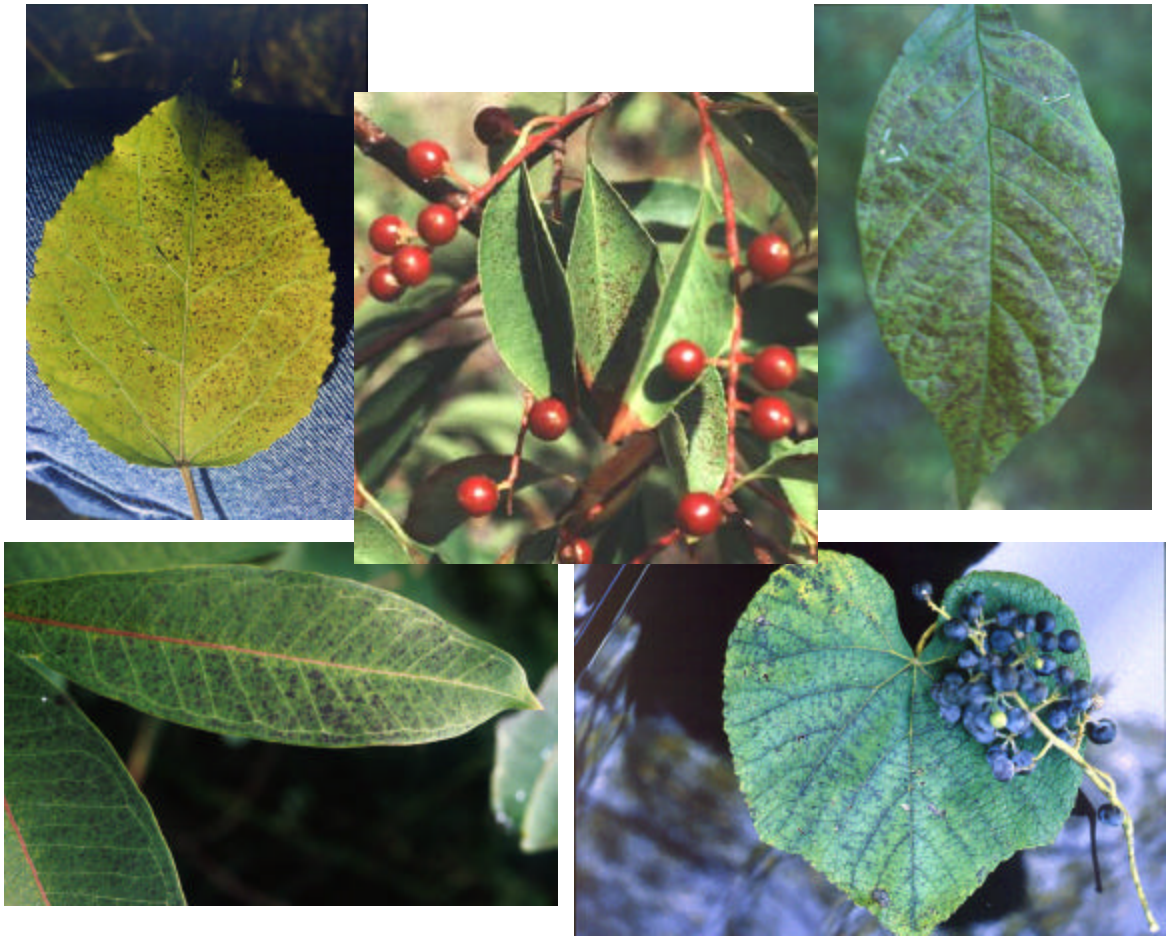
Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands:

Results of a June 24-25, 2003 Workshop
Baltimore, Maryland



National Park Service Air Resources Division
U.S. Fish and Wildlife Service Air Quality Branch

November 2003

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November 2003

NPS D1522
Natural Resource Report NPS/NRARD/NRR-2003/01

Acknowledgements:
Drs. Art Chappelka, Howie Neufeld, Donald Davis, Robert Kohut and Pat Temple provided scientific expertise at the Baltimore Workshop. Dr. Gretchen Smith, Jim Renfro, Dr. David Peterson, Ed Jepsen, Dr. John Skelly, and Dr. William Manning provided additional scientific expertise and peer review. The author wishes to thank Tonnie Maniero, Tamara Blett, and Kristi Morris for helpful editing comments.

This report is available at: www2.nature.nps.gov/ard/pubs/index.htm

Cover photos by Dr. Donald Davis

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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 scientists provided review and 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 (USEPA 1996). 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 (USEPA 1996). Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems (USEPA 1996). The Environmental Protection Agency (EPA) 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 (Heck and Cowling 1997).

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 (Skelly 2000). 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 on natural vegetation have been documented throughout the country, particularly in many areas of the eastern U.S. 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 (NPS 2000a; NPS 2002), and Edwin B. Forsythe, Cape Romain, Moosehorn, Seney, and Mingo National Wildlife Refuges (Davis 2001; Davis 2003a; Davis 2003b; Davis 2003c; Davis 2003d).

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 (NPS 2000b). 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, 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:

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.

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, also produce foliar symptoms.

A third list was developed for species suspected to be sensitive to ozone:

Suspect species: for suspect species, there is some evidence of sensitivity; however, 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.

Appendix A: **Baltimore Workshop Participants**

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Appendix C: Lists of Sensitive, Bioindicator, and Suspect Species

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

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

Updated: 27 October 2003

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

Updated: 27 October 2003

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.

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

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

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

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

Updated: 27 October 2003

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