URBAN ORNAMENTAL PLANTS: SENSITIVITY TO OZONE AND POTENTIAL ECONOMIC LOSSES

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Prepared by:
Abt Associates, Inc.

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1.0 Overview

Ozone remains the most prevalent and least tractable air pollution problem in the United States. About 150 million people reside in areas that currently are in non-attainment with the National Ambient Air Quality Standard for ozone.

A substantial amount of analysis has been conducted to ascertain the potential health and welfare losses associated with elevated concentrations of ozone. The analysis of welfare effects has focused primarily on potential economic losses from materials damage, reductions in yields of agricultural crops, and reductions in growth rates of trees of commercial importance. One remaining potentially significant area of welfare loss associated with ozone is damage to urban ornamental plants. These are plants used in the urban (and suburban) landscape, such as grass, flowers, shrubs, and trees. Welfare losses would occur if ozone-induced injury impaired the aesthetic (or other) services provided by urban ornamental plants, reduced their resistance to other environmental stresses, reduced their lifespans, or led to the use of more expensive or less aesthetically pleasing ozone-resistant plants.

This report focuses on the economic implications of potential injury to urban ornamental plants from elevated levels of ambient ozone. Section 2 provides a data base of plant species for which experimental work has been conducted to assess sensitivity to ozone, describes criteria for establishing plant sensitivities to ozone, assigns temperature zones to plant species, and develops a method for determining which plants included in the database are likely to be injured from ambient ozone levels in non-attainment areas. Section 3 develops a conceptual framework for organizing the types of economic losses that may occur from ozone-induced injury to urban ornamental plants. Section 4 summarizes information obtained from conversations with knowledgeable individuals regarding the extent of ongoing injury to urban ornamental plants and factors that may have mitigated such injury.

Assessing economic losses from ozone-induced damage to urban ornamental plants is difficult. There are many types and uses of ornamental plants, sensitivities to ozone vary widely across and within plant species, ambient ozone levels vary across non-attainment areas, and the value associated with specific types of injury to plants is difficult to monetize. There is no comprehensive set of quantitative information available on the current extent of injury to plants in the urban landscape from ozone. Likewise, there is no information available from published sources on either the value people assign to changes in the appearance of plants injured by ozone, the value lost through substitution of more resistant plants, or the additional expenditures that may be incurred to mitigate the effects of ozone-induced injury to plants (e.g., the use of more fertilizer or pesticides or the replacement of plants). Consequently, this study has focused on framing the issues involved in estimating ozone-induced economic losses to urban ornamental plants, rather than on developing quantified measures of damages.

. Current economic losses from elevated ambient ozone levels have been substantially affected by the dynamic response of natural and commercial systems over the lengthy period of time that ambient ozone has posed an environmental problem. There is evidence that natural systems self-select for ozone tolerant strains and species. Further, the commercial system for developing, growing, and distributing urban ornamental plants clearly has been selecting for plant species and cultivars that are tolerant to urban stresses, including ozone. Our research suggests that selection processes over the past several decades have resulted in an urban landscape populated mostly by plants that are resistant to ozone. This, in combination with the downward trend in urban ozone levels, probably explains why the bulk of plants in the eastern urban landscape do not appear to suffer visible signs of ozone-induced injury, even though ambient ozone levels remain high enough to cause reduced agricultural yields in areas adjoining the major metropolitan non-attainment areas and to affect some sensitive species remaining in the urban landscape.[1]

2.0 Identification of Plant Species Potentially at Risk in Ozone Non-Attainment Areas

This section describes the approach used to develop a data base of plant species for which experimental data are available on sensitivity to ozone. It provides criteria for classifying plant sensitivity to ozone, assigns plants to temperature zones, and provides a means for identifying plant species in the data base that potentially could suffer injury from ambient ozone levels typically present in ozone non-attainment areas.

2.1 Database of Plant Species

A significant amount of research has been conducted over the past three decades to investigate the sensitivity of plant species to ozone. We conducted a thorough review of the

[1] We contacted individuals knowledgeable regarding conditions and activities on the East Coast. For the most part, we did not have discussions with individuals knowledgeable regarding the effects of the high ambient ozone levels on plants in the Los Angeles area

literature[2] and identified about 65 key studies.[3] For each of the urban ornamental plant species examined or referenced in these studies we extracted data on: measures of exposure to ozone (concentration, duration, and frequency), a measure or description of the type and extent of injury, and a characterization of the sensitivity to ozone. The resulting data base, provided as Appendix A, is organized by species. There are multiple entries for the same species if more than one study examined the species in question, or if the effects of ozone on a species are reported for varying levels or durations of exposure. To our knowledge, this is the most comprehensive set of information on plant sensitivities to ozone yet to be developed.

An annotated bibliography describing the general nature of the major studies used in compiling the database is provided as Appendix B.

2.2 Plant Sensitivity to Ozone

Most of the studies we examined subjected plants to short-term (1 to 8 hour exposure) to ozone, although some studies reported the effects of exposure experienced over longer durations (e.g., 6 hours per day over 4 weeks). Additionally, most of the studies reported visible foliar injury to plants as the indicator of injury (although some report effects on growth). The studies generally identify the exposure levels at which such effects begin to occur and at which such effects become more extensive.

Physical injury to specific species and cultivars may be represented as a function of:

- concentration of ozone (ppm);
- duration of exposure (hours); and
- frequency of exposure (number of days).

The National Research Council (NRC) developed a method for classifying plants in three categories of sensitivity to ozone -- sensitive, intermediate, and resistant -- based on a statistical

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[2] The online databases used to locate studies on the effects of ozone on plants include: the Boston Library service (includes titles from card catalogues and articles from journals held by Boston area libraries), AGRICOLA (National Agricultural Library), and the Environmental Bibliography. (Search parameters were: (1) ozone not (UV or stratospher$ or deplet$), (2) and not crop, (3) and not forest$, (4) and plant$.)

[3] We focused on those studies that provided information on numerous species or that summarized the results of previous studies. A list of studies that assessed the effects of ozone on plants, but that are <u>not</u> incorporated in the data base because of time and budget constraints is provided as Appendix C. This list is quite extensive, suggesting that examination of these studies could expand the database considerably and could yield useful information regarding the issue of selection of ozone resistant species and cultivars.

analysis of exposure, duration, and injury levels for single-incident exposures.[4] This classification scheme is useful for maintaining a similar definition of plant sensitivity across studies. Chart 1.1 shows the combinations of ozone concentrations and durations of exposure developed by the NRC to classify plants when foliar injury is 5% and Chart 1.2 shows such combinations when foliar injury is 20%. Chart 1.1 may be viewed as indicating the threshold combinations of ozone concentrations and durations of exposure at which plants with different ozone sensitivities begin to have visibly noticeable injury.

We classified plant species in the data base for sensitivity to ozone based on the following procedure.

- The NRC criteria were used to assign plant sensitivities whenever sufficient data on exposures and effects were reported in the original study.

- The sensitivity classification assigned in the original study was used if data reported on exposure and effects did not enable us to use the NRC criteria.

- A range of sensitivities was assigned to plant species if information on the same plant species from the same study or from multiple studies differed.

- Sensitivities were not assigned if there was insufficient information on exposures and effects and if the original study did not assign ozone sensitivities.

Tables 1.1 to 1.8 provide a list of the unique species in the database, grouped according to general plant category and sorted by their ozone sensitivity classification. A summary of the number of unique species in the data base, by major plant category, and the number in each ozone sensitivity class is provided in Table 2. The major plant categories are grasses and clover, flowers, shrubs, deciduous trees, and conifers. (Minor categories are ground covers, desert flowers, house plants, weeds, and wild plants.) This data base is the result of an initial effort to develop a comprehensive source of information on plant sensitivities. Further research is needed to: (1) assign ozone sensitivities to a number of plant species in the database; (2) resolve differences in sensitivity classifications between studies; (3) remove some plant species that are not urban ornamental plants; and (4) incorporate in the data base additional plant species from studies not yet reviewed, particularly those plants frequently used in the urban landscape.

There are a number of problems inherent with these data and their interpretation. First, there is wide genetic variation within plant species regarding sensitivity to ozone. Differences among species can be as large as differences across species. Second, the studies relied on cover a time span of some twenty years. Commercial and natural selection over time may result in

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[4] See, National Research Council, Ozone and other Photochemical Oxidants, 1977, Chapter 11. EPA also has adopted this classification scheme. (See OAQPS Staff Paper, 1989, p x-4).

species (or commercially important strains) becoming more resistant to ozone than such studies indicate.[5] Third, experimental techniques used and the conditions assessed differ among studies, making cross-study comparisons of ozone sensitivities difficult. And fourth, the criteria used to classify plants' sensitivity to ozone do not necessarily result in consistent classifications across studies. Thus, we urge caution in using the data base in its current form.

2.3 Temperature Zones

To develop a general notion of the plant species that could be grown, or may be present, in various ozone non-attainment areas we:

- obtained information on temperature zones for a limited number of plant species in the database, as shown in Tables 1.1 through 1.8;[6] and
- classified ozone non-attainment areas by temperature zone.[7]

Map 1 shows the location and classification of areas in non-attainment with ozone standards in 1991, and Map 2 shows an overlay of the temperature zones for the continental U.S. on the ozone non-attainment areas.[8] Non-attainment areas in the Midwest, East, and Southeast are in temperature zones 5 through 7; in Texas and Louisiana are in temperature zones 8 and 9; and in California are in temperature zones 8 through 10. Maps 3 through 5 show an overlay of the temperature zones on ozone non-attainment areas for various sections of the U.S.

In general, plants will not grow in temperature zones below the zone indicated for that species (because they are intolerant to cold winter conditions), but may grow in higher temperature zones, generally several or more additional zones. Grasses are classified as either cool or warm grasses. Cool weather grasses generally are used in temperature zones 6 and less, whereas warm weather grasses are used in temperature zones 7 and higher, though there is some overlap. Annuals (flowers) may be grown in a wide range of temperature zones because they are grown only during the warm summer season.

Temperature zone information provides only a crude method of linking specific plant species to non-attainment areas. Other factors, such as rainfall, humidity, and soil conditions may

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[5] Indeed, the orientation of some of the experimental studies we reviewed was to foster the use and development of ozone resistant species and cultivars.

[6] Information on temperature zones for plant species was developed from Wyman's Encyclopedia of Plants. Due to limitations in time and budget, temperature zone information obtained for plant species in the data base is incomplete.

[7] Temperature zones are based on information from the USDA's Plant Hardiness Zone Map.

[8] Tables D1 and D2 in Appendix D provide temperature zone designations for specific ozone non-attainment areas

preclude certain species from being grown in specific non-attainment areas. Likewise, commercial practices and consumer preferences will determine the actual extent of use of plant species that are suitable for growing in specific geographic areas. Intensive horticultural practices can adjust moisture, drainage, soil conditions, etc., allowing plants to be grown outside their traditional range. However, temperature zones do establish a natural limit on species ranges, chiefly through winter low temperatures and to a lesser extent from summer maximum temperatures.

2.4 At Risk Plants

The curves shown in Charts 1.1 and 1.2 show that the sensitivity of plants to ozone concentrations increases significantly as the duration of exposure increases. For example, for sensitive species, the concentration at which threshold injury occurs for a single eight hour exposure is roughly a sixth of that for a one hour exposure. If there are multiple exposures over several days, or if exposure at some average level extends over several weeks or over the growing season, threshold damage is likely to occur at lower concentrations for each corresponding duration of exposure. This means that the curves would tend to shift downward if there are multiple, rather than single exposures. But the extent of the shift is not clear and the data to estimate such shifts for specific species are not readily available.

To determine how this threshold-injury relationship relates to likely patterns of exposure to ambient ozone in various classes of ozone non-attainment areas, we overlaid the plant sensitivity classification scheme on curves showing the expected peak average ozone concentrations over several durations (1, 4 and 8 hours).[9] The results of this exercise are shown in Charts 2.1 through 4.2. These charts indicate that:

- plants are most likely to be affected by the longer duration exposure incidents expected to occur in ozone non-attainment areas, rather than the expected short-term hourly peaks;
- sensitive plants probably would suffer minor injury even at exposures typical in areas in attainment with ozone standards, and may well experience extensive injury in areas with ozone design values near the "moderate" level;

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[9] The curves for the ozone non-attainment areas are based on Table A-4, Appendix A, of the June 1989 OAQPS Staff Report on ozone. We used the information in this table to develop a rough relationship between one-hour design values and corresponding four-hour and eight-hour design values. The table suggests that a one-hour design value of 0.12 ppm would correspond to an eight-hour design value of about 0.09 ppm. We then assumed that a four-hour design value would be somewhat less than a linear combination of the one-hour and eight-hour design values and assigned it a value of 0.10 ppm. All other curves are proportionally constructed based on the one-hour design value for each non-attainment designation. The curves were developed to provide a means of identifying the classes of plants likely to be affected in areas with different severity of ozone problems. We emphasize that the curves were <u>not</u> developed through extensive analysis of ozone concentration data.

- threshold injury to plants with intermediate sensitivity probably occurs within the range of ozone concentrations typically expected in moderate through serious ozone non-attainment areas;

- plants with intermediate sensitivity would appear to benefit most from reductions in ozone concentrations, whereas some ozone sensitive plants would appear to continue to suffer significant (20%) injury, even in areas just in attainment with ozone standards; and

- resistant plants are unlikely to show visible signs of injury in moderate through serious ozone non-attainment areas.[10]

These charts suggest that a significant number of plant species included in the data base -- those identified as sensitive and intermediate -- could suffer injury if exposed to ambient ozone levels experienced in ozone non-attainment areas.

2.5 Damage Functions

There are several variants of damage functions. Such functions typically relate measures of emissions, concentration, or exposure to:

- the extent of some form of physical injury;
- changes in some (commercially important) attribute, such as yield, growth rate, surface weathering, etc.; or
- economic losses measured in dollars.

Although the desired endpoint of economic analysis is the development of a damage function in monetary terms, in this project we focus on foliar injury because that is the type of information available from literature. (Other measures of injury, such as reduced growth rates, shorter life expectancy, reduced height, or reduced canopy generally are not available.) The additional step of translating physical measures of injury to economic losses, as discussed below, is complex and data are not now available to support that type of analysis.

In general, visible signs of foliar injury to plants is an imperfect indicator of the presence of economic losses. For example, if there are visible signs of injury to plants that are harvested for their commercial value (agricultural crops and trees), but no reduction in yield or growth rates, economic losses may be minimal. On the other hand, there often are reductions in yields or growth rates of commercially important plants due to ambient ozone levels (with consequent economic losses) without the manifestation of visible signs of injury.

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[10] In Charts 4.1 and 4.2 we designate as "highest" the highest ozone design value (0.25 ppm) of all ozone non-attainment areas, excepting Los Angeles (which has a design value of 0.33 ppm). The threshold curve (5% injury) for resistant plants lies above this "design value curve."

However, visible foliar injury from ozone would seem to be a more suitable indicator of the presence of economic losses for urban ornamental plants than for plants harvested for their commercial value. This is because economic losses associated with injury to urban ornamental plants are directly related to the "aesthetic services" provided by such plants, which would be affected by the presence and extent of visible foliar injury. Yet, one should keep in mind that studies that focus only on visible plant injury from short term exposures to ozone are unlikely to uncover other potential effects from episodic or continual exposure to ozone, such as whether plants would: (1) be more susceptible to other stresses, such as insects or fungus; (2) have reduced growth rates or reductions in height or foliage, making them less attractive over their lifetime; or (3) have shorter expected life spans. If such effects are significant at ambient ozone levels now experienced in many urban areas, focusing only on visible injury could lead to an understatement of potential economic losses.

2.6 Example of Plants at Risk in a Specific Geographic Area

Most of the ozone non-attainment areas along the East Coast, from Virginia northward to the New York metropolitan area, are in temperature zones 6 and 7. Plant species assigned temperature zones 3, 4, 5, and 6 probably could grow throughout most of these areas. Although our database is not as complete as we would prefer regarding assignments of temperature zones and plant sensitivities, for illustration purposes we grouped all the species in the major plant groups for which we have both temperature zone and ozone sensitivity assignments. The resulting list of plant species, shown in Table 3, indicates those sensitive and intermediate plant species that potentially could be injured by ozone levels in these non-attainment areas, along with resistant plant species. (Note that we have not determined whether the identified plants currently are used or are present in the eastern urban landscape. We know that some species, such as sequoia and lodgepole pine, are not.)

Table 4 shows the number of plants species by ozone classification and type of plant. There are about 130 species/cultivars of woody plants (shrubs and trees) in the data base with complete information (ozone and temperature zone classifications) that could grow in the eastern landscape. Of these, about 33 percent are classified as sensitive, 17 percent are classified as having intermediate sensitivity to ozone, and 50 percent are classified as ozone resistant. Based solely on these percentages, it might be expected that a significant fraction of plants in the eastern landscape suffer ozone-induced injury. However, ozone-induced injury is unlikely to be so extensive for the following reasons.

- There are many hundreds of woody plants suitable for the eastern landscape and that are in commerce. The wholesale nurseries we contacted each carry from about 250 to 400 species of woody plants. Though our data base may be a comprehensive listing of plant species that have been studied for sensitivity to zone, it by no means contains the bulk of the plants now available for use in the urban landscape. Nor does it indicate the relative use in the urban landscape of various species/cultivars.

- Some of the classifications of ozone sensitivity appear to be questionable. For example, many species of bentgrass are listed as being sensitive to ozone. Yet, bentgrass used on East Coast golf courses apparently does not exhibit the symptoms associated with injury to ozone. Likewise, azaleas are prevalent on the East Coast, yet most do not manifest symptoms of ozone injury. The same may be said for the strains of tulip poplars now in commerce.

- There is wide variation in sensitivity to ozone among species. For example, the eastern white pine often is identified as a tree that is highly sensitive to ozone. Yet, it has been observed in some settings that about 5 to 10 percent of the trees are highly sensitive (exhibiting chlorotic dwarfism), another 10 percent exhibit less sensitivity (tip burn), and the remainder are more resistant. The distribution of ozone sensitivity within a species can change over time due to natural selection and commercial breeding programs. Ozone sensitivity classifications based on older studies or on observed injury to "sensitive" members of a species can be misleading.

3.0 Framework for Estimating Economic Losses

This section provides general estimates of consumer expenditures on urban ornamental plants and associated services, develops a conceptual framework for organizing the types of economic losses associated with ozone-induced injury to urban ornamental plants, and outlines the types of studies and research needed to quantify economic losses.

3.1 Size of Market Potentially Affected by Ozone

There is no direct measure available of the total value of the aesthetic and other services provided by urban ornamental plants. An imperfect indicator of this value is annual expenditures on landscaping and related services and materials.[11] A survey conducted for the National Gardening Association estimated that household spending on plants, turf, associated pest control and maintenance, and landscaping (which includes non-plant items) totalled about $23 billion in

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[11] Note that this measure provides a lower bound to the value of aesthetic and other services provided by urban ornamental plants -- neither the consumer surplus to property owners, nor the public value, associated with such services are incorporated in the measure. Another approach to imputing part of the value of the aesthetic services provided by urban ornamental plants is to use the differences in selling prices between well and poorly landscaped homes. According to realtors, landscaping a home typically increases the sales price of detached, single family homes by 5 to 15%. A measure of the annual services provided by a landscape would be the increase in selling price (above an identical house with no, or a poor, landscape), annualized over the expected life of the landscape (which may be difficult to ascertain). In addition, one should add the expected maintenance and replacement costs to be incurred over the lifetime of the landscape.

1992.[12] This does not include expenditures for similar items by business, municipalities, and golf courses. Data developed by the USDA indicates that retail expenditures on environmental horticulture (nursery plants, unfinished plant material, turfgrass, bulbs, flower and vegetable seeds, and cut Christmas trees) was about $23 billion in 1991.[13]

The aggregate size of expenditures on, or related to, urban ornamental plants provides no indication of the size of economic losses from ozone induced-injury to such plants. Yet, expenditures can provide some indication of the potential value of the resource that is "at stake." If total annual expenditures are relatively small compared to other monetized categories of health and welfare damage stemming from ozone, omitting this category of economic loss will not materially affect estimates of the benefits associated with reducing ozone levels. On the other hand, if expenditures are relatively large, there is the possibility that even small amounts of ozone damage might result in significant economic losses. For example, if about one percent of the $23 billion in annual expenditures on landscaping is related to ozone damage, the direct cost would be in the hundreds of millions of dollars. Losses from decreased aesthetic values from damaged plants would add to the economic loss. Such a potentially sizable damage category cannot be summarily dismissed as unimportant and may warrant more careful consideration to measure losses.

3.2 Conceptual Framework for Economic Losses

In economic terms, one may view an urban ornamental plant as providing a stream of aesthetic and other services (e.g., shade and habitat) over its lifetime. The value of a plant would depend on its characteristics (type, size, appearance, etc.), its use (as a specimen, in hedges, in mixed settings, etc.), its replacement cost, and the preferences of the property owner.

The types of economic losses that potentially can arise from ozone-induced injury are illustrated in Chart 5 for a single hypothetical plant that suffers injury from ozone.[14] Such losses could include:

- A reduction in aesthetic services over the realized lifetime of a plant. This is depicted as shaded area S. It represents the difference in the dollar value of the stream of services provided by an uninjured versus an injured plant, over the realized lifetime of the injured plant. This period of aesthetic loss could also coincide with changes in other services that the plant provides, such as shade or habitat.

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[12] See, National Gardening Survey, 1992-1993, National Gardening Association, 1993, p 14.

[13] See, "Financial Performance of U.S. Floriculture and Environmental Horticulture Farm Businesses, 1987-91," Statistical Bulletin 862, USDA, p. 2.

[14] To simplify, we do not show the normal replacement of the uninjured plant at the end of its expected lifetime.

- The loss of aesthetic services resulting from the premature death (or early replacement) of an injured plant. This is depicted as shaded area A_1. It is the difference between the aesthetic services that would have been provided by an uninjured plant over its extended lifetime (areas A_1 plus A_2), minus the aesthetic services provided by a replacement plant represented by area A_2. The loss in aesthetic services over this timespan narrows as the replacement plant grows and matures over time (For illustration purposes we show the replacement plant always providing less aesthetic services than the uninjured original and, presumably, the preferred plant.)

- The cost associated with removing the injured plant and replacing it with a new plant. These costs are depicted by shaded areas R and P.

- Any additional costs incurred over the lifetime of the injured plant to mitigate the effects of ozone-induced injury. (These are not depicted on the chart.) This could include the cost of additional fertilizer or pesticides and the costs of using additional professional services.

The first two elements of economic loss are distributed among many citizens, i.e., there are both private and quasi-public elements.[15] The largest share of these losses would be experienced by the owner or tenant of the property served by the plant. Presumably, non-owners would each experience much smaller losses, but there could be many affected individuals. The last two elements of economic loss (removal and planting, and mitigation costs) would be incurred by property owners.

The present value of economic loss would be the discounted sum of the composite stream of aesthetic losses and other costs incurred over time, as given by the following equation:

$$C = \sum_{i=1}^{I} \sum_{t=0}^{T_i} \left(\frac{1}{1+r}\right)^t [S_{it} + R_{it} + A_{1_{it}} + A_{2_{it}} + \Theta_{it}(p_{it} - A_{2_{it}})]$$

The designated expenses and losses in the above equation would not necessarily be incurred for each injured plant. For example, if plants do not experience premature death (or are not so badly injured as to be replaced prematurely), no additional removal or replacement costs would be incurred. If a plant is replaced, the substitute plant could provide a lesser, equal, or greater stream of aesthetic services. (If there are many equally good ozone-resistant substitutes, the only loss likely would arise from the difference in aesthetic services provided by a mature and a young

[15] Quasi-public goods are goods that are similar to public goods in the consumption externality that they provide, but the beneficial externality is not perfectly available. There typically are congestion problems that limit enjoyment. For example, one person's use of a public park does not much detract from the enjoyment of another person's use, but eventually crowding either ruins the park or spoils the view.

plant.) Removal and replacement costs and losses due to differences in services provided by young versus mature plants would tend to be higher for long-lived large plants that suffered injury, such as trees, rather than shorter-lived small plants, such as flowers or shrubs.

3.3 Quantifying Economic Losses

The information currently available from the published literature is not sufficient to quantify and monetize potential economic losses from ozone-induced injury to urban ornamental plants. Additional information would have to be developed in three general areas:

- Plant use. Data needs to be developed on the current distribution of plant species in the urban landscape and the distribution of plant species now being sold to urban areas.

- Injury. More complete information needs to be developed on the extent and type (foliage, growth rates, plant lifetime) of ozone-induced injury to plants in the urban environment.

- Valuation of injury. Given that significant ozone-induced injury is present in the urban landscape, information would need to be developed on: the cost of removing and replacing plants; consumer valuations of the aesthetic differences between injured and non-injured plants; and valuations of the aesthetic differences (if any) between ozone-sensitive plant species and possible substitute, ozone-resistant plants.

Information in the first area could be developed through surveys of landscapers and nurseries regarding plant material now used and whether sales patterns have changed over time. Data also could be developed through the use of stratified sampling (urban areas, suburban areas, golf courses, commercial properties, etc.) of actual plant use. Such sampling would best be directed to long-lived plants that are more likely to be affected by ozone. The distribution of types of short-lived plants in the urban landscape would be more directly related to current sales of nurseries.

Information in the second area could be developed through surveys of individuals highly knowledgeable about conditions in specific non-attainment areas. Alternatively, monitoring programs could be set up to observe a large sample of urban plant species during several summer seasons.

Developing information in the third area would be challenging. Because ozone-induced changes in a plant's aesthetic services are not priced directly in the market, contingent valuation surveys would have to be used to value aesthetic losses from identified plant injury. Such surveys could be designed to estimate losses both to private homeowners and to the public at large. At a minimum, the contingent valuation surveys would have to define precisely for people the kind of injury associated with ozone, the effects on a plant's appearance, the timing and duration of such effects, the likely frequency of injury, and the kind of plants that are injured. The surveys should be designed to elicit values for ongoing injury to plants and, possibly, for differences in value between newly planted and mature plants and differences in value (if any) between plant species likely to be replaced and substitute, ozone-resistant plants. Estimates of the costs incurred to remove and replace old plants could be developed using information from landscapers, nurseries, and homeowners (time and aggravation for replacing plants).

4.0 Observations Regarding the Extent of Economic Losses

The kind of studies discussed in the previous section that are necessary to estimate the dollar value of economic losses from ozone-induced injury to urban ornamental plants are beyond the scope of this study. However, we attempted to develop a general notion of whether current economic losses are likely to be large or small by contacting a number of experts in horticulture and plant pathology and professionals in commercial businesses related to urban ornamental plants.[16] We were specifically interested in their observations and opinions regarding: (1) the extent to which ozone damage to urban ornamental plants currently is observed; (2) commercial use of resistant species and cultivars and development of ozone-resistant cultivars; and (3) the availability of resistant species and cultivars for urban landscaping.

In general, our research indicates that economic losses from ozone-induced injury to urban ornamental plants has been limited significantly by a combination of the following factors.

- There is wide genetic variability across and within plant species with regard to tolerance to ozone. This facilitates both natural and commercial selection of ozone-resistant plants.
- The commercial system self-selects for plants that are resistant to the environmental stresses present in the urban landscape, including ozone. Similarly, the commercial system develops new strains of plants with the goal of improving their performance in the urban landscape. Implicit in this is selection for tolerance to ozone.
- There are large numbers of ozone-tolerant plant species and cultivars (strains) of grass, flowers, shrubs, and trees available for use in the urban landscape. This suggests that ozone levels in urban areas have not significantly limited the range of plant material available to the urban landscape.[17]

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[16] We identified knowledgeable individuals informally by following up on leads from various conversations. We did not use a formal sampling methodology, nor did we attempt to determine whether the individuals and businesses contacted were "representative."

[17] When functionally equivalent substitute plants are available, the economic losses associated with the loss, or the inability to use, specific ozone-sensitive plants in the urban landscape is significantly reduced. In economic terms, when there are many substitutes, the demand curve for any on type of plant species or cultivar is likely to be flat, i.e., there is little consumer surplus associated with any particular plant species, even though there probably is substantial consumer surplus associated with the urban landscape in general.

- Ozone levels are on a downward trend in the major non-attainment areas. Long-lived plants remaining in the urban landscape now face less potential stress from ozone than they did in the 1970s and 80s.

The dynamic adjustments made by natural and commercial systems also make it more difficult to assess the current extent of injury to plants in the urban landscape and to estimate economic losses. A data base of plant sensitivities to ozone compiled using the results of research conducted over the past three decades may not be wholly reliable as an indicator of the sensitivities of plants currently used for residential, commercial, and golf course landscaping.

4.1 Extent of Current Injury

The information we obtained regarding the extent of current injury to urban ornamental plants is mixed. People involved in landscaping and nursery businesses were unconcerned about ozone damage, though they were generally aware that ozone adversely affected plants. They considered other environmental stresses, particularly in the city landscape, such as root constriction, soil compaction, soil PH, and lack of adequate moisture, to be of much greater importance than ozone. No one (including a commercial tree specialist) identified any instances where ozone damage had occurred to woody plants . Ozone was not considered to be a problem for plant species carried by wholesale nurseries either on-location (all of those contacted are located in ozone non-attainment areas) or in final market areas. Yet, the individuals contacted have not been trained to recognize air pollution damage and may not recognize injury to plants caused by ozone.

The plant pathologists and horticulturalists contacted indicated that some woody plants in the urban landscape show signs of ozone-induced injury, but that it tends to be subtle and difficult to recognize. White pines generally have been eliminated from the Washington, DC and Baltimore area. (In the central Virginia area every several years there is substantial ozone damage to white pine saplings, though mature trees are largely unaffected). Some varieties of maples and birch may have premature leaf drop in the summer due to ozone, though that also can result from wet springs followed by dry summers. Sycamore trees apparently also show subtle signs of ozone injury (a fine stipple that looks like damage from spider mites), but because they are fast growing the injury has little effect on the aesthetics of the trees.

Ambient ozone levels clearly are high enough to affect agricultural crops in the East Coast non-attainment areas. Ongoing studies on Maryland's eastern shore indicate reductions in yields of watermelons and beans due to long-term exposure to ambient ozone, and leaf injury to such plants has been observed from short term exposures to high ambient ozone levels. Likewise, crops grown in the Beltsville agricultural research station show reduced yields of 10% to 20%. This suggests that ambient ozone levels may be affecting some of the metabolic functions of urban ornamental plants, but without causing significant visible signs of injury.

In 1970, there was a four day ozone incident in the Washington, DC area in which peak ozone concentrations ranged from 0.14 to 0.22 ppm. Ozone-induced injury was observed in 31 tree, 15 shrub, and 18 herbaceous species.[18] However, we did not find mention of similar events occurring more recently.

Ambient ozone levels in the East Coast non-attainment areas do not appear to be causing visible injury to the strains of grass now used on golf courses and lawns. Varieties of grass also are available that do well in the high ozone conditions of the Los Angeles area.

3.2 Commercial Selection of Plants

The commercial markets for turf, flowers, and woody plants actively develop, test and select new plant cultivars for use in the urban landscape. Breeders and nurseries select for hardy cultivars that are resistant to the environmental stresses present in the urban landscape. Though breeding programs may not select specifically for ozone-resistant strains, they indirectly select for ozone-resistance. Many of the breeders and nurseries themselves are located in high ozone areas. Plant varieties developed in breeding programs that do not initially do well at the nursery generally are discarded. Likewise, plant species that either do poorly at the nursery or in the market areas served by the nursery are not carried. Nurseries selling at the wholesale level indicated that they are keenly interested in the performance of their plant material in final markets and will visit locations to determine the cause of problems, should they arise.

New strains of grasses continually are under development by university-based plant breeders and commercial seed companies. New seed varieties undergo extensive testing in a wide range of locations across the country, including high ozone areas, in USDA sponsored test programs.[19] This has led to an increase in varieties of grass available in the market. For example, in 1980 there were about 10 varieties of bentgrass available, whereas now there are over 30. Likewise, there has been a large increase in the availability of other types of "cool" grasses, such as ryegrass and bluegrass.

Most flower nurseries specialize either in perennials, which are grown out doors or in unheated green houses year round, or annuals, which are grown in heated green houses primarily during the winter and early spring. The flower nursery we contacted grows both perennials and annuals, is located in an ozone non-attainment area, and sells primarily to markets in non-

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[18] See, National Research Council, op. cit., p. 491.

[19] USDA turf testing programs began in 1980 and are on five year cycles. Testing programs for ryegrass typically would have about a hundred seed types, bentgrass and bluegrass about 80 to 100 seed types, and fescues about 40 to 60 seed types. The various strains are evaluated for color, texture, density, uniformity, and smoothness. The results are published and serve as the basis for recommendations regarding the suitability of grass varieties for various geographic areas and uses.

attainment areas. Perennial flowers are not carried if they do poorly at the nursery or in final markets. Likewise, annuals that have not performed well in final markets have been phased out for business reasons. Commercial seed companies are the major source of new flower varieties.

New strains of woody plants are developed by wholesale nurseries and university-based breeders and under a program at the National Arboretum (it focuses on plant species that are not as commercially popular and that are less likely to be included in private breeding programs). One of the nurseries contacted long has been involved in breeding new varieties of trees. (Nurseries with breeding programs tend to focus on shrubs and flowers rather than trees, as it is less time consuming and costly.) This nursery is located in an ozone non-attainment area and tests new varieties of trees both at its own location and various locations in urban areas, most of which also are in ozone non-attainment areas. Clearly, new varieties that are successful in that breeding program will be ozone-tolerant. Likewise, the National Arboretum is located in an ozone non-attainment area, and new varieties developed there also would be ozone-tolerant.

Plant species that do poorly either when raised at the nursery or when used in final markets generally would not be carried for obvious business reasons. Thus, because most East Coast nurseries are located in non-attainment areas and sell to markets in non-attainment areas, plant material that is ozone-sensitive tends to be screened out. Additionally, there are many publications available to landscapers and landscape architects that identify woody plants that do well in certain conditions, which leads to the use of hardy plants in the urban landscape and to selection away from ozone-sensitive plant species.

3.3 Availability of Plants for the Urban Landscape

The wholesale nurseries we contacted that specialize in woody plants carried from about 250 to 400 plant species. The wholesale flower nursery we contacted carries about 200 annuals and 800 perennials. All individuals contacted that deal with the commercial landscaping business or the wholesale nursery business indicated that there is a wide palate of plant material available that is suitable for use in the urban landscape. The range of trees and shrubs that will survive in high density urban areas, such as New York City, is more limited. But this is due primarily to factors other than ambient ozone, such as moisture, salt, soil compaction, and root constriction. The palate of plant material expands quickly for the suburban locations, which may not have some of the environmental stresses associated with high density locations, but probably have ambient ozone levels equivalent to those in central city areas.

Table 1.1
Grasses and Clover:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
Grasses:			
	Agropyron caninum		I
	Desmazeria rigida		I
bentgrass (colonial)	Agrostis tenuis "Astoria"	cool	S
bentgrass (colonial)	Agrostis tenuis "Dryland"	cool	S
bentgrass (colonial)	Agrostis tenuis "Exeter"	cool	I
bentgrass (colonial)	Agrostis tenuis "Highland"	cool	I
bentgrass (creeping)	Agrostis palustris "Astoria"	cool	S
bentgrass (creeping)	Agrostis palustris "Cohansey"	cool	S
bentgrass (creeping)	Agrostis palustris "Emerald"	cool	I
bentgrass (creeping)	Agrostis palustris "Highland"	cool	I
bentgrass (creeping)	Agrostis palustris "Holfior"	cool	S
bentgrass (creeping)	Agrostis palustris "Kingstown"	cool	I
bentgrass (creeping)	Agrostis palustris "Penncross"	cool	S-R
bentgrass (creeping)	Agrostis palustris "Seaside"	cool	S
bentgrass (redtop,common)	Agrostis alba	cool	I
Bermudagrass	Cynodon dactylon	warm	R
Bermudagrass	Cynodon dactylon (common)	warm	R
Bermudagrass	Cynodon doctylon "Kansas P-16"	warm	I
Bermudagrass	Cynodon doctylon "Tufcote"	warm	R
Bermudagrass	Cynodon hyb. "Santa Ana"	warm	R
Bermudagrass	Cynodon hyb. "Tufgrass"	warm	R
bluegrass	Poa trivialis	cool	I
bluegrass (annual)	Poa annua	cool	S
bluegrass (Canada)	Poa compressa "Canada"	cool	R
bluegrass (Kentucky)	Poa pratensis	cool	I
bluegrass (Kentucky)	Poa pratensis "A-34"	cool	I
bluegrass (Kentucky)	Poa pratensis "Adelphi"	cool	I
bluegrass (Kentucky)	Poa pratensis "Arista"	cool	R
bluegrass (Kentucky)	Poa pratensis "Baron"	cool	I
bluegrass (Kentucky)	Poa pratensis "Birks"	cool	I
bluegrass (Kentucky)	Poa pratensis "Cheri"	cool	S
bluegrass (Kentucky)	Poa pratensis "Cougar"	cool	R
bluegrass (Kentucky)	Poa pratensis "Delta"	cool	I
bluegrass (Kentucky)	Poa pratensis "Fylking"	cool	R
bluegrass (Kentucky)	Poa pratensis "Glads"	cool	R
bluegrass (Kentucky)	Poa pratensis "Kenblue"	cool	R
bluegrass (Kentucky)	Poa pratensis "Merion"	cool	I-R
bluegrass (Kentucky)	Poa pratensis "Newport"	cool	R
bluegrass (Kentucky)	Poa pratensis "Nugget"	cool	I
bluegrass (Kentucky)	Poa pratensis "P-142"	cool	I
bluegrass (Kentucky)	Poa pratensis "Park"	cool	I
bluegrass (Kentucky)	Poa pratensis "Pennstar"	cool	R
bluegrass (Kentucky)	Poa pratensis "Plush"	cool	I
bluegrass (Kentucky)	Poa pratensis "Prato"	cool	S
bluegrass (Kentucky)	Poa pratensis "Primo"	cool	R
bluegrass (Kentucky)	Poa pratensis "Skofti"	cool	I
bluegrass (Kentucky)	Poa pratensis "Sydsport"	cool	I
bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	cool	R
bluegrass (Kentucky)	Poa pratensis "Touchdown"	cool	I
bluegrass (Kentucky)	Poa pratensis "Vicia"	cool	I
bluegrass (Kentucky)	Poa pratensis "Windsor"	cool	R
bluegrass (Kentucky)	Poa pratensis (common)	cool	R
fescue	Festuca octoflora	cool	R
fescue (Charwings)	Festuca rubra var. commutata	cool	S
fescue (Charwings)	Festuca rubra var. commutata "Jamestown"	cool	I
fescue (creeping red)	Festuca rubra "Illahoe"	cool	I

Table 1.1
Grasses and Clover:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
fescue (creeping red)	Festuca rubra "Pennlawn"	cool	S–I
fescue (red)	Festuca rubra "Highlight"	cool	I
fescue (sheep)	Festuca ovina	cool	I
fescue (tall)	Festuca arundinaceae	cool	
fescue (tall)	Festuca arundinaceae "Altae	cool	S
fescue (tall)	Festuca arundinaceae "Fawn"	cool	I
fescue (tall)	Festuca arundinaceae "K–31"	cool	I–R
grass	Hordeum murinum		I
grass	Koeleria macrantha		I
grass (brome)	Bromus brizaformis		R
grass (brome)	Bromus carinatus		I
grass (brome)	Bromus erectus		I
grass (brome)	Bromus rubens		I
grass (brome)	Bromus rubens (air pollution ecotype)		I
grass (brome)	Bromus rubens (non–air pollution ecotype)		S
grass (brome)	Bromus sp. "Sac Smooth"		S
grass (brome)	Bromus sterilis		R
grass (brome, soft)	Bromus tectorum		S
grass (Canary)	Phalaris aquatica		
grass (Canary)	Phalaris canariensis	annual	S
grass (crinkled hair)	Deschampsia flexuosa		I
grass (Johnson)	Sorghum halepense	7	R
grass (manna)	Glyceria nubigena		S
grass (orchard)	Dactylis glomerata		R
grass (orchard)	Dactylis glomerata "Potomac"		R
grass (pepper)	Lepidum lasiocarpum	annual	R
grass (pepper)	Lepidum virginicum	annual	S
grass (rabbitfoot)	Polypogon monspeliensis		I
grass (tall oats)	Arrhenatherum elatius	3	I
grass (velvet)	Holcus lanatus		I
grass (wild wheat?)	Triticum vulgare		
ryegrass (Italian)	Lolium multiflorum	cool	R
ryegrass (perennial)	Lolium perenne	cool	I
ryegrass (perennial)	Lolium perenne "Lamora"	cool	I
ryegrass (perennial)	Lolium perenne "Linn"	cool	I
ryegrass (perennial)	Lolium perenne "Manhattan"	cool	I
ryegrass (perennial)	Lolium perenne "NK–100"	cool	I
ryegrass (perennial)	Lolium perenne "Norlea"	cool	R
ryegrass (perennial)	Lolium perenne "Pelo"	cool	R
ryegrass (perennial)	Lolium perenne "Pennfine"	cool	R
ryegrass (perennial)	Lolium perenne "Splendor"	cool	I
ryegrass (perennial)	Lolium perenne "Talbot"	cool	R
St. Augustine grass	Stenotaphrum secundatum	warm.	R
zoysia grass (common)	Zoysia sp.	warm.	R
zoysia grass (emerald)	Zoysia hyb.	warm.	R
zoysia grass (Japanese)	Zoysia japonica (common)	warm.	R
zoysia grass (Meyer)	Zoysia japonica	warm.	R
Clovers:			
alsike clover	Trifolium hybridum	3	R
crimson clover	Trifolium incarnatum	annual	
ladino clover	Trifolium repens "Tillman"	3	
red clover	Trifolium pratense	3	
red clover	Trifolium pratense "Chesapeake"	3	I
red clover	Trifolium pratense "Kenland"	3	S
red clover	Trifolium pratense "Ottawa"	3	I
red clover	Trifolium pratense "Pennscott"	3	I

Table 1.1
Grasses and Clover:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
white clover	Trifolium repens (ozone resistant clone)	3	I
white clover	Trifolium repens (ozone sensitive clone)	3	I
white or ladino clover	Trifolium repens	3	I
white or ladino clover	Trifolium repens "Alban"	3	I
white or ladino clover	Trifolium repens "Ladino California"	3	S
white or ladino clover	Trifolium repens "Ladino Sacramento"	3	S
white or ladino clover	Trifolium repens "Milkanova"	3	R
white or ladino clover	Trifolium repens "Sonja"	3	R
white sweet clover	Melilotus alba	3	I

Table 1.2
Flowers — — Annual and Perennial:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
	Collomia linearis		I
aster (Engelmann)	Aster engelmanni		S
aster (purple stemmed)	Aster puniceus	3	S
aster (whorled wood)	Aster acuminatus		S
avens (mountain)	Geum radiatum		R
baneberry	Actaea arguta	3–5	I
begonia	Begonia rex	annual	R
begonia	Begonia sp. "Christmas"	annual	R
begonia	Begonia sp. "Linda"	annual	I
begonia	Begonia sp. "Scarletta"	annual	R
begonia	Begonia sp. "Thousand Wonders White"	annual	I
begonia	Begonia sp. "White Tausendschon"	annual	I
begonia (Elatior)	Begonia x hiemalis "Ballerina"	annual	S
begonia (Elatior)	Begonia x hiemalis "Fantasy"	annual	R
begonia (Elatior)	Begonia x hiemalis "Heirloom"	annual	I
begonia (Elatior)	Begonia x hiemalis "Improved Krefeld Orange"	annual	I
begonia (Elatior)	Begonia x hiemalis "Mikkell Limelight"	annual	S
begonia (Elatior)	Begonia x hiemalis "Nixe"	annual	I
begonia (Elatior)	Begonia x hiemalis "Renaissance"	annual	I
begonia (Elatior)	Begonia x hiemalis "Schwabenland Red"	annual	S
begonia (Elatior)	Begonia x hiemalis "Turo"	annual	R
begonia (Elatior)	Begonia x hiemalis "Whisper O' Pink"	annual	I
black–eyed Susan	Rudbeckia hirta	4	S
black–eyed Susan	Rudbeckia occidentalis		R
bluebell or lungwort	Mertensia arizonica	3–5	R
carnation (white sim)	Dianthus caryophyllus	8	S
chrysanthemum	Chrysanthemum morifolium	5	R
chrysanthemum	Chrysanthemum sp. "Corsage Cushion"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Ann Ladygo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Baby Tears"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Bonnie Jean"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Bright Yellow Tuneful"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Cameo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Chris Columbus"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Crystal Pat"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Dark Yellow Tokyo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Distinctive"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Dolli–ette"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Flair"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Fuji Jess Williams"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Fuji–Mefo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Gay Blade"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Golden Arrow"	3–5, to 8	I
chrysanthemum	Chrysanthemum sp. "Golden Cushion"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Golden Peking"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Golden Yellow Princess Anne"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Indian Summer"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Jessamine Williams"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "King's Ransom"	3–5, to 8	S
chrysanthemum	Chrysanthemum sp. "Larry"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Lipstick"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Mandalay"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Mango"	3–5, to 8	S
chrysanthemum	Chrysanthemum sp. "Mermaid"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Minn White"	3–5, to 8	S
chrysanthemum	Chrysanthemum sp. "Mt Snow"	3–5, to 8	S
chrysanthemum	Chrysanthemum sp. "Muted Sunshine"	3–5, to 8	R

Table 1.2
Flowers -- Annual and Perennial: Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
chrysanthemum	Chrysanthemum sp. "Oregon"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Pancho"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Penguin"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Pink Chief"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Queen's Lace"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Red Desert"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Red Mischief"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Redskin"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Resolute"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Rosey Nook"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Ruby Mound"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Silver Sheen"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Sleighride"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Spinwheel"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Tinkerbell"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Touchdown"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Tranquility	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Tranquility"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Trident"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "White Grandchild"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Jeanette"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Jess Williams"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Moon"	3-5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Supreme"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp.	3-5, to 8	S
coleus	Coleus sp. "Pastel Rainbow"	annual	S
coleus (common)	Coleus blumei	annual	R
coneflower (cutleaf)	Rudbeckia Laciniata	3	S
coreopsis	Coreopsis bigelovii		I
croton	Codiaeum variegatum pictum	10	I
dahlia	Dahlia sp.	annual/bie	S
geranium	Geranium fremontii		S
geranium	Geranium richardsonii		S
geranium	Geranium sp.	2 - 7	R
geranium (common)	Pelargonium hortorum	annual	I
lily (Easter)	Lilium longiflorum		I
lily (Sego)	Calochortus nuttallii	3	R
lupine	Lupinus cocinnus		I
marigold	Tagetes patula	annual	
marigold	Tagetes patula "King Tut"	annual	I
monkeyflower (yellow)	Mimulus guttatus	5	R
morning glory	Pharbitis "Scarlet O'Hara"	annual	S
muskflower	Mimulus moschatus		R
petunia	Petunia double grandiflora "Blue Danube"	annual	R
petunia	Petunia grandiflora bicolor "Calypso"	annual	R
petunia	Petunia grandiflora "Blue Jeans"	annual	R
petunia	Petunia grandiflora "Blue Sea"	annual	R
petunia	Petunia grandiflora "Cherry Blossom"	annual	R
petunia	Petunia grandiflora "Lilac Time"	annual	R
petunia	Petunia grandiflora "Parti Pink" (pink)	annual	R
petunia	Petunia grandiflora "Peach Blossom"	annual	R
petunia	Petunia grandiflora "Red Magic" (red)	annual	I
petunia	Petunia grandiflora "Roulette"	annual	I
petunia	Petunia grandiflora "Warrior"	annual	I
petunia	Petunia hybrida "Rose Charm"	annual	I
petunia	Petunia multiflora bicolor "Peaches and Cream"	annual	R
petunia	Petunia multiflora "Festival"	annual	I

Table 1.2
Flowers –– Annual and Perennial:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
petunia	Petunia multiflora "Victory"	annual	R
petunia	Petunia sp.	annual	S
petunia	Petunia sp. "Blue Danube"	annual	R
petunia	Petunia sp. "Blue Jeans"	annual	R
petunia	Petunia sp. "Blue Sea"	annual	R
petunia	Petunia sp. "Bonanza"	annual	R
petunia	Petunia sp. "Calypso"	annual	R
petunia	Petunia sp. "Canadian – All Double Mix	annual	R
petunia	Petunia sp. "Capri"	annual	S
petunia	Petunia sp. "Cherry Blossom"	annual	R
petunia	Petunia sp. "Comanche"	annual	I
petunia	Petunia sp. "Festival"	annual	R
petunia	Petunia sp. "Lilac Time"	annual	R
petunia	Petunia sp. "Parti Pink"	annual	R
petunia	Petunia sp. "Peach Blossom"	annual	R
petunia	Petunia sp. "Peaches and Cream"	annual	R
petunia	Petunia sp. "Pink Cascade"	annual	S
petunia	Petunia sp. "Red Magic"	annual	R
petunia	Petunia sp. "Roulette"	annual	R
petunia	Petunia sp. "Snowstorm"	annual	I
petunia	Petunia sp. "Victory"	annual	R
petunia	Petunia sp. "Warrior"	annual	R
petunia	Petunia sp. "White Cascade"	annual	
phlox family	Polemonium foliosissimum	4	I
primrose (evening)	Oenothera californica		I
salvia	Salvia columbariae		R
snakeroot (white)	Eupatorium rugosum	3	R
snapdragon "Floral Carpet"	Scrophularia? "Floral Carpet"	4	R
snapdragon "Rocket Mixture"	Scrophularia? "Rocket Mixture"		R
sunflower (common)	Helianthus annuus	annual	R
sweet pea	Lathyrus lanzwertii		R
sweet pea	Lathyrus pauciflorus		I
trumpet creeper	Campsis radicans	4	R
violet	Viola italica		S
violet (hooked spur)	Viola adunca		R

Table 1.3
Shrubs -- Deciduous, Coniferous, and Broad-leaved Evergreen: Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
	Chilopsis linearis	7	R
	Rhus trilobata		I
azalea	Rhododendron indicum	6	R
azalea	Rhododendron kurume "Snow"	6	S
azalea	Rhododendron sp.	3-8	S-R
azalea	Rhododendron sp. "Alaska"		R
azalea or rhododendron	Rhododendron carolinianum	5	R
azalea or rhododendron	Rhododendron kaemferi "Camp fire"	4	S
azalea or rhododendron	Rhododendron mollis	7	R
azalea or rhododendron	Rhododendron nova zembla		S
azalea (Glenn Dale hybrid)	Rhododendron sp. "Glacier"		I
azalea (Hinodegiri)	Rhododendron obtusum "Hinodegiri"	6	S
azalea (Indian hybrid)	Rhododendron sp. "Mrs. G.G. Gerbing"		R
azalea (Indian hybrid)	Rhododendron sp. "Red Wing"		R
azalea (Korean)	Rhododendron poukhanensis		S
azalea (Kurume hybrid)	Rhododendron sp. "Hershey Red"		I
azalea (Kurume hybrid)	Rhododendron sp. "Red Luann"		R
azalea (Kurume hybrid)	Rhododendron sp. "Snow"		R
azalea (Pericat hybrid)	Rhododendron sp. "Mme Pericat"		R
azalea (Satsuki hybrid)	Rhododendron sp. "Pink Gumpo"		R
azalea (woolly)	Rhododendron roseum elegans	3	S
azelea (Delaware white)	Rhododendron sp. "Delaware white"		I
blackberry	Rubus sp.		S
blackberry (thornless)	Rubus canadensis		S
boxelder maple	Acer negundo	3	R
boxwood	Buxus sp.	6	R
cinquefoil (bush)	Potentilla fruticosa	2	R
cotoneaster	Cotoneaster divaricata	5	I
cotoneaster	Cotoneaster horizontalis	5	I
cotoneaster (spreading)	Cotoneaster sp.	5	I
currant (Indian)	Ribes sp.		S
dracaena	Dracaena fragrans massangeana	10	R
elderberry	Sambucus metanocarpa		R
elderberry (American)	Sambucus canadensis	3	S
elderberry (black)	Sambucus sp.	3-6	S-I
elderberry (blue)	Sambucus glauca		
euonymous	Euonymous alatus compacta	3	R
euonymus (winged)	Euonymous alatus	3	R
firethorn (scarlet)	Pyracantha coccinea "Lalandei"	6	R
forsythia	Forsythia intermedia spectabilis "Lynwood gold"	5	S
fuchsia	Fuchsia hybrida	9	I
gooseberry	Ribes hudsonianum		R
highbush blueberry	Vaccinium corymbosum	3	R
holly (Hetz Japanese)	Ilex crenata	6	R
honeysuckle (Japanese)	Lonicera japonica		R
honeysuckle (morrow)	Lonicera morrowii		R
juniper (Pfitzer)	Juniperus chinensis "Pfitzeriana"		
juniper (Savin)	Juniperus sabina "Tamariscifolia	4	
juniper (shore)	Juniperus sp.	2-5	S
juniper (western)	Juniperus occidentalis		I
lilac (Chinese)	Syringa chinensis	5	S
lilac (common)	Syringa vulgaris	3	I
mahonia (creeping)	Berberis repens		R
mock-orange (sweet)	Philadelphus coronarius	4	S-I
mountain laurel	Kalmia latifolia	5	R
ninebark (dwarf)	Physocarpus opulifolius	2	S
pieris	Pieris japonica	6	R

Table 1.3
Shrubs -- Deciduous, Coniferous, and Broad-leaved Evergreen: Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
privet (Amur)	Ligustrum amurense		R
raspberry (red)	Rubus idaeus	3	R
rhododendron	Rhododendron sp. - rhododendrun	3-8	R
rhododendron (Catawba)	Rhododendron catawbiense album	5	S
rose	Rosa sp.	2-7	S
rose	Rosa woodsii		R
rose (multiflora)	Rosa multiflora		S-I
sagebrush (big)	Artemesia tridentata	5	R
snowberry	Symphoricarpos albus		S
snowberry or coralberry	Symphoricarpos vaccinioides		R
snowberry (white)	Symphoricarpus alba		R
spicebush	Lindera benzoin	4	R
sumac	Rhus canadensis		S
sumac (smooth)	Rhus glabra	2	S-I
sumac (staghorn)	Rhus typhina	3	S
sumac (winged)	Rhus copallina	4	S
viburnum	Viburnum carlesi	4	S
viburnum (arrowwood)	Viburnum dentatum	2	R
viburnum (linden)	Viburnum dilatatum	5	I-R
viburnum (mapleleaf)	Viburnum acerifolia	3	R
viburnum (tea)	Viburnum setigerum		I-R
yew	Taxus sp.		R
yew	Taxus cuspidata	5	R
yew	Taxus x media "Hicksi"	4	R
yew (dense)	Taxus media "Densiformis"	4	
yew (Hatfields Anglojap)	Taxus x media	4	R

Table 1.4
Trees -- Deciduous:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
acacia	Acacia greggi	9	R
alder	Alnus incana (seedings)	2	S
alder (European black)	Alnus glutinosa	4	R
ash	Fraxinus sp.	3-6	S-R
ash (blue)	Fraxinus quadrangulata		R
ash (European mountain)	Sorbus aucuparia	3	S
ash (flowering)	Fraxinus ornus	6	R
ash (green)	Fraxinus pennsylvanica	3	S-I
ash (Hesse European)	Fraxinus excelsior	4	I-R
ash (Oregon)	Fraxinus oregana		S
ash (white)	Fraxinus americana	4	S-I
aspen (quaking)	Populus tremuloides	2	S
basswood (white)	Tilia heterophylla		I
beech	Fagus americana		
beech (American)	Fagus grandifolia		R
beech (European)	Fagus sylvatica	5	R
birch	Betula pubescens (seedings)		S
birch	Betula verrucosa (seedlings)		S
birch (black)	Betula lenta	3	R
birch (European white)	Betula pendula	2	R
birch (grey)	Betula populifolia		R
birch (river)	Betula nigra	5	R
birch (yellow)	Betula alleghaniensis		I
birch (yellow)	Betula allegheniensis		I
blackgum	Nyssa sylvatica	4	R
buckeye (Ohio)	Aesculus glabra		S
buckeye (yellow)	Aesculus octandra		S
catalpa	Catalpa bignonioides	5	R
catalpa (northern)	Catalpa speciosa	5	
cherry	Prunus spp.	2-7	S
cherry (black)	Prunus serotina	4	S-I
cherry (Cornelian)	Cornus mas		R
cherry (Sargent)	Prunus sargentii	5	R
cherry (sweet)	Prunus avium	4	R
coffee tree (Kentucky)	Gymnocladus dioica	4	R
cottonwood	Populus deltoides		S
cottonwood (black)	Populus tricocarpa	4	S
crabapple	Malus toringoides		R
cucumber tree	Magnolia acuminata	5	R
dogwood (flowering)	Cornus florida	5	S-R
dogwood (gray)	Cornus racemosa		R
dogwood (red-osier)	Cornus stlonifera		I
dogwood (silky)	Cornus amomum		I
elm	Ulmus sp.	3-6	R
elm (American)	Ulmus americana	3	R
elm (Chinese)	Ulmus parvifolia	6	S-R
empresstree	Paulownia tomentosa	5	R
filbert (Turkish)	Corylus colurna	5	R
ginkgo	Ginkgo biloba	5	R
hackberry (common)	Celtis occidentalis	2	R
hawthorn (cockspur)	Crategus crusgalli	4	I
hawthorn (Washington)	Crataegus phaenopyrum	4	R
hickory (mockernut)	Carya tomentosa		R
hickory (pignut)	Carya glabra	4	R
hickory (shagbark)	Carya ovata		R
hophornbeam (Eastern)	Ostrya virginiana	4	R
hornbeam (European)	Carpinus betulus	5	R

Table 1.4
Trees –– Deciduous:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
horse chestnut	Aesculus hippocastanum	4	S–R
Japanese pagoda tree	Sophora japonica	4	R
larch (European)	Larix decidua	3	I
larch (European)	Tilia europea	4	I
larch (Japanese)	Larix leptolepsis	4	R
linden (American)	Tilia americana	3	S–R
linden (bigleaf)	Tilia platyphyllos	4	S
linden (Crimean)	Tilia euchlora	5	S
linden (littleleaf)	Tilia cordata	4	R
linden (silver)	Tilia petiolaris	6	I–R
locust (black)	Robinia pseudo–acacia	4	I–R
locust (thornless honey)	Gleditsia triacanthos inermis	5	I
maple (Amur)	Acer ginnala	5	R
maple (big–tooth)	Acer grandidentatum		R
maple (black)	Acer nigrum		R
maple (broadleaf)	Acer macrophyllum		
maple (hedge)	Acer campestre	5	R
maple (Norway)	Acer platanoides	4	R
maple (red)	Acer rubrum	3	I
maple (silver)	Acer saccharinum	3	R
maple (sugar)	Acer saccharum	3	R
maple (sycamore)	Acer pseudoplatanus	5	R
mulberry	Morus sp.	4–7	I
oak	Quercus patraea		
oak (black)	Quercus velutina	5	R
oak (chestnut)	Quesrcus prinus		R
oak (English)	Quercus robur	5	S–R
oak (Gambel)	Quercus gambelii		I
oak (northern red)	Quercus rubra	5	R
oak (Oregon white)	Quercus garryana		S
oak (pin)	Quercus palustris	5	S–R
oak (scarlet)	Quercus coccinea	5	S–R
oak (shingle)	Quercus imbrecaria		R
oak (white)	Quercus alba	5	R
oak (white)	Quercus phellos	5	R
olive (autumn)	Elaegnus umbellata		I
Osage orange	Maclura pomifera	5–6	R
peach	Prunus persica		I
pine (bristlecone)	Pinus Aristata; Pinus longaeva	5	R
planetree (London)	Platanus acerifolia	5	S–I
poplar (hybrid)	Populus sp.	2–5	
raintree (panicled golden)	Koelreuteria paniculata	5	S–R
redbud (Eastern)	Cercis canadensis	6	I
redbud (Eastern)	Cercis canadensis		I
sassafras	Sassafra albidum	4	S–R
serviceberry (alder–leaf)	Amelanchier alnifolia		I
serviceberry (Allegheny)	Amelanchier laevis	5	R
serviceberry (roundleaf)	Amelanchier grandiflora		R
seviceberry (western)	Amelanchier florida		S–I
sweet gum	Liquidambar styraciflua	5	S
sycamore	Platanus sp.	5–6	I
sycamore (American)	Platanus occidentalis	5	I
sycamore (California)	Platanus racemosa		S
tree of heaven	Ailanthus altissima	4–5	S–I
tulip poplar	Liriodendron tulipifera	5	S
walnut (black)	Juglans nigra	5	R
willow	Salix gooddingii		I

Table 1.4
Trees -- Deciduous:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
yellowwood	Cladrastis lutea	3	S-R
zelkova	Zelkova serrata	6	I-R

Table 1.5
Trees -- Conifers:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
Arborvitae (N. white cedar)	Thuja occidentalis	2	R
cedar (incense)	Calocedrus decurrens		
cedar (incense)	Calocedrus decurrens, Libocedrus decurrens	6	R
cedar (Northern white)	Thuja occidentalis "Pyramidalis"	2	
cedar (red)	Juniperus virginiana	2	R
fir	Abies magnifica		I
fir (balsam)	Abies balsamea	3	R
fir (big cone Douglas)	Pseudotsuga macrocarpa		S-R
fir (Douglas)	Pseudotsuga macrophylla		S
fir (Douglas)	Pseudotsuga menziesii	4	R
fir (Fraser)	Abies fraseri		R
fir (white)	Abies concolor	6	I-R
hemlock (Eastern)	Tsuga canadensis	4	R
holly (American)	Ilex opaca	6	R
holly (English)	Ilex aquifolium	7	R
magnolia (umbrella)	Magnolia tripetela		R
pine (Afghanistan)	Pinus brutia		
pine (Aleppo)	Pinus halepensis		S
pine (Austrian)	Pinus nigra	4	I
pine (Canary Island)	Pinus canariensis		S
pine (Coulter)	Pinus coulteri	7	S-I
pine (digger)	Pinus sabiniana		R
pine (Eastern white)	Pinus strobus	3	S
pine (jack)	Pinus banksiana		S
pine (Japanese black)	Pinus thunbergii	5	I-R
pine (Japanese red)	Pinus densiflora	4	
pine (Japanese white)	Pinus parviflora	4	S
pine (Jeffrey)	Pinus jeffreyi	5	S
pine (Jeffrey/Coulter hybrid)	Pinus jeffreyi x Pinus coulteri		S
pine (knobcone)	Pinus attenuata		I
pine (knobcone/Monterey hybrid	Pinus radiata x Pinus attenuata		I
pine (loblolly)	Pinus taeda		S
pine (lodgepole)	Pinus contorta	6	I
pine (maritime)	Pinus pinaster	7	
pine (Mexican weeping)	Pinus patula		
pine (Monterey)	Pinus radiata	7	S
pine (Montezuma)	Pinus montezumae	8	
pine (oocarpa)	Pinus oocarpa		
pine (pitchpitch)	Pinus rigida		R
pine (ponderosa)	Pinus ponderosa	9	S
pine (ponderosa)	Pinus ponderosa var. scopulorum		R
pine (red)	Pinus resinosa		R
pine (scotch)	Pinus sylvestris	3	R
pine (shortleaf)	Pinus echinata		
pine (single leaf pinyon)	Pinus monophylla		
pine (Southwestern white)	Pinus strobiformis		I-R
pine (sugar)	Pinus lambertiana		I-R
pine (table mountain)	Pinus pungens		S-R
pine (Torrey)	Pinus torreyana		I
pine (Virginia)	Pinus virginiana		S
pine (Western white)	Pinus monticola		S
redwood (Coast)	Sequoia sempervirens	7	R
sequoia (giant)	Sequoia gigantea		R
sequoia (giant)	Sequoiadendron giganteum	6	S
spruce (Black Hills)	Picea glauca var. densata		R
spruce (black)	Picea mariana	3	R
spruce (blue)	Picea pungens?	3	R

Table 1.5
Trees -- Conifers:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
spruce (Colorado blue)	Picea pungens	3	R
spruce (Norway)	Picea abies	2	R
spruce (red)	Picea rubens		
spruce (white)	Picea glauca	3	R

Table 1.6
Ground Covers:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
canby	Pachystima myrsinites	5	R
ivy (English)	Hedera helix	5	R
ivy (grape)	Cissus rhombifolia		R
juniper (creeping)	Juniperus communis depressa plumosa	2	R
mahonia (creeping)	Mahonia repens	5	R
pachysandra	Pachysandra terminalis	4	R
periwinkle	Vinca minor	5	R
periwinkle	Vinca minor "Bright Eyes"	5	R
rush	Juncus sp.	5	R
sage (wood)	Teucrium scorodonia "0221"	5	I
sage (wood)	Teucrium scorodonia "0223"	5	I
sedge	Carex siccata		R
strawberry	Fragaria ovalis		R
Virginia creeper	Parthenocissus quinquifolia	3	S

Table 1.7
Desert Flowers:
Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
Corsican heron bill	Erodium cicutarium	annual	I
cream cups	Platystemon californica	annual	I
desert annual	Baileya pleniradiata	annual	R
desert annual	Camissonia californica	annual	I
desert annual	Chaneactis fremontii	annual	I–R
desert annual	Chorizanthe brevicornu	annual	R
desert annual	Cryptantha circumscissa	annual	I
desert annual	Cryptantha micrantha	annual	I
desert annual	Cryptantha nevadensis	annual	S
desert annual	Descurainia californica		I
desert annual	Descurainia pinnata	annual	S
desert annual	Descurainia sp.	annual	I
desert annual	Eriastrum wilcoxii	annual	I
desert annual	Eschscholzia parishii	annual	S
desert annual	Eucrypta micrantha	annual	I
desert annual	Gilia stellata	annual	I
desert annual	Langoisia schotti	annual	I
desert annual	Malacothrix glabrata	annual	S
desert annual	Pectocarya heterocarpa	annual	S
desert annual	Pectocarya platycarpa	annual	S
desert annual	Perityle emoryi	annual	R
desert annual	Sphaeralcea ambigua	annual	R
desert annual	Stephanomeria exigua	annual	I
desert annual	Strepanthella longirostris	annual	I
desert annual	Stylocline filiaginea	annual	I
desert perennial	Viguiera deltoidea		R
desert winter annual	Camissonia claviformis	annual	I
desert winter annual	Camissonia hirtella	annual	I
desert winter annual	Caulanthus cooperi	annual	I–R
desert winter annual	Chaneactis carphoclinia	annual	I–R
desert winter annual	Chaneactis stevioides	annual	I–R
desert winter annual	Cryptantha angustifolia	annual	I
desert winter annual	Cryptantha pterocarya	annual	I
desert winter annual	Thelypodium lasiophyllum	annual	I
desert winter annual	Thyanocarpus curvipes	annual	R
phacelia	Phacelia heterophylla	annual	S
phacelia (harebell)	Phacelia campanularia	annual	I

Table 1.8
Weeds, Wild Plants, Houseplants, and Uncategorized: Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
Weeds:			
	Epilobium watsoni		R
bedstraw or madder	Galium bifolium		R
bladder campion	Silene cucubalus		S
chickweed	Cerastium fontanum		R
crabgrass	Digitaris sanguinalis		I
dandelion	Taraxacum officinale	3	R
dock (bitter)	Rumex obtusifolius	3	I
dock (curly)	Rumex crispus	3	I
goosefoot	Chenopodium fremontii		I
ironweed (New York)	Vernonia noveboracensis	5	S
knotweed (prostrate)	Polygonum aviculare	annual	S
lambsquarters	Chenopodium album	annual	I
milkweed (common)	Asclepias syriaca	3	S
milkweed (tall)	Ascelpias exaltata		S
plantain	Plantago coronopus		I
plantain	Plantago insularis		I
plantain	Plantago maritima		I
plantain (common)	Plantago major "a"		S
plantain (common)	Plantago major "b"		S
plantain (common)	Plantago major "Greek"		R
plantain (English)	Plantago lanceolata		I
plantain (hoary)	Plantago media		R
poison ivy	Rhus radicans (Toxicodendron radicans)	3	R
ragweed	Ambrosia artemisiifolia	annual	R
ragweed (western)	Ambrosia psilostachya	3	R
ragwort	Senecio serra		S
ragwort (Rugel's)	Cacalia rugelia		S
smartweed	Polygonum douglasii		S
vetch (American)	Vicia americana	3	R
vetch (sweet)	Hedysarum boreale		S
willow weed (hairy)	Epilobium hirsutum	3	R
yarrow	Achillea millefolium	2	I
Wild:			
angelica	Angelica pinnata		I
angelica	Angelica triquinata		R
aniseroot	Osmorhiza occidentalis		I
belladonna	Atropa belladonna	6	S
bittersweet (American)	Celastrus scandens	2	R
chickory (common)	Cichorium intybus	3	I
crownbeard	Verbesina occidentalis		S
dandilion (mountain)	Krigia montana		S
Dyer's woad	Isatis tinctoria	5	S
ephiphytic bromeliad	Tillandsia balbisiana	10	R
ephiphytic bromeliad	Tillandsia paucifolia	10	R
ephiphytic bromeliad	Tillandsia recurvata	10	R
ephiphytic bromeliad	Tillandsia utriculata	10	R
fireweed	Epilobium angustifolium	3	R
ginseng (American)	Panax quinquifolius	3	I–R
grape	Vitis vinifera	6	S–I
hemlock (poison)	Conium maculatum	3	R
hyssop (nettle leafgiant	Agastache urticifolia		I
marsh pink	Gentiana amarella		I
miterwort	Mitella stenpetala	3	R
moss (sphagnum)	Sphagnum flexuosum		
moss (sphagnum)	Sphagnum magellanicum		

Table 1.8
Weeds, Wild Plants, Houseplants, and Uncategorized: Temperature Zones and Sensitivity to Ozone

Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
moss (sphagnum)	Sphagnum rubellum		
nettle	Urtica gracilis	3	R
nettle (stinging)	Urtica dioica	3	I
onion/garlic? (wild)	Allium acuminatum		I
rue (meadow)	Thalictrum fendleri		R
saxifrage	Saxifrage arguta		I
sorrel (green)	Rumex acetosa	3	R
sorrel (sheep)	Rumex acetosella	3	I
speedwell	Veronica anagallis–aquatica		I
tarweed	Madia glomerata	annual	S
thistle (Canadian)	Circium arvense	2	R
tickseed (wood)	Coreopsis major	7	R
trefoil	Lotus tomentellus		I
wild buckwheat	Erigonum heraclioides		R
Houseplants:			
fern (Boston)	Nephrolepis exaltata	10	R
gloxinia	Sinningia speciosa	10	I
kalanchoe	Kalanchoe blossfeldiana	9	I
philodendron	Philodendron cordatum	10	R
poinsettia	Euphorbia pulcherrima	10	I
pothos	Scindapsus aureus	10	R
schefflera	Schefflera actinophylla	9	I
violet (African)	Saintpaulia ionantha	10	R
Uncategorized:			
	Brachypodium pinnatum		I
	Gayophytum recemosum		R
	Lingusticum porteri		S
	Menzelia albicaulis		S
bridlewreath	Sirese vanhouti		S
epiphytic orchid	Eocyclia tampensis		R
epiphytic orchid	Epidendrum rigidum		R

Table 2

Summary of Ozone Sensitivity Classifications, by Plant Category

Ozone Sensitivity	Grasses	Clovers	Flowers	Shrubs	Trees: Deciduous	Trees: Conifers	Ground Covers	Desert Flowers	Total
Sensitive*	19	3	25	26	34	17	1	7	132
Intermediate**	47	8	36	12	24	10	2	24	163
Resistant	34	3	86	41	53	23	11	6	257
No Assignment	3	3	2	4	5	11	--	--	28
Total	103	17	149	83	116	61	14	37	580

* Includes plants listed as sensitive only and as sensitive through intermediate or resistant.

** Includes plants listed as intermediate only and as intermediate through resistant.

Table 3

List of Plants for Eastern Ozone Non-Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
bentgrass (colonial)	Agrostis tenuis "Exeter"	cool	I
bentgrass (colonial)	Agrostis tenuis "Highland"	cool	I
bentgrass (creeping)	Agrostis palustris "Emerald"	cool	I
bentgrass (creeping)	Agrostis palustris "Highland"	cool	I
bentgrass (creeping)	Agrostis palustris "Kingstown"	cool	I
bentgrass (redtop,common)	Agrostis alba	cool	I
bluegrass	Poa trivialis	cool	I
bluegrass (Kentucky)	Poa pratensis	cool	I
bluegrass (Kentucky)	Poa pratensis "A-34"	cool	I
bluegrass (Kentucky)	Poa pratensis "Adelphi"	cool	I
bluegrass (Kentucky)	Poa pratensis "Baron"	cool	I
bluegrass (Kentucky)	Poa pratensis "Birks"	cool	I
bluegrass (Kentucky)	Poa pratensis "Delta"	cool	I
bluegrass (Kentucky)	Poa pratensis "Nugget"	cool	I
bluegrass (Kentucky)	Poa pratensis "P-142"	cool	I
bluegrass (Kentucky)	Poa pratensis "Park"	cool	I
bluegrass (Kentucky)	Poa pratensis "Plush"	cool	I
bluegrass (Kentucky)	Poa pratensis "Skofti"	cool	I
bluegrass (Kentucky)	Poa pratensis "Sydsport"	cool	I
bluegrass (Kentucky)	Poa pratensis "Touchdown"	cool	I
bluegrass (Kentucky)	Poa pratensis "Vicia"	cool	I
fescue (Charwings)	Festuca rubra var. commutata "Jamestown"	cool	I
fescue (creeping red)	Festuca rubra "Illaboe"	cool	I
fescue (red)	Festuca rubra "Highlight"	cool	I
fescue (sheep)	Festuca ovina	cool	I
fescue (tall)	Festuca arundinaceae "Fawn"	cool	I
grass (tall oats)	Arrhenatherum elatius	3	I
ryegrass (perennial)	Lolium perenne	cool	I
ryegrass (perennial)	Lolium perenne "Lamora"	cool	I
ryegrass (perennial)	Lolium perenne "Linn"	cool	I
ryegrass (perennial)	Lolium perenne "Manhattan"	cool	I
ryegrass (perennial)	Lolium perenne "NK-100"	cool	I
ryegrass (perennial)	Lolium perenne "Splendor"	cool	I
bluegrass (Kentucky)	Poa pratensis "Merion"	cool	I-R
fescue (tall)	Festuca arundinaceae "K-31"	cool	I-R
bluegrass (Canada)	Poa compressa "Canada"	cool	R
bluegrass (Kentucky)	Poa pratensis "Arista"	cool	R
bluegrass (Kentucky)	Poa pratensis "Cougar"	cool	R
bluegrass (Kentucky)	Poa pratensis "Fylking"	cool	R
bluegrass (Kentucky)	Poa pratensis "Glads"	cool	R
bluegrass (Kentucky)	Poa pratensis "Kenblue"	cool	R
bluegrass (Kentucky)	Poa pratensis "Newport"	cool	R
bluegrass (Kentucky)	Poa pratensis "Pennstar"	cool	R
bluegrass (Kentucky)	Poa pratensis "Primo"	cool	R
bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	cool	R
bluegrass (Kentucky)	Poa pratensis "Windsor"	cool	R
bluegrass (Kentucky)	Poa pratensis (common)	cool	R
fescue	Festuca octoflora	cool	R
grass (pepper)	Lepidum lasiocarpum	annual	R
ryegrass (Italian)	Lolium multiflorum	cool	R
ryegrass (perennial)	Lolium perenne "Norlea"	cool	R
ryegrass (perennial)	Lolium perenne "Pelo"	cool	R
ryegrass (perennial)	Lolium perenne "Pennfine"	cool	R
ryegrass (perennial)	Lolium perenne "Talbot"	cool	R
bentgrass (colonial)	Agrostis tenuis "Astoria"	cool	S
bentgrass (colonial)	Agrostis tenuis "Dryland"	cool	S

Table 3

List of Plants for Eastern Ozone Non-Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
bentgrass (creeping)	Agrostis palustris "Astoria"	cool	S
bentgrass (creeping)	Agrostis palustris "Cohansey"	cool	S
bentgrass (creeping)	Agrostis palustris "Holfior"	cool	S
bentgrass (creeping)	Agrostis palustris "Seaside"	cool	S
bluegrass (annual)	Poa annua	cool	S
bluegrass (Kentucky)	Poa pratensis "Cheri"	cool	S
bluegrass (Kentucky)	Poa pratensis "Prato"	cool	S
fescue (Charwings)	Festuca rubra var. commutata	cool	S
fescue (tall)	Festuca arundinaceae "Altae	cool	S
grass (Canary)	Phalaris canariensis	annual	S
grass (pepper)	Lepidum virginicum	annual	S
fescue (creeping red)	Festuca rubra "Pennlawn"	cool	S-I
bentgrass (creeping)	Agrostis palustris "Penncross"	cool	S-R
Clovers:			
red clover	Trifolium pratense "Chesapeake"	3	I
red clover	Trifolium pratense "Ottawa"	3	I
red clover	Trifolium pratense "Pennscott"	3	I
white clover	Trifolium repens (ozone resistant clone)	3	I
white clover	Trifolium repens (ozone sensitive clone)	3	I
white or ladino clover	Trifolium repens	3	I
white or ladino clover	Trifolium repens "Alban"	3	I
white sweet clover	Melilotus alba	3	I
alsike clover	Trifolium hybridum	3	R
white or ladino clover	Trifolium repens "Milkanova"	3	R
white or ladino clover	Trifolium repens "Sonja"	3	R
red clover	Trifolium pratense "Kenland"	3	S
white or ladino clover	Trifolium repens "Ladino California"	3	S
white or ladino clover	Trifolium repens "Ladino Sacramento"	3	S
Flowers:			
baneberry	Actaea arguta	3-5	I
begonia	Begonia sp. "Linda"	annual	I
begonia	Begonia sp. "Thousand Wonders White"	annual	I
begonia	Begonia sp. "White Tausendschon"	annual	I
begonia (Elatior)	Begonia x hiemalis "Heirloom"	annual	I
begonia (Elatior)	Begonia x hiemalis "Improved Krefeld Orange"	annual	I
begonia (Elatior)	Begonia x hiemalis "Nixe"	annual	I
begonia (Elatior)	Begonia x hiemalis "Renaissance"	annual	I
begonia (Elatior)	Begonia x hiemalis "Whisper O' Pink"	annual	I
chrysanthemum	Chrysanthemum sp. "Corsage Cushion"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Baby Tears"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Chris Columbus"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Crystal Pat"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Gay Blade"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Golden Arrow"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Pancho"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Penguin"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Sleighride"	3-5, to 8	I
chrysanthemum	Chrysanthemum sp. "Yellow Supreme"	3-5, to 8	I
geranium (common)	Pelargonium hortorum	annual	I
marigold	Tagetes patula "King Tut"	annual	I
petunia	Petunia grandiflora "Red Magic" (red)	annual	I
petunia	Petunia grandiflora "Roulette"	annual	I
petunia	Petunia grandiflora "Warrior"	annual	I
petunia	Petunia hybrida "Rose Charm"	annual	I

Table 3

List of Plants for Eastern Ozone Non–Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
petunia	Petunia multiflora "Festival"	annual	I
petunia	Petunia sp. "Comanche"	annual	I
petunia	Petunia sp. "Snowstorm"	annual	I
phlox family	Polemonium foliosissimum	4	I
begonia	Begonia rex	annual	R
begonia	Begonia sp. "Christmas"	annual	R
begonia	Begonia sp. "Scarletta"	annual	R
begonia (Elatior)	Begonia x hiemalis "Fantasy"	annual	R
begonia (Elatior)	Begonia x hiemalis "Turo"	annual	R
bluebell or lungwort	Mertensia arizonica	3–5	R
chrysanthemum	Chrysanthemum morifolium	5	R
chrysanthemum	Chrysanthemum sp. "Ann Ladygo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Bonnie Jean"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Bright Yellow Tuneful"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Cameo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Dark Yellow Tokyo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Distinctive"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Dolli–ette"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Flair"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Fuji Jess Williams"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Fuji–Mefo"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Golden Cushion"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Golden Peking"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Golden Yellow Princess Anne"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Indian Summer"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Jessamine Williams"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Larry"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Lipstick"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Mandalay"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Mermaid"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Muted Sunshine"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Oregon"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Pink Chief"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Queen's Lace"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Red Desert"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Redskin"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Resolute"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Rosey Nook"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Ruby Mound"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Silver Sheen"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Spinwheel"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Tinkerbell"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Touchdown"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Tranquility	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Trident"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "White Grandchild"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Jeanette"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Jess Williams"	3–5, to 8	R
chrysanthemum	Chrysanthemum sp. "Yellow Moon"	3–5, to 8	R
coleus (common)	Coleus blumei	annual	R
geranium	Geranium sp.	2 – 7	R
lily (Sego)	Calochortus nuttallii	3	R
monkeyflower (yellow)	Mimulus guttatus	5	R
petunia	Petunia double grandiflora "Blue Danube"	annual	R
petunia	Petunia grandiflora bicolor "Calypso"	annual	R
petunia	Petunia grandiflora "Blue Jeans"	annual	R

Table 3

List of Plants for Eastern Ozone Non-Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
petunia	Petunia grandiflora "Blue Sea"	annual	R
petunia	Petunia grandiflora "Cherry Blossom"	annual	R
petunia	Petunia grandiflora "Lilac Time"	annual	R
petunia	Petunia grandiflora "Parti Pink" (pink)	annual	R
petunia	Petunia grandiflora "Peach Blossom"	annual	R
petunia	Petunia multiflora bicolor "Peaches and Cream"	annual	R
petunia	Petunia multiflora "Victory"	annual	R
petunia	Petunia sp. "Blue Danube"	annual	R
petunia	Petunia sp. "Blue Jeans"	annual	R
petunia	Petunia sp. "Blue Sea"	annual	R
petunia	Petunia sp. "Bonanza"	annual	R
petunia	Petunia sp. "Calypso"	annual	R
petunia	Petunia sp. "Canadian - All Double Mix	annual	R
petunia	Petunia sp. "Cherry Blossom"	annual	R
petunia	Petunia sp. "Festival"	annual	R
petunia	Petunia sp. "Lilac Time"	annual	R
petunia	Petunia sp. "Parti Pink"	annual	R
petunia	Petunia sp. "Peach Blossom"	annual	R
petunia	Petunia sp. "Peaches and Cream"	annual	R
petunia	Petunia sp. "Red Magic"	annual	R
petunia	Petunia sp. "Roulette"	annual	R
petunia	Petunia sp. "Victory"	annual	R
petunia	Petunia sp. "Warrior"	annual	R
snakeroot (white)	Eupatorium rugosum	3	R
snapdragon "Floral Carpet"	Scrophularia? "Floral Carpet"	4	R
sunflower (common)	Helianthus annuus	annual	R
trumpet creeper	Campsis radicans	4	R
aster (purple stemmed)	Aster puniceus	3	S
begonia (Elatior)	Begonia x hiemalis "Ballerina"	annual	S
begonia (Elatior)	Begonia x hiemalis "Mikkell Limelight"	annual	S
begonia (Elatior)	Begonia x hiemalis "Schwabenland Red"	annual	S
black-eyed Susan	Rudbeckea hirta	4	S
chrysanthemum	Chrysanthemum sp. "King's Ransom"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Mango"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Minn White"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Mt Snow"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Red Mischief"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp. "Tranquility"	3-5, to 8	S
chrysanthemum	Chrysanthemum sp.	3-5, to 8	S
coleus	Coleus sp. "Pastel Rainbow"	annual	S
coneflower (cutleaf)	Rudbeckia Laciniata	3	S
dahlia	Dahlia sp.	annual/bien	S
morning glory	Pharbitis "Scarlet O'Hara"	annual	S
petunia	Petunia sp.	annual	S
petunia	Petunia sp. "Capri"	annual	S
petunia	Petunia sp. "Pink Cascade"	annual	S
Shrubs:			
cotoneaster	Cotoneaster divaricata	5	I
cotoneaster	Cotoneaster horizontalis	5	I
cotoneaster (spreading)	Cotoneaster sp.	5	I
lilac (common)	Syringa vulgaris	3	I
viburnum (linden)	Viburnum dilatatum	5	I-R
azalea	Rhododendron indicum	6	R
azalea or rhododendron	Rhododendron carolinianum	5	R
boxelder maple	Acer negundo	3	R

Table 3

List of Plants for Eastern Ozone Non–Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
boxwood	Buxus sp.	6	R
euonymous	Euonymous alatus compacta	3	R
euonymus (winged)	Euonymous alatus	3	R
firethorn (scarlet)	Pyracantha coccinea "Lalandei"	6	R
highbush blueberry	Vaccinium corymbosum	3	R
holly (Hetz Japanese)	Ilex crenata	6	R
mountain laurel	Kalmia latifolia	5	R
pieris	Pieris japonica	6	R
raspberry (red)	Rubus idaeus	3	R
rhododendron	Rhododendron sp. – rhododendrun	3–8	R
sagebrush (big)	Artemesia tridentata	5	R
spicebush	Lindera benzoin	4	R
viburnum (mapleleaf)	Viburnum acerifolia	3	R
yew	Taxus cuspidata	5	R
yew	Taxus x media "Hicksi"	4	R
yew (Hatfields Anglojap)	Taxus x media	4	R
azalea	Rhododendron kurume "Snow"	6	S
azalea or rhododendron	Rhododendron kaemferi "Camp fire"	4	S
azalea (Hinodegiri)	Rhododendron obtusum "Hinodegiri"	6	S
azalea (woolly)	Rhododendron roseum elegans	3	S
elderberry (American)	Sambucus canadensis	3	S
forsythia	Forsythia intermedia spectabilis "Lynwood gold"	5	S
juniper (shore)	Juniperus sp.	2–5	S
lilac (Chinese)	Syringa chinensis	5	S
rhododendron (Catawba)	Rhododendron catawbiense album	5	S
rose	Rosa sp.	2–7	S
sumac (staghorn)	Rhus typhina	3	S
sumac (winged)	Rhus copallina	4	S
viburnum	Viburnum carlesi	4	S
elderberry (black)	Sambucus sp.	3–6	S–I
mock–orange (sweet)	Philadelphus coronarius	4	S–I
azalea	Rhododendron sp.	3–8	S–R
Trees – –Deciduous:			
hawthorn (cockspur)	Crataegus crusgalli	4	I
larch (European)	Larix decidua	3	I
larch (European)	Tilia europea	4	I
locust (thornless honey)	Gleditsia triacanthos inermis	5	I
maple (red)	Acer rubrum	3	I
mulberry	Morus sp.	4–7	I
redbud (Eastern)	Cercis canadensis	6	I
sycamore	Platanus sp.	5–6	I
sycamore (American)	Platanus occidentalis	5	I
ash (Hesse European)	Fraxinus excelsior	4	I–R
linden (silver)	Tilia petiolaris	6	I–R
locust (black)	Robinia pseudo–acacia	4	I–R
zelkova	Zelkova serrata	6	I–R
alder (European black)	Alnus glutinosa	4	R
ash (flowering)	Fraxinus ornus	6	R
beech (European)	Fagus sylvatica	5	R
birch (black)	Betula lenta	3	R
birch (river)	Betula nigra	5	R
blackgum	Nyssa sylvatica	4	R
catalpa	Catalpa bignonioides	5	R
cherry (Sargent)	Prunus sargentii	5	R
cherry (sweet)	Prunus avium	4	R

Table 3

List of Plants for Eastern Ozone Non-Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
coffee tree (Kentucky)	Gymnocladus dioica	4	R
cucumber tree	Magnolia acuminata	5	R
elm	Ulmus sp.	3–6	R
elm (American)	Ulmus americana	3	R
empresstree	Paulownia tomentosa	5	R
filbert (Turkish)	Corylus colurna	5	R
ginkgo	Ginkgo biloba	5	R
hawthorn (Washington)	Crataegus phaenopyrum	4	R
hickory (pignut)	Carya glabra	4	R
hophornbeam (Eastern)	Ostrya virginiana	4	R
hornbeam (European)	Carpinus betulus	5	R
Japanese pagoda tree	Sophora japonica	4	R
larch (Japanese)	Larix leptolepsis	4	R
linden (littleleaf)	Tilia cordata	4	R
maple (Amur)	Acer ginnala	5	R
maple (hedge)	Acer campestre	5	R
maple (Norway)	Acer platanoides	4	R
maple (silver)	Acer saccharinum	3	R
maple (sugar)	Acer saccharum	3	R
maple (sycamore)	Acer pseudoplatanus	5	R
oak (black)	Quercus velutina	5	R
oak (northern red)	Quercus rubra	5	R
oak (white)	Quercus alba	5	R
oak (white)	Quercus phellos	5	R
Osage orange	Maclura pomifera	5–6	R
pine (bristlecone)	Pinus Aristata; Pinus longaeva	5	R
serviceberry (Allegheny)	Amelanchier laevis	5	R
walnut (black)	Juglans nigra	5	R
ash (European mountain)	Sorbus aucuparia	3	S
cherry	Prunus spp.	2–7	S
cottonwood (black)	Populus tricocarpa	4	S
linden (bigleaf)	Tilia platyphyllos	4	S
linden (Crimean)	Tilia euchlora	5	S
sweet gum	Liquidambar styraciflua	5	S
tulip poplar	Liriodendron tulipifera	5	S
ash (green)	Fraxinus pennsylvanica	3	S–I
ash (white)	Fraxinus americana	4	S–I
cherry (black)	Prunus serotina	4	S–I
planetree (London)	Platanus acerifolia	5	S–I
tree of heaven	Ailanthus altissima	4–5	S–I
ash	Fraxinus sp.	3–6	S–R
dogwood (flowering)	Cornus florida	5	S–R
elm (Chinese)	Ulmus parvifolia	6	S–R
horse chestnut	Aesculus hippocastanum	4	S–R
linden (American)	Tilia americana	3	S–R
oak (English)	Quercus robur	5	S–R
oak (pin)	Quercus palustris	5	S–R
oak (scarlet)	Quercus coccinea	5	S–R
raintree (panicled golden)	Koelreuteria paniculata	5	S–R
sassafras	Sassafra albidum	4	S–R
yellowwood	Cladrastis lutea	3	S–R
Trees—Conifers:			
pine (Austrian)	Pinus nigra	4	I
pine (lodgepole)	Pinus contorta	6	I
fir (white)	Abies concolor	6	I–R

Table 3

List of Plants for Eastern Ozone Non–Attainment Areas by Type and Sensitivity to Ozone

Plant Type/ Common Name	Species Name	Temp. Zone	Sensitivity to Ozone
pine (Japanese black)	Pinus thunbergii	5	I–R
cedar (incense)	Calocedrus decurrens, Libocedrus decurrens	6	R
fir (balsam)	Abies balsamea	3	R
fir (Douglas)	Pseudotsuga menziesii	4	R
hemlock (Eastern)	Tsuga canadensis	4	R
holly (American)	Ilex opaca	6	R
pine (scotch)	Pinus sylvestris	3	R
spruce (black)	Picea mariana	3	R
spruce (blue)	Picea pungens?	3	R
spruce (Colorado blue)	Picea pungens	3	R
spruce (white)	Picea glauca	3	R
pine (Eastern white)	Pinus strobus	3	S
pine (Japanese white)	Pinus parviflora	4	S
pine (Jeffrey)	Pinus jeffreyi	5	S
sequoia (giant)	Sequoiadendron giganteum	6	S

Table 4

Summary of Ozone Sensitivity Classifications for Plants Potentially Used in East Coast Urban Landscapes, by Plant Category

Ozone Sensitivity	Grasses	Clovers	Flowers	Shrubs	Trees: Deciduous	Trees: Conifers	Woody Plants*	Grand Total
Sensitive*	15	3	19	16	23	4	43	80
Intermediate**	35	8	29	5	13	4	22	94
Resistant	19	3	79	19	37	10	66	167
Total	69	14	127	40	73	18	131	341

* Includes shrubs and trees.

** Includes plants listed as sensitive only and as sensitive through intermediate or resistant.

*** Includes plants listed as intermediate only and as intermediate through resistant.

Chart 1.1
Ozone Concentrations by Plant Sensitivity: 5% Injury

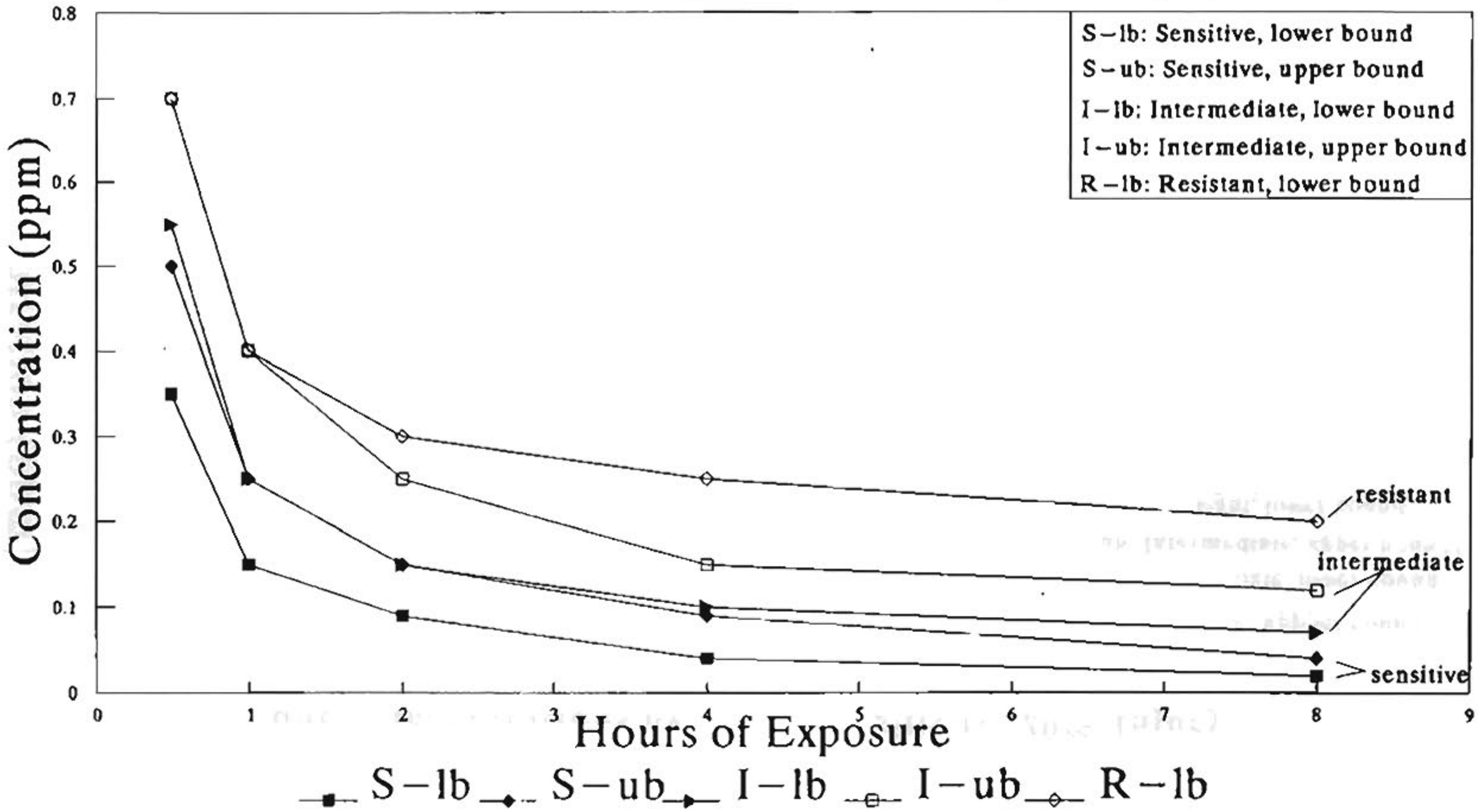


Chart 1.2

Ozone Concentrations by Plant Sensitivity: 20% Injury

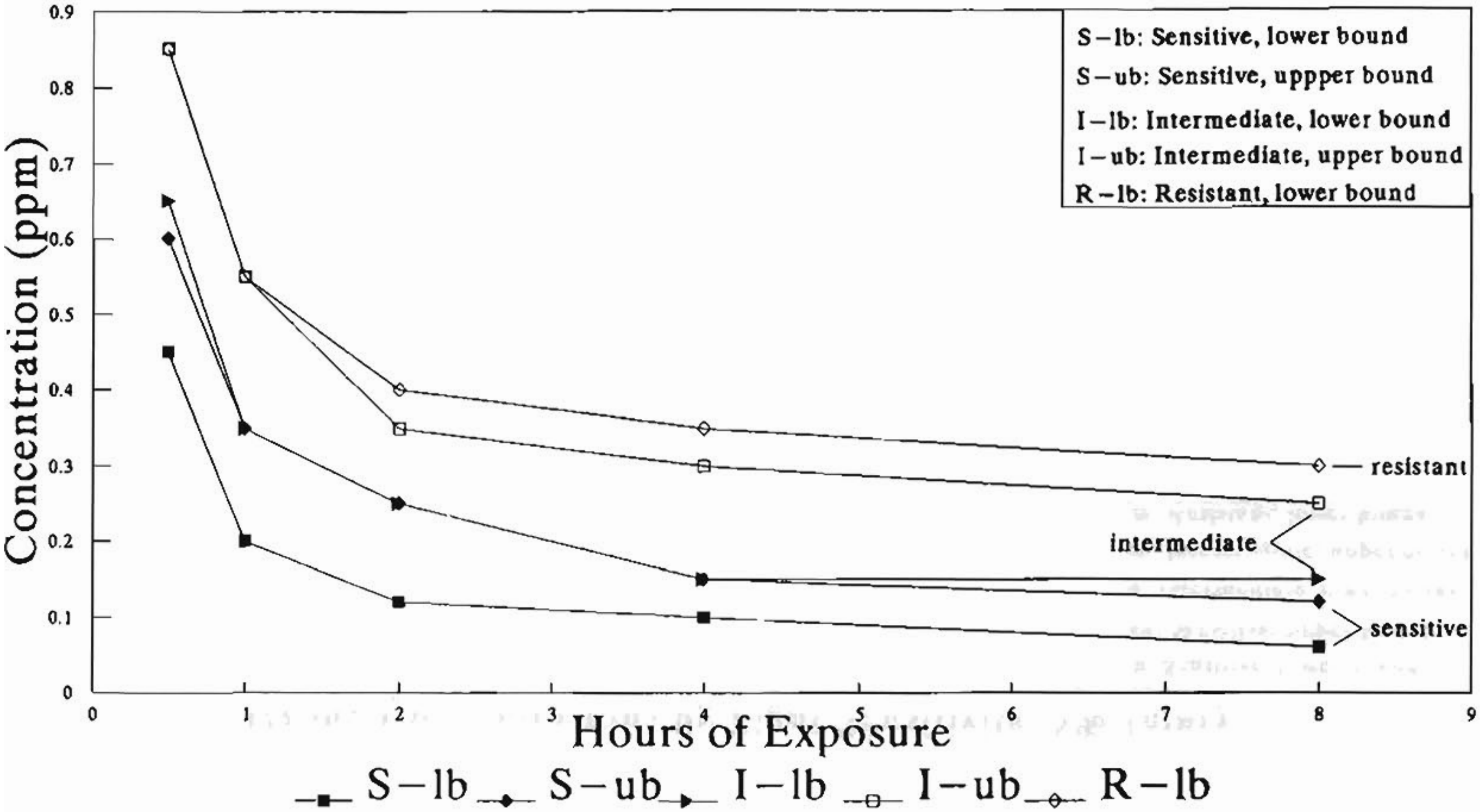


Chart 2.1

Ozone Sensitive Plants: 5% Injury

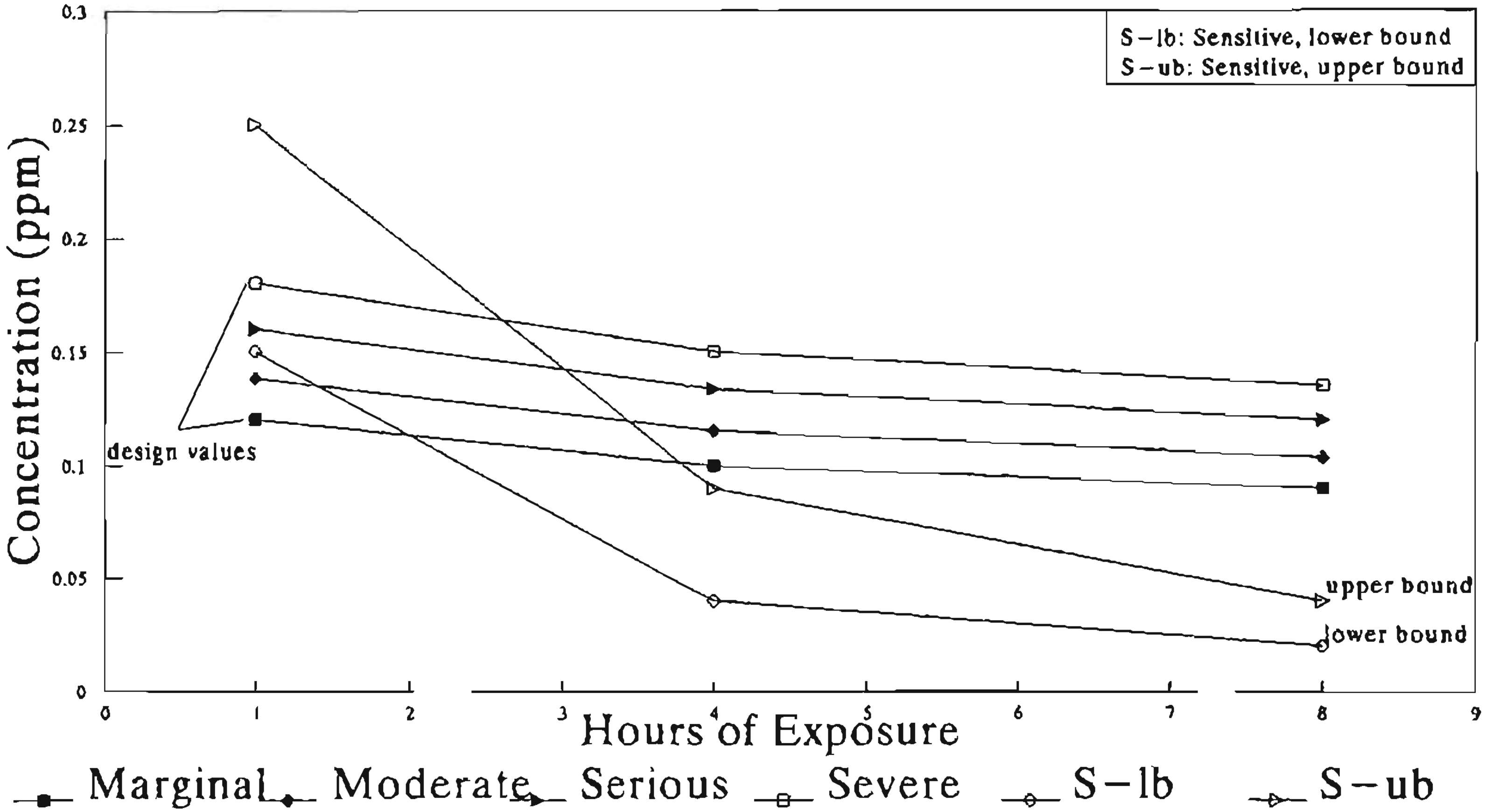


Chart 2.2
Ozone Sensitive Plants: 20% Injury

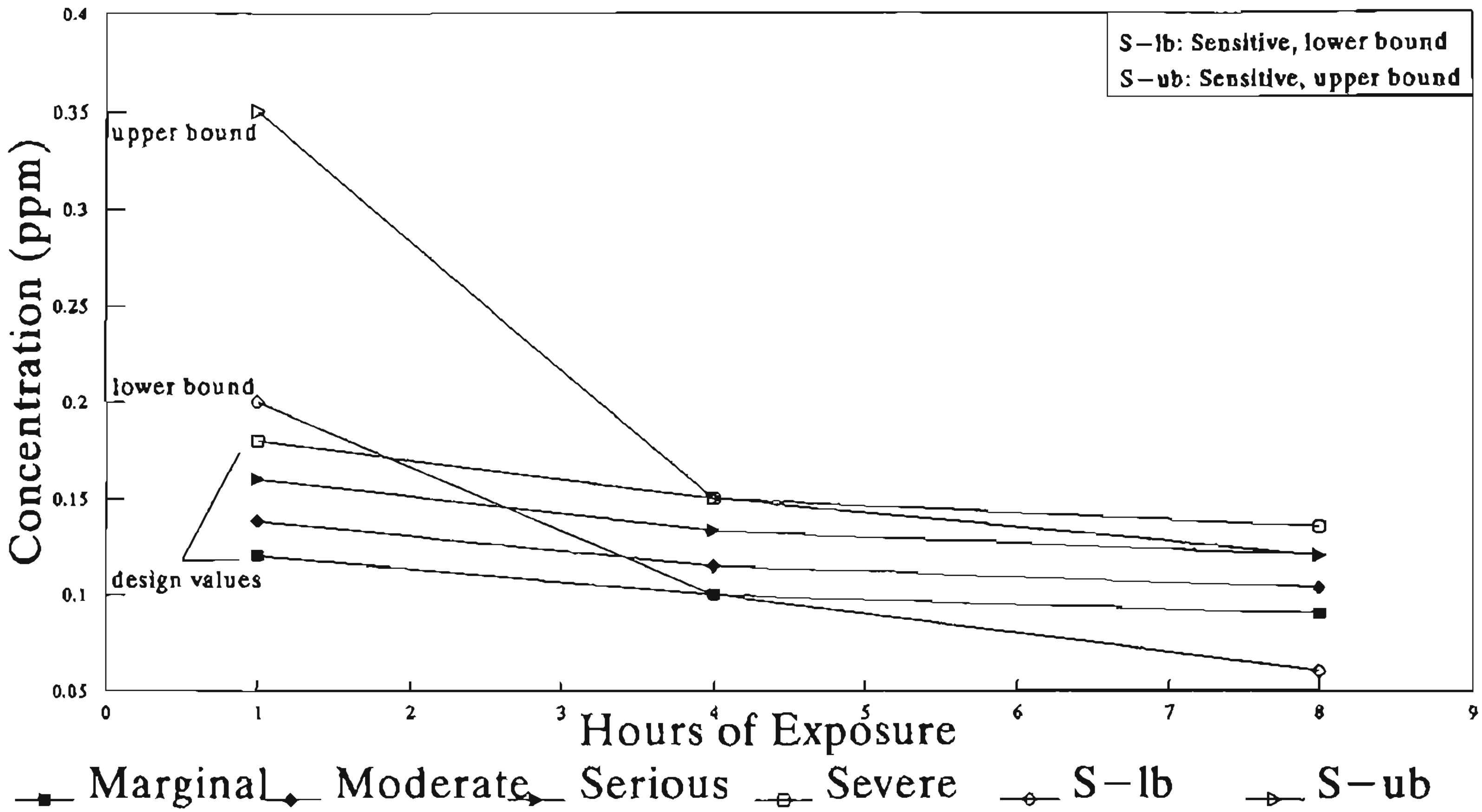


Chart 3.1

Plants with Intermediate Sensitivity to Ozone: 5% Injury

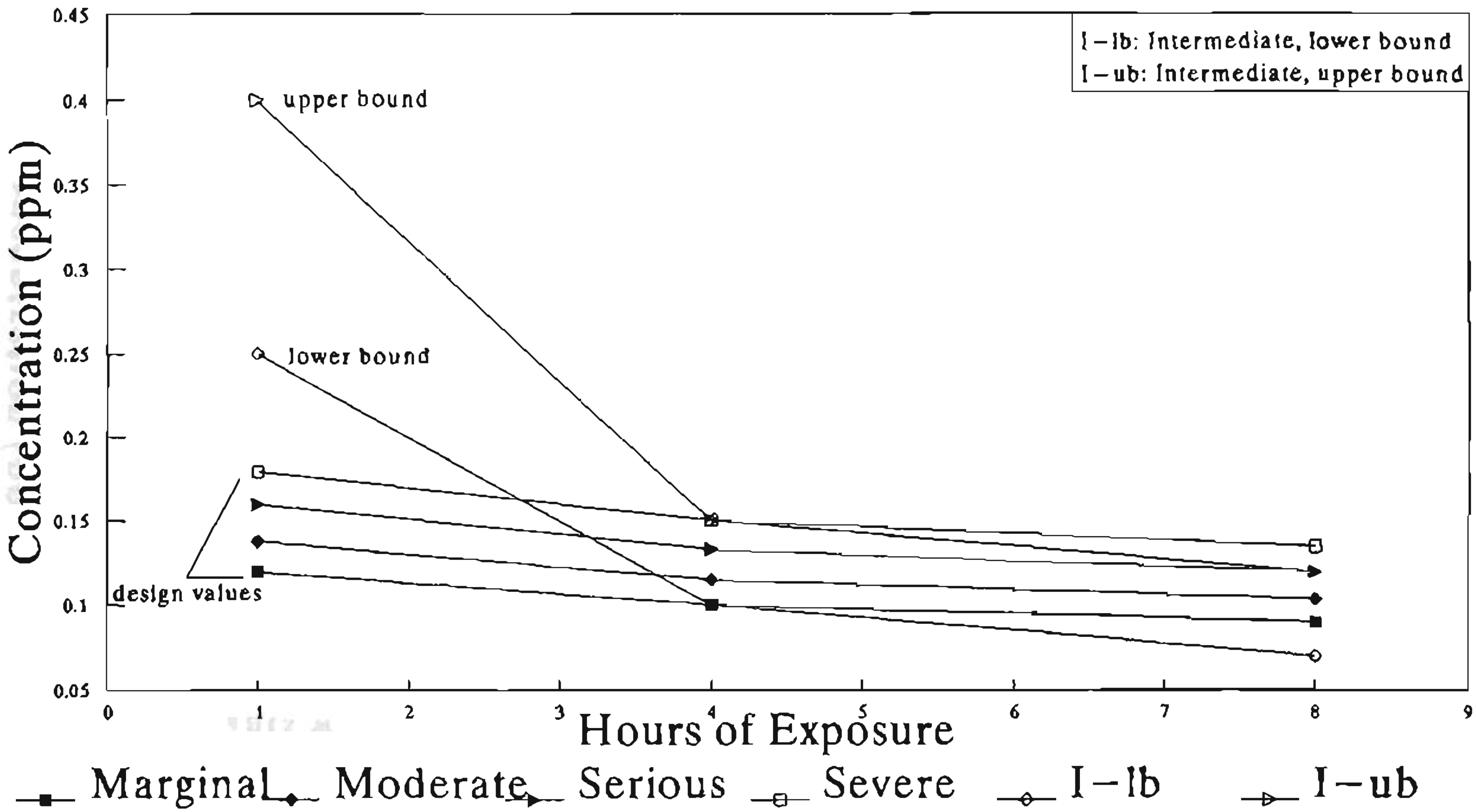


Chart 3.2

Plants with Intermediate Sensitivity to Ozone: 20% Injury

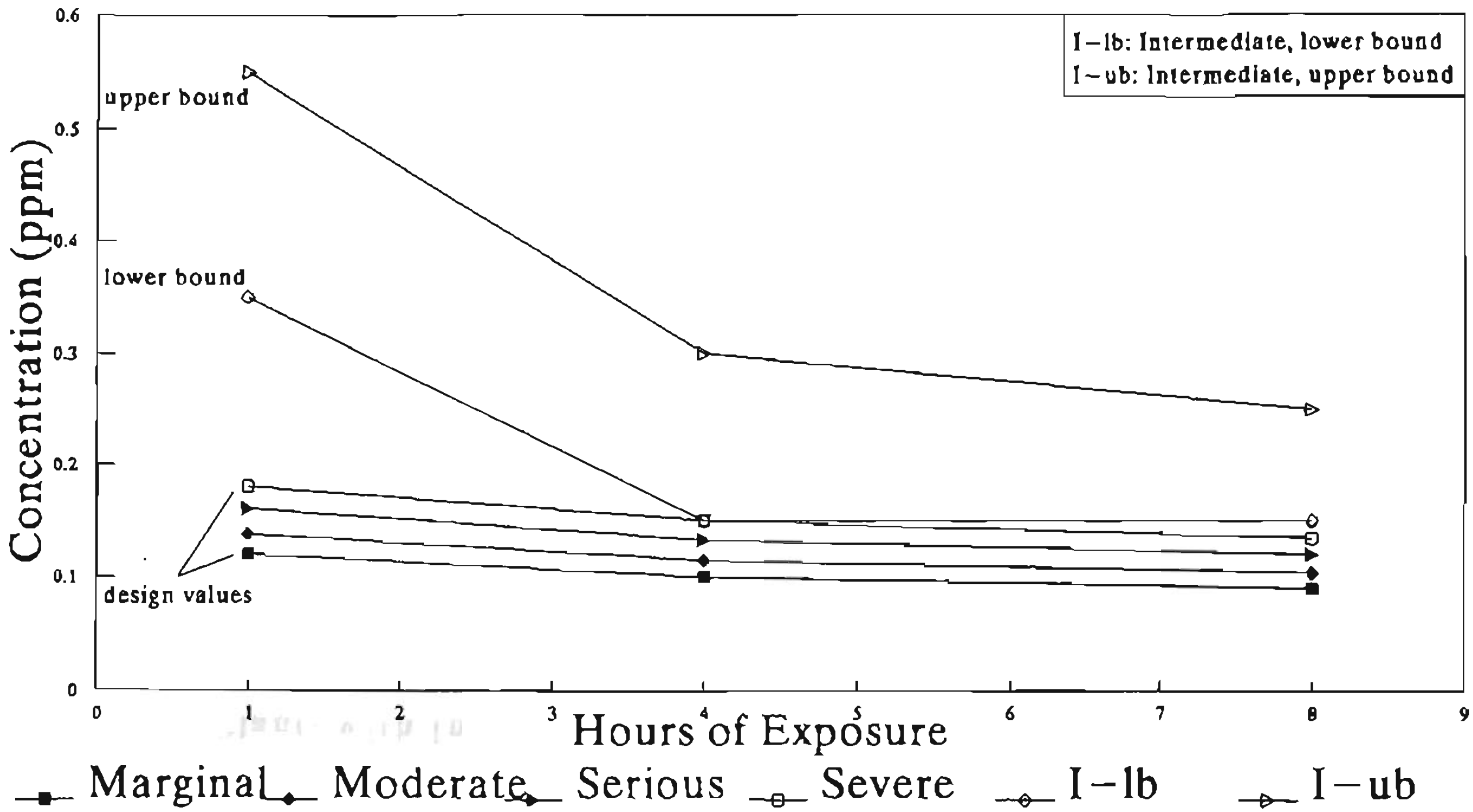


Chart 4.1
Ozone Resistant Plants: 5% Injury

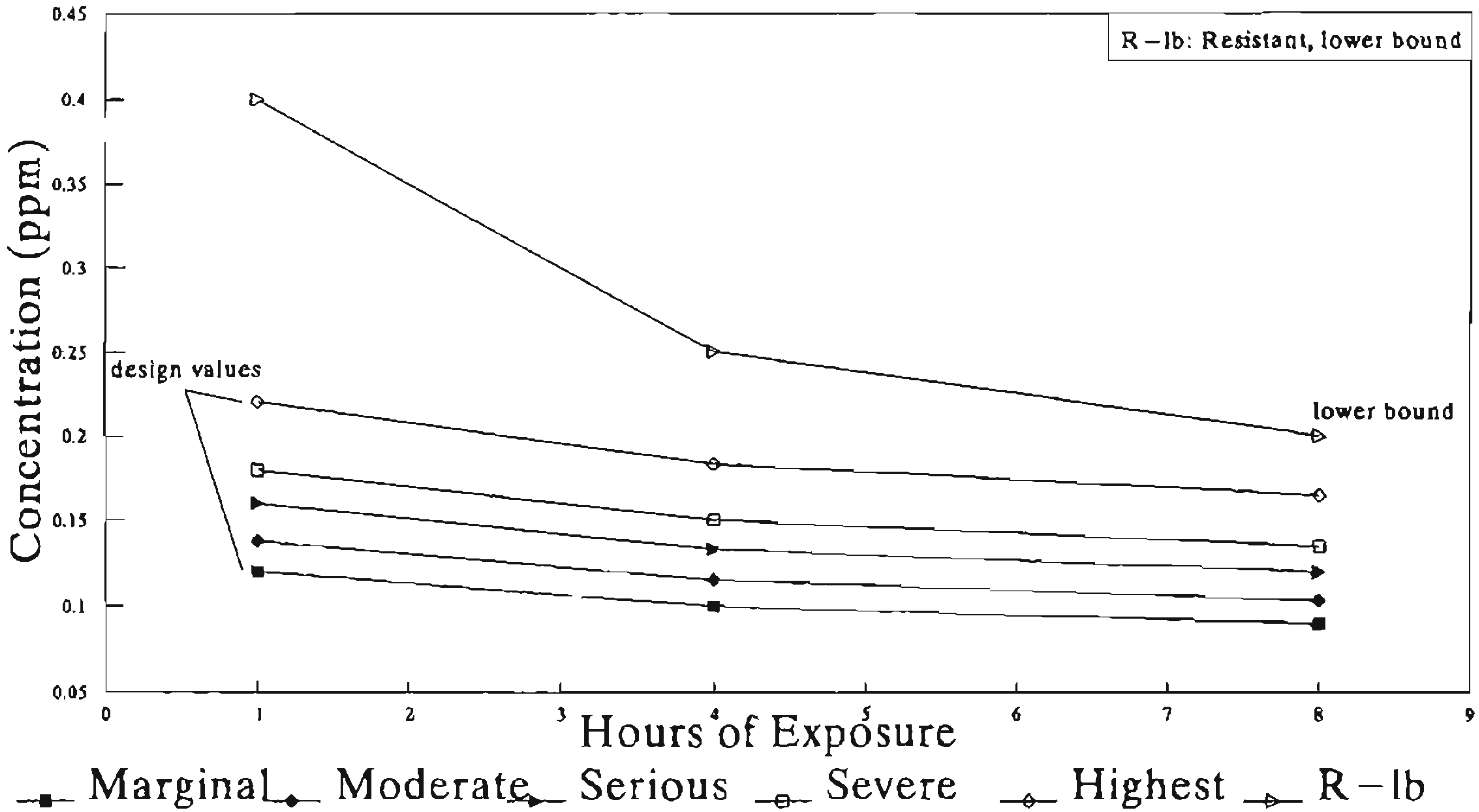


Chart 4.2

Ozone Resistant Plants: 20% Injury

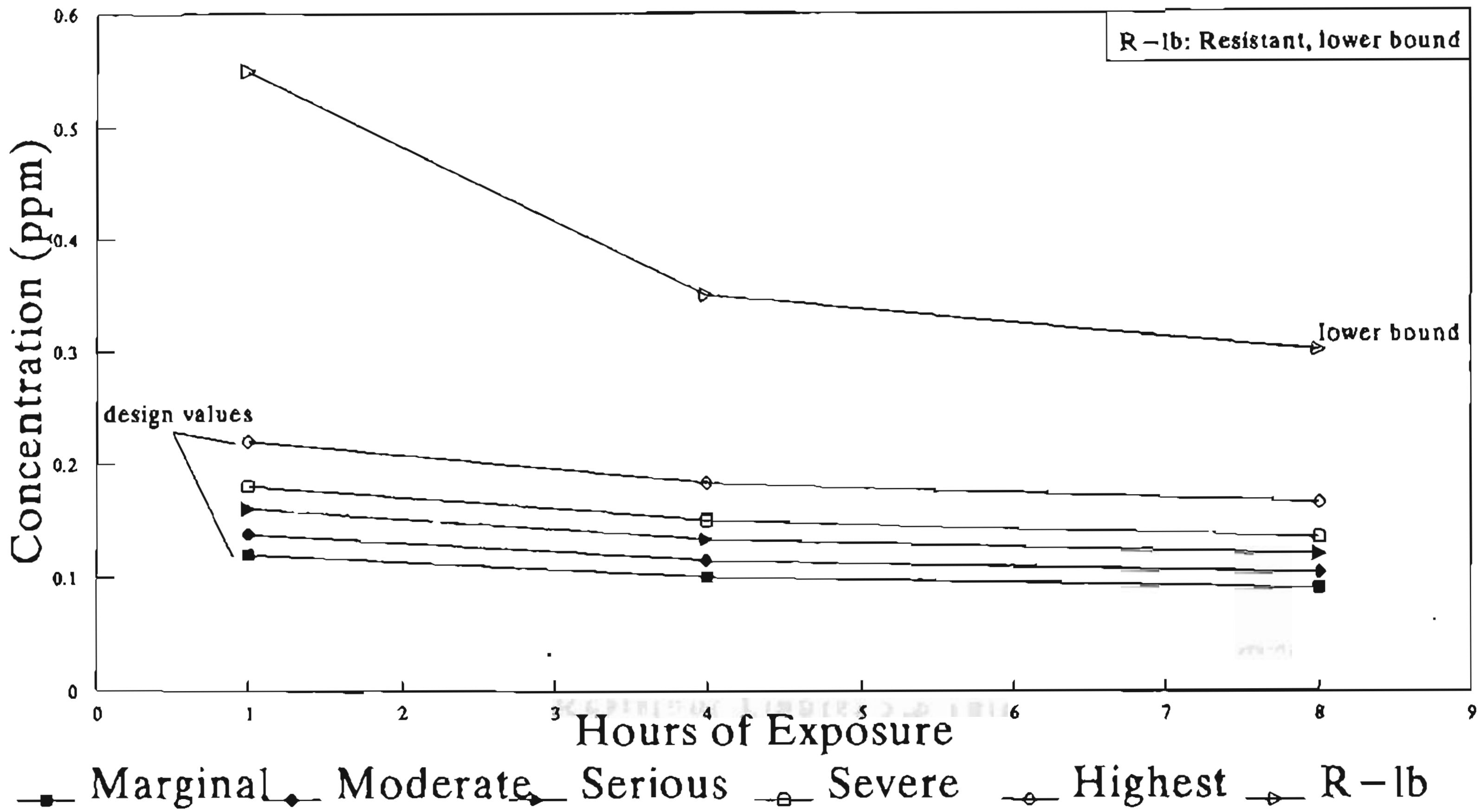
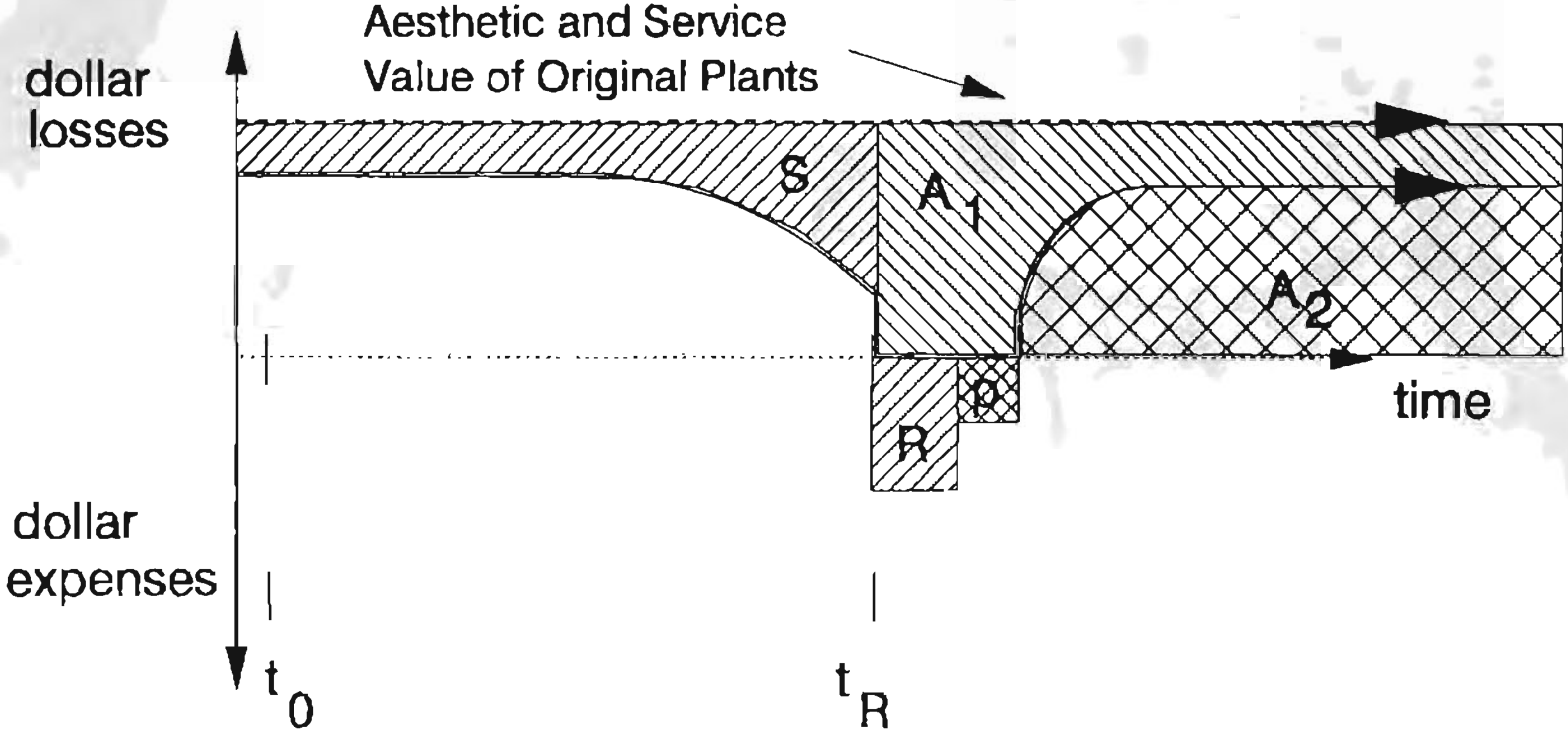
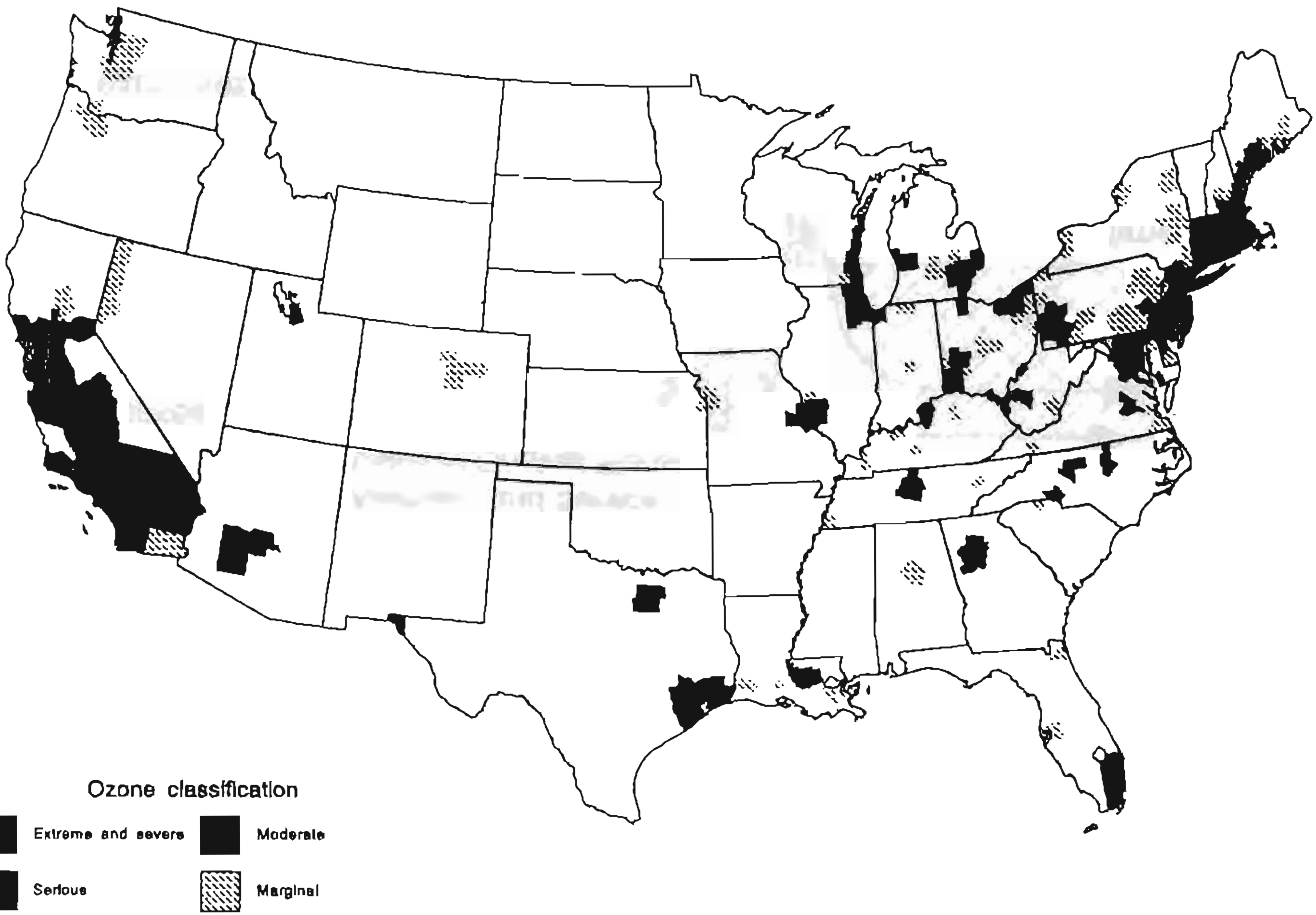


Chart 5: Illustration of Economic Losses Due to Ozone Damage to Ornamental Plants.



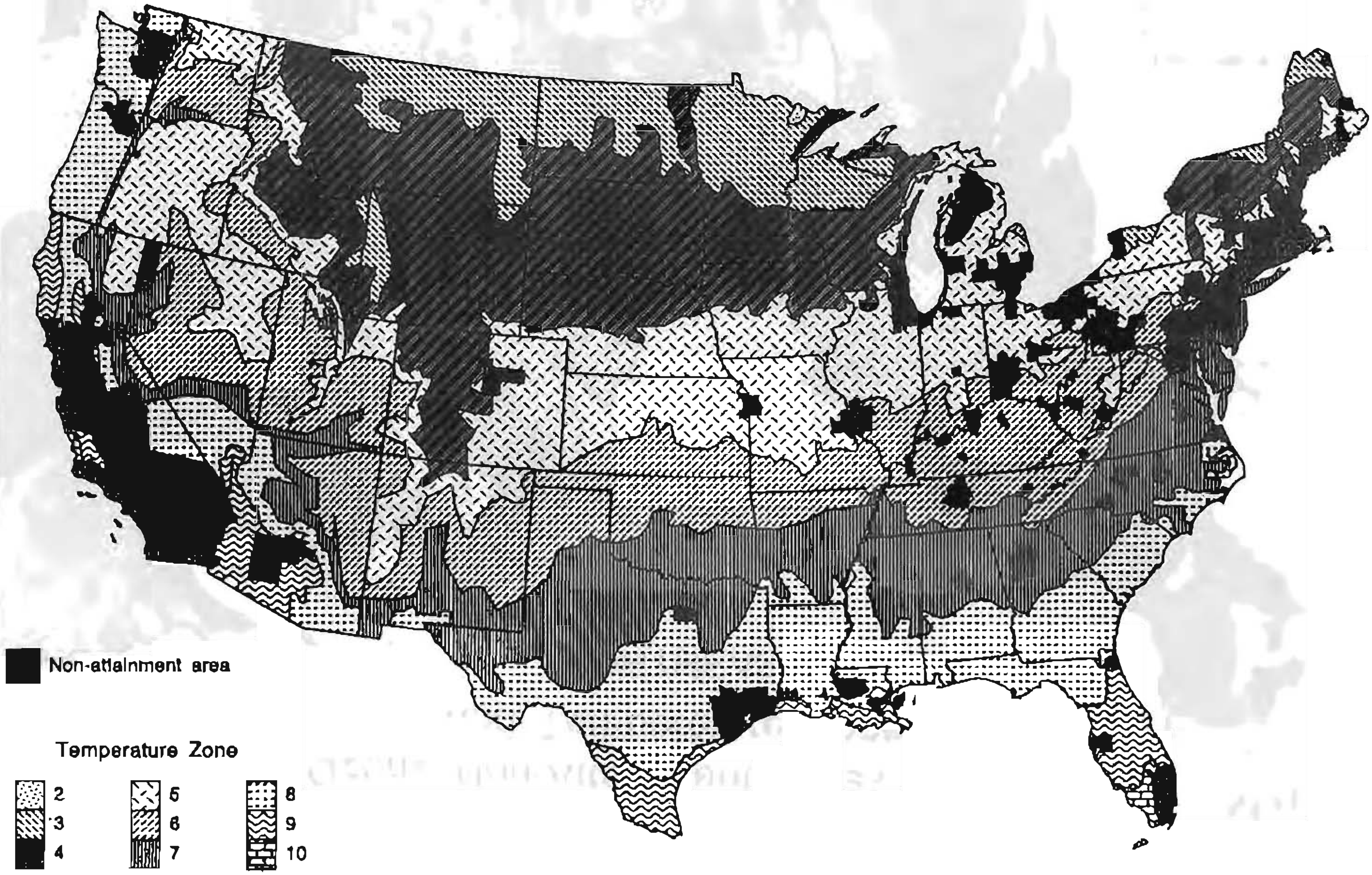
Ozone Non-Attainment Areas (1991)

Map 1

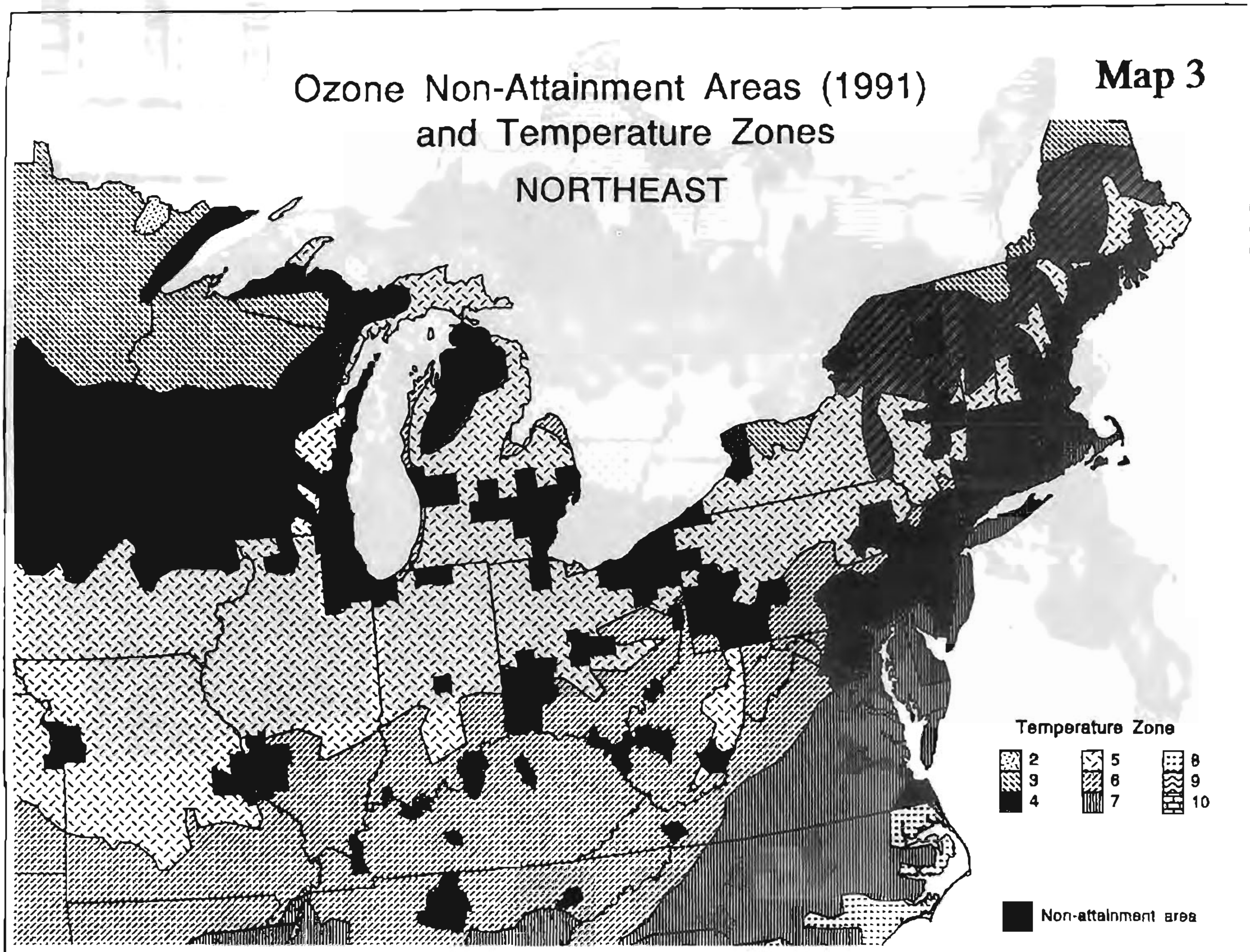


Map 2

Ozone Non-Attainment Areas (1991) and Temperature Zones

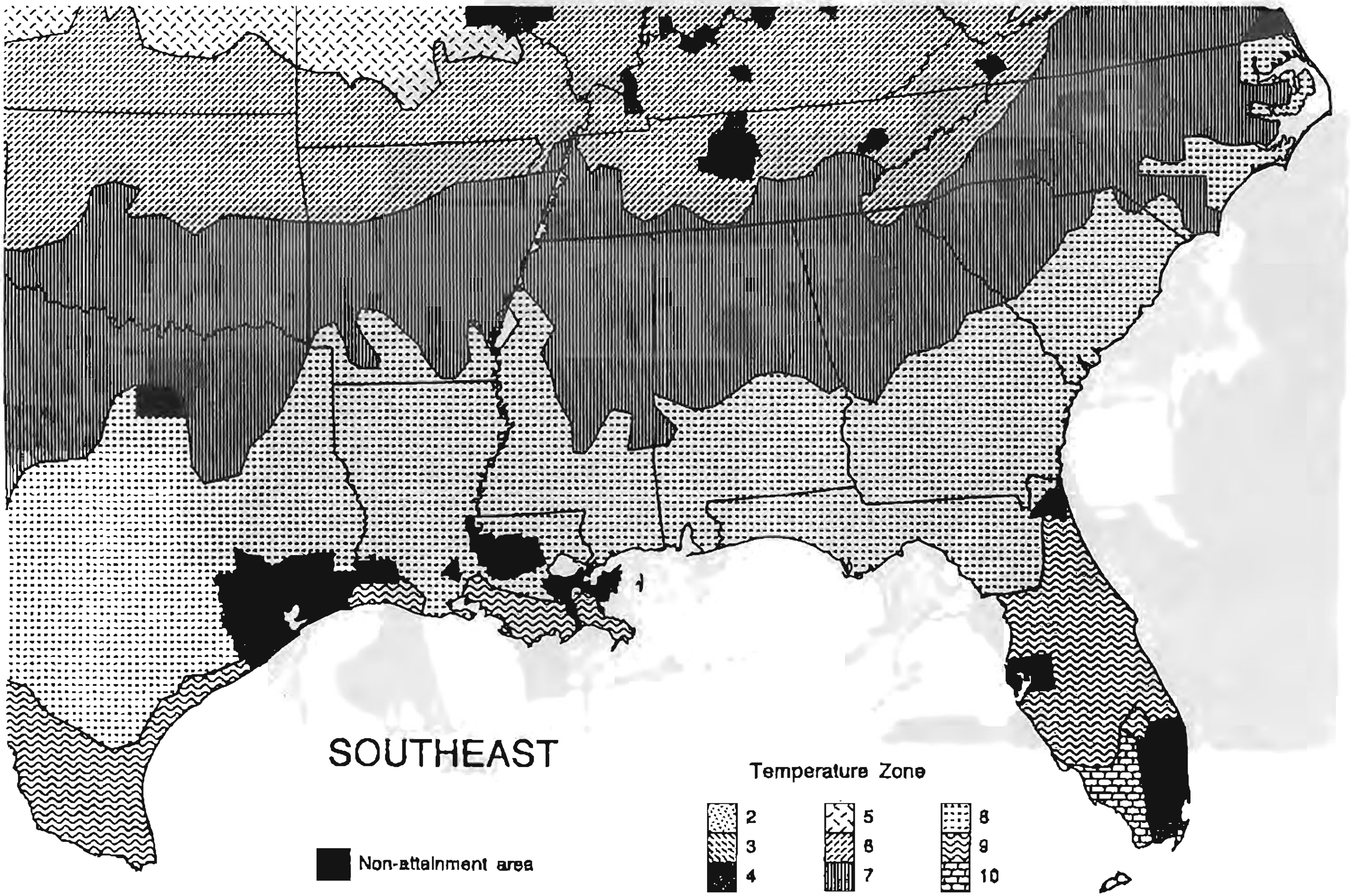


Map 3


Ozone Non-Attainment Areas (1991)
and Temperature Zones
NORTHEAST
Temperature Zone
2
3
4
5
6
7
8
9
10
Non-attainment area

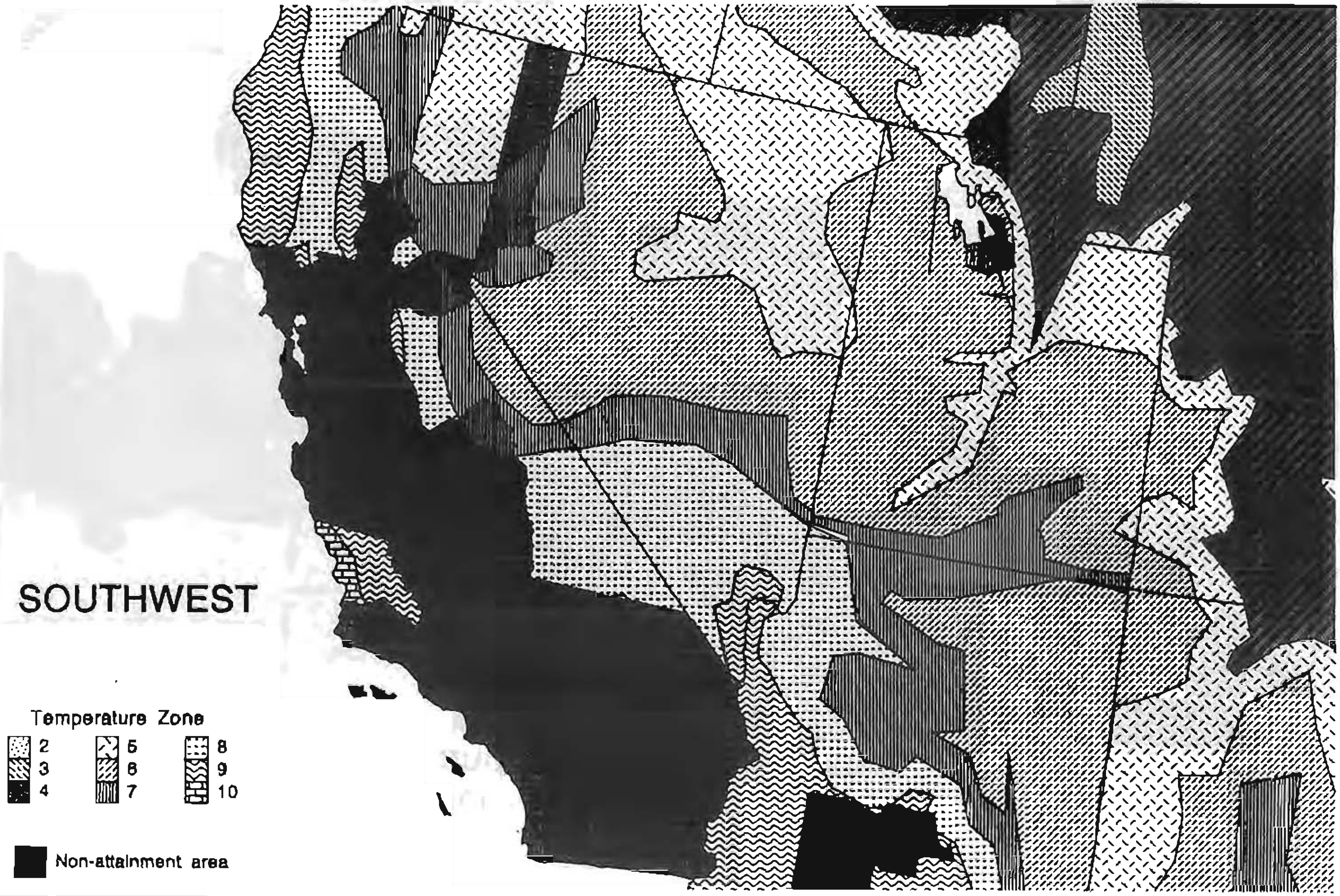
Map 4

Ozone Non-Attainment Areas (1991) and Temperature Zones



Ozone Non-Attainment Areas (1991) and Temperature Zones

Map 5



Appendix A

Data Base of Plants and Sensitivity to Ozone

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
5	fir (balsam)	Abies balsamea	R	R	R	5	Table			ozone	44
5	fir (balsam)	Abies balsamea	R		R	3	na	na	no injury - greenhouse study	ozone	57
5	fir (white)	Abies concolor	I		I - R	6	na	na	na	ozone	9
5	fir (white)	Abies concolor	na		I - R	6	na	na	decrease in growth	ozone, SO2, heavy me	32
5	fir (white)	Abies concolor		I	I - R	6	0.36 ppm	12 hrs/day for 37 days	5 in order of decr. sens (1 = highest)	ozone	39
5	fir (white)	Abies concolor	I		I - R	6	ambient - - CA forests	tree lifetime through 1970	premature aging to senescence	oxidant air pollution	40
5	fir (white)	Abies concolor	R	R	I - R	6	Table			ozone	44
5	fir (white)	Abies concolor	R		I - R	6	na	na	no injury - greenhouse study	ozone	57
5	fir (white)	Abies concolor	I		I - R	6	na	na	chlorosis	ozone	57
5	fir (white)	Abies concolor	I		I - R	6	0.25 ppm	2 hrs	detectable injury	ozone	60
5	fir (Fraser)	Abies fraseri	na		R		na	na	decrease in growth	ozone, SO2	32
5	fir (Fraser)	Abies fraseri	R		R		na	na	no injury - field/g.house studies	ozone	57
5	fir	Abies magnifica			I		0.36 ppm	12 hrs/day for 37 days	7 in order of decr. sens (1 = highest)	ozone	39
4	acacia?	Acacia greggi	R	R	R	9	0.05 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	acacia?	Acacia greggi	R	R	R	9	0.10 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	acacia?	Acacia greggi	R	R	R	9	0.15 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	acacia?	Acacia greggi	R	R	R	9	0.20 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	maple (hedge)	Acer campestre	R		R	5	na	na	no injury - field study	ozone	57
4	maple (Amur)	Acer ginnala	R		R	5	na	na	no injury - field study	ozone	57
4	maple (big-tooth)	Acer grandidentatum	R		R		na	na	no injury - greenhouse study	ozone	57
4	maple (big-tooth)	Acer grandidentatum	R		R		0.40 > ppm	2 hrs	detectable injury	ozone	60
4	maple (broadleaf)	Acer macrophyllum	na				na	na	ozone-type lesions	ozone	52
3	boxelder maple	Acer negundo	I		R	3	na	na	chlorosis	ozone	57
3	boxelder maple	Acer negundo	R	R	R	3	0.25 > ppm	2 hrs	detectable injury	ozone	60
4	maple (black)	Acer nigrum	R		R		na	na	no injury - field study	ozone	57
4	maple (Norway)	Acer platanoides	R		R	4	na	na	no injury - field/g.house studies, dark stippl	ozone	57
4	maple (sycamore)	Acer pseudoplatanus	R		R	5	na	na	no injury - field study	ozone	57
4	maple (red)	Acer rubrum	na	I	I	3	0.04 ppmh	7 hr/day for 8 weeks	na	ozone, acidic precip., $	13
4	maple (red)	Acer rubrum	na	I	I	3	0.08 ppm	7 hr/day for 8 weeks	avg. leaf injury of 11%; less growth in stem d	ozone, acidic precip., $	13
4	maple (red)	Acer rubrum	I		I	3	0, 0.075, or 0.15 ul, L-1	6 hrs d-1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	maple (red)	Acer rubrum			I	5	0.30 ppm	8 hrs/day for 3 months	premature leaf drop	ozone	33
4	maple (red)	Acer rubrum	S	I	I	5	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	foliar injury; reduction in height, leaf mass +	ozone	35
4	maple (red)	Acer rubrum	S		I	3	na	na	dark stipple	ozone	57
4	maple (red)	Acer rubrum	R		I	3	na	na	no injury - field study; dark stipple	ozone	57
4	maple (silver)	Acer saccharinum	na		R	3	na	na	reduced carbohydrate production	ozone	11
4	maple (silver)	Acer saccharinum			R	3	0.30 ppm	8 hrs/day for 5 months	significant growth reduction, premature leaf	ozone	33
4	maple (silver)	Acer saccharinum	R		R	3	na	na	no injury - field study	ozone	57
4	maple (sugar)	Acer saccharum	I		R	3	0, 0.07, or 0.15 ppm	3 days for 16 weeks	growth reduction; no foliar injury	ozone/acid rain	29
4	maple (sugar)	Acer saccharum			R	3	0.30 ppm	8 hrs/day for 5 months	significant growth reduction, premature leaf	ozone	33
4	maple (sugar)	Acer saccharum	I	R	R	3	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	no foliar injury; 2-5% growth reduction	ozone	35
4	maple (sugar)	Acer saccharum			R	3	0.10-0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
4	maple (sugar)	Acer saccharum	R	R	R	3	Table			ozone	44
4	maple (sugar)	Acer saccharum	I		R	3	na	na	dark stipple	ozone	57
4	maple (sugar)	Acer saccharum	R		R	3	na	na	no injury - field/g.house studies, dark stippl	ozone	57
4	maple (sugar)	Acer saccharum	S		R	3	na	na	dark stipple	ozone	57
10	yarrow	Achillea millefolium	S		I	2	0.05 - 0.07 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
10	yarrow	Achillea millefolium	S	I	I	2	0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	10 % leaf injury	ozone	27
10	yarrow	Achillea millefolium	S		I	2	0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	70 % leaf injury, substantial growth red.	ozone	27
10	yarrow	Achillea millefolium	R		I	2	na	na	no injury - greenhouse study	ozone	57
10	yarrow	Achillea millefolium	R		I	2	0.30 > ppm	2 hrs	detectable injury	ozone	60
2	baneberry	Actaea rubra	I		I	3 - 5	0.25 ppm	2 hrs	detectable injury	ozone	60
4	buckeye (Ohio)	Aesculus glabra	S		S		na	na	dark stipple	ozone	57
4	horse chestnut	Aesculus hippocastanum	S		S - R	4	na	na	dark stipple	ozone	57

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
4	horse chestnut	Aesculus hippocastanum	R		S-R	4	na	na	no injury - field study; dark stipple	ozone	57
4	buckeye (yellow)	Aesculus octandra	S		S		na	na	tan stipple	ozone	57
11	hyssop (nettle leaf...)	Agastache urticifolia	I	I	I		0.20 ppm	2 hrs	detectable injury	ozone	60
1		Agropyron caninum	R	I	I		0.25 > ppm	2 hrs	detectable injury	ozone	60
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.15 ppm	6 hrs/day for 10 days	15 % > leaf injury	ozone	16
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf injury	O3/SO2/NO2	16
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.30 ppm	3 hrs (66-71 days after emergence)	25 % of blade area injured	ozone	53
1	bentgrass (redtop, common)	Agrostis alba	I	I	I	cool	0.30 ppm	3 hrs (9-14 days after emergence)	10 % of blade area injured	ozone	53
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.40 ppm	3 hrs (9-14 days after emergence)	21 % of blade area injured	ozone	53
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.40 ppm	3 hrs (66-71 days after emergence)	30 % of blade area injured	ozone	53
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.50 ppm	3 hrs (9-14 days after emergence)	43 % of blade area injured	ozone	53
1	bentgrass (redtop, common)	Agrostis alba	S	I	I	cool	0.50 ppm	3 hrs (66-71 days after emergence)	24 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Astoria"	S		S	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Astoria"	S		S	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Cohansey"	S		S	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Cohansey"	S		S	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Cohansey"	S	S	S	cool	Table			ozone	44
1	bentgrass (creeping)	Agrostis palustris "Emerald"	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	bentgrass (creeping)	Agrostis palustris "Highland"	R		I	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Highland"	S		I	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Highland"	I	I	I	cool	Table			ozone	44
1	bentgrass (creeping)	Agrostis palustris "Holfior"	I		S	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Holfior"	S		S	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Holfior"	S	S	S	cool	Table			ozone	44
1	bentgrass (creeping)	Agrostis palustris "Kingstown"	R		I	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Kingstown"	S		I	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Kingstown"	I	I	I	cool	Table			ozone	44
1	bentgrass (creeping)	Agrostis palustris "Penncross"	I		S-R	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S		S-R	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S		S-R	cool	0.23-0.30 ppm	6 hrs	tan necrosis, bleaching	ozone	7
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	I	S-R	cool	0.15 ppm	6 hrs/day for 10 days	15 % > leaf area injured	ozone	16
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S		S-R	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	S	S-R	cool	Table			ozone	44
1	bentgrass (creeping)	Agrostis palustris "Penncross"	I	R	S-R	cool	0.20 ppm	2 hrs	13 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	R	R	S-R	cool	0.30 ppm	3 hrs (9-14 days after emergence)	3 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	I	S-R	cool	0.30 ppm	2 hrs	16 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	R	R	S-R	cool	0.30 ppm	3 hrs (66-71 days after emergence)	5 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	R	R	S-R	cool	0.40 ppm	3 hrs (9-14 days after emergence)	5 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	I	S-R	cool	0.40 ppm	2 hrs	26 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	I	R	S-R	cool	0.40 ppm	3 hrs (66-71 days after emergence)	11 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	R	S-R	cool	0.50 ppm	3 hrs (66-71 days after emergence)	16 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Penncross"	S	R	S-R	cool	0.50 ppm	3 hrs (9-14 days after emergence)	40 % of blade area injured	ozone	53
1	bentgrass (creeping)	Agrostis palustris "Seaside"	S		S	cool	0.25 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Seaside"	S		S	cool	0.30 ppm	6 hrs	na	ozone	6
1	bentgrass (creeping)	Agrostis palustris "Seaside"	S	S	S	cool	Table			ozone	44
1	bentgrass (colonial)	Agrostis tenuis "Astoria"	S	S	S	cool	Table			ozone	44
1	bentgrass (colonial)	Agrostis tenuis "Astoria"	S		S	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	bentgrass (colonial)	Agrostis tenuis "Dryland"	S		S	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	bentgrass (colonial)	Agrostis tenuis "Exeter"	R	I	I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1	bentgrass (colonial)	Agrostis tenuis "Exeter"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1	bentgrass (colonial)	Agrostis tenuis "Highland"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
4	tree of heaven	Ailanthus altissima	I		S-I	4-5	na	na	dark stipple	ozone	57
4	tree of heaven	Ailanthus altissima	S		S-I	4-5	na	na	dark stipple, tan stipple	ozone	57

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
11	onion/garlic? (wild)	Allium acuminatum	I	I	I		0.25 ppm	2 hrs	detectable injury	ozone	60
4	alder (European black)	Alnus glutinosa			R	4	0.30 ppm	8 hrs/day for 5 months	premature leaf drop	ozone	33
4	alder (European black)	Alnus glutinosa	R		R	4	na	na	no injury – field study	ozone	57
4	alder	Alnus incana (seedlings)		S	S	2	0.025 ppm	7 hrs/day for 50 days	lower shoot/root growth	ozone	43
4	alder	Alnus incana (seedlings)		S	S	2	0.035 ppm	7 hrs/day for 50 days	wilting, lower shoot/root growth	ozone	43
4	alder	Alnus incana (seedlings)		S	S	2	0.053 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
4	alder	Alnus incana (seedlings)		S	S	2	0.082 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
10	ragweed	Ambrosia artemisiifolia	R		R	annual	na	na	no injury – greenhouse study	ozone	57
10	ragweed (western)	Ambrosia psilostachya	R		R	3	0.40 > ppm	2 hrs	detectable injury	ozone	60
4	serviceberry (alder-leaf)	Amelanchier alnifolia	I		I		0.20 ppm	2 hrs	detectable injury	ozone	60
4	serviceberry (western)	Amelanchier florida	S		S-I		na	na	chlorosis	ozone	57
4	serviceberry (western)	Amelanchier florida	I		S-I		na	na	chlorosis	ozone	57
4	serviceberry (roundleaf)	Amelanchier grandiflora	R		R		na	na	no injury – field study	ozone	57
4	serviceberry (Allegheny)	Amelanchier laevis	R		R	5	na	na	no injury – field study	ozone	57
11	angelica	Angelica pinnata	I	I	I		0.25 < ppm	2 hrs	detectable injury	ozone	60
11	angelica	Angelica triquinata	R		R		na	na	no injury – field and greenhouse studies	ozone	57
1	oatgrass (tall oats)	Arrhenatherum elatius		I	I	3	0.07 ppm	7 hrs/day for two weeks	5 % reduced growth rate	ozone	48
3	sagebrush (big)	Artemesia tridentata	R		R	5	na	na	no injury – greenhouse study	ozone	57
3	sagebrush (big)	Artemesia tridentata	R		R	5	0.30 ppm	2 hrs	detectable injury	ozone	60
10	milkweed (tall)	Asclepias exaltata	S		S		na	na	dark stipple	ozone	57
10	milkweed (common)	Asclepias syriaca	S	S	S	3	0.129 ppm (max)	growing season 1989 – wet conditions	widespread foliar stippling (in many plants/si	ozone	36
10	milkweed (common)	Asclepias syriaca	S		S	3	0.197 ppm (max)	growing season 1988 – drought conditions	some stippling	ozone	36
2	aster (whorled wood)	Aster acuminatus	S		S		na	na	other symptoms	ozone	57
2	aster (Engelmann)	Aster engelmannii	S		S		0.15 ppm	2 hrs	detectable injury	ozone	60
2	aster (purple stemmed)	Aster puniceus	S		S	3	na	na	other symptoms	ozone	57
11	belladonna	Atropa belladonna	S		S	6	na	na	na	ozone	36
7	desert annual	Baileya pleniradiata	R		R	annual	0.30 > ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
2	begonia	Begonia rex	R		R	annual	0.10–0.15 ppm	13 days	leaf tip necrosis	ozone	10
2	begonia	Begonia sp. "Christmas"	R	R	R	annual	Table			ozone	44
2	begonia	Begonia sp. "Linda"	I	I	I	annual	Table			ozone	44
2	begonia	Begonia sp. "Scarlotta"	R	R	R	annual	Table			ozone	44
2	begonia	Begonia sp. "Thousand Wonders White"	I	I	I	annual	Table			ozone	44
2	begonia	Begonia sp. "White Tausendschon"	I	I	I	annual	Table			ozone	44
2	begonia (Elatior)	Begonia x hiemalis "Ballerina"	S		S	annual	na	na	na	ozone	47
2	begonia (Elatior)	Begonia x hiemalis "Fantasy"	I	R	R	annual	0.25 ppm	4hr/day every 6 days: 4x	2 % leaf injury	ozone	49
2	begonia (Elatior)	Begonia x hiemalis "Heirloom"	I		I	annual	na	na	na	ozone	47
2	begonia (Elatior)	Begonia x hiemalis "Improved Krefeld Orang	S		I	annual	na	na	na	ozone	47
2	begonia (Elatior)	Begonia x hiemalis "Mikkell Limelight"	S		S	annual	na	na	na	ozone	47
2	begonia (Elatior)	Begonia x hiemalis "Nixe"	I		I	annual	na	na	na	ozone	47
2	begonia (Elatior)	Begonia x hiemalis "Renaissance"	I	I	I	annual	0.25 ppm	4 hrs/day every 6 days: 4x	15 % leaf injury	ozone	49
2	begonia (Elatior)	Begonia x hiemalis "Schwabenland Red"	S	S	S	annual	0.25 ppm	4hr/day every 6 days: 4x	54 % leaf injury	ozone	49
2	begonia (Elatior)	Begonia x hiemalis "Turo"	R	R	R	annual	0.25 ppm	4hr/day every 6 days: 4x	8 % leaf injury	ozone	49
2	begonia (Elatior)	Begonia x hiemalis "Whisper O' Pink"	S	I	I	annual	0.25 ppm	4hr/day every 6 days: 4x	25 % leaf injury	ozone	49
3	mahonia (creeping)	Berberis repens	R		R		na	na	no injury – greenhouse study	ozone	57
4	birch	Betula pubescens (seedlings)		S	S		0.025 ppm	7 hrs/day for 50 days	lower shoot/root growth	ozone	43
4	birch	Betula pubescens (seedlings)		S	S		0.035 ppm	7 hrs/day for 50 days	wilting, lower shoot/root growth	ozone	43
4	birch	Betula pubescens (seedlings)		S	S		0.053 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
4	birch	Betula pubescens (seedlings)		S	S		0.082 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
4	birch (yellow)	Betula alleghaniensis	S	I	I		0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	foliar injury; slight decrease in height, growth	ozone	35
4	birch (yellow)	Betula alleghaniensis	I		I		na	na	dark stipple	ozone	57
4	birch (yellow)	Betula alleghaniensis	S		I		na	na	dark stipple	ozone	57
4	birch (yellow)	Betula alleghaniensis	I		I		0, 0.035, or 0.15 ul l−1	6 hrs d−1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	birch (black)	Betula lenta	R		R	3	na	na	no injury – field study	ozone	57

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
4	birch (river)	Betula nigra	R		R	5	na	na	no injury – field study	ozone	57
4	birch (European white)	Betula pendula	R		R	2	na	na	no injury – field/ghouse studies	ozone	57
4	birch (grey)	Betula populifolia	R		R		na	na	no injury – field study	ozone	57
4	birch	Betula verrucosa (seedlings)		S	S		0.025 ppm	7 hrs/day for 50 days	lower shoot/root growth	ozone	43
4	birch	Betula verrucosa (seedlings)		S	S		0.035 ppm	7 hrs/day for 50 days	wilting, lower shoot/root growth	ozone	43
4	birch	Betula verrucosa (seedlings)		S	S		0.053 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
4	birch	Betula verrucosa (seedlings)		S	S		0.082 ppm	7 hrs/day for 50 days	leaf death, lower shoot/root growth	ozone	43
12		Brachypodium pinnatum		I	I		0.07 ppm	7 hrs/day for two weeks	5 % reduced growth rate	ozone	48
1	grass (brome)	Bromus briziformis	R	R	R		0.30 ppm	2 hrs	detectable injury	ozone	60
1	grass (brome)	Bromus carinatus	I	I	I		0.25 < ppm	2 hrs	detectable injury	ozone	60
1	grass (brome)	Bromus erectus		I	I		0.07 ppm	7 hrs/day for two weeks	no reduced growth	ozone	48
1	grass (brome)	Bromus rubens	I		I		0.2–0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
1	grass (brome)	Bromus rubens (air pollution ecotype)		I	I		0.10 ppm	8 hrs/day 5days/wk for 5 wks	5 % tip necrosis	ozone	46
1	grass (brome)	Bromus rubens (air pollution ecotype)			I		0.20 ppm	8 hrs/day 5days/wk for 5 wks	30 % tip necrosis	ozone	46
1	grass (brome)	Bromus rubens (air pollution ecotype)			I		0.40 ppm	8 hrs/day 5days/wk for 5 wks	50 % tip and blade necrosis	ozone	46
1	grass (brome)	Bromus rubens (non-air pollution ecotype)		S	S		0.10 ppm	8 hrs/day 5days/wk for 5 wks	20 % tip necrosis	ozone	46
1	grass (brome)	Bromus rubens (non-air pollution ecotype)			S		0.20 ppm	8 hrs/day 5days/wk for 5 wks	50 % tip necrosis	ozone	46
1	grass (brome)	Bromus rubens (non-air pollution ecotype)			S		0.40 ppm	8 hrs/day 5days/wk for 5 wks	80 % tip and blade necrosis	ozone	46
1	grass (brome)	Bromus sp. "Sac Smooth"	S	S	S		Table			ozone	44
1	grass (brome)	Bromus sterilis		R	R		0.07 ppm	7 hrs/day for two weeks	2 % reduced growth rate	ozone	48
1	grass (brome, soft)	Bromus tectorum	S		S		na	na	chlorosis	ozone	57
1	grass (brome, soft)	Bromus tectorum	S		S		0.15 ppm	2 hrs	detectable injury	ozone	60
3	boxwood	Buxus sp.	R		R	6	na	na	no injury – field study	ozone	57
10	ragwort (Rugel's)	Cacalia rugelia	S		S		na	na	na	ozone	57
3	cedar (incense)	Calocedrus decurrens	I				ambient -- CA forests	tree lifetime through 1970	premature aging or senescence	oxidant air pollution	40
5	cedar (incense)	Calocedrus decurrens, Libocedrus decurrens			R	6	0.36 ppm	12 hrs/day for 37 days	10 in order of decr. sens. (1=highest)	ozone	39
2	lily (Sego)	Calochortus nuttallii	R	R	R	3	0.40 > ppm	2 hrs	detectable injury	ozone	60
7	desert annual	Camissonia californica	I	I	I	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
7	desert winter annual	Camissonia claviformis	S	I	I	annual	0.133 ppm	35 hrs over 216 hrs	2 % total foliar damage	ozone	8
7	desert annual	Camissonia claviformis	S	I	I	annual	0.10 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
7	desert winter annual	Camissonia bistorta	S	I	I	annual	0.133 ppm	35 hrs over 216 hrs	1 % total foliar damage	ozone	8
7	desert annual	Camissonia bistorta	S	I	I	annual	0.10 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
2	trumpet creeper	Campsis radicans	R		R	4	na	na	no injury – field study	ozone	57
6	sedge	Carex siccata	R		R		na	na	chlorosis	ozone	57
6	sedge	Carex siccata	I		R		na	na	chlorosis	ozone	57
6	sedge	Carex siccata	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
4	hornbeam (European)	Carpinus betulus	R		R	5	na	na	no injury – field study	ozone	57
4	hickory (pignut)	Carya glabra	R		R	4	na	na	no injury – field study	ozone	57
4	hickory (shagbark)	Carya ovata	R		R		0, 0.07, or 0.15 ppm	3 days for 16 weeks	none	ozone/acid rain	34
4	hickory (shagbark)	Carya ovata	R	R	R		0.15 ppm	8 hrs/day, 5 consec. days/wk for 16 wks	no effect	ozone	35
4	hickory (shagbark)	Carya ovata	R		R		na	na	no injury – field study	ozone	57
4	hickory (mockernut)	Carya tomentosa	R		R		na	na	no injury – field study	ozone	57
4	catalpa	Catalpa bignonioides	R		R	5	na	na	no injury – field study	ozone	57
4	catalpa (northern)	Catalpa speciosa	na			5	na	na	ozone-type lesions	ozone	52
7	desert winter annual	Caulanthus cooperi	R		I-R	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Caulanthus cooperi	I		I-R	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
11	bittersweet (American)	Celastrus scandens	R		R	2	na	na	no injury – greenhouse study	ozone	57
4	hackberry (common)	Celtis occidentalis	R		R	2	na	na	no injury – field study	ozone	57
10	chickweed	Cerastium fontanum		I	R		0.07 ppm	7 hrs/day for two weeks	10 % reduced growth rate	ozone	48
4	redbud (Eastern)	Cercis canadensis	S		I	6	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
4	redbud (Eastern)	Cercis canadensis	S		I		na	na	dark stipple	ozone	57
4	redbud (Eastern)	Cercis canadensis	I		I		na	na	dark stipple	ozone	57
4	redbud (Eastern)	Cercis canadensis	R		I		na	na	no injury – field study	ozone	57

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
7	desert winter annual	Chaenactis carphoclinia	R		I-R	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Chaenactis carphoclinia	I		I-R	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
7	desert annual	Chaenactis fremontii	I		I-R	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
7	desert winter annual	Chaenactis stevioides	R		I-R	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Chaenactis stevioides	I		I-R	anuual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
10	lambsquarters	Chenopodium album	I		I	annual	0.05 – 0.07 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
10	lambsquarters	Chenopodium album	I		I	annual	0.15 ppm	3 hrs day/5 days/wk for 4 mo	35 % leaf injury	ozone	27
10	lambsquarters	Chenopodium album	I		I	annual	0.30 ppm	3 hrs day/5 days/wk for 4 mo	40 % leaf injury, growth not sig reduc.	ozone	27
10	lambsquarters	Chenopodium album		I	I	annual	0.07 ppm	7 hrs/day for two weeks	1 % reduced growth rate	ozone	48
10	goosefoot	Chenopodium fremontii	S		I		0.15 ppm	3 hrs day/5 days/wk for 4 mo	35 % leaf injury	ozone	27
10	goosefoot	Chenopodium fremontii	S	I	I		0.30 ppm	3 hrs day/5 days/wk for 4 mo	90 % leaf injury, substantial growth red.	ozone	27
10	goosefoot	Chenopodium fremontii	S		I		0.50 – 0.70 ppm (ambient)	2 hrs/day	10 % foliar injury	ozone	27
10	goosefoot	Chenopodium fremontii	I		I		na	na	chlorosis	ozone	57
10	goosefoot	Chenopodium fremontii	I		I		0.25 < ppm	2 hrs	detectable injury	ozone	60
3		Chilopsis linearis	R	R	R	7	0.05 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
3		Chilopsis linearis	R	R	R	7	0.10 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
3		Chilopsis linearis	R	R	R	7	0.15 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
3		Chilopsis linearis	R	R	R	7	0.20 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
7	desert annual	Chorizanthe brevicornu	I	R	R	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
2	chrysanthemum	Chrysanthemum morifolium	R		R	5	0.10–0.15 ppm	12 days	light colored spots between veins in leaves	ozone	10
2	chrysanthemum	Chrysanthemum sp.	S		S	3–5, to 8	na	na	"browning" of either surface	smog	26
2	chrysanthemum	Chrysanthemum sp. "Corsage Cushion"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Ann Ladygo"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Baby Tears"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Bonnie Jean"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Bright Yellow Tuneful"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Cameo"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Chris Columbus"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Crystal Pat"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Dark Yellow Tokyo"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Distinctive"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Dolli-ette"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Flair"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Fuji Jean Williams"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Fuji-Mefo"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Gay Blade"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Golden Arrow"	I	I	I	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Golden Cushion"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Golden Peking"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Golden Yellow Princess	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Indian Summer"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Jessamine Williams"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "King's Ransom"	S	S	S	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Larry"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Lipstick"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Mandalay"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Mango"	S	S	S	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Mermaid"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Mion White"	S	S	S	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Mt Snow"	S	S	S	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Muted Sunshine"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Oregon"	R	R	R	3–5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Pancho"	I	I	I	3–5, to 8	Table			ozone	44

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
2	chrysanthemum	Chrysanthemum sp. "Penguin"	I	I	I	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Pink Chief"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Queen's Lace"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Red Desert"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Red Mischief"	S	S	S	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Redskin"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Resolute"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Rosey Nook"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Ruby Mound"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Silver Sheen"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Sleighride"	I	I	I	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Spinwheel"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Tinkerbell"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Touchdown"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Tranquility"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Tranquility"	S	S	S	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Trident"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "White Grandchild"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Yellow Jeanette"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Yellow Jess Williams"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Yellow Moon"	R	R	R	3-5, to 8	Table			ozone	44
2	chrysanthemum	Chrysanthemum sp. "Yellow Supreme"	I	I	I	3-5, to 8	Table			ozone	44
11	chickory (common)	Cichorium intybus	I		I	3	na	na	chlorosis	ozone	57
11	chicory	Cichorium intybus	I		I	3	0.25 ppm	2 hrs	detectable injury	ozone	60
11	thistle (Canadian)	Cirsium arvense	R		R	2	na	na	no injury - greenhouse study	ozone	57
11	thistle (Canadian)	Cirsium arvense	R	R	R	2	0.30 ppm	2 hrs	detectable injury	ozone	60
11	thistle (Canadian)	Cirsium arvense	R		R	2	0.40 < ppm	2 hrs	detectable injury	ozone	60
6	ivy (grape)	Cissus rhombifolia	R		R		0.10 - 0.15 ppm	2 wks	author did not separate from ethylene/ozone	ozone	10
4	yellowwood	Cladrastis lutea	R		S - R	3	na	na	dark stipple	ozone	57
4	yellowwood	Cladrastis lutea	S		S - R	3	na	na	dark stipple	ozone	57
2	croton	Codiaeum variegatum pictum	I		I	10	0.10 - 0.15 ppm	2 wks	epinastic response of petioles	ozone	10
2	coleus (common)	Coleus blumei	R		R	annual	0.10 - 0.15 ppm	8 days	author did not separate from ethylene/ozone	ozone	10
2	coleus	Coleus sp. "Pastel Rainbow"	S	S	S	annual	Table			ozone	44
2		Collomia linearis	I		I		0.25 < ppm	2 hrs	detectable injury	ozone	60
11	hemlock (poison)	Conium maculatum	R		R	3	0.25 > ppm	2 hrs	detectable injury	ozone	60
2	coreopsis	Coreopsis bigelovii	I		I		0.20 - 0.30 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
11	tickseed (wood)	Coreopsis major	R		R	7	na	na	no injury - field/g.house studies	ozone	57
4	dogwood (silky)	Cornus amomum	I		I		na	na	dark stipple	ozone	57
4	dogwood (flowering)	Cornus florida	S		S - R	5	na	na	dark stipple	ozone	57
4	dogwood (flowering)	Cornus florida	R		S - R	5	na	na	no injury - greenhouse study	ozone	57
4	dogwood (flowering)	Cornus florida	I		S - R	5	na	na	dark stipple	ozone	57
4	cherry (Cornelian)	Cornus mas	R		R		na	na	no injury - field study	ozone	57
4	dogwood (gray)	Cornus racemosa	R		R		na	na	no injury - greenhouse study	ozone	57
4	dogwood (red-osier)	Cornus stolonifera	I		I		na	na	dark stipple	ozone	57
4	filbert (Turkish)	Corylus colurna	R		R	5	na	na	no injury - field study	ozone	57
3	cotoneaster	Cotoneaster divaricata	S		I	5	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	cotoneaster	Cotoneaster horizontalis	S		I	5	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	cotoneaster (spreading)	Cotoneaster sp.	I		I	5	na	na	dark stipple	ozone	57
4	hawthorn (Washington)	Crataegus phaenopyrum	R		R	4	na	na	no injury - field study	ozone	57
4	hawthorn (cockspur)	Crataegus crusgalli	I		I	4	na	na	dark stipple	ozone	57
7	desert winter annual	Cryptantha angustifolia	R		I	annual	0.135 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Cryptantha angustifolia	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
7	desert annual	Cryptantha circumscissa	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
7	desert annual	Cryptantha micrantha	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
7	desert annual	Cryptantha nevadensis	S		S	annual	0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
7	desert winter annual	Cryptantha pterocarya	R		I	annual	0.153 ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Cryptantha pterocarya	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
1a	Bermudagrass	Cynodon dactylon	R		R	warm	na	na	na	smog	7
1a	Bermudagrass	Cynodon dactylon (common)	R	R	R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	Bermudagrass	Cynodon dactylon "Kansas P-16"	I	I	I	warm	Table			ozone	44
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.20 ppm	2 hrs	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.30 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.30 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.30 ppm	2 hrs	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.40 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.40 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.40 ppm	2 hrs	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.50 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon dactylon "Tufcote"	R	R	R	warm	0.50 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	Bermudagrass	Cynodon hyb. "Santa Ana"	R	R	R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	Bermudagrass	Cynodon hyb. "Tufgrass"	R	R	R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	grass (orchard)	Dactylis glomerata	S		R		0.35 ppm	2 hrs	na	ozone	7
1a	grass (orchard)	Dactylis glomerata	na		R		na	na	dry weight reduction	ozone	11
1a	grass (orchard)	Dactylis glomerata	S		R		0.35 ppm	2 hrs	detectable injury symptoms	ozone	31
1a	grass (orchard)	Dactylis glomerata "Potomac"	R	R	R		Table			ozone	44
2	dahlia	Dahlia sp.	S		S	annual/bie	na	na	water-soaked appearance of leaf under-sur	smog	26
1a	grass (crinkled hair)	Deschampsia flexuosa		I	I		0.07 ppm	7 hrs/day for two weeks	4 % reduced growth rate	ozone	48
7	desert annual	Descurainia californica	I		I		0.25 ppm	2 hrs	detectable injury	ozone	60
7	desert annual	Descurainia pinnata	S		S	annual	0.06 – 0.07 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
7	desert annual	Descurainia pinnata	S		S	annual	0.15 ppm	3 hrs day/5 days/wk for 4 mo	90 % leaf injury	ozone	27
7	desert annual	Descurainia pinnata	S		S	annual	0.30 ppm	3 hrs day/5 days/wk for 4 mo	100 % leaf injury, substantial growth red.	ozone	27
7	desert annual	Descurainia pinnata	I		S	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
7	desert annual	Descurainia sp.	I		I	annual	0.06 – 0.07 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
7	desert annual	Descurainia sp.	I		I	annual	0.15 ppm	3 hrs day/5 days/wk for 4 mo	15 % leaf injury	ozone	27
7	desert annual	Descurainia sp.	I		I	annual	0.30 ppm	3 hrs day/5 days/wk for 4 mo	55 % leaf injury, substantial growth red.	ozone	27
1a		Desmazeria rigida		I	I		0.07 ppm	7 hrs/day for two weeks	9 % reduced growth rate	ozone	48
2	carnation (white sim)	Dianthus caryophyllus	S		S	8	0.075 ppm	8 weeks	tip burn	ozone	22
2	carnation (white sim)	Dianthus caryophyllus	S		S	8	0.075 ppm	10 days	depressed bud formation	ozone	22
2	carnation (white sim)	Dianthus caryophyllus	S		S	8	0.18 – 0.20 ppm	2 days	tip burn	ozone	22
10	crabgrass	Digitaria sanguinalis	I		I		na	na	na	smog	7
3	dracaena	Dracaena fragrans massangeana	R		R	10	0.10 – 0.15 ppm	25 days	little effect; light stippling	ozone	10
4	olive (autumn)	Elaeagnus umbellata	I		I		na	na	dark stipple	ozone	57
12	epiphytic orchid	Encyclia tampensis	R		R		0.15 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
12	epiphytic orchid	Encyclia tampensis	R		R		0.30 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
12	epiphytic orchid	Encyclia tampensis	R		R		0.45 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
12	epiphytic orchid	Epidendrum rigidum	R		R		0.15 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
12	epiphytic orchid	Epidendrum rigidum	R		R		0.30 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
12	epiphytic orchid	Epidendrum rigidum	R		R		0.45 ppm	6 hrs	no visible injury, change in foliar conductanc	ozone	45
11	fireweed	Epilobium angustifolium	R		R	3	0.30 ppm	2 hrs	detectable injury	ozone	60
10	willow weed (hairy)	Epilobium hirsutum		R	R	3	0.07 ppm	7 hrs/day for two weeks	2 % reduced growth rate	ozone	48
10		Epilobium watsonii	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
7	desert annual	Eriastrum wilcoxii	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
11	wild buckwheat	Eriogonum heracleoides	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
7	Corsican heron bill	Erodium cicutarium	S	I	I	annual	0.153 ppm	35 hrs over 216 hrs	2 % total foliar damage	ozone	8
7	Corsican heron bill	Erodium cicutarium	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
7	desert annual	Eschscholzia parishii	S		S	annual	0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
7	desert annual	Eucrypta micrantha	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4–5 days	leaf injury	ozone	59
3	euonymus (winged)	Euonymous alatus	R		R	3	ns	ns	no injury – field study	ozone	57
3	euonymous	Euonymous alatus compacta	R		R	3	0.25 ppm	8 hrs	none	ozone	61
2	snakeroot (white)	Eupatorium rugosum	R		R	4	ns	ns	ns	ozone	57
9	poinsettia	Euphorbia pulcherrima	I		I	10	0.10 – 0.15 ppm	12 days	author did not separate from ethylene/ozone	ozone	10
4	beech	Fagus americana	ns				ns	ns	decrease in growth	ozone, SO2, heavy me	32
4	beech (American)	Fagus grandifolia	R		R		0, 0.07, or 0.15 ppm ozone	0 days for 16 weeks	none	ozone/acid rain	34
4	beech (American)	Fagus grandifolia	R		R		0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	no effect	ozone	35
4	beech (American)	Fagus grandifolia	R		R		ns	ns	no injury – field study	ozone	57
4	beech (European)	Fagus sylvatica	R		R	5	0, 0.07, or 0.15 ppm	0 days for 16 weeks	none	ozone/acid rain	34
4	beech (European)	Fagus sylvatica	R		R	5	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	no effect	ozone	35
4	beech (European)	Fagus sylvatica	R		R	5	ns	ns	no injury – field study; dark stipple	ozone	57
1a	fescue (tall)	Festuca arundinacea	ns			cool	ns	ns	decreased root weight 32%; increased shoot	ozone	11
1a	fescue (tall)	Festuca arundinacea 'Alta'	S		S	cool	0–0.40 ppm	6 hrs/day, once a week, for 7 weeks	decrease in yield (44%) and weight per tiller	ozone	24
1a	fescue (tall)	Festuca arundinacea "Fawn"	S		I	cool	0–0.40 ppm	6 hrs/day, once a week, for 7 weeks	decrease in yield (35%) and weight per tiller	ozone	24
1a	fescue (tall)	Festuca arundinacea "Fawn"	R	I	I	cool	0.30 ppm	3 hrs (66–71 days after emergence)	8 % in blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "Fawn"	I	I	I	cool	0.30 ppm	3 hrs (9–14 days after emergence)	10 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "Fawn"	I	I	I	cool	0.40 ppm	3 hrs (66–71 days after emergence)	10 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "Fawn"	S	I	I	cool	0.40 ppm	3 hrs (9–14 days after emergence)	21 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "Fawn"	S	I	I	cool	0.50 ppm	3 hrs (9–14 days after emergence)	26 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "Fawn"	S	I	I	cool	0.50 ppm	3 hrs (66–71 days after emergence)	15 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	S		I-R	cool	0–0.40 ppm	6 hrs/day, once a week, for 7 weeks	decrease in yield (53%) and weight per tiller	ozone	24
1a	fescue (tall)	Festuca arundinacea "K-31"		R	I-R	cool	0.50 ppm	June 20 – Oct 19 1979	no effect	ozone	42
1a	fescue (tall)	Festuca arundinacea "K-31"		R	I-R	cool	0.80 ppm	7 hrs/day from June 20 – Oct 19 1979	no effect	ozone	42
1a	fescue (tall)	Festuca arundinacea "K-31"	R	I	I-R	cool	0.20 ppm	2 hrs	6 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	R	I	I-R	cool	0.30 ppm	3 hrs (66–71 days after emergence)	8 % in blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	I	I	I-R	cool	0.30 ppm	2 hrs	10 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	I	I	I-R	cool	0.30 ppm	3 hrs (9–14 days after emergence)	10 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	S	I	I-R	cool	0.40 ppm	3 hrs (66–71 days after emergence)	15 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	I	I	I-R	cool	0.40 ppm	2 hrs	11 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	S	I	I-R	cool	0.40 ppm	3 hrs (9–14 days after emergence)	23 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	S	I	I-R	cool	0.50 ppm	3 hrs (66–71 days after emergence)	20 % of blade area injured	ozone	53
1a	fescue (tall)	Festuca arundinacea "K-31"	S	I	I-R	cool	0.50 ppm	3 hrs (9–14 days after emergence)	30 % of blade area injured	ozone	53
1a	fescue	Festuca octoflora	R	R	R	cool	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
1a	fescue	Festuca octoflora	R	R	R	cool	0.30 > ppm	8 hrs/day for 4–5 days	no injury	ozone	59
1a	fescue (sheep)	Festuca ovina		I	I	cool	0.07 ppm	7 hrs/day for two weeks	6 % of blade area injured	ozone	48
1a	fescue (Chewings)	Festuca rubra var. commutata	S		S	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	fescue (Chewings)	Festuca rubra var. commutata "Jamestown"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	fescue (red)	Festuca rubra "Highlight"	R		I	cool	0.25 – 0.30 ppm	6 hrs	some brown stippling	ozone	7
1a	fescue (red)	Festuca rubra "Highlight"	R	I	I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	fescue (red)	Festuca rubra "Highlight"	R		I	cool	0.15 ppm each	6 hrs/day for 10 days	7 % < leaf injury	O3/SO2/NO2	16
1a	fescue (red)	Festuca rubra "Highlight"	I	I	I	cool	Table			ozone	44
1a	fescue (creeping red)	Festuca rubra "Illahee"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	I		S-I	cool	0.25 – 0.30 ppm	6 hrs	brown stippling, trace of bleaching	ozone	7
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	R		S-I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	R		S-I	cool	0.15 ppm each	6 hrs/day for 10 days	7 % < leaf injury	O3/SO2/NO2	16
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	I	I	S-I	cool	Table			ozone	44
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S	S	S-I	cool	0.20 ppm	2 hrs	36 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	R		S-I	cool	0.30 ppm	3 hrs (9–14 days after emergence)	3 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S-I	cool	0.30 ppm	3 hrs (66–71 days after emergence)	15 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S-I	cool	0.30 ppm	2 hrs	26 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S-I	cool	0.40 ppm	2 hrs	30 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S-I	cool	0.40 ppm	3 hrs (66–71 days after emergence)	28 % of blade area injured	ozone	53

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S – I	cool	0.40 ppm	0 hrs (9 – 14 days after emergence)	26 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S – I	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	20 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	S		S – I	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	31 % of blade area injured	ozone	53
1a	fescue (creeping red)	Festuca rubra "Pennlawn"	I		S – I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
3	forsythia	Forsythia intermedia spectabilis "Tywood g	S		S	5	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
6	strawberry	Fragaria ovalis	R		R		na	na	chlorosis	ozone	57
6	strawberry	Fragaria ovalis	I		R		na	na	chlorosis	ozone	57
6	strawberry	Fragaria ovalis	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
4	ash (white)	Fraxinus americana	na		S – I	4	0.10 ppm	4 hr/day for 5 days/wk for 6 weeks	decrease in biomass	ozone, acidic precip..	13
4	ash (white)	Fraxinus americana	I		S – I	4	0, 0.075, or 0.15 ul. L – 1	6 hrs d – 1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	ash (white)	Fraxinus americana			S – I	4	0.30 ppm	8 hrs/day for 5 months	premature leaf drop	ozone	33
4	ash (white)	Fraxinus americana	S		S – I	4	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	foliar injury; slight decrease in height, growth	ozone	35
4	ash (white)	Fraxinus americana	I	I	S – I	4	Table			ozone	44
4	ash (white)	Fraxinus americana	S	S	S – I	4	0.129 ppm (max)	growing season 1989 – wet conditions	widespread foliar stippling (in many plants/s	ozone	56
4	ash (white)	Fraxinus americana	S		S – I	4	0.197 ppm (max)	growing season 1988 – drought conditions	no visible injury	ozone	56
4	ash (white)	Fraxinus americana	R		S – I	4	na	na	dark stipple	ozone	57
4	ash (white)	Fraxinus americana	S		S – I	4	na	na	dark stipple, chlorosis	ozone	57
4	ash (white)	Fraxinus americana	I		S – I	4	na	na	dark stipple	ozone	57
4	ash (European)	Fraxinus excelsior	I		I – R	4	na	na	dark stipple	ozone	57
4	ash (Hesse European)	Fraxinus excelsior	R		I – R	4	na	na	no injury – field study	ozone	57
4	ash (European)	Fraxinus excelsior	R		I – R	4	na	na	dark stipple	ozone	57
4	ash (Oregon)	Fraxinus oregana	S		S		na	na	na	ozone	9
4	ash (flowering)	Fraxinus ornus	R		R	6	na	na	no injury – field study	ozone	57
4	ash (green)	Fraxinus pennsylvanica	na		S – I	3	na	na	reduced sugar and starch content of roots	ozone	11
4	ash (green)	Fraxinus pennsylvanica	na		S – I	3	0.10 ppm	4 hr/day for 5 days/wk for 6 weeks	decrease in biomass	ozone, acidic precip..	13
4	ash (green)	Fraxinus pennsylvanica			S – I	3	0.30 ppm	8 hrs/day for 5 months	premature leaf drop	ozone	33
4	ash (green)	Fraxinus pennsylvanica			S – I	3	0.10 – 0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
4	ash (green)	Fraxinus pennsylvanica	R		S – I	3	na	na	no injury – field study; dark stipple	ozone	57
4	ash (green)	Fraxinus pennsylvanica	I		S – I	3	na	na	dark stipple	ozone	57
4	ash (green)	Fraxinus pennsylvanica	S		S – I	3	na	na	dark stipple	ozone	57
4	ash (blue)	Fraxinus quadrangulata	R		R		na	na	no injury – field study	ozone	57
4	ash	Fraxinus sp.	S		S – R	3 – 6	na	na	na	ozone	9
4	ash	Fraxinus sp.	na		S – R	3 – 6	na	na	abnormal growth	ozone	32
4	ash	Fraxinus sp.	R		S – R	3 – 6	na	na	no injury – field study	ozone	57
3	fuchsia	Fuchsia hybrida	I		I	9	0.10 – 0.15 ppm	2 wks	severe defoliation	ozone	10
10	bedstraw or madder	Galium bifolium	R		R		0.30 > ppm	2 hrs	detectable injury	ozone	60
12		Gayophytum racemosum	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
11	marsh pink	Gentiana amarella	I		I		na	na	chlorosis	ozone	57
11	marsh pink	Gentiana amarella	S		I		na	na	chlorosis	ozone	57
11	marsh pink	Gentiana amarella	I		I		0.15 > ppm	2 hrs	detectable injury	ozone	60
2	geranium	Geranium fremontii	S	S	S		0.05 – 0.07 ppm	2 hrs/day	7 % leaf injury	ozone (ambient)	27
2	geranium	Geranium fremontii	S		S		0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	50 % leaf injury	ozone	27
2	geranium	Geranium fremontii	S		S		0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	90 % leaf injury, substantial growth red.	ozone	27
2	geranium	Geranium fremontii	I		S		0.25 < pphm	2 hrs	detectable injury	ozone	60
2	geranium	Geranium richardsonii	S		S		0.15 ppm	2 hrs	detectable injury	ozone	60
2	geranium	Geranium sp.	R		R	2 – 7	0.41 ppm	2 hrs	detectable injury symptoms	ozone	31
2	avens (mountain)	Geum radiatum	R		R		na	na	no injury – field/g.house studies	ozone	57
7	desert annual	Gilia stellata	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
4	ginkgo	Ginkgo biloba	R		R	5	na	na	no injury – field study; dark stipple	ozone	57
4	locust (thornless honey)	Gleditsia triacanthos inermis	R		I	5	na	na	dark stipple	ozone	57
4	locust (thornless honey)	Gleditsia triacanthos inermis	S		I	5	na	na	dark stipple	ozone	57
4	locust (thornless honey)	Gleditsia triacanthos inermis	I		I	5	na	na	dark stipple	ozone	57
4	locust (thornless honey)	Gleditsia triacanthos inermis	S		I	5	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61

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1	grass (manna)	Glyceria nubigena	S		S		na	na	na	ozone	57
4	coffee tree (Kentucky)	Gymnocladus dioica	R		R	4	na	na	dark stipple	ozone	57
6	ivy (English)	Hedera helix	R		R	5	0.25 ppm	8 hrs	none	ozone	61
10	vetch (sweet)	Hedysarum boreale	S		S		0.15 ppm	2 hrs	detectable injury	ozone	60
2	sunflower (common)	Helianthus annuus	R		R	annual	na	na	no injury - greenhouse study	ozone	57
2	sunflower (common)	Helianthus annuus	R		R	annual	0.30 > ppm	2 hrs	detectable injury	ozone	60
2	sunflower (common)	Helianthus annuus			R	annual	0.10 ppm	30 min/hr 8 hrs/day for 18 days	no visible injury or change in dry weight, ozb	ozone	63
1	grass (velvet)	Holcus lanatus		I	I		0.07 ppm	7 hrs/day for two weeks	4 % reduced growth rate	ozone	48
1	grass	Hordeum murinum		I	I		0.07 ppm	7 hrs/day for two weeks	5 % reduced growth rate	ozone	48
5	holly (English)	Ilex aquifolium	R	R	R	7	Table			ozone	44
5	holly (English)	Ilex aquifolium	R		R	7	na	na	no injury - field study	ozone	57
3	holly (Hetz Japanese)	Ilex crenata	R		R	6	na	na	no injury - greenhouse study	ozone	57
5	holly (American)	Ilex opaca	R		R	6	na	na	no injury - greenhouse study	ozone	57
11	Dyer's woad	Isatis tinctoria	S		S	5	0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	25 % leaf injury	ozone	27
11	Dyer's woad	Isatis tinctoria	S		S	5	0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	70 % leaf injury, substantial growth red.	ozone	27
11	Dyer's woad	Isatis tinctoria	S		S	5	0.50 - 0.70 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
4	walnut (black)	Juglans nigra			R	5	0.30 ppm	8 hrs/day for 5 months	premature leaf drop	ozone	33
4	walnut (black)	Juglans nigra	R		R	5	na	na	no injury - field study	ozone	57
6	rush	Juncus sp.	I		R	5	na	na	chlorosis	ozone	57
6	rush	Juncus sp.	R		R	5	0.25 > ppm	2 hrs	detectable injury	ozone	60
3	juniper (Pfitzer)	Juniperus chinensis "Pfitzeriana"					0.20 - 0.40 ppm	4 days/wk for 6 - 7 wks	decreased chlorophyll	ozone	38
6	juniper (creeping)	Juniperus communis depressa plumosa	R		R	2	0.25 ppm	8 hrs	none	ozone	61
3	juniper (western)	Juniperus occidentalis	I		I		na	na	na	ozone	9
3	juniper (western)	Juniperus occidentalis	R		R		ambient - - CA forests	tree lifetime through 1970	no chlorosis on needles	oxidant air pollution	40
3	juniper (Savin)	Juniperus sabina "Tamariscifolia				4	0.20 - 0.40 ppm	4 days/wk for 6 - 7 wks	decreased chlorophyll	ozone	38
3	juniper (shore)	Juniperus sp.	S		S	2 - 5	na	na	other symptoms	ozone	57
5	cedar (red)	Juniperus virginiana	R		R	2	na	na	no injury - field study	ozone	57
9	kalanchoe	Kalanchoe blossfeldiana	I		I	9	0.10 - 0.15 ppm	9 days	severely delayed flowering with considerable	ozone	10
3	mountain laurel	Kalmia latifolia	R		R	5	na	na	no injury - greenhouse study	ozone	57
1	grass	Koeleria macrantha		I	I		0.07 ppm	7 hrs/day for two weeks	5 % reduced growth rate	ozone	48
4	raintree (panicled golden)	Koelreuteria paniculata	R		S - R	5	na	na	dark stipple	ozone	57
4	raintree (panicled golden)	Koelreuteria paniculata	S		S - R	5	na	na	dark stipple	ozone	57
11	dandelion (mountain)	Krigia montana	S		S		na	na	other symptoms	ozone	57
7	desert annual	Langloisia schottii	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4 - 5 days	leaf injury	ozone	59
4	larch (European)	Larix decidua	I	I	I	3	Table			ozone	44
4	larch (European)	Larix decidua	S		I	3	na	na	chlorosis	ozone	57
4	larch (Japanese)	Larix leptolepsis	R	R	R	4	Table			ozone	44
4	larch (Japanese)	Larix leptolepsis	S		R	4	na	na	chlorosis	ozone	57
2	sweet pea	Lathyrus laetiflorus	R		R		0.25 > ppm	2 hrs	detectable injury	ozone	60
2	sweet pea	Lathyrus pauciflorus	I		I		0.25 ppm	2 hrs	detectable injury	ozone	60
1	grass (pepper)	Lepidum lasiocarpum	R		R	annual	0.30 > ppm	8 hrs/day for 4 - 5 days	no injury	ozone	59
1	grass (pepper)	Lepidum virginicum	S		S	annual	0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury	ozone	27
1	grass (pepper)	Lepidum virginicum	S		S	annual	0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury, substantial growth red.	ozone	27
1	grass (pepper)	Lepidum virginicum	S		S	annual	0.50 - 0.70 ppm (ambient)	2 hrs/day	50 % leaf injury	ozone	[illegible]
3	privet (Amur)	Ligustrum amurense	R		R		na	na	no injury - greenhouse study	ozone	57
2	lily (Easter)	Lilium longiflorum	I		I		0.10 - 0.15 ppm	2 wks (emergence)	stem elongation	ozone	10
2	lily (Easter)	Lilium longiflorum	I		I		0.10 - 0.15 ppm	2 wks (flowering)	shortened stems, damaged lower leaves	ozone	10
2	lily (Easter)	Lilium longiflorum	I		I		0.10 - 0.15 ppm	16 days (elongation)	shortened stems, damaged lower leaves	ozone	10
3	spicebush	Lindera benzoin	R		R	4	na	na	no injury - field study	ozone	57
12		Linguisticum porteri	S		S		0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	50 % leaf injury	ozone	27
12		Linguisticum porteri	S		S		0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury, substantial growth red	ozone	27
12		Linguisticum porteri	S		S		0.50 - 0.70 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
4	sweet gum	Liquidambar styraciflua	I		S	5	0, 0.035, or 0.15 ul. l - 1	6 hrs d - 1 on 2 consecutive days for 12 wks	dark adaxial stipple	ozone	15

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4	sweet gum	Liquidambar styraciflua	S		S	5	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	foliar injury; reduction in height, leaf mass +	ozone	35
4	sweet gum	Liquidambar styraciflua			S	5	0.10 – 0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
4	sweet gum	Liquidambar styraciflua	S	S	S	5	0.129 ppm (max)	growing season 1989 – wet conditions	widespread foliar stippling (in many plants/sl	ozone	56
4	sweet gum	Liquidambar styraciflua	S		S	5	0.197 ppm (max)	growing season 1988 – drought conditions	no visible injury	ozone	56
4	sweet gum	Liquidambar styraciflua	S		S	5	na	na	dark stipple, chlorosis	ozone	57
4	sweet gum	Liquidambar styraciflua	R		S	5	na	na	no injury – field study	ozone	57
4	sweet gum	Liquidambar styraciflua	I		S	5	na	na	dark stipple	ozone	57
4	tulip poplar	Liriodendron tulipifera	na		S	5	na	na	reduced carbohydrate production	ozone	11
4	tulip poplar	Liriodendron tulipifera	na		S	5	0.04 ppmh	7 hrs/day for 8 weeks	na	ozone, acidic precip.,	13
4	tulip poplar	Liriodendron tulipifera	na	S	S	5	0.08 ppm	7 hrs/day for 8 weeks	average leaf injury of 33%; greater defoliatio	ozone, acidic precip.,	13
4	tulip poplar	Liriodendron tulipifera	I		S	5	0, 0.075, or 0.15 ul L – 1	6 hrs d – 1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	tulip poplar	Liriodendron tulipifera			S	5	0.30 ppm	8 hrs/day for 5 months	premature leaf drop	ozone	33
4	tulip poplar	Liriodendron tulipifera	S		S	5	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	foliar injury; reduction in height, leaf mass +	ozone	35
4	tulip poplar	Liriodendron tulipifera	S	S	S	5	0.129 ppm (max)	growing season 1989 – wet conditions	widespread foliar stippling (in many plants/sl	ozone	56
4	tulip poplar	Liriodendron tulipifera	S	R	S	5	0.197 ppm (max)	growing season 1988 – drought conditions	no visible injury	ozone	56
4	tulip poplar	Liriodendron tulipifera	S		S	5	na	na	dark stipple	ozone	57
4	tulip poplar	Liriodendron tulipifera	R		S	5	na	na	no injury – field study	ozone	57
4	tulip poplar	Liriodendron tulipifera	I		S	5	na	na	dark stipple	ozone	57
	ryegrass (Italian)	Lolium multiflorum		R	R	cool	0.30 ppm	hrs/day for 6 weeks	< 10 % reduction in leaf area	ozone	3
	ryegrass (Italian)	Lolium multiflorum		R	R	cool	0.90 ppm	hrs/day for 6 weeks	35 % reduction in leaf area	ozone	3
	ryegrass (Italian)	Lolium multiflorum	na		R	cool	na	na	reduced root weight (32%) and shoot weight	ozone	11
	ryegrass (Italian)	Lolium multiflorum	S	I	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne	na		I	cool	na	na	dry weight reduction	ozone	11
	ryegrass (perennial)	Lolium perenne	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne "Lamora"	I		I	cool	0.23 – 0.30 ppm	6 hrs	necrosis, dark – brown discoloration	ozone	7
	ryegrass (perennial)	Lolium perenne "Lamora"	I	I	I	cool	Table			ozone	44
	ryegrass (perennial)	Lolium perenne "Lamora"	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne "Linn"	R	I	I	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	8 % fo blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	I	I	I	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	10 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	I	I	I	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	S	I	I	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	S	I	I	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	21 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	S	I	I	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	15 % of blade area injued	ozone	53
	ryegrass (perennial)	Lolium perenne "Linn"	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.23 – 0.30 ppm	6 hrs	necrosis, dark – brown discoloration	ozone	7
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.15 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	16
	ryegrass (perennial)	Lolium perenne "Manhattan"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
	ryegrass (perennial)	Lolium perenne "Manhattan"	I	I	I	cool	Table			ozone	44
	ryegrass (perennial)	Lolium perenne "Manhattan"	R		I	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	6 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	R		I	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	3 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	11 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	16 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	16 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	I		I	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	11 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Manhattan"	S		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne "NK – 100"	I	I	I	cool	0.20 ppm	2 hrs	8 % fo blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "NK – 100"	I	I	I	cool	0.30 ppm	2 hrs	11 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "NK – 100"	S	I	I	cool	0.40 ppm	2 hrs	26 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "NK – 100"	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
	ryegrass (perennial)	Lolium perenne "Norlea"	R	R	R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Norlea"	S	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	16 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Norlea"	I	R	R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
	ryegrass (perennial)	Lolium perenne "Norlea"	S	R	R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53

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1	ryegrass (perennial)	Lolium perenne 'Norlea'	S	R	R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	15 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Norlea'	S	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	25 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	I	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	11 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	R	R	R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	I	R	R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	10 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	S	R	R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	I	R	R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	S	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	20 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pelo'	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	R	R	R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	I	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	11 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	I	R	R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	11 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	S	R	R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	21 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	S	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	S	R	R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	16 % of blade area injured	ozone	53
1	ryegrass (perennial)	Lolium perenne 'Pennfine'	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	ryegrass (perennial)	Lolium perenne 'Splendor'	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	ryegrass (perennial)	Lolium perenne 'Talbot'		R	R	cool	0.07 ppm	7 hrs/day for two weeks	2 % reduced growth rate	ozone	48
3	honeysuckle (Japanese)	Lonicera japonica	R		R		na	na	no injury – field study	ozone	57
3	honeysuckle (morrow)	Lonicera morrowii	R		R		na	na	no injury – greenhouse study	ozone	57
11	trefoil	Lotus tomentellus	I		I		0.20 – 0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
2	lupine	Lupinus cochinus	R		I		0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
2	lupine	Lupinus cochinus	I		I		0.20 – 0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
4	Osage orange	Maclura pomifera	R		R	5 – 6	na	na	no injury – field study	ozone	57
11	tarweed	Madia glomerata	S		S	annual	0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury	ozone	27
11	tarweed	Madia glomerata	S		S	annual	0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury, substantial growth red.	ozone	27
11	tarweed	Madia glomerata	S		S	annual	0.50 – 0.70 ppm (ambient)	2 hrs/day	40 % leaf injury	ozone	27
4	cucumber tree	Magnolia acuminata	R		R	5	na	na	no injury – field study	ozone	57
5	magnolia (umbrella)	Magnolia tripetala	R		R		na	na	no injury – field study	ozone	57
5	magnolia (umbrella)	Magnolia tripetala	R		R		na	na	dark stipple	ozone	57
6	mahonia (creeping)	Mahonia repens	R		R	5	0.40 > ppm	2 hrs	detectable injury	ozone	60
7	desert annual	Malacothrix glabrata	S		S	annual	0.10 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
4	crabapple	Malus coronarioides	R		R		na	na	no injury – field study	ozone	57
11	white sweet clover	Melilotus alba	I	I	I	3	Table			ozone	44
12		Monardella albicaulis	S		S		0.10 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
2	bluebell or lungwort	Mertensia sibirica	R		R	3 - 5	0.30 ppm	2 hrs	detectable injury	ozone	60
2	monkeyflower (yellow)	Mimulus guttatus	R		R	5	0.25 > ppm	2 hrs	detectable injury	ozone	60
2	muskflower	Mimulus moschatus	R		R		0.40 < pphm	2 hrs	detectable injury	ozone	60
11	miter wort	Mitella stauropetala	R		R	3	0.30 > ppm	2 hrs	detectable injury	ozone	60
4	mulberry	Morus sp.	I		I	4 – 7	na	na	dark stipple	ozone	57
9	fern (Boston)	Nephrolepis exaltata	R		R	10	0.10 – 0.15 ppm	22 days	author did not separate from ethylene/ozone	ozone	10
4	blackgum	Nyssa sylvatica	R		R	4	na	na	no injury – field/g.house studies	ozone	57
2	primrose (evening)	Oenothera californica	R		I		0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
2	primrose (evening)	Oenothera californica	I		I		0.20 – 0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
11	aniseroot	Osmorhiza occidentalis	I		I		0.25 ppm	2 hrs	detectable injury	ozone	60
4	hophornbeam (Eastern)	Ostrya virginiana	R		R	4	na	na	no injury – field study	ozone	57
6	pachysandra	Pachysandra terminalis	R		R	4	0.25 ppm	8 hrs	none	ozone	64
6	paxistima	Pachystima myrsinites	R		R	5	na	na	no injury – greenhouse study	ozone	57
6	paxistima	Pachystima myrsinites	R		R	5	0.30 > ppm	2 hrs	detectable injury	ozone	60
11	ginseng (American)	Panax quinquefolius	I		I – R	3	na	na	dark stipple	ozone	57
11	ginseng (American)	Panax quinquefolius	R		I – R	3	na	na	no injury – field/g.house studies, dark stipple	ozone	57
6	Virginia creeper	Parthenocissus quinquefolia	S		S	3	na	na	dark stipple	ozone	57
4	empresstree	Paulownia tomentosa	R		R	5	na	na	no injury – field study	ozone	57

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2	desert annual	Pectocarya heterocarpa	S		S	annual	0.10 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
2	desert annual	Pectocarya platycarpa	S		S	annual	0.10 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
2	geranium (common)	Pelargonium hortorum	I		I	annual	0.10-0.15 ppm	6 days	longer flower stalks, defoliation	ozone	10
2	desert annual	Perityle emoryi	R		R	annual	0.30 > ppm	8 hrs/day for 4-5 days	no injury	ozone	59
2	petunia	Petunia double grandiflora "Blue Danube"	R	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia double grandiflora "Blue Danube"	R	R	R	annual	0.50 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia double grandiflora "Blue Danube"	R	R	R	annual	1.0 ppm	1 hr	2 % injury to plant	ozone	21
2	petunia	Petunia grandiflora bicolor "Calypso"	I	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora bicolor "Calypso"	I	R	R	annual	0.50 ppm	1 hr	3 % injury to plant	ozone	21
2	petunia	Petunia grandiflora bicolor "Calypso"	I	R	R	annual	1.0 ppm	1 hr	10 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Blue Jeans"	R	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Blue Jeans"	R	R	R	annual	0.50 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Blue Jeans"	R	R	R	annual	1.0 ppm	1 hr	14 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Blue Sea"	S	R	R	annual	0.25 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Blue Sea"	S	R	R	annual	0.50 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Blue Sea"	S	R	R	annual	1.0 ppm	1 hr	38 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Cherry Blossom"	R	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Cherry Blossom"	R	R	R	annual	0.50 ppm	1 hr	5 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Cherry Blossom"	R	R	R	annual	1.0 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Lilac Time"	R	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Lilac Time"	R	R	R	annual	0.50 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Lilac Time"	R	R	R	annual	1.0 ppm	1 hr	3 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Parti Pink" (pink)	I	R	R	annual	0.25 ppm	3 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Parti Pink" (pink)	I	R	R	annual	0.50 ppm	3 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Parti Pink" (pink)	I	R	R	annual	1.0 ppm	1 hr	22 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Peach Blossom"	I	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Peach Blossom"	I	R	R	annual	0.50 ppm	1 hr	1 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Peach Blossom"	I	R	R	annual	1.0 ppm	1 hr	27 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Red Magic" (red)	S	I	I	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Red Magic" (red)	S	I	I	annual	0.50 ppm	1 hr	12 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Red Magic" (red)	S	I	I	annual	1.0 ppm	1 hr	37 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Roulette"	S	I	I	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Roulette"	S	I	I	annual	0.50 ppm	1 hr	9 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Roulette"	S	I	I	annual	1.0 ppm	1 hr	36 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Warrior"	S	I	I	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia grandiflora "Warrior"	S	I	I	annual	0.50 ppm	1 hr	7 % injury to plant	ozone	21
2	petunia	Petunia grandiflora "Warrior"	S	I	I	annual	1.0 ppm	1 hr	30 % injury to plant	ozone	21
2	petunia	Petunia hybrida "Rose Charm"	I		I	annual	0.34 ppm	2 hrs	detectable injury symptoms	ozone	31
2	petunia	Petunia multiflora bicolor "Peaches and Crea	I	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia multiflora bicolor "Peaches and Crea	I	R	R	annual	0.50 ppm	1 hr	3 % injury to plant	ozone	21
2	petunia	Petunia multiflora bicolor "Peaches and Crea	I	R	R	annual	1.0 ppm	1 hr	25 % injury to plant	ozone	21
2	petunia	Petunia multiflora "Festival"	S	I	I	annual	0.25 ppm	3 hr	1 % injury	ozone	21
2	petunia	Petunia multiflora "Festival"	S	I	I	annual	0.50 ppm	1 hr	9 % injury to plant	ozone	21
2	petunia	Petunia multiflora "Festival"	S	I	I	annual	1.0 ppm	1 hr	38 % injury to plant	ozone	21
2	petunia	Petunia multiflora "Victory"	R	R	R	annual	0.25 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia multiflora "Victory"	R	R	R	annual	0.50 ppm	1 hr	no effect	ozone	21
2	petunia	Petunia multiflora "Victory"	R	R	R	annual	1.0 ppm	1 hr	7 % injury to plant	ozone	21
2	petunia	Petunia sp.	S		S	annual	na	na	"silvering" of the lower surface	smog	26
2	petunia	Petunia sp.	S		S	annual	na	na	na	ozone	56
2	petunia	Petunia sp. "Blue Danube"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Blue Jeans"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Blue Sea"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Bonanza"	R	R	R	annual	Table			ozone	44

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
2	petunia	Petunia sp. "Calypso"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Canadian – All Double Mix	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Capri"	S	S	S	annual	Table			ozone	44
2	petunia	Petunia sp "Cherry Blossom"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Comanche"	I	I	I	annual	Table			ozone	44
2	petunia	Petunia sp. "Festival"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Lilac Time"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Patti Pink"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Peach Blossom"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Peaches and Cream"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Pink Cascade"	S	S	S	annual	Table			ozone	44
2	petunia	Petunia sp. "Red Magic"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Roulette"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Snowstorm"	I		I	annual	0.10 ppm	2 hrs	no effect	ozone	30
2	petunia	Petunia sp. "Snowstorm"	I		I	annual	0.25 ppm	2 hrs	slight adaxial flecking in apical tissue of basa	ozone	30
2	petunia	Petunia sp. "Snowstorm"	I		I	annual	Brooklyn, NY air	5 – 7 months	adaxial/bifacial/interveinal white necrosis on	ambient air	30
2	petunia	Petunia sp. "Victory"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "Warrior"	R	R	R	annual	Table			ozone	44
2	petunia	Petunia sp. "White Cascade"				annual	0.125,0.078,0.103 ppm peak	Aug 2 – Sept 15, 1968	flecking/chlorosis, some necrosis mostly on lo	ambient Cincinnati air	50
7	phacelia (harebell)	Phacelia campanularia	I		I	annual	0.20 – 0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
7	phacelia	Phacelia heterophylla	S		S	annual	0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	35 % leaf injury	ozone	27
7	phacelia	Phacelia heterophylla	S		S	annual	0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	80 % leaf injury, growth not sig reduc.	ozone	27
7	phacelia	Phacelia heterophylla	S		S	annual	0.50 – 0.70 ppm (ambient) ??	2 hrs/day	3 % leaf injury	ozone	27
7	phacelia	Phacelia heterophylla	I		S	annual	0.25 < ppm	2 hrs	detectable injury	ozone	60
1	grass (Canary)	Phalaris aquatica	na				na	na	dry weight reduction	ozone	11
1	grass (Canary)	Phalaris canariensis	S		S	annual	na	na	na	ozone	7
2	morning glory	Pharbitis "Scarlet O'Hara"	S		S	annual	na	na	other symptoms	ozone	57
3	mock – orange (sweet)	Philadelphus coronarius	I		S – I	4	na	na	tan stipple	ozone	57
3	mock – orange (sweet)	Philadelphus coronarius	S		S – I	4	na	na	tan stipple	ozone	57
9	philodendron	Philodendron cordatum	R		R	10	0.10 – 0.15 ppm	3 wks	author did not separate from ethylene/ozone	ozone	10
3	ninebark (dwarf)	Physocarpus opulifolius	S		S	2	na	na	dark stipple	ozone	57
5	spruce (Norway)	Picea abies	na		R	2	na	na	decrease in growth	ozone, SO2, heavy me	32
5	spruce (Norway)	Picea abies	R	R	R	2	Table			ozone	44
5	spruce (Norway)	Picea abies	R		R	2	na	na	no injury – field/ghouse studies	ozone	57
5	spruce (white)	Picea glauca	R	R	R	3	Table			ozone	44
5	spruce (white)	Picea glauca	R		R	3	na	na	no injury – greenhouse study	ozone	57
5	spruce (Black Hills)	Picea glauca var. densata	R		R		na	na	no injury – greenhouse study	ozone	57
5	spruce (black)	Picea mariana	R	R	R	3	Table			ozone	44
5	spruce (Colorado blue)	Picea pungens	R		R	3	na	na	no injury – greenhouse study	ozone	57
5	spruce (blue)	Picea pungens?	R	R	R	3	Table			ozone	44
5	spruce (red)	Picea rubens	na				na	na	decrease in growth	ozone, SO2	32
3	pieris	Pieris japonica	R		R	6	0.25 ppm	8 hrs	none	ozone	61
4	pine (bristlecone)	Pinus Aristata; Pinus longaeva	R		R	5	na	na	other symptoms	ozone	57
5	pine (knobcone)	Pinus attenuata	I		I		na	na	na	ozone	9
5	pine (knobcone)	Pinus attenuata			I		0.36 ppm	12 hrs/day for 37 days	9 in order of decr. sens (1 = highest)	ozone	39
5	pine (knobcone)	Pinus attenuata	I		I		ambient – – CA forests	tree lifetime through 1970	3 – 4 annual needle whorls retained, chlorosi	oxidant air pollution	40
5	pine (knobcone)	Pinus attenuata	na		I		na	na	ozone – type mottling	ozone	51
5	pine (Jack)	Pinus banksiana	I	S	S		0.25 ppm	2 hrs	45 % of plants were injured	ozone	5
5	pine (Jack)	Pinus banksiana	S	S	S		0.50 ppm	2 hrs	97 % of plants were injured	ozone	5
5	pine (Jack)	Pinus banksiana	S	S	S		Table			ozone	44
5	pine (Jack)	Pinus banksiana	S		S		na	na	chlorosis, other	ozone	57
5	pine (Jack)	Pinus banksiana	I		S		na	na	chlorosis	ozone	57
5	pine (Jack)	Pinus banksiana	R		S		na	na	chlorosis	ozone	57

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant			Sensitivity Class			Temp.	Level of	Duration of			Data
Type	Common Name	Species Name	Auth.	NRC	Final	Zone	Exposure	Exposure	Effects	Pollutant	Source
5	pine (Afghanistan)	Pinus brutia	na				na	na	ozone-type mottling	ozone	51
5	pine (Canary Island)	Pinus canariensis	S		S		0.30 ppm	7 hrs for 14 days	chlorotic mottle	ozone	51
5	pine (Canary Island)	Pinus canariensis			S		0.30 ppm	7 hr/day for 14 days	chlorotic mottling on needles	ozone	51
5	pine (lodgepole)	Pinus contorta	I		I	6	na	na	na	ozone	9
5	pine (lodgepole)	Pinus contorta	I		I	6	ambient -- CA forests	tree lifetime through 1970	4+ needle whorls retained, oldest whorls chl	oxidant air pollution	40
5	pine (Coulter)	Pinus coulteri	S		S-I	7	na	na	na	ozone	9
5	pine (Coulter)	Pinus coulteri		I	S-I	7	0.36 ppm	12 hrs/day for 37 days	6 in order of decr. sens (1=highest)	ozone	39
5	pine (Coulter)	Pinus coulteri	S		S-I	7	ambient -- CA forests	tree lifetime through 1970	1-2 ann. needle whorls, short, chlorotic, ner	oxidant air pollution	40
5	pine (Japanese red)	Pinus densiflora	na			4	na	na	ozone-type mottling	ozone	51
5	pine (shortleaf)	Pinus echinata	na				na	na	decrease in growth	ozone, SO2	32
5	pine (Aleppo)	Pinus halepensis			S		0.30 ppm	7 hr/day for 14 days	chlorotic mottling on needles	ozone	51
5	pine (Aleppo)	Pinus halepensis	S		S		0.30 ppm	7 hrs for 14 days ??	chlorotic mottle	ozone	51
5	pine (Jeffrey)	Pinus jeffreyi	S		S	5	na	na	na	ozone	9
5	pine (Jeffrey)	Pinus jeffreyi			S	5	0.36 ppm	12 hrs/day for 37 days	4 in order of decr. sens. (1=highest)	ozone	39
5	pine (Jeffrey)	Pinus jeffreyi	S		S	5	ambient -- CA forests	tree lifetime through 1970	1-2 ann. needle whorls, short, chlorotic, ner	oxidant air pollution	40
5	pine (Jeffrey)	Pinus jeffreyi	na		S	5	na	na	ozone-type mottling	ozone	51
5	pine (Jeffrey/Coulter hybrid)	Pinus jeffreyi x Pinus coulteri			S		0.36 ppm	12 hrs/day for 37 days	1 in order of decr. sens. (1=highest)	ozone	39
5	pine (sugar)	Pinus lambertiana	I		I-R		na	na	na	ozone	9
5	pine (sugar)	Pinus lambertiana		R	I-R		0.36 ppm	12 hrs/day for 37 days	12 in order of decr. sens. (1=highest)	ozone	39
5	pine (sugar)	Pinus lambertiana	I		I-R		ambient -- CA forests	tree lifetime through 1970	4+ needle whorls retained, oldest whorls chl	oxidant air pollution	40
5	pine (single leaf pinyon)	Pinus monophylla	R				ambient -- CA forests	tree lifetime through 1970	4+ annual needle whorls retained w/ no chlo	oxidant air pollution	40
5	pine (Montezuma)	Pinus montezumae	na			8	na	na	ozone-type mottling	ozone	51
5	pine (Western white)	Pinus monticola	S		S		na	na	na	ozone	9
5	pine (Western white)	Pinus monticola			S		0.36 ppm	12 hrs/day for 37 days	2 in order of decr. sens. (1=highest)	ozone	39
5	pine (Austrian)	Pinus nigra	I	I	I	4	Table			ozone	44
5	pine (Austrian)	Pinus nigra	I		I	4	na	na	chlorosis	ozone	57
5	pine (Austrian)	Pinus nigra	R		I	4	na	na	no injury - field/g.house studies	ozone	57
5	pine (Austrian)	Pinus nigra	S		I	4	na	na	other symptoms	ozone	57
5	pine (oocarpa)	Pinus oocarpa	na				na	na	chlorotic mottling on needles	ozone	51
5	pine (Japanese white)	Pinus parviflora	S		S	4	na	na	other symptoms	ozone	57
5	pine (Mexican weeping)	Pinus patula	na				na	na	chlorotic mottling on needles	ozone	51
5	pine (maritime)	Pinus pinaster	na			7	na	na	chlorotic mottling on needles	ozone	51
5	pine (ponderosa)	Pinus ponderosa	S		S	9	na	na	na	ozone	9
5	pine (ponderosa)	Pinus ponderosa	na		S	9	na	na	increased soluble sugar levels in current year	ozone	31
5	pine (ponderosa)	Pinus ponderosa			S	9	0.36 ppm	12 hrs/day for 37 days	3 in order of decr. sens. (1=highest)	ozone	39
5	pine (ponderosa)	Pinus ponderosa	S		S	9	ambient -- CA forests	tree lifetime through 1970	1-2 ann. needle whorls, short, chlorotic, nec	oxidant air pollution	40
5	pine (ponderosa)	Pinus ponderosa	S		S	9	0.50 ppm	9-18 days	chlorotic mottle, terminal die-back, abscissi	ozone	41
5	pine (ponderosa)	Pinus ponderosa			S	9	0.20 ppm	7hr/day, up to 21 days	chlorotic mottling on needles	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	0.30 ppm	up to 21 days	chlorotic mottling on needles	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	0.40 ppm	up to 21 days	chlorotic mottling on needles	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	0.50 ppm	up to 21 days	chlorotic mottling on needles	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	1.0 ppm	7 hrs	acute needle tip necrosis	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	3.0 ppm	7 hrs	acute needle tip necrosis	ozone	51
5	pine (ponderosa)	Pinus ponderosa			S	9	Brooklyn,NY air	8 hrs	chlorotic mottling on needles	ozone polluted ambie	51
5	pine (ponderosa)	Pinus ponderosa	S		S	9	na	na	no injury - greenhouse study	ozone	57
5	pine (ponderosa)	Pinus ponderosa	R		S	9	na	na	other symptoms	ozone	57
5	pine (ponderosa)	Pinus ponderosa var. scopulorum			R		0.36 ppm	12 hrs/day for 37 days	13 in order of decr. sens (1=highest)	ozone	39
5	pine (table mountain)	Pinus pungens	R		S-R		na	na	na	ozone	57
5	pine (table mountain)	Pinus pungens	S		S-R		na	na	na	ozone	57
5	pine (Monterey)	Pinus radiata	S		S	7	na	na	na	ozone	9
5	pine (Monterey)	Pinus radiata	S		S	7	ambient -- CA forests	tree lifetime through 1970	1-2 ann. needle whorls, short, chlorotic, nec	oxidant air pollution	40
5	pine (Monterey)	Pinus radiata	S		S	7	0.30 ppm	7 hrs for 14 days	chlorotic mottle	ozone	51
5	pine (Monterey)	Pinus radiata			S	7	0.30 ppm	7 hr/day for 14 days	chlorotic mottling on needles	ozone	51

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
5	pine (knobcone/Monterey hybrid)	Pinus radiata x Pinus attenuata			I		0.36 ppm	12 hrs/day for 37 days	8 in order of decr. sens (1 = highest)	ozone	39
5	pine (red)	Pinus resinosa	R	I	R		0.25 ppm	2 hrs	7 % of plants were injured	ozone	5
5	pine (red)	Pinus resinosa	S	I	R		0.50 ppm	2 hrs	87 % of plants were injured	ozone	5
5	pine (red)	Pinus resinosa	R	R	R		Table			ozone	44
5	pine (red)	Pinus resinosa	R		R		na	na	no injury – greenhouse study	ozone	57
5	pine (pitchpitch)	Pinus rigida	na		R		na	na	decrease in growth	ozone, SO2	32
5	pine (pitchpitch)	Pinus rigida			R		0.10 - 0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
5	pine (pitchpitch)	Pinus rigida	R	R	R		Table			ozone	44
5	pine (pitchpitch)	Pinus rigida	na		R		na	na	needle mottle, premature senescence, needle	ozone	52
5	pine (pitchpitch)	Pinus rigida	R		R		na	na	no injury – field/ghouse studies	ozone	57
5	pine (pitchpitch)	Pinus rigida	S		R		na	na	chlorosis	ozone	57
5	pine (digger)	Pinus sabiniana	R		R		ambient -- CA forests	tree lifetime through 1970	4+ annual needle whorls retained w/ no chl	oxidant air pollution	40
5	pine (Southwestern white)	Pinus strobiformis	I		I - R		na	na	other symptoms	ozone	57
5	pine (Southwestern white)	Pinus strobiformis	R		I - R		na	na	other symptoms	ozone	57
5	pine (Eastern white)	Pinus strobus	R		S	3	0.25 ppm	2 hrs	10 % of plants injured	ozone	5
5	pine (Eastern white)	Pinus strobus	S		S	3	0.50 ppm	2 hrs	79 % of plants injured	ozone	5
5	pine (Eastern white)	Pinus strobus	na		S	3	na	na	accelerated senescence of older needles	ozone	11
5	pine (Eastern white)	Pinus strobus	S	S	S	3	0.03 ppm	4 hrs	needle blight	ozone	12
5	pine (Eastern white)	Pinus strobus	S	S	S	3	0.07 ppm	4 hrs	needle blight	ozone	12
5	pine (Eastern white)	Pinus strobus	S		S	3	Brooklyn,NY air	5 – 7 months	chlorotic/brown/rust flecks on needles, musta	ambient NYC air poll	30
5	pine (Eastern white)	Pinus strobus	S	S	S	3	Table			ozone	44
5	pine (Eastern white)	Pinus strobus	I		S	3	na	na	chlorosis	ozone	57
5	pine (Eastern white)	Pinus strobus	R		S	3	na	na	chlorosis, other	ozone	57
5	pine (Eastern white)	Pinus strobus	S		S	3	na	na	chlorosis	ozone	57
5	pine (Eastern white)	Pinus strobus	R		S	3	na	na	no injury – field/ghouse studies, other injur	ozone	57
5	pine (scotch)	Pinus sylvestris	R	R	R	3	Table			ozone	44
5	pine (scotch)	Pinus sylvestris	R		R	3	na	na	no injury – field study	ozone	57
5	pine (scotch)	Pinus sylvestris	S		R	3	na	na	chlorosis, other	ozone	57
5	pine (loblolly)	Pinus taeda	S		S		3x normal forest air	na	80 % reduction in photosynthesis	ozone	1
5	pine (loblolly)	Pinus taeda			S		0.10 - 0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
5	pine (loblolly)	Pinus taeda	na		S		na	na	ozone – type mottling	ozone	55
5	pine (loblolly)	Pinus taeda	R		S		na	na	no injury – greenhouse study	ozone	57
5	pine (Japanese black)	Pinus thunbergii	na		I - R	5	na	na	ozone – type mottling	ozone	51
5	pine (Japanese black)	Pinus thunbergii	R		I - R	5	na	na	other symptoms	ozone	57
5	pine (Japanese black)	Pinus thunbergii	I		I - R	5	na	na	other symptoms	ozone	57
5	pine (Torrey)	Pinus torreyana	I		I		na	na	na	ozone	9
5	pine (Torrey)	Pinus torreyana	I		I		ambient -- CA forests	tree lifetime through 1970	4+ needle whorls retained, oldest whorls chl	oxidant air pollution	40
5	pine (Virginia)	Pinus virginiana	S		S		0.25 ppm	4 hrs	Chlorotic mottle, tip or needle necrosis	ozone	14
5	pine (Virginia)	Pinus virginiana	S	S	S		Table			ozone	44
5	pine (Virginia)	Pinus virginiana	S		S		na	na	chlorosis	ozone	57
5	pine (Virginia)	Pinus virginiana	R		S		na	na	no injury – field/ghouse studies	ozone	57
10	plantain	Plantago coronopus			I		0.07 ppm	7 hrs/day for two weeks	13 % reduced growth rate	ozone	48
10	plantain	Plantago insularis	R		I		0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
10	plantain	Plantago insularis	?		I		0.20 – 0.30 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
10	plantain (English)	Plantago lanceolata			I		0.07 ppm	7 hrs/day for two weeks	9 % reduced growth rate	ozone	48
10	plantain (common)	Plantago major "a"			S		0.07 ppm	7 hrs/day for two weeks	24 % reduced growth rate	ozone	48
10	plantain (common)	Plantago major "b"			S		0.07 ppm	7 hrs/day for two weeks	23 % reduced growth rate	ozone	48
10	plantain (common)	Plantago major "Greek"			R		0.07 ppm	7 hrs/day for two weeks	1 % reduced growth rate	ozone	48
10	plantain	Plantago maritima			I		0.07 ppm	7 hrs/day for two weeks	5 % reduced growth rate	ozone	48
10	plantain (hoary)	Plantago media			R		0.07 ppm	7 hrs/day for two weeks	no reduced growth	ozone	48
4	planetree (London)	Platanus acerifolia	S		S - I	5	na	na	dark stipple	ozone	57
4	planetree (London)	Platanus acerifolia	I		S - I	5	na	na	dark stipple	ozone	57
4	sycamore (American)	Platanus occidentalis	na		I	5	na	na	reduced root weight (73%) and shoot weight	ozone	11

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
4	sycamore (American)	Platanus occidentalis			I	5	0.30 ppm	8 hrs/day for 5 months	significant growth reduction, premature leaf	ozone	33
4	sycamore (American)	Platanus occidentalis			I	5	0.10 – 0.15 ppm	6 hrs/day for 28 days	significant height and mass reduction	ozone	37
4	sycamore (American)	Platanus occidentalis	S		I	5	na	na	dark stipple	ozone	57
4	sycamore (American)	Platanus occidentalis	S		I	5	na	na	dark stipple	ozone	57
4	sycamore (California)	Platanus racemosa	S		S		na	na	na	ozone	9
4	sycamore (California)	Platanus racemosa	na		S		na	na	ozone – type lesions	ozone	52
4	sycamore	Platanus sp.	I		I	5 – 6	na	na	dark stipple	ozone	57
7	cream cups	Platystemon californica	R		I	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	cream cups	Platystemon californica	I		I	annual	0.20 – 0.3 ppm	8 hrs/day for 4 – 5 days	leaf injury	ozone	59
1a	bluegrass (annual)	Poa annua	S		S	cool	0.23 – 0.30 ppm	6 hrs	tan to yellow necrosis, bleaching	ozone	7
1a	bluegrass (annual)	Poa annua	R		S	cool	0.64 ppm	2 hrs	detectable injury symptoms	ozone	31
1a	bluegrass (annual)	Poa annua	S		S	cool	na	na	na	ozone	36
1a	bluegrass (annual)	Poa annua	S	S	S	cool	Table			ozone	44
1a	bluegrass (annual)	Poa annua		I	S	cool	0.07 ppm	7 hrs/day for two weeks	7 % reduced growth rate	ozone	48
1a	bluegrass (annual)	Poa annua	S	S	S	cool	0.20 ppm	2 hrs	20 % of blade area injured	ozone	53
1a	bluegrass (annual)	Poa annua	S	S	S	cool	0.30 ppm	2 hrs	30 % of blade area injured	ozone	53
1a	bluegrass (annual)	Poa annua	S	S	S	cool	0.40 ppm	2 hrs	38 % of blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	I	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	13 % of blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	R	R	R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	R	R	R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	8 % fo blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	S	R	R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	S	R	R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	18 % of blade area injured	ozone	53
1a	bluegrass (Canada)	Poa compressa "Canada"	S	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	38 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis	I		I	cool	na	na	chlorosis	ozone	57
1a	bluegrass (Kentucky)	Poa pratensis	I		I	cool	0.25 ppm	2 hrs	detectable injury	ozone	60
1a	bluegrass (Kentucky)	Poa pratensis "A – 34"	S	I	I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleac	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Adelphi"	R	I	I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Adelphi"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Adelphi"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleac	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Arista"	R		R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleac	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Baron"	R		I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Baron"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Baron"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleac	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Birks"	R		I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Birks"	R		I	cool	0.15 ppm each	6 hrs/day for 10 days	7 % < leaf injury	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.15 ppm	6 hrs/day for 10 days	15 % > leaf area injured	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.10 ppm	6 hrs/day for 10 days	15 % > leaf area injured	ozone	17
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.10 ppm	6 hrs/day for 10 days	15 % > leaf area injured	O3/H2O mist	17
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	15 % > leaf area injured	O3/NO2/SO2/H2O mi	17
1a	bluegrass (Kentucky)	Poa pratensis "Chorl"	S		S	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	15 % > leaf area injured	O3/NO2/SO2	17
1a	bluegrass (Kentucky)	Poa pratensis "Cougar"	R	R	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleac	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Delta"	I		I	cool	0.23 – 0.30 ppm	6 hrs	white necrosis, bleaching	ozone	7
1a	bluegrass (Kentucky)	Poa pratensis "Delta"	I	I	I	cool	Table			ozone	44
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R		R	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	I		R	cool	0.15 ppm each	6 hrs/day for 10 days	8 – 15% leaf was injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	I	R	R	cool	0.10 ppm	3.3 hrs/day for 5 days	8 % fo blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	I	R	R	cool	0.10 ppm	7 hrs/day for 5 days	13 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R	R	R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R	R	R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	3 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	I	R	R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	13 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R	R	R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	S	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	30 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Fylking"	R	R	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Glade"	I	R	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	S	R	R	cool	0.10 ppm	7 hrs/day for 5 days	16 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	I	R	R	cool	0.10 ppm	3.5 hrs/c/day for 5 days	11 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.20 ppm	2 hrs	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.30 ppm	3 hrs (66 - 71 days after emergence)	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.30 ppm	2 hrs	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.30 ppm	3 hrs (9 - 14 days after emergence)	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	I	R	R	cool	0.40 ppm	3 hrs (9 - 14 days after emergence)	11 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	I	R	R	cool	0.40 ppm	2 hrs	13 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.40 ppm	3 hrs (66 - 71 days after emergence)	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	R	R	R	cool	0.50 ppm	3 hrs (66 - 71 days after emergence)	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Kenblue"	I	R	R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	11 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I		I - R	cool	0.23 – 0.30 ppm	6 hrs	white necrosis, bleaching	ozone	7
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I		I - R	cool	0.15 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I		I - R	cool	0.15 ppm each	6 hrs/day for 10 days	8 – 15% leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I		I - R	cool	0.10 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	17
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I		I - R	cool	0.10 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	O3/H2O mist	17
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	S		I - R	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	15 % > leaf area injured	O3/NO2/SO2	17
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	S		I - R	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	15 % > leaf area injured	O3/NO2/SO2/H2O m	17
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	I	I - R	cool	Table			ozone	44
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	R	I - R	cool	0.10 ppm	3.5 hrs/c/day for 5 days	8 % fo blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	R	I - R	cool	0.10 ppm	7 hrs/day for 5 days	13 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	R	R	I - R	cool	0.20 ppm	2 hrs	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	R	R	I - R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	6 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	R	R	I - R	cool	0.30 ppm	2 hrs	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	R	I - R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	10 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	R	R	I - R	cool	0.40 ppm	2 hrs	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	S	R	I - R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	28 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	R	I - R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	S	R	I - R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	15 % of blade area injued	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	S	R	I - R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	38 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Merion"	I	R	I - R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Newport"	R	R	R	cool	0.10 ppm	3.5 hrs/c/day for 5 days	no visible damage	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Newport"	R	R	R	cool	0.10 ppm	7 hrs/day for 5 days	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Newport"	R	R	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Nugget"	I		I	cool	0.15 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Nugget"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Nugget"	R		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "P – 142"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Park"	I		I	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Pennstar"	R		R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Plush"	R		I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Plush"	I		I	cool	0.15 ppm each	6 hrs/day for 10 days	8 – 15% leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Prato"	S		S	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Primo"	R		R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	bluegrass (Kentucky)	Poa pratensis "Skofti"	R		I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Skofti"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Sydsport"	I		I	cool	0.15 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	16
1a	bluegrass (Kentucky)	Poa pratensis "Sydsport"	S		I	cool	0.15 ppm each	6 hrs/day for 10 days	15 % > leaf area injured	O3/SO2/NO2	16
1a	bluegrass (Kentucky)	Poa pratensis "Sydsport"	R		I	cool	0.10 ppm	3.5 hrs/c/day for 5 days	5 % of blade area injured	ozone	53
1a	bluegrass (Kentucky)	Poa pratensis "Sydsport"	I		I	cool	0.10 ppm	7 hrs/day for 5 days	11 % of blade area injured	ozone	53

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	S		R	cool	0.10 ppm	7 hrs/day for 5 days	16 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	I		R	cool	0.10 ppm	3.5 hrs/day for 5 days	10 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	R		R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	R		R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	I		R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	R		R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	5 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	I		R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	8 % to blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "S.Dakota Certified"	I		R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	13 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	R		I	cool	0.15 ppm	6 hrs/day for 10 days	7 % < leaf injury	ozone	16
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	R		I	cool	0.15 ppm each	6 hrs/day for 10 days	7 % < leaf injury	O3/SO2/NO2	16
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	I		I	cool	0.10 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	O3/H2O mist	17
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	R		I	cool	0.10 ppm	6 hrs/day for 10 days	< 7% leaf area injured	ozone	17
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	S		I	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	15 % > leaf area injured	O3/NO2/SO2/H2O m	17
1	bluegrass (Kentucky)	Poa pratensis "Touchdown"	I		I	cool	0.10 ppm O3, 0.15 ppm NO2/S	6 hrs/day for 10 days	8 – 15% leaf area injured	O3/NO2/SO2	17
1	bluegrass (Kentucky)	Poa pratensis "Vicia"	I	I	I	cool	0.15 ppm	6 hrs/day for 10 days	8 – 15% leaf area injured	ozone	16
1	bluegrass (Kentucky)	Poa pratensis "Vicia"	R		I	cool	0.15 ppm each	6 hrs/day for 10 days	7 % < leaf injury	O3/SO2/NO2	16
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	S		R	cool	0.10 ppm	7 hrs/day for 5 days	15 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	R		R	cool	0.10 ppm	3.5 hrs/day for 5 days	6 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	R	R	R	cool	0.30 ppm	3 hrs (9 – 14 days after emergence)	3 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	R		R	cool	0.30 ppm	3 hrs (66 – 71 days after emergence)	5 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	R		R	cool	0.40 ppm	3 hrs (66 – 71 days after emergence)	8 % to blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	S		R	cool	0.40 ppm	3 hrs (9 – 14 days after emergence)	23 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	S		R	cool	0.50 ppm	3 hrs (9 – 14 days after emergence)	31 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	I		R	cool	0.50 ppm	3 hrs (66 – 71 days after emergence)	10 % of blade area injured	ozone	53
1	bluegrass (Kentucky)	Poa pratensis "Windsor"	I		R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	bluegrass (Kentucky)	Poa pratensis (common)	R	R	R	cool	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1	bluegrass	Poa trivialis		I	I	cool	0.07 ppm	7 hrs/day for two weeks	4 % reduced growth rate	ozone	48
2	phlox family	Polemonium foliosissimum	I		I	4	na	na	chlorosis	ozone	57
2	phlox family	Polemonium foliosissimum	R		I	4	0.30 ppm	2 hrs	detectable injury	ozone	60
10	knotweed (prostrate)	Polygonum aviculare	S		S	annual	0.15 ppm	3 hrs day/5 days/wk for 4 mo	95 % leaf injury	ozone	27
10	knotweed (prostrate)	Polygonum aviculare	S		S	annual	0.30 ppm	3 hrs day/5 days/wk for 4 mo	95 % leaf injury, substantial growth red.	ozone	27
10	knotweed (prostrate)	Polygonum aviculare	S		S	annual	0.50 – 0.70 ppm (ambient)	2 hrs/day	30 % leaf injury	ozone	27
10	smartweed	Polygonum douglasii	S		S		0.15 ppm	3 hrs day/5 days/wk for 4 mo	35 % leaf injury	ozone	27
10	smartweed	Polygonum douglasii	S		S		0.30 ppm	3 hrs day/5 days/wk for 4 mo	95 % leaf injury, substantial growth red.	ozone	27
10	smartweed	Polygonum douglasii	S		S		0.50 – 0.70 ppm (ambient)	2 hrs/day	5 % leaf injury	ozone	27
10	smartweed	Polygonum douglasii	R		S		0.25 > ppm	2 hrs	detectable injury	ozone	60
1	grass (rabbitfoot)	Polypogon monspeliensis	I		I		na	na	na	smog	7
4	cottonwood	Populus deltoides	S		S		0.20 ppm	5 hr	early leaf abscission; higher nitrogen content	ozone	23
4	poplar (hybrid)	Populus sp.	na			2 – 5	na	na	reduced carbohydrate production	ozone	11
4	aspen (quaking)	Populus tremuloides	S		S	2	na	na	na	ozone	9
4	aspen (quaking)	Populus tremuloides	S	S	S	2	Table			ozone	44
4	aspen (quaking)	Populus tremuloides	R		S	2	na	na	dark stipple	ozone	57
4	aspen (quaking)	Populus tremuloides	I		S	2	na	na	dark stipple	ozone	57
4	aspen (quaking)	Populus tremuloides	S		S	2	na	na	necrosis	ozone	57
4	aspen (quaking)	Populus tremuloides	S		S	2	na	na	dark stipple	ozone	57
4	aspen (quaking)	Populus tremuloides	S		S	2	0.15 ppm	2 hrs	detectable injury	ozone	60
4	cottonwood (black)	Populus trichocarpa	S		S	4	na	na	na	ozone	6
3	cinquefoil (bush)	Potentilla fruticosa	I		R	2	na	na	chlorosis	ozone	57
3	cinquefoil (bush)	Potentilla fruticosa	R		R	2	na	na	chlorosis	ozone	57
3	cinquefoil (bush)	Potentilla fruticosa	R		R	2	0.30 ppm	2 hrs	detectable injury	ozone	60
4	cherry (sweet)	Prunus avium	R		R	4	na	na	no injury – field study	ozone	57
4	peach	Prunus persica	I		I		0.28 ppm	2 hrs	detectable injury symptoms	ozone	31
4	peach	Prunus persica	S		I		na	na	necrosis	ozone	57

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
4	cherry (Sargent)	Prunus sargentii	R		R	5	na	na	no injury - field study	ozone	57
4	cherry (black)	Prunus serotina	na		S - I	4	0.04 ppm	7 hr/day for 8 weeks	na	ozone, acidic precip.,	13
4	cherry (black)	Prunus serotina	na	S	S - I	4	0.08 ppm	7 hr/day for 8 weeks	average leaf injury of 61%; less biomass	ozone, acidic precip.,	13
4	cherry (black)	Prunus serotina	S		S - I	4	0, 0.075, or 0.15 uL L-1 ozone	6 hrs d-1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	cherry (black)	Prunus serotina	S	I	S - I	4	0.129 ppm (max)	growing season 1989 - wet conditions	no visible injury	ozone	56
4	cherry (black)	Prunus serotina	S		S - I	4	0.197 ppm (max)	growing season 1988 - drought conditions	no visible injury	ozone	56
4	cherry (black)	Prunus serotina	S		S - I	4	na	na	dark stipple	ozone	57
4	cherry (black)	Prunus serotina	I		S - I	4	na	na	dark stipple, chlorosis	ozone	57
4	cherry (black)	Prunus serotina	S		S - I	4	na	na	dark stipple	ozone	57
4	cherry	Prunus spp.	S		S	2 - 7	na	na	na	ozone	9
5	fir (big cone Douglas)	Pseudotsuga macrocarpa	S		S - R		na	na	na	ozone	9
5	fir (Douglas)	Pseudotsuga macrocarpa		R	S - R		0.36 ppm	12 hrs/day for 37 days	(1 in order of decr. sens. (1=highest)	ozone	39
5	fir (Douglas)	Pseudotsuga macrophylla	S		S		ambient - - CA forests	tree lifetime through 1970	chlorotic mottle, defoliation, short needles	oxidant air pollution	40
5	fir (Douglas)	Pseudotsuga menziesii	R	R	R	4	Table			ozone	44
5	fir (Douglas)	Pseudotsuga menziesii	R		R	4	na	na	no injury - greenhouse study	ozone	57
3	firethorn (scarlet)	Pyracantha coccinea "Lalandei"	R		R	6	0.25 ppm	8 hrs	none	ozone	61
4	oak (white)	Quercus alba	R		R	5	0, 0.075, or 0.15 uL L-1	6 hrs d-1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	oak (white)	Quercus alba	R		R	5	0.15 ppm	8 hrs/day, 3 consec. days/wk for 16 wks	no effect	ozone	35
4	oak (white)	Quercus alba	S		R	5	na	na	dark stipple, chlorosis	ozone	57
4	oak (white)	Quercus alba	R		R	5	na	na	no injury - field/g.house studies	ozone	57
4	oak (scarlet)	Quercus coccinea	I		S - R	5	na	na	dark stipple, chlorosis	ozone	57
4	oak (scarlet)	Quercus coccinea	S		S - R	5	na	na	dark stipple	ozone	57
4	oak (scarlet)	Quercus coccinea	R		S - R	5	na	na	no injury - field study	ozone	57
4	oak (Gambel)	Quercus gambelii	I		I		na	na	chlorosis	ozone	57
4	oak (Gambel)	Quercus gambelii	I		I		0.25 ppm	2 hrs	detectable injury	ozone	60
4	oak (Oregon white)	Quercus garryana	S		S		na	na	na	ozone	9
4	oak (shingle)	Quercus imbricaria	R		R		na	na	no injury - field/g.house studies	ozone	57
4	oak (pin)	Quercus palustris	S		S - R	5	na	na	chlorosis, necrosis	ozone	57
4	oak (pin)	Quercus palustris	I		S - R	5	na	na	necrosis	ozone	57
4	oak (pin)	Quercus palustris	R		S - R	5	na	na	no injury - field study	ozone	57
4	oak	Quercus petraea	na				na	na	abnormal growth	ozone	32
4	oak (white)	Quercus phellos	R		R	5	na	na	no injury - greenhouse study	ozone	57
4	oak (English)	Quercus robur	na		S - R	5	na	na	abnormal growth	ozone	32
4	oak (English)	Quercus robur	S		S - R	5	na	na	dark stipple	ozone	57
4	oak (English)	Quercus robur	R		S - R	5	na	na	no injury - field/g.house studies, dark stipple	ozone	57
4	oak (English)	Quercus robur	I		S - R	5	na	na	dark stipple	ozone	57
4	oak (northern red)	Quercus rubra	na		R	5	0.04 ppm	7 hr/day for 8 weeks	na	ozone, acidic precip.,	13
4	oak (northern red)	Quercus rubra	na		R	5	0.08 ppm	7 hr/day for 8 weeks	less fresh and dry weight of roots and greater	ozone, acidic precip.,	13
4	oak (northern red)	Quercus rubra	R		R	5	0, 0.075, or 0.15 uL L-1	6 hrs d-1 on 2 consecutive days for 12 wks.	dark adaxial stipple	ozone	15
4	oak (northern red)	Quercus rubra	R		R	5	na	na	no injury - field/g.house studies	ozone	57
4	oak (northern red)	Quercus rubra	R		R	5	na	na	no injury - field/g.house studies	ozone	57
4	oak (black)	Quercus velutina	R		R	5	na	na	no injury - greenhouse study	ozone	57
4	oak (chestnut)	Quercus prinus	R		R		na	na	no injury - field/g.house studies	ozone	57
3	azalea or rhododendron	Rhododendron carolinianum	R		R	5	0.25 ppm	8 hrs	none	ozone	61
3	rhododendron (Catawba)	Rhododendron catawbiense album	S		S	5	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	azalea	Rhododendron indicum	R		R	6	0.10 - 0.15 ppm	7 wks	no observed effect	ozone	10
3	azalea or rhododendron	Rhododendron kaempferi "Camp fire"	S		S	4	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	azalea	Rhododendron kurume "Snow"	S		S	6	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	azalea or rhododendron	Rhododendron mollis	R		R	7	0.25 ppm	8 hrs	none	ozone	61
3	azalea or rhododendron	Rhododendron nova zembla	S		S		0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	azalea (Hinodegiri)	Rhododendron obtusum "Hinodegiri"	S		S	6	na	na	dark stipple	ozone	57
3	azalea (Korean)	Rhododendron poukhanensis	S		S		na	na	na	ozone	57
3	azalea (woolly)	Rhododendron roseum elegans	S		S	3	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61

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Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
3	azalea	Rhododendron sp.	I		S - R	3 - 8	na	na	dark stipple	ozone	57
3	azalea	Rhododendron sp.	R		S - R	3 - 8	na	na	no injury - field/g.house studies	ozone	57
3	azalea	Rhododendron sp.	S		S - R	3 - 8	na	na	dark stipple	ozone	57
3	rhododendron	Rhododendron sp. - rhododendron	R		R	3 - 8	na	na	no injury - field study	ozone	57
3	azalea	Rhododendron sp. "Alaska"	R	R	R		Table			ozone	44
3	azalea (Delaware white)	Rhododendron sp. "Delaware white"	I		I		na	na	dark stipple	ozone	57
3	azalea (Glenn Dale hybrid)	Rhododendron sp. "Glacier"	I		I		0.25 ppm	3 hrs, 6x over 4 wks	24 % leaf injury	ozone	54
3	azalea (Kurume hybrid)	Rhododendron sp. "Hershey Red"	I		I		0.25 ppm	3 hrs, 6x over 4 wks	21 % leaf injury	ozone	54
3	azalea (Pericat hybrid)	Rhododendron sp. "Mme Pericat"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	4 % leaf injury	ozone	54
3	azalea (Indica hybrid)	Rhododendron sp. "Mrs. G.G. Gerbing"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	9 % leaf injury	ozone	54
3	azalea (Satsuki hybrid)	Rhododendron sp. "Pink Gumpo"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	0 % leaf injury	ozone	54
3	azalea (Kurume hybrid)	Rhododendron sp. "Red Luster"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	8 % leaf injury	ozone	54
3	azalea (Indian hybrid)	Rhododendron sp. "Red Wing"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	1 % total leaf area injured	ozone	54
3	azalea (Kurume hybrid)	Rhododendron sp. "Snow"	R		R		0.25 ppm	3 hrs, 6x over 4 wks	7 % leaf injury	ozone	54
3	sumac	Rhus canadensis	S		S		na	na	dark stipple	ozone	57
3	sumac (winged)	Rhus copallina	S		S	4	na	na	na	ozone	57
3	sumac (smooth)	Rhus glabra	S		S - I	2	na	na	dark stipple	ozone	57
3	sumac (smooth)	Rhus glabra	I		S - I	2	na	na	dark stipple	ozone	57
10	poison ivy	Rhus radicans (Toxicodendron radicans)	I		R	3	na	na	dark stipple, chlorosis	ozone	57
10	poison ivy	Rhus radicans (Toxicodendron radicans)	R		R	3	na	na	chlorosis	ozone	57
10	poison ivy	Rhus radicans (Toxicodendron radicans)	R		R	3	0.30 > pphm	2 hrs	detectable injury	ozone	60
3		Rhus trilobata	R	I	I		0.05 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
3		Rhus trilobata	R	I	I		0.10 ppm	4 hrs/day for 4 days	1 % foliar injury	ozone	58
3		Rhus trilobata	I	I	I		0.15 ppm	4 hrs/day for 4 days	10 % foliar injury	ozone	58
3		Rhus trilobata	S	I	I		0.20 ppm	4 hrs/day for 4 days	18 % foliar injury	ozone	58
3	sumac (staghorn)	Rhus typhina	S		S	3	na	na	dark stipple	ozone	57
3	gooseberry	Ribes hudsonianum	R		R		na	na	chlorosis	ozone	57
3	gooseberry	Ribes hudsonianum	I		R		na	na	chlorosis	ozone	57
3	gooseberry	Ribes hudsonianum	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
3	currant (Indian)	Ribes sp.	S		S		na	na	dark stipple	ozone	57
4	locust (black)	Robinia pseudo-acacia	I		I - R	4	na	na	dark stipple, tan stipple	ozone	57
4	locust (black)	Robinia pseudo-acacia	R		I - R	4	na	na	no injury - field study	ozone	57
3	rose (multiflora)	Rosa multiflora	S		S - I		na	na	dark stipple	ozone	57
3	rose (multiflora)	Rosa multiflora	I		S - I		na	na	dark stipple	ozone	57
3	rose	Rosa sp.	S		S	2 - 7	0.10 - 0.15 ppm	2 wks	defoliation and bud abortion	ozone	10
3	rose	Rosa sp.	R		S	2 - 7	na	na	no injury - greenhouse study	ozone	57
3	rose	Rosa woodsii	R		R		0.30 > ppm	2 hrs	detectable injury	ozone	60
3	blackberry (thornless)	Rubus canadensis	S		S		na	na	other symptoms	ozone	57
3	raspberry (red)	Rubus idaeus	R		R	5	na	na	no injury - field/g.house studies	ozone	57
3	blackberry	Rubus sp.	S	S	S		0.129 ppm (max)	growing season 1989 - wet conditions	widespread foliar stippling (in many plants/l	ozone	56
3	blackberry	Rubus sp.	S		S		0.197 ppm (max)	growing season 1988 - drought conditions	no visible injury	ozone	56
2	black-eyed Susan	Rudbeckia hirta	S		S	4	na	na	necrosis	ozone	57
2	coneflower (cutleaf)	Rudbeckia Laciniata	S		S	3	na	na	dark stipple	ozone	57
2	black-eyed Susan	Rudbeckia occidentalis	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
11	sorrel (green)	Rumex acetosa		R	R	3	0.07 ppm	7 hrs/day for two weeks	1 % reduced growth rate	ozone	48
11	sorrel (sheep)	Rumex acetosella		I	I	3	0.07 ppm	7 hrs/day for two weeks	10 % reduced growth rate	ozone	48
10	dock (curly)	Rumex crispus	I		I	3	na	na	other symptoms	ozone	57
10	dock (curly)	Rumex crispus	I		I	3	0.25 ppm	2 hrs	detectable injury	ozone	60
10	dock (bitter)	Rumex obtusifolius		I	I	3	0.07 ppm	7 hrs/day for two weeks	9 % reduced growth rate	ozone	48
9	violet (African)	Saintpaulia ionantha	R		R	10	0.10 - 0.15 ppm	2 wks	author did not separate from ethylene/ozone	ozone	10
4	willow	Salix gooddingii	R	I	I		0.05 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	willow	Salix gooddingii	R	I	I		0.10 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58
4	willow	Salix gooddingii	R	I	I		0.15 ppm	4 hrs/day for 4 days	no foliar injury	ozone	58

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4	willow	Salix gooddingii	I	I	I		0.20 ppm	4 hr/day for 4 days	12% foliar injury	ozone	58
2	salvia	Salvia columbariae	R	R	R		0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
2	salvia	Salvia columbariae	I		I		0.20-0.30 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
3	elderberry (American)	Sambucus canadensis	S		S	3	na	na	dark stipple	ozone	57
3	elderberry	Sambucus canadensis	S		S	3	na	na	dark stipple	ozone	57
3	elderberry (blue)	Sambucus glauca	na				na	na	ozone-type lesions	ozone	52
3	elderberry	Sambucus melanocarpa	R		R		na	na	chlorosis	ozone	57
3	elderbery	Sambucus melanocarpa	I		R		na	na	chlorosis	ozone	57
3	elderberry	Sambucus melanocarpa	R		R		0.25 > ppm	2 hrs	detectable injury	ozone	60
3	elderberry (black)	Sambucus sp.	S		S-I	3-6	na	na	dark stipple	ozone	57
3	elderberry (black)	Sambucus sp.	I		S-I	3-6	na	na	dark stipple	ozone	57
4	sassafras	Sassafras albidum	R		S-R	4	na	na	no injury - field study	ozone	57
4	sassafras	Sassafras albidum	S		S-R	4	na	na	dark stipple	ozone	57
11	saxifrage	Saxifraga arguta	I		I		na	na	chlorosis	ozone	57
11	saxifrage	Saxifraga arguta	R		I		0.30 < ppm	2 hrs	detectable injury	ozone	60
9	schefflera	Schefflera actinophylla	I		I	9	0.10-0.15 ppm	15 days	author did not separate from ethylene/ozone	ozone	10
9	pothos	Scindapsus aureus	R		R	10	0.10-0.15 ppm	3 wks	author did not separate from ethylene/ozone	ozone	10
2	snapdragon "Floral Carpet"	Scrophularia? "Floral Carpet"	R	R	R	4	Table			ozone	44
2	snapdragon "Rocket Mixture"	Scrophularia? "Rocket Mixture"	R	R	R		Table			ozone	44
10	ragwort	Senecio serra	S		S		0.35 ppm	2 hrs	detectable injury	ozone	60
5	sequoia (giant)	Sequoia gigantea	I		R		na	na	na	ozone	9
5	sequoia (giant)	Sequoia gigantea	R		R		ambient -- CA forests	tree lifetime through 1970	no chlorosis on needles	oxidant air pollution	40
5	redwood (Coast)	Sequoia sempervirens	I		R	7	na	na	na	ozone	9
5	redwood (Coast)	Sequoia sempervirens	R		R	7	ambient -- CA forests	tree lifetime through 1970	no chlorosis on needles	oxidant air pollution	40
5	sequoia (giant)	Sequoiadendron giganteum	S		S	6	na	na	increased levels of carbon, reduction in phot	ozone	1
5	sequoia (giant)	Sequoiadendron giganteum			S	6	0.10-0.221 ppm**	summers 1986, 1987	needle death -- linear response to dose	ozone	20
5	sequoia (giant)	Sequoiadendron giganteum			S	6	0.15-0.332 ppm**	summers 1986, 1987	needle death -- linear response to dose	ozone	20
10	bladder campion	Silene cucubalus			S		160 ug/m3 SO2/70 ug/m3 O3	4 weeks	growth heavily affected, no flowering	O3/SO2	19
10	bladder campion	Silene cucubalus			S		70 ug/m3	4 weeks	growth heavily affected, no flowering	ozone	19
9	gloxinia	Sinningia speciosa	I		I	10	0.10-0.15 ppm	15 days	severely retarded flowering	ozone	10
12	bridlewreath	Sirene vanhoutt	S		S		na	na	dark stipple	ozone	57
4	Japanese pagoda tree	Sophora japonica	R		R	4	na	na	no injury - field study	ozone	57
4	ash (European mountain)	Sorbus aucuparia	I		S	3	na	na	dark stipple	ozone	57
4	ash (European mountain)	Sorbus aucuparia	S		S	3	na	na	dark stipple	ozone	57
4	ash (European mountain)	Sorbus aucuparia	R		S	3	na	na	no injury - field study	ozone	57
4	ash (European mountain)	Sorbus aucuparia	S		S	3	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
1	grass (Johnson)	Sorghum halepense	R		R	7	na	na	na	smog	7
7	desert annual	Sphaeralcea ambigua	R		R	annual	0.30 > ppm	8 hrs/day for 4-5 days	no injury	ozone	59
11	moss (sphagnum)	Sphagnum flexuosum					0.08-0.12 ppm	80 hrs over 10 weeks	lower growth, Chl, net psls, no visible injury	ozone	25
11	moss (sphagnum)	Sphagnum magellanicum					0.08-0.12 ppm	80 hrs over 10 weeks	lower growth, Chl, net psls, no visible injury	ozone	25
11	moss (sphagnum)	Sphagnum rubellum					0.08-0.12 ppm	80 hrs over 10 weeks	lower growth, Chl, net psls, no visible injury	ozone	25
1	St. Augustine grass	Stenotaphrum secundatum	R		R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
7	desert annual	Stephanomeria exigua	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
7	desert annual	Streptanthella longirostris	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
7	desert annual	Stylocline filaginea	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
3	snowberry	Symphoricarpos albus	S		S		na	na	dark stipple	ozone	57
3	snowberry or coralberry	Symphoricarpos vaccinioides	R		R		0.30 ppm	2 hrs	detectable injury	ozone	60
3	snowberry (white)	Symphoricarpus alba	R		R		na	na	no injury - greenhouse study	ozone	57
3	lilac (Chinese)	Syringa chinensis	S		S	5	na	na	necrosis	ozone	57
3	lilac (common)	Syringa vulgaris		I	I	3	0.10 ppm	2 hrs/day for 14 days	no effect	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	0.10 ppm	2 hrs	no effect	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	0.10 ppm	4 hrs	no effect	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	0.25 ppm	4 hrs	interveinal and marginal scorch, shock) tear	ozone	30

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3	lilac (common)	Syringa vulgaris		I	I	3	0.25 ppm	2 hrs	intervelnal and marginal scorch, abaxial tann	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	0.50 ppm	4 hrs	intervelnal and marginal scorch, abaxial tann	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	0.50 ppm	2 hrs	intervelnal and marginal scorch, abaxial tann	ozone	30
3	lilac (common)	Syringa vulgaris		I	I	3	Brooklyn, NY air	5-7 months	intervelnal and marginal scorch, abaxial tann	ambient NYC air poll	30
3	lilac (common)	Syringa vulgaris	S		I	3	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
2	marigold	Tagetes patula	na			annual	na	na	reduced root weight (26%) and shoot weight	ozone	11
2	marigold	Tagetes patula 'King Tut'		I	I	annual	0.30 ppm	3 hrs 3 times over 3 days	15% (up to) foliar injury	ozone	55
10	dandelion	Taraxacum officinale	R		R	3	0.25 > pphm	2 hrs	detectable injury	ozone	60
3	yew	Taxus cuspidata	R		R	5	0.25 ppm	8 hrs	none	ozone	61
3	yew (dense)	Taxus media 'Densiformis'				4	0.20 - 0.40 ppm	4 days/wk for 6-7 wks	decreased chlorophyll	ozone	38
3	yew	Taxus sp.	R		R		na	na	no injury - field study	ozone	57
3	yew (Hatfields Anglojap)	Taxus x media	R		R	4	na	na	no injury - greenhouse study	ozone	57
3	yew	Taxus x media 'Hicksi'	R		R	4	0.25 ppm	8 hrs	none	ozone	61
6	sage (wood)	Teucrium scorodonia '0221'		I	I	5	0.07 ppm	7 hrs/day for two weeks	10% reduced growth rate	ozone	48
6	sage (wood)	Teucrium scorodonia '0225'		I	I	5	0.07 ppm	7 hrs/day for two weeks	10% reduced growth rate	ozone	48
11	rue (meadow)	Thalictrum fendleri	R		R		0.25 > ppm	2 hrs	detectable injury	ozone	60
7	desert winter annual	Thelypodium lasiophyllum	R		I	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Thelypodium lasiophyllum	I		I	annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
5	Arborvitae (N. white cedar)	Thuja occidentalis	R	R	R	2	Table			ozone	44
5	Arborvitae (white cedar)	Thuja occidentalis	R		R	2	na	na	no injury - field and greenhouse studies	ozone	57
5	cedar (Northern white)	Thuja occidentalis 'Pyramidalis'				2	0.20 - 0.40 ppm	4 days/wk for 6-7 wks	decreased chlorophyll	ozone	38
7	desert winter annual	Thysanocarpus curvipes	R		R	annual	0.133 > ppm	35 hrs over 216 hrs	no injury	ozone	8
7	desert winter annual	Thysanocarpus curvipes	I			annual	0.20 - 0.3 ppm	8 hrs/day for 4-5 days	leaf injury	ozone	59
4	linden (American)	Tilia americana	I		S-R	3	na	na	dark stipple	ozone	57
4	linden (American)	Tilia americana	R		S-R	3	na	na	no injury - greenhouse study	ozone	57
4	linden (American)	Tilia americana	S		S-R	3	na	na	dark stipple	ozone	57
4	linden (littleleaf)	Tilia cordata	R		R	4	na	na	no injury - field/g.house studies	ozone	57
4	linden (Crimean)	Tilia euchlora	S		S	5	na	na	dark stipple	ozone	57
4	linden (European)	Tilia europea	I		I	4	na	na	dark stipple	ozone	57
4	basswood (white)	Tilia heterophylla	I		I		na	na	dark stipple	ozone	57
4	linden (silver)	Tilia petiolaris	R		I-R	6	na	na	no injury - field study	ozone	57
4	linden (silver)	Tilia petiolaris	I		I-R	6	na	na	dark stipple	ozone	57
4	linden (bigleaf)	Tilia platyphyllos	S		S	4	na	na	dark stipple	ozone	57
11	ephiphytic bromeliad	Tillandsia balbisiana	R	R	R	10	0.15 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia balbisiana	R	R	R	10	0.30 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia balbisiana	R	R	R	10	0.45 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia paucifolia	R	R	R	10	0.15 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia paucifolia	R	R	R	10	0.30 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia paucifolia	R	R	R	10	0.45 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia recurvata	R	R	R	10	0.15 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia recurvata	R	R	R	10	0.30 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia recurvata	R	R	R	10	0.45 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia utriculata	R	R	R	10	0.15 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia utriculata	R	R	R	10	0.30 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
11	ephiphytic bromeliad	Tillandsia utriculata	R	R	R	10	0.45 ppm	6 hrs	no visible injury, change in foliar conductance	ozone	4
1	alsike clover	Trifolium hybridum	R	R	R	3	Table			ozone	44
1	crimson clover	Trifolium incarnatum				annual	0.30 ppm	7 hrs/day for 6 weeks	10% < reduction in leaf area	ozone	3
1	crimson clover	Trifolium incarnatum				annual	0.90 ppm	7 hrs/day for 6 weeks	50% reduction in leaf area	ozone	3
1	crimson clover	Trifolium incarnatum	na			annual	na	na	reduced root weight (27%) and shoot weight	ozone	11
1	red clover	Trifolium pratense	S			3	0.35 ppm	2 hrs	detectable injury symptoms	ozone	31
1	red clover	Trifolium pratense 'Chesapeake'	I	I	I	3	Table			ozone	44
1	red clover	Trifolium pratense 'Kenland'	S	S	S	3	Table			ozone	44
1	red clover	Trifolium pratense 'Ottawa'			I	3	0.20 ppm	6 hrs/day for 4 days	lower N-fixation, leaf bronzing	ozone	18

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	NRC	Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
11	red clover	Trifolium pratense "Pennscott"	I	I	I	3	Table			ozone	44
11	white or ladino clover	Trifolium repens	na	I	I	3	0.05 – 0.15 ppm	na	reduced root and dry weight	ozone	31
11	white or ladino clover	Trifolium repens	na	I	I	3	0.30 ppm	2 hrs	foliar dry weight fell 7%; root weights dropp	ozone	11
11	white or ladino clover	Trifolium repens	na	I	I	3	0.60 ppm	2 hrs	foliar dry weight fell 21%; root weights dropp	ozone	11
11	white or ladino clover	Trifolium repens	I	I	I	3	Table			ozone	44
11	white or ladino clover	Trifolium repens "Alban"	I		I	3	146 ug/m3 mean (204 ug/m3 m	8 hrs/day for 4 days	40.7 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Alban"	I		I	3	44 – 160 ug/m3 mean (64 – 206	8 hrs/day for 8 days	17.4 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Alban"	I		I	3	ambient (55 – 160 ug/m3)	5 – 9 weeks	leaf injury after high O3 episodes	ozone	2
11	white or ladino clover	Trifolium repens "Ladino California"	S		S	3	146 ug/m3 mean (204 ug/m3 m	8 hrs/day for 4 days	59.1 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Ladino California"	S		S	3	44 – 160 ug/m3 mean (64 – 206	8 hrs/day for 8 days	25.8 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Ladino California"	S		S	3	ambient (55 – 160 ug/m3)	5 – 9 weeks	leaf injury after high O3 episodes	ozone	2
11	white or ladino clover	Trifolium repens "Ladino Sacramento"	S		S	3	146 ug/m3 mean (204 ug/m3 m	8 hrs/day for 4 days	55.6 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Ladino Sacramento"	S		S	3	44 – 160 ug/m3 mean (64 – 206	8 hrs/day for 8 days	45.7 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Ladino Sacramento"	S		S	3	ambient (55 – 160 ug/m3)	5 – 9 weeks	leaf injury after high O3 episodes	ozone	2
11	white or ladino clover	Trifolium repens "Milkanova"	R		R	3	146 ug/m3 mean (204 ug/m3 m	8 hrs/day for 4 days	35.2 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Milkanova"	R		R	3	44 – 160 ug/m3 mean (64 – 206	8 hrs/day for 8 days	8 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Milkanova"	R		R	3	ambient (55 – 160 ug/m3)	5 – 9 weeks	leaf injury after high O3 episodes	ozone	2
11	white or ladino clover	Trifolium repens "Sonja"	R		R	3	44 – 160 ug/m3 mean (64 – 206	8 hrs/day for 8 days	9.2 % of plants showed injuries	ozone	2
11	white or ladino clover	Trifolium repens "Sonja"	I		I	3	ambient (55 – 160 ug/m3)	5 – 9 weeks	leaf injury after high O3 episodes	ozone	2
11	ladino clover	Trifolium repens "Tillman"				3	0.50 ppm (ambient)	June 20 – Oct 19 1979	reduced root + shoot dry weight, therefore N	ozone	42
11	ladino clover	Trifolium repens "Tillman"				3	0.80 ppm	7 hrs/day from June 20 – Oct 19 1979	reduced root + shoot dry weight, therefore N	ozone	42
11	white clover	Trifolium repens (ozone resistant clone)	R	I	I	3	0.082 ppm	6 hrs/day for 4 days	slight foliar injury, no change to growth	ozone	28
11	white clover	Trifolium repens (ozone sensitive clone)	S	I	I	3	0.082 ppm	6 hrs/day for 4 days	extensive foliar injury, decreased growth	ozone	28
1	ingrass (wild wheat?)	Triticum vulgare	na				0.05 – 0.15 ppm	na	na	ozone	53
5	hemlock (Eastern)	Tsuga canadensis	R	R	R	4	Table			ozone	44
5	hemlock (Eastern)	Tsuga canadensis	R		R	4	na	na	no injury – field study	ozone	57
5	hemlock (Eastern)	Tsuga canadensis	S		R	4	na	na	chlorosis	ozone	57
5	hemlock (Eastern)	Tsuga canadensis	R		R	4	na	na	no injury – field/g.house studies	ozone	57
4	elm (American)	Ulmus americana	na		R	3	na	na	carbohydrated reduction	ozone	11
4	elm (American)	Ulmus americana	R		R	3	na	na	no injury – field study	ozone	57
4	elm (Chinese)	Ulmus parvifolia	S		S – R	6	na	na	tan stipple	ozone	57
4	elm (Chinese)	Ulmus parvifolia	R		S – R	6	na	na	no injury – field study	ozone	57
4	elm	Ulmus sp.	R		R	3 – 6	na	na	no injury – field study	ozone	57
11	nettle (stinging)	Urtica dioica		I	I	3	0.07 ppm	7 hrs/day for two weeks	12 % reduced growth rate	ozone	48
11	nettle	Urtica gracilis	I		R	3	na	na	chlorosis	ozone	57
11	nettle	Urtica gracilis	R		R	3	na	na	chlorosis	ozone	57
11	nettle	Urtica gracilis	R		R	3	0.30 ppm	2 hrs	detectable injury	ozone	60
3	highbush blueberry	Vaccinium corymbosum	R		R	3	na	na	no injury – field study	ozone	57
11	crownbeard	Verbesina occidentalis	S		S		na	na	dark stipple	ozone	57
10	ironweed (New York)	Vernonia noveboracensis	S		S	5	na	na	other symptoms	ozone	57
11	speedwell	Veronica anagallis – aquatica	I		I		na	na	other symptoms	ozone	57
11	speedwell	Veronica anagallis – aquatica	I		I		0.25 ppm	2 hrs	detectable injury	ozone	60
3	viburnum (mapleleaf)	Viburnum acerifolia	R		R	3	na	na	no injury – field study	ozone	57
3	viburnum	Viburnum carlesi	S		S	4	0.25 ppm	8 hrs	brown to black necrotic stipples on upper lea	ozone	61
3	viburnum (arrowwood)	Viburnum dentatum	R		R	2	na	na	no injury – field study	ozone	57
3	viburnum (linden)	Viburnum dilatatum	I		I – R	5	na	na	dark stipple	ozone	57
3	viburnum (linden)	Viburnum dilatatum	R		I – R	5	na	na	dark stipple	ozone	57
3	viburnum (tea)	Viburnum setigerum	I		I – R		na	na	dark stipple	ozone	57
3	viburnum (tea)	Viburnum setigerum	R		I – R		na	na	dark stipple	ozone	57
10	vetch (American)	Vicia americana	I		R	3	na	na	chlorosis	ozone	57
10	vetch (American)	Vicia americana	R		R	3	na	na	no injury – greenhouse study	ozone	57
10	vetch (American)	Vicia americana	R		R	3	0.25 > ppm	2 hrs	detectable injury	ozone	60
10	vetch (American)	Vicia americana	R		R	3	0.40 > ppm	2 hrs	detectable injury	ozone	60

Appendix A: Data Base of Plants and Sensitivity to Ozone

Plant Type	Common Name	Species Name	Sensitivity Class Auth.	Sensitivity Class NRC	Sensitivity Class Final	Temp. Zone	Level of Exposure	Duration of Exposure	Effects	Pollutant	Data Source
7	desert perennial	Viguiera deltoidea	R		R		0.10 > ppm	8 hrs/day for 4 – 5 days	no injury	ozone	59
6	periwinkle	Vinca minor	R		R	5	0.25 ppm	8 hrs	none	ozone	61
6	periwinkle	Vinca minor 'Bright Eyes'	R	R	R	5	Table			ozone	44
2	violet (hooked spur)	Viola adunca	R		R		na	na	no injury – greenhouse study	ozone	57
2	violet (hooked spur)	Viola adunca	R		R		0.30 > ppm	2 hrs	detectable injury	ozone	60
2	violet	Viola italica	S		S		0.05 – 0.07 ppm (ambient)	2 hrs/day	0 % leaf injury	ozone	27
2	violet	Viola italica	S		S		0.15 ppm	3 hrs day/ 5 days/wk for 4 mo	80 % leaf injury	ozone	27
2	violet	Viola italica	S		S		0.30 ppm	3 hrs day/ 5 days/wk for 4 mo	100 % leaf injury, substantial growth red.	ozone	27
11	grape	Vitis vinifera	I		S – I	6	0.34 ppm	2 hrs	detectable injury symptoms	ozone	31
11	grape (wild)	Vitis vinifera	S	S	S – I	6	0.129 ppm (max)	growing season 1989 – wet conditions	widespread foliar stippling (in many plants/il	ozone	56
11	wild grape	Vitis vinifera	S		S – I	6	0.197 ppm (max)	growing season 1988 – drought conditions	no visible injury	ozone	56
11	grape	Vitis vinifera	S		S – I	6	na	na	necrosis	ozone	57
11	grape	Vitis vinifera	I		S – I	6	na	na	dark stipple	ozone	57
4	zelkova	Zelkova serrata	R		I – R	6	na	na	dark stipple	ozone	57
4	zelkova	Zelkova serrata	I		I – R	6	na	na	dark stipple	ozone	57
4	zelkova	Zelkova serrata	I		I – R	6	na	na	dark stipple	ozone	57
1a	zoysia grass (emerald)	Zoysia hyb.	R	R	R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.23 – 0.30 ppm	6 hrs	no injury	ozone	7
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	Table			ozone	44
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.20 ppm	2 hrs	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.30 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.30 ppm	2 hrs	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.30 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.40 ppm	2 hrs	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.40 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.40 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.50 ppm	3 hrs (9 – 14 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	9	R	R	warm	0.50 ppm	3 hrs (66 – 71 days after emergence)	no visible damage	ozone	53
1a	zoysia grass (Meyer)	Zoysia japonica	R	R	R	warm	0.50 ppm	3 hrs	water soaked areas near leaf tips, then bleach	ozone	62
1a	zoysia grass (Japanese)	Zoysia japonica (common)	R	R	R	warm	0.23 – 0.30 ppm	6 hrs	no injury	ozone	7
1a	zoysia grass (common)	Zoysia sp.	R	R	R	warm	Table			ozone	44

Appendix A: List of Data Sources

No.	Source
1	1989. Science News 136:189.
2	Becker, K. et al. 1989. New Phytol. 112: 235–43.
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15	Davis, D.D. et al. 1992. Water, Air, and Soil Pollution 62:269–277
16	Elkiey, T. et al. 1980. J. Am. Soc. Hort. Sci. 105(5): 664–8
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27	Harward, M. and M. Treshow. 1975. Environmental Conservation 2(1): 17–23.
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36	Juhren, Marcella, et al. 1957. Plant Physiology. 32:576–586.
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39	Miller et al (1983) ref. in CARB, Crop Assessment Program, 1991.
40	Miller, P. et al. 1971. Plant Disease Reporter. 55(6): 555–560.
41	Miller, P.R. et al. 1963. Phytopathology 53:1072–1076
42	Moser, R.A. 1983. Can. J. Bot. 61: 2159–48.
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Appendix A: Plant Types

Code	Type
1a	Grass
1b	Clover
2	Flowers
3	Shrubs
4	Trees -- Deciduous
5	Trees -- Conifers
6	Ground Covers
7	Desert Flowers
9	Houseplants
10	Weeds
11	Wild
12	Uncategorized

Appendix B

Annotated Bibliography of Selected Sources on Ozone Damage to Ornamentals

Appendix B

Annotated Bibliography of Selected Sources on Ozone Damage to Ornamentals

1987. Plant Hormone: Key to Ozone Toxicity? ***Science News*****. 131: 357-358.** Researchers found that pea seedlings exposed to between 50 and 150 ppb O_3 for seven hours daily for their first three weeks of growth showed no visible leaf injury. When seedlings grown in the absence of ozone for three weeks were exposed to between 50 and 150 ppb ozone for seven hours on day 21, they immediately developed severe leaf-tissue death. It was found the plants' production of the hormone ethylene was twice as great in the single-exposure group than the control group. The three-week exposure group produced 92 percent less ethylene than the controls.

1989. Ozone Needles Loblolly Pines... and Saps Sequoia Seedlings. ***Science News*****. 136(12): 189.** Duke University researchers have found that high levels of ozone diminish long-term photosynthesis rates in the loblolly pine. They exposed trees in 54 chambers to five different levels of ozone and three of acid rain. At ozone levels triple those normally found in forest air (levels that exist in large cities like Atlanta and Houston), the trees experienced an 80 percent decrease in photosynthesis compared to those trees exposed to ambient ozone levels. New needles showed an unexplained increase in their photosynthetic rate which leveled off as cumulative ozone exposure increased. In another study, researchers discovered that loblolly pines, red spruce, and scotch pines exposed to high levels of ozone produce more antioxidants to overcome oxygen stress. Experiments by the U.S. Forest Service discovered that giant sequoia seedlings exposed to increased ozone levels lost carbon, indicating reduced photosynthesis and possible cell damage. Seedlings exposed to ozone required more light to retain carbon. "Seedlings on forest floors typically get only about two hours of sunlight per day and have a relatively high mortality rate, with only 10 to 15 percent surviving their first year."

Becker, K., M. Saurer, A. Egger and J. Fuhrer. 1989. Sensitivity of White Clover to Ambient Ozone in Switzerland. ***New Phytologist*****. 112: 235-243.** Three experiments were done to test the sensitivity of five cultivars of white clover (*Trifolium repens*) to ambient ozone levels in Switzerland: 1) exposure to ambient air, 2) exposure to increased ozone for eight hours per day for four days, and 3) exposure to filtered air with ozone added daily. For all experiments, the relative sensitivities of the cultivars were: *T. repens* Ladino Sacramento > *T. repens* Ladino California >> *T. repens* Alban > *T. repens* Sonja > *T. repens* Milkanova. Injury symptoms were seen when plants were exposed to ambient ozone levels. In the most sensitive cultivars, injury occurred after episodes with one hour maximum concentrations of above 120 to 140 ug/m3 occurring on several consecutive days. Differences in ozone sensitivity were related to differences in stomatal density, and somewhat to the length of the stomatal pore.

Bennet, J., and V.C. Runeckles. 1977. Effects of Low Levels of Ozone on Plant Competition. ***Journal of Applied Ecology*****. 14: 877-880.** Monocultures and mixtures of crimson clover (*Trifolium incarnatum*) and annual ryegrass (*Lolium multiflorum*) were exposed to 0.03 ppm and 0.09 ppm ozone for eight hours per day for six weeks. Yield and leaf area of ryegrass in mixtures was less affected by ozone at 0.09 ppm than was clover, so competed more successfully than in the lower ozone concentrations. Total dry weight, leaf area, leaf area ratio, and tiller number were decreased more in monocultures than in mixtures. Exposure to 0.03 ppm ozone reduced yields by less than 10 percent. Exposure to 0.09 ppm reduced clover leaf area by 50 percent and of ryegrass by 35 percent in monocultures, while total mixture leaf area was decreased by only 26 percent.

Benzing, David H., Joseph Arditti, Leslie Nyman, Patric Temple and James Bennett. 1992. Effects of Ozone and Sulfur Dioxide on Four Epiphytic Bromeliads. *Environmental and Experimental Botany*. 32(1): 25-32. This study is similar to that of Nyman, et al. 1990, which was performed on epiphytic orchids. It was conducted to 1) establish threshold exposures for injury and physiological effects from exposure to SO_2 and O_3, and, 2) to determine whether epiphytic bromeliads could replace lichens for air quality monitoring in Florida national parks. Plants were exposed to similar levels as the prior study: SO_2 (0.3, 0.6, and 1.2 ppm) or O_3 (0.15, 0.3 and 0.45 ppm) for six hours on four consecutive nights, followed by sequential exposure to O_3, O_3 and SO_2 in combination, and SO_2 alone for a total of six hours each time. No visible injury was observed, nor was foliar conductance or crassulacean acid metabolism (CAM) affected. Tolerance to the pollutants was probably due to low stomatal conductance, the "insulating indumentum of absorbing foliar hairs," and slow metabolism. Epiphytic *Tillandsia* species were found to offer advantages over lichens for air quality assessments. They exhibit ozone-sensitive, easily measured responses and can be transplanted with ease to areas where neither they nor lichens appear naturally.

Berry, C.R. 1971. Relative Sensitivity of Red, Jack, and White Pine Seedlings to Ozone and Sulfur Dioxide. *Phytopathology*. 61: 231-232. Different age groups (three, five, and seven weeks) of red pine (*Pinus resinosa*), jack pine (*P. banksiana*), and white pine (*P. strobus*) seedlings were exposed to 25 pphm and 50 pphm O_3 for two-hour intervals. No difference in sensitivity among the different age groups was detected. The study concluded that ozone is more injurious to these species than sulfur dioxide. Jack pine was the most sensitive, while red pine was intermittently more tolerant. The article includes a table that compares the relative sensitivities of the three species to both O_3 and SO_2.

Brennan, E., and P.M. Halisky. 1970. Response of Turfgrass Cultivars to Ozone and Sulfur Dioxide in the Atmosphere. *Phytopathology*. 60: 1544-1546. Turfgrasses were exposed for six hours to an atmosphere containing ozone (0.23 to 0.30 ppm) or sulfur dioxide (0.75 to 1.80 ppm). The article includes a table that lists the degree of ozone injury for eleven turfgrass cultivars (seven species) from exposure to 0.30 ppm ozone for six hours. The table comparatively ranks the cultivars' degree of injury, expressed numerically on a scale of zero (no damage) to nine (severe damage).

Bytnerowicz, A., D.M. Olszyk, C.A. Fox, P.J. Dawson, G. Kats, C.L. Morrison, and J. Wolf. 1988. Responses of Desert Annual Plants to Ozone and Water Stress in an *In Situ* Experiment. *JAPCA*. 38(9): 1145-1151. Due to spreading urbanization in the Los Angeles area, plant communities in the Mojave Desert may be exposed to increasing levels of ozone. To determine the effects of ozone exposure on desert winter annual plants, several species growing in irrigated and non-irrigated plots were exposed *in situ* to ozone from an open air exposure system. The species used were: *Camissonia claviformis*, *Camissonia hirtella*, *Caulanthus cooperi*, *Chaneactis carphoclinia*, *Chaneactis stevioides*, *Cryptantha angustifolia*, *Cryptantha pterocarya*, *Erodium* *cicutarium*, *Festuca octoflora*, *Lupinus concinnus*, *Oenothera californica*, *Plantago insularis*, *Platystemon californica*, *Salvia columbariae*, *Thylepodium lasiophyllum*, and *Thysanocarpus curvipes*. Plants were exposed intermittently to a gradient of ozone of concentrations ranging between 44 and 133 ppb (nL/L) for 35 hours over a total of 216 hours (nine days). Only three species were injured by ozone at the highest concentrations: *Camissionia claviformis* (two percent total foliar injury), *Camissonia hirtella* (one percent total foliar injury), and *Erodium cicutarium* (two percent total foliar injury).

California Air Resource Board. 1991. Crop Loss Assessment Program. (Incomplete reference). A literature search was performed to obtain all relevant references to ozone effects on ponderosa pine (*Pinus ponderosa*) and Jeffery pine (*Pinus jefferyi*), two species thought to be most susceptible to ozone. Literature included specific dose-response information. CARB also calculated seven- and 12-hour average ozone concentrations at monitoring sites near or in forested areas to develop ozone isopleths in the forested areas of California. CARB cited Miller et al. (1983) who fumigated 11 species of western conifer seedlings and two hybrids with 0.36 ppm ozone for 12 hours per day for 37 days under natural forest conditions. Ranked in order from most to least sensitive are: *Pinus jefferyi* x *P. coulteri* hybrid, *P. monticola*, *P. ponderosa*, *P. jefferyi*, *Abies concolor*, *P. coulteri*, *A. magnifica*, *P. radiata* x *P. attenuata*, *Calocedrus decurrens*, *Pseudotsuga macrocarpa*, *Pinus lambertiana*, *P. ponderosa* var. scopulorum. Ozone levels in forest ecosystems have been observed to be sufficiently high to alter tree species composition in forest succession. The report includes a substantial summary of results from field studies of ozone damage in California conifer spp. It also includes seven and 12-hour ozone monitoring data, by month, for various areas in California, and maps of coincident ozone and Ponderosa and Jeffery pine distribution

Colorado State University Experiment Station. n.d. ***Ozone and Ethylene Effects on Some Ornamental Plant Species.*** **General Series 974.** While ethylene is not a major pollutant, it is "a common and serious problem in the florist industry." Nineteen ornamental plant species, usually at "saleable" size were exposed to 500 ppb ethylene, 100 to 150 ppb ozone, or 500 ppb ethylene and 100 to 150 ppb ozone combined for two or three weeks. Acute effects were observed on most species, with greater damage from combined ethylene/ozone exposure. Injury included collapsed tissue, black necrosis of leaf tips and margins, glossy and deformed leaflets, epinasty, and other conditions. Despite the high dosage of ethylene, typical ethylene effects were not always observed. In general, slower growing species such as Boston fern, Croton, Pothos and Philodendron showed less damage than Coleus, Fuchsia, Geranium or Schefflera. The bulletin contains extensive photographs of damage to species to be used as an aid in diagnosis.

Committee on Medical and Biologic Effects of Environmental Pollutants. 1977. ***Ozone and Other Photochemical Oxidants.*** **Washington, DC: National Academy of Sciences. Ch. 11.** This chapter is a critical review of research on the effects in plants and microorganisms of photochemical oxidants, including ozone, and includes an extensive bibliography on related work. The text describes vegetative injury. visible and subtle, acute and chronic, and symptoms. It discusses physiological and biochemical effects, chemical basis of toxicity, effect on reproduction and life cycles, biomass and yields, ambient level field studies and chamber studies, environmental factors affecting plant response, pollutant interactions, pollutant-pathogen interactions, plant protection through breeding, sprays, and cultural (land use) practices, and plants as biological pollutant monitors. The chapter lists tables of growth reductions from short and long term exposures for selected agricultural, tree, understory, and ornamental flower species, sensitive and resistant cultivars for agricultural and ornamental flowers, response to ozone as a function of environmental factors for trees and crop species, and foliar and growth responses to sulfur dioxide and ozone mixtures. It briefly discusses economic assessment of ozone injury to plants, but focuses largely on crop plants. It examines dose-response relationships in plants and gives tables listing: 1) ozone concentrations for short term exposures that produce five percent or 20 percent injury to vegetation grown under sensitive conditions for sensitive, intermediate, and resistant plants, 2) concentration, time, response equations for three susceptibility groups and for selected plants or plant types with respect to ozone, and 3) rates of ozone uptake by selected species. It gives a substantial species list of sensitive, intermediate, and resistent plants including reference.

Cooley, D.R., and W.J. Manning. 1987. The Impact of Ozone on Assimilate Partitioning in Plants: A Review. *Environmental Pollution*. 47: 95-113. The authors examined experiments which compared weights of various plant organs (root, leaves, stems, etc.) from plants grown in ozone and control atmospheres. Their goal was to answer the question: "Do plants compensate for O_3 stress by partitioning relatively greater amounts of assimilate to economically important sinks?" At relatively low levels of ozone (0.05 to 0.10 ppm), plants will generally divert assimilate to leaves in favor of roots. Ozone exposure reduces the number of flowers, fruits and/or seeds. At higher ozone levels (greater than 0.10 ppm), exposure severely reduces photosynthesis, causing dramatic growth reductions.

Costonis, A.C., and W.A. Sinclair. 1969. Relationships of Atmospheric Ozone to Needle Blight of Eastern White Pine. *Phytopathology*. 59: 1566-1574. Studies indicated that needle blight is a symptom caused by ozone injury. Sensitive trees developed symptoms of severe injury after exposure to three pphm ozone for 48 hours or seven pphm for four hours. Polyethylene bags (covering selected branches) proved to prevent injury.

Cox, R.M., J. Spavold-Tims and R.N. Hughes. 1989. Acid Fog and Ozone: Their Possible Role in Birch Deterioration Around the Bay of Fundy, Canada. *Water, Air and Soil Pollution*. 48: 263-276. Areas of deteriorating white birch stands overlap with the often acidic (pH 3.6 April to October) "Fundy Fog." Leaf browning was not significantly related to ozone levels, but there was an inverse relationship between ozone level (up to 100 ppb difference) and fog, which warrants more study.

Davis, D.D., and J.M. Skelly. 1992. Growth Response of Four Species of Eastern Hardwood Tree Seedlings Exposed to Ozone, Acidic Precipitation, and Sulfur Dioxide. *Journal of the Air & Waste Management Association*. 42(3): 309-311. The goal of this study was to determine if air pollutants affect the growth and productivity of black cherry (*Prunus serotina*), red maple (*Acer rubrum*), northern red oak (*Quercus rubra*), and yellow-poplar (*Liriodendron tulipifera*) seedlings. Seedlings were treated with either 40 or 80 ppb O_3, combined with acidic precipitation at pH 3.0 or

4.2 and SO_2 at zero or 300 ppb. Foliar injury was commonly a dark adaxial stipple on the oldest leaves. The most sensitive species was black cherry (61 percent leaf injury). Yellow-poplar exhibited an average of 33 percent leaf injury, and red maple had 11 percent. Red oak only averaged five percent foliar injury. The article includes a table that lists different response variables based on either 40 or 80 ppb ozone exposure.

Davis, D.D., and J.M. Skelly. 1992. Foliar Sensitivity of Eight Eastern Hardwood Tree Species to Ozone. *Water, Air, and Soil Pollution.* 62: 269-277. Seedlings of black cherry (*Prunus serotina*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), sweetgum (*Liquidambar styraciflua*), white ash (*Fraxinus americana*), white oak (*Quercus alba*), yellow-poplar (*Liriodendron tulipifera*), and yellow birch (*Betula allegheniensis*) were exposed to zero, 0.075, or 0.15 uL/L O_3 for six hours per day on two consecutive days for 12 weeks. "Based on percent leaf tissue showing stipple and defoliation following exposure to 0.15 uL/L O_3, the most sensitive species to O_3 was black cherry, followed by sweetgum, yellow-poplar, white ash, red maple, and yellow birch. Red oak and white oak foliage did not exhibit stipple." The article contains figures detailing the influence of leaf position on injury, and includes a table that lists the influence of ozone on foliar response of the eight hardwood species to various exposure levels.

Davis, D.D., and F.A. Wood. 1973. The Influence of Environmental Factors on the Sensitivity of Virginia Pine to Ozone. *Phytopathology.* 63: 371-376. Virginia pine seedlings and plants were exposed to 25 pphm O_3 for four hours to test for the influence of humidity, temperature, and light on ozone sensitivity. Seedlings and three-year old plants were injured more severely during exposure to ozone and higher humidity than when exposed to ozone and lower humidity. Plants conditioned or maintained at higher temperatures before or after exposure were more severely injured than plants kept at a lower temperature. Seedlings and plants kept in the dark before exposure to ozone suffered injury; those kept in light were not injured. The article contains several figures that illustrate the influence of humidity, temperature, and light on the sensitivity of Virginia pine to ozone.

Davis, D.D., and F.A. Wood. 1973. The Influence of Plant Age on the Sensitivity of Virginia Pine to Ozone. *Phytopathology.* 63: 381-388. Seedlings were exposed to 25 pphm O_3 for four hours at various stages of growth to determine the influence of plant age on sensitivity to ozone. Three-year old dormant plants were exposed to 10 or 25 pphm for 24 or 48 hours, or 50 pphm for one, two, or four hours. To establish dose-response curves, seedlings of each leaf type were exposed to 25 pphm O_3 for one to eight hours. This article includes several figures that show the influence of age on the sensitivity of Virginia pine. Influence of tissue age and needle age are also detailed. In an early study, the author found Virginia pine to be the most susceptible of 18 coniferous species exposed to ozone.

Dowsett, Salley, Robert Anderson and William Hoffard. 1992. *Review of Selected Articles on Ozone Sensitivity and Associated Symptoms for Plants Commonly Found in the Forest Environment.* Atlanta, GA: USDA Forest Service Southern Region, Forest Pest Management. Technical Publication R8-TP 18. December. Plant species are used as bio-indicators of ozone presence and intensity. This review of 97 articles identifies 201 species that could be used as indicators, rating them on the basis of high, intermediate or low sensitivity to ozone. Species are listed based on visible damage to leaves, not on effects on e.g., shoot growth, root growth, biomass production, or photosynthesis. Based on the review, 126 species were classified as tolerant, 56 as intermediate and 89 as susceptible to visible damage from ozone. Species are presented in tables listing common name, scientific name, symptom type, test method, and information source.

Edwards, Nelson, Gerry Edwards, J. Michael Kelly and George Taylor. 1992. Three-year Growth Responses of *Pinus taeda L.* [loblolly pine] to Simulated Rain Chemistry, Soil Magnesium Status, and Ozone. *Water, Air, and Soil Pollution.* 63: 105-118. Height, diameter, and mass were measured for loblolly pine seedlings exposed to sub-ambient (about 20 nL/L average, 40 nL/L peak), ambient (about 35 nL/L average, 70 nL/L peak), and twice-ambient (about 60 nL/L average, 110 nL/L peak) ozone concentrations from May to October 1987, 1988, and 1989. Annual reductions in biomass accumulation in seedings exposed to the highest to lowest ozone levels were 14 percent, 11.4 percent, and eight percent, respectively. Twice-ambient ozone-exposed seedlings had the greatest height growth; sub-ambient ozone-exposed seedlings had the greatest diameter growth. Elevated ozone concentrations reduced tissue density.

Elkiey, T., and D.P. Ormrod. 1981. Sulphur and Nitrogen Nutrition and Misting Effects on the Response of Bluegrass to Ozone, Sulphur Dioxide, Nitrogen Dioxide or Their Mixture. *Water, Air, and Soil Pollution.* 16: 177-186. "Cheri," "Merion," and "Touchdown" Kentucky bluegrass (*Poa pratensis*) cultivars were grown with complete nutrition or with low S or low N. Treatments included 1) control; 2) 10 pphm O_3 for six hours per day; 3) 15 pphm SO_2 24 hours per day; 4) 15 pphm NO_2 24 hours per day; and; 5) a combination of 2), 3) and 4). Exposures lasted for 10 days without misting. Treatments were conducted a second time, adding a mist of deionized water for five min. periods twice daily In most cases, severity of injury increased when the plants were misted with the deionized water, especially in the relatively insensitive "Touchdown" cultivar. Low S or low N usually increased the impact of SO_2 or NO_2, respectively, but not ozone.

Elkiey, T., and D.P. Ormrod. 1980. Response of Turfgrass Cultivars to Ozone, Sulfur Dioxide, Nitrogen Dioxide, or their Mixture. *Journal of the American Society of Horticultural Science.* 105(5): 664-668. Eighteen cultivars of six species (*Poa pratensis, Agrostis alba, A. palustris, A. tenuis, Festuca rubra,* and *Lollium perenne*) of cool season turf grass were exposed to 15 pphm ozone or a mixture of 15 pphm O_3, 15 pphm sulfur dioxide, and 15 pphm sulfur dioxide for six hours daily for ten days. Each variable contained two replicates of two pots each. Most common symptoms of injuries on sensitive cultivars were bleaching and necrosis of leaves, with some cultivars showing dark brown necrosis and stippling due to O_3 exposure. Cultivars varied from very sensitive to insensitive. Some cultivars showed less leaf area production but no visible injury symptoms; others had leaf injury without reduced area of uninjured leaves. Combined exposure caused more leaf injury and reduced leaf area production than exposure to single gases. Studies that test exposure to single pollutants could provide inaccurate estimates of sensitivity outdoors where several pollutants may occur simultaneously. The article includes a table of species and cultivars and leaf injury or decreased leaf area due to air pollutants.

Ensing, J., and G. Hofstra. 1982. Impact of the Air Pollutant Ozone on Acetylene Reduction and Shoot Growth of Red Clover. *Journal of Plant Pathology*. 4: 237-42. Red clover (*Trifolium pratense*) was exposed to ambient ozone levels (a maximum of 0.8 ppm to 0.12 ppm) and to 0.20 ppm ozone for six hours per day for four days. In both experiments, plants exposed to ozone showed leaf bronzing. Bronzing was only observed at 0.12 ppm levels; 0.10 ppm did not produce detectable injuries. By seven to ten days following exposure, nitrogen fixation in exposed plants approached that of unexposed plants. The authors concluded that ambient levels of ozone in Ontario have the potential to injure red clover leaves and reduce growth and nitrogen fixation.

Evans, Lance, and Michael Leonard. 1991. Histological Determination of Ozone Injury Symptoms of Primary Needles of Giant Sequoia (Sequoiadendron giganteum Bucch.). *New Phytologist*. 117: 557-64. Giant sequoia seedings were exposed to ambient (100 to 221 ppm per hour in 1986, 125 to 216 ppm per hour in 1987) and 1.5 times ambient levels of ozone in Sequoia and Kings Canyon National Parks in California in 1986 and 1987. The percentage of plasmolyzed primary needle cells did not correlate with ozone levels, but, in 1986 only, the percentage of amorphously stained and dead cells taken together showed a significant response to dose ($y = 29.9 + 0.260x$). In both years, higher ozone levels killed more needle cells. Cell death in the experiments ranged from 0.9 to 6.2 percent. Cell death averaged 5.1 percent from all samples taken from the two parks

Feder, W.A., and F.J. Campbell. 1968. Influence of Low Levels of Ozone on Flowering of Carnations. *Phytopathology*. 58: 1038-1039. Tip burn appeared 48 hours after carnations were exposed to oxidant levels of 0.12 to 0.15 ppm for eight hours. Also, an average of 0.075 ppm for approximately 10 days caused damage if the plants were exposed around the time of bud initiation. The authors concluded that "carnations grown in the presence of ozone at levels below which visible injury usually appears were adversely affected."

Feder, W.A., F.L. Fox, W.W. Heck, and F.J. Campbell. 1969. Varietal Responses of Petunia to Several Air Pollutants. *Plant Disease Reporter*. 53(7): 506-10. Fifteen varieties of petunia were exposed to ozone, sulfur, dioxide, peroxyacetyl nitrate, nitrogen dioxide and irradiated auto exhaust (each separately). Varieties resistant to one kind of pollutant are often resistant to the others. The most sensitive variety was "White Cascade," while "Red Magic" was "quite sensitive" to four individual pollutants. The least sensitive were "Cherry Blossom" and "Blue Danube."

Findlay, S., and C.G. Jones. 1990. Exposure of Cottonwood Plants to Ozone Alters Subsequent Leaf Decomposition. *Oecologia*. 82: 248-250. The authors investigated the effects of acute ozone exposure on subsequent decomposition of leaf litter from cottonwood (*Populus deltoides*), by exposing plants to 200 ppb ozone for five hours. This resulted in early leaf abscission and higher nitrogen content in the leaves. Contrary to general predictions, the high nitrogen leaves were slower to decompose.

Flagler, R.B., and V.B. Youngner. 1982. Ozone and Sulfur Dioxide Effects on Three Tall Fescue Cultivars. *Journal of Environmental Quality*. 2(3): 413-416. This study examines the effects of ozone on the marketable yields of three cultivars of tall fescue (*Festuca arundinacea*). "Alta," "Fawn," and "Kentucky 31." The cultivars were exposed to zero to 0.40 ppm O_3 six hours per day, once a week, for seven to nine weeks. Increased ozone exposure significantly decreased the yield and weight per tiller of each cultivar.

Gagnon, Z.E., and D.F. Karnosky. 1992. Physiological Response of Three Species of *Sphagnum* to Ozone Exposure. *Journal of Bryol.* 17: 81-91. Peatlands have become more threatened due to the increasing number of nearby air pollution sources. Very little is known about the affects of pollutants on *Sphagnum*, especially ozone. In this study, three species of *Sphagnum* (*Sphagnum magellanicum*, *Sphagnum flexuosum*, and *Sphagnum rubellum*) were placed in open-top chambers. Two chamber treatments (charcoal-filtered and twice ambient [2X]) and an open, non-chambered plot were used, with the total ozone exposures being 80, 40, and 0.4 ppm respectively. After ten weeks of exposure, the results clearly indicated that ozone had a significant effect on growth in length, photosynthesis, and chlorophyll content. Differences were also recorded among species.

Glater, R.A.B. 1956. Smog Damage to Ferns in the Los Angeles Area. *Phytopathology*. 46: 696-698. Smog damage to ferns is distinct from injury caused to other plants. "Damage manifested itself as a tan spotting of leaflets, followed by local or general dehydration of the affected areas, ending in necrosis of the entire leaf." Approximately 24 hours after smog exposure, injury to ferns was evident. Within 48 hours, the leaves become "completely dehydrated, turn brown and brittle, and crumble on pressure."

Haagen-Smit, A.J., Ellis Darley, Milton Zaitlin, Herbert Hull and Wilfred Noble. 1952. Investigation on Injury to Plants from Air Pollution in the Los Angeles Area. *Plant Physiology*. 27: 18-34. Spinach, endive, beets, oats, and alfalfa were exposed to 0.20 ppm ozone by volume for five hours. Beets and oats showed no injury, and spinach, endive and alfalfa showed injury not typical of smog damage However, when ozone, peroxide, and unsaturated hydrocarbons were mixed, typical smog damage occurred after 4.5 to five hours damage.

Harward, Max, and Michael Treshow. 1975. Impact of Ozone on the Growth and Reproduction of Understorey Plants in the Aspen Zone of Western U.S.A. *Environmental Conservation.* 2(1): 17-23. Fourteen plants representative of the aspen community understory of the western U.S. were exposed to ambient air (peaks of five to seven pphm for two hours per day), 15 pphm, and 30 pphm for three hours per day, five times a week, for three growing seasons (June to September). Chlorosis, necrosis, and leaf senescence were seen in the more sensitive species. Symptoms appeared in the most sensitive species after three to four weeks of exposure to ambient levels. All species were injured at 15 pphm and 30 pphm, with sensitive species showing symptoms within a week of exposure. Percent leaf injury at harvest ranged from zero to 50 at ambient levels (seven plants damaged), 15 to 100 at 15 pphm, and 55 to 100 at 30 pphm. Root and shoot dry weight and seeds produced per plant were also measured. Growth was reduced at higher ozone levels. Timing of flowering was changed, and the numbers of flowers and fruits produced were decreased in some species due to ozone exposure. Most species were highly sensitive to ozone. Only two (*Chenopodium album* and *Descurania* sp.) were moderately resistant.

Heagle, Allen, Joseph Miller, Dorothy Sherrill and John Rawlings. 1993. Effects of Ozone and Carbon Dioxide Mixtures on Two Clones of White Clover. ***New Phytologist.*** **123: 751-62.** Ozone sensitive (NC-S) and resistant (NC-R) clones of white clover were treated with ozone levels of five and 82 nL/L for six hours per day and with carbon dioxide treatments of 380 (ambient), 490, 600, and 710 ppm for 24 hours per day for eight weeks. CO_2 enrichment decreased foliar gas exchange in NC-R more than in NC-S, while O_3 decreased gas exchange of NC-S more than that of NC-R. NC-S was severely injured by ozone, while NC-R was slightly injured. Ozone decreased the growth of NC-S, but not NC-R, while CO_2 enrichment increased the growth of both.

Heagle, Allen, Michael McLaughlin, Joseph Miller, Ronald Joyner and Susan Spruill. 1991. Adaptation of a White Clover Population to Ozone Stress. ***New Phytologist.*** **119: 61-68.** White clover (*Trifolium repens* "Regal") and tall fescue (*Festuca arundinacea* "Kentucky 31") were grown together in a field for two seasons and exposed to six ozone regimes ranging from 0.59 times ambient (27 ppb average) to 1.95 times ambient (89 ppb average). More clover plants survived in the low ozone treatments than in the high ozone treatments. Fescue was less sensitive to ozone than white clover. Surviving clover plants were cloned and exposed to ozone regimes from 150 ppb to 300 ppb ozone for 5.5 hours. Only one of the 33 clones that survived the 0.59 times ambient exposure regime was resistant to short term ozone exposure, while 19 of the 30 clones surviving 1.95 times ambient exposure were resistant to short term ozone exposure. As well, eight clones that survived the 0.59 times ambient exposure regime were sensitive to short term ozone exposure (more plants injured, average foliar injury 58 percent), while none of the clones surviving 1.95 times ambient exposure were sensitive (fewer plants injured, 34 percent average foliar injury). This series of experiments indicates that white clover can develop ozone resistance when ozone is a predominant selection pressure.

Heck, Walter, John Dunning and I.J. Hindawi. 1965. Interactions of Environmental Factors on the Sensitivity of Plants to Air Pollution. ***Journal of the Air Pollution Control Association.*** **15(11): 511-515.** This article reviews research done on the impact of several environmental variables on air pollution sensitivity in plants. Variables discussed are: light (quality, intensity, and duration), temperature, carbon dioxide concentration, humidity, wind, and soil (moisture, aeration, nutrient levels, and texture). Relative dose-response levels are given for: photoperiod in annual bluegrass; light intensity in alfalfa, tomato, pinto bean, cotton, tobacco, and endive; temperature and tobacco, alfalfa, and buckwheat; soil moisture and petunias; nutrient levels and alfalfa, buckwheat, tobacco, pinto bean, spinach, lettuce, barley, and oats.

Hibben, C.R. 1969. Ozone Toxicity to Sugar Maple. ***Phytopathology.*** **59: 1423-1428.** Experiments were conducted both in a laboratory and in the field. Sugar maples (*Acer saccharum*) were exposed to various doses of ozone at different exposure intervals. It was concluded that the "threshold level for visible injury to maple foliage after short exposures was 20 to 30 pphm for two hours." In addition, "extended intermittent doses as low as 10 pphm at two hours per day for 14 days caused slight injury."

Hibben, C.R. 1969. Plant Injury by Oxidant-type Pollutants in the New York City

Atmosphere. ***Plant Disease Reporter.*** **53(7): 544-48.** Over a period of four years, snowstorm petunia, ornamental tobacco, eastern white pine, common and hybrid lilacs and oxidant-sensitive rubber strips were exposed to Brooklyn air, unfiltered and filtered (at the time, the most heavily polluted "industrial area" in the country). Oxidants were present in unfiltered air at phytotoxic levels, as shown by cracked rubber strips and damage to plants, including adaxial and bifacial flecks and abaxial glaze and discoloration. Most severely injured were ornamental tobacco and eastern white pine. Although growth was not measured, plants in unfiltered air clearly showed less growth than those in filtered air. While the oxidants were not specifically identified, damage resembling that caused by ozone in other experiments implicated that ozone was one of the phytotoxicants.

Hill, A.C. 1961. Plant Injury Induced by Ozone. ***Phytopathology.*** **51: 356-362.** Phytotoxicity of ozone to 34 (mostly agricultural) species was studied in controlled-atmosphere greenhouses. Plants were exposed to 0.13 to 0.72 ppm ozone for two-hour periods every one to two weeks. The plants were grouped into sensitivity categories based on the level of ozone required to produce injury symptoms (chlorotic mottling, necrotic bleaching of the upper leaf surface, and bifacial necrotic spots that extended throughout the leaf). Sensitive plants were those injured at ozone levels of less than 0.30 ppm, intermediate plants were injured at ozone levels of 0.30 to 0.40 ppm, and resistent plants were not injured (if at all) by levels below 0.40 ppm.

Hirichsen, Don. 1987. The Forest Decline Enigma: What Underlies Extensive Dieback on Two Continents? ***BioScience.*** **37(8): 542-546.** This article examines the potential causes (ozone, sulphur dioxide, nitrogen, ammonia, organic chemicals, acid rain) and extent of forest decline in North American and Europe. The total affected area is at least seven million hectares (16.5 million acres). The Union of German Forest Owners estimated the 1985 loss due to forest death at $1 billion for the Federal Republic of Germany. Forest decline differs among the two continents. In Europe, only 11 species are affected: four of the most important conifers (Norway spruce, silver fir, Scotch pine, and European larch) and seven broad-leafed trees (European beech, silver birch, European ash, European alder. common maple [*Acer pseudoplatanus*]), and two species of oak (*Quercus robar* and *Quercus patraea*). In North America, forest death appears to affect only conifers.

Jagels, R., J. Carlisle, R. Cunningham, S. Serreze and P. Tsai. 1989. Impact of Acid Fog and Ozone on Coastal Red Spruce. ***Water, Air, and Soil Pollution.*** **48: 193-208.** Red spruce with decline symptoms have been associated with the combination of high levels of ozone and acid fog along the coast of Maine. Trees in the mid-coast in well-buffered soils develop symptoms of late winter injury. Trees on poorer soils develop chlorosis on upper surfaces of older needles. Ozone levels contributed by plumes from the Boston area were 130-154 ppb. Mid-coast ozone levels were even higher: 200 ppm at Isle au Haut in June, 150 to 180 ppb at south coast sites. Researchers found that some ozone was possibly generated from NO_x and hydrocarbons from trees. Coastal ozone levels exceeded those found at any inland site in Maine.

Jensen, Keith and Leon Dochinger. 1989. Response of Eastern Hardwood Species to Ozone, Sulfur Dioxide, and Acid Precipitation. ***JAPCA.*** **39: 852-55.** For 16 weeks seedlings of ten eastern hardwood species were subjected to fumigation and acid rain treatments in greenhouse conditions. The treatments were: zero, 0.07 and 0.15 ppm O_3; zero and 0.02 ppm SO_2; and acid rain treatments with pHs of 3.0, 3.5 and 4.2. Ozone and acid rain exposure significantly affected leaf dry weight, leaf area and/or new-growth dry weight of six of the species. The ten species were divided into two groups: those sensitive to air pollution which showed foliar injury or diminished growth, and those that were tolerant. Sensitive species included white ash, yellow birch, sweetgum, red maple, yellow-poplar and sugar maple. Tolerant species were white oak, shagbark hickory, American beech and European beech. The study concludes that ozone is probably more harmful than acid rain.

Jensen, Keith. 1973. Response of Nine Forest Tree Species to Chronic Ozone Fumigation. ***Plant Disease Reporter.*** **57(11): 914-17.** One-year old seedlings of nine tree species were exposed to 30 pphm of ozone for eight hours per day for five months. Height and leaf development were measured against a control group. Sycamore, sugar maple and silver maple showed the greatest reductions in growth as a result of exposure to ozone, while yellow-poplar, silver maple and white ash showed significant decline in leaf production.

Juhren, Marcella, Wilfred Noble and F.W. Went. 1957. The Standardization of *Poa annua* as an Indicator of Smog Concentrations. I. Effects of Temperature, Photoperiod and Light Intensity During Growth of the Test-plants. ***Plant Physiology.*** **32: 576-586.** *Poa annua* (annual bluegrass) has been reported as one of the most smog-sensitive plants observed in the field. Because it is also easy to grow and shows injury with measurable bands of damage on its leaves, it was suggested for use as an indicator species for detecting smog concentrations. Ten *Poa annua* plants were placed in test chambers each day in 12 locations around Los Angeles County. Plant injuries were measured daily and judged high, medium, or low. Sensitivity to smog differed among growing conditions, but overall *Poa annua* stayed sensitive except in very hot conditions. Young-mature tissues were the most susceptible. Damage was consistently greater in shorter (eight-hour) photoperiods than longer (12- or 16-hour) photoperiods. Plants grown in warm conditions showed the highest sensitivity to smog, while plants grown in hot temperatures showed the lowest sensitivity. Plants grown in hot conditions gained in sensitivity when exposed to cool temperatures, and plants grown in cool temperatures lost sensitivity when moved to hot temperatures. Damage was greater in unshaded versus shaded plants (because of stomatal opening).

Koritz, Helen G., and F.W. Went. 1953. The Physiological Action of Smog on Plants. I. Initial Growth and Transportation Studies. ***Plant Physiology.*** **28: 50-62.** Tomato plants were tested for biomass as a function of exposure to smog. Plants were fumigated for one hour daily for six days with 0.1 ppm ozone and 1-n-hexene vapors and then harvested on the seventh day. Plants exposed to smog had decreased leaf area, total biomass, and height compared to controls. Damage possibly varied as a function of plant age. Factors favoring the opening of stomata appeared to also increase smog sensitivity.

Lumis, G.P., and D.P. Ormrod. 1978. Effects of Ozone on Growth of Four Woody Ornamental Plants. ***Canadian Journal of Plant Science.*** **58: 769-773.** Four coniferous species: Pfitzer juniper, tamarix juniper, dense yew and pyramid white cedar, were exposed to zero, 10 or 20 pphm of ozone for four consecutive days each week, six hours per day, for six or seven weeks. No visible injury was observed. Pfitzer juniper and especially dense yew showed an increase in shoot elongation after exposure to low levels of ozone, while white cedar elongated most at high levels of ozone. Tamarix juniper grew most with no ozone exposure. Under high levels of ozone, plants had generally lower chlorophyll content, while Pfitzer juniper had increased levels of chlorophyll *a* and *b* under low levels of ozone. It was proposed that ozone may promote stem elongation by interfering with the balance of growth promoters and inhibitors.

Miller, P.R., J.R. Parmeter, O.C. Taylor, and E.A. Cardiff. 1963. Ozone Injury to the Foliage of *Pinus ponderosa*. *Phytopathology*. 53: 1072-1076. Ozone injury occurred in needles of ponderosa pine exposed to 0.5 ppm O_3 for nine to 18 days. The chlorophyll content of needles was decreased when exposed to ozone for 18 days.

Miller, Paul R., and Arthur Millecan. 1971. Extent of Oxidant Air Pollution Damage to Some Pines and Other Conifers in California. *Plant Disease Reporter*. 55(6): 555-60. Air pollution damage was investigated on 16 native conifer species in California over a three-year period. *Pinus ponderosa, P. jeffreyi, P. coulteri, P. radiata and Pseudotsuga macrocarpa* were the most susceptible to damage. Damage to trees was consistently associated with areas downwind of population centers. "Choose-and-cut" Christmas tree farms in the south coast air basin, using *P radiata*, showed significant injury from air pollution, with up to 10 percent of the trees unmarketable. Oxidant air pollution damage is synonymous with X-disease, chlorotic decline and ozone needle mottle.

Montes, R.A., U. Blum, A.S. Heagle, and R.J. Volk. 1983. The Effects of Ozone and Nitrogen Fertilizer on Tall Fescue, Ladino Clover, and a Fescue-Clover Mixture. II. Nitrogen Content and Nitrogen Fixation. *Canadian Journal of Botany*. 61: 2159-2168. The authors demonstrate that "nitrogen fixation and system nitrogen of a clover and fescue-clover pasture could potentially be reduced by ambient O_3 concentrations, that the concomitant loss of clover in fescue-clover pastures could result in reduced forage quality, and that the effects of O_3 on net system nitrogen were not modified by nitrogen fertilization."

Mortensen, Leiv M., and Oddvar Skre. 1990. Effects of Low Ozone Concentrations on Growth of *Betula pubescens* Ehrh., *Betula verrucosa* Ehrh., and *Alnus incana* L. Moench. *New Phytologist*. 115: 156-170. Seedlings of these three species were exposed in growth chambers to four levels of ozone concentration (25, 35, 53 and 82 nL/L) for 50 days. In all three species shoot and root dry weight decreased almost linearly with increasing ozone concentrations. Shoot/root and leaf/stem dry weight ratios were unaffected by ozone concentration, while leaf senescence was significantly increased by greater concentrations of ozone. Visible injury was observed at ozone concentrations of 53 nL/L and above. Wilting occurred at 35 nL/L ozone.

Nyman, Leslie, David Benzing, Patric Temple and Joseph Arditti. 1990. Effects of Ozone and Sulfur Dioxide on Two Epiphytic Orchids. *Environmental and Experimental Botany*. 30(2): 207-13. *Encyclia tampensis* and *Epidendrum rigidum*, two epiphytic orchids, are species that carry out gas exchange at night via crassulacean acid metabolism or CAM. In this study they were exposed to SO_2 (0.3, 0.6, and 1.2 ppm) or Q (0.15, 0.3 and 0.45 ppm) for six hours on four consecutive nights, "during the period of maximal stomatal conductance." Some plants were then exposed sequentially to O_3, O_3 and SO_2 in combination, and then SO_2 for a total of six hours each time. This exposure did not cause visible injury to the plants, nor did exposure effect stomatal conductance and nighttime carbon fixation. The resistance to the pollutants may be due to structural factors of the plants as well as to generally higher resistance of CAM plants to air pollutants.

Preston, Kris. 1993. Selection for Sulfur Dioxide and Ozone Tolerance in *Bromus rubens* Along the South Central Coast of California. *Annals of the Association of American Geographers*. 83(1): 141-55. *Bromus rubens* plants, a species of exotic annual grass widely distributed in central and southern California, were exposed to three levels of SO_2 (0.05, 0.2 and 0.5 ppm) and O_3 (0.1, 0.2 and 0.4 ppm), alone and in combination, for five weeks. Seeds from two populations were used in the experiment, one from an area growing downwind from an oil refinery, the other from a relatively pollution-free area. Plants originating from the polluted site were found to be substantially more vigorous when exposed to SO_2 and slightly more resistant to O_3 than those from the unpolluted site. Resistance to pollutants may be due to a decrease in stomatal conductance (a pollution-avoidance mechanism) and/or a fertilizer effect from SO_2. The results have implications for natural selection of pollutant-sensitive and -resistant strains of plants.

Reiling, K., and A.W. Davison. 1992. The Response of Native, Herbaceous Species to Ozone: Growth and Fluorescence Screening. *New Phytologist*. 120: 29-37. Thirty-two native European species were tested for sensitivity to ozone levels of 70 nL/L given for seven hours per day for two weeks. Six species showed visible injury symptoms, and 14 showed significant reductions in relative growth rates. There was little correlation between visible symptoms and growth reduction. There was significant variation within genera and species. Root/shoot allometry was also affected in 14 species, most markedly in grasses.

Reinert, R.A., A.S. Heagle, J.R. Miller, and W.R. Geckeler. 1970. Field Studies of Air Pollution Injury to Vegetation in Cincinnati, Ohio. *Plant Disease Reporter*. 54(1): 8-11. Plantings of petunia, bean, radish, squash, tomato, alfalfa, oats and tobacco in three different locations were used to determine the effects of ambient air pollution in the Cincinnati area. Two plots were planted in air chambers and exposed to unfiltered and filtered air, and a third was left open to ambient air. Levels of ozone, nitrogen dioxide, and sulfur dioxide were measured from June to September, 1968, and correlated with damage to plants. Injury to plants, including stipple, fleck and upper-surface necrosis, was similar to greenhouse experiments exposing plants to ozone. Injury was highest after days with high concentrations of ozone (up to 20.1 pphm).

Reinert, R.A., and P.V. Nelson. 1980. Sensitivity and Growth of Five *Elatior begonia* Cultivars to SO_2 and O_3, Alone and in Combinations. *Journal of the American Society of Horticultural Science*. 105(5): 721-23. Five cultivars of Elatior begonia ("Schwabenland Red," "Whisper O' Pink," "Fantasy," "Renaissance," and "Turo") were exposed alone and in combination to SO_2 and O_3. "Schwabenland Red" and "Whisper O' Pink" were the most sensitive to ozone (0.25 ppm) based on foliage and flower weight. "Fantasy" was the most sensitive to SO_2 (0.5 ppm) with reduced flower production, though showed no visible injury. The combination of SO_2 and O_3 affected only the flower weight of "Schwabenland Red," though less than was expected from an additive model. "Turo" showed no ill effects from exposure to the pollutants.

Richards, B.L., Sr., O.C. Taylor and G.F. Edmunds, Jr. 1968. Ozone Needle Mottle of Pine in Southern California. ***JAPCA.*** **18(2): 73-77.** This paper presents the results of earlier (1959 and 1960) studies of experimental exposures of a number of pine species to synthesized ozone and ambient ozone-polluted atmospheres at a station in Riverside CA, along with subsequent field studies and observations. The researchers found 1) that chlorotic mottling of pine needles occurs in a wide range of pine species, 2) that X-disease, needle dieback, chlorotic decline and ozone needle mottle are different names for the same disease, and 3) that atmospheric ozone is the prime etiological factor in this disease. The research also clarifies the sequence of the disease: mottling at the needle tip, continuing toward the base, followed by chlorosis and yellowing, premature senescence, and finally needle drop.

Richards, G.A., C.L. Mulchi, and J.R. Hall. 1980. Influence of Plant Maturity on the Sensitivity of Turfgrass Species to Ozone. ***Journal of Environmental Quality.*** **9(1): 49-53.** Both warm and cool season turfgrass species were exposed to various concentrations of ozone at several stages of plant development. Warm season species exhibited a high tolerance to ozone. The cool season turfgrasses displayed a wide range of tolerance. Relative susceptibility was influenced by ozone concentration, length of exposure, and stage of plant development. The article gives several tables that list various vegetative damage ratings.

Sanders, J.S., and R.A. Reinert. 1982. Screening Azalea Cultivars for Sensitivity to Nitrogen Dioxide, Sulfur Dioxide, and Ozone Alone and in Mixtures. ***Journal of the American Society of Horticultural Science.*** **107(1): 87-90.** Eight cultivars of azalea ("Redwing," "Snow," "Glacier," "Hershey Red," Pink Gumbo," "Madame Pericat," "Red Luann" and "Mrs. G.G. Gerbing") were exposed to 0.25 ppm each of nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone (O_3), alone and in combinations. After pruning, the one-year old plants were exposed to the pollutants for six three-hour sessions over a four-week period. Neither NO_2 nor SO_2 caused foliar injury on any of the plants, while ozone alone and in combinations with other pollutants caused foliar injury of greater than 10 percent on "Red Luann," "Glacier," and "Hershey Red." Significant weight loss occurred in leaves or stems from exposure of "Hershey Red," "Red Luann," and "Red Wing" to treatments containing O_3 and from exposure of "Mrs. G.G. Gerbing," "Glacier," and "Red Luann" to treatments containing SO_2.

Sanders, J.S., and R.A. Reinert. 1982. Weight Changes to Radish and Marigold Exposed at Three Ages to NO_2, SO_2, and O_3 Alone and in Mixture. ***Journal of the American Society of Horticultural Science.*** **107(4): 726-30.** Radish and marigold plants of three different ages were exposed three times every other day for three hours to 0.3 ppm of NO_2, SO_2 and O_3. The age groups ranged from five to nine days to 28 to 32 days after seeding. Radish was most sensitive to ozone at 19 to 23 days, while marigold responses to pollutants did not depend on age. Visible radish injury increased with the age of the plant. Ozone mixtures reduced the radish root dry weight by 48 percent compared to controls. NO_2, SO_2 and O_3 in combination had a significant impact on the weight of marigold plants. SO_2 by itself reduced the dry weight of marigold flower and roots; this effect was reversed in the presence of NO_2 or O_3.

Schulze, E.D. 1989. Air Pollution and Forest Decline in a Spruce (*Picea abies*) Forest. *Science*. 244: 776-783. This study found that deposition of sulfur, nitrate and ammonium significantly modified plant nutrition for spruce trees and soil chemistry in northeast Bavaria, West Germany. Gaseous pollutants, such as SO_2, NO_x and ozone, and pathogens had less significant direct effects on needle yellowing or loss. Uptake of ammonium by spruce roots hinders uptake of magnesium, while nitrate leaches with sulfate into groundwater, increasing soil acidification. Increased canopy uptake of atmospheric nitrogen stimulated growth. This, combined with hindered nutrient uptake by roots, created a nitrogen to cation imbalance which, the author theorized, resulted in forest decline.

Semuniuk, K., and H.E. Heggestad. 1981. Differences Among *Coleus* cultivars in Tolerance to Ozone and Sulfur Dioxide. *The Journal of Heredity*. 72: 459-460. Fifteen cultivars of *Coleus* were exposed to 0.6, 0.8, or 1.3 ppm ozone for four hours in growth chambers. The species showed a wide range of tolerances, from highly sensitive to insensitive to ozone at these levels. This indicates that tolerant cultivars might be selected for polluted areas.

Showman, R.E. 1991. A Comparison of Ozone Injury to Vegetation During Moist and Drought Years. *Journal of the Air & Waste Management Association*. 41(1): 63-64. The study demonstrated that injury to ozone-sensitive plants is lowered during periods of drought even if ozone levels are high. In contrast, during periods of optimal growing conditions, ozone-sensitive plants were injured, even at lower ozone levels.

Temple, P.J. 1989. Oxidant Air Pollution Effects on Plants of Joshua Tree National Monument. *Environmental Pollution*. 57: 35-47. Ozone concentrations in Joshua Tree National Monument (JOTR) routinely exceed 0.10 ppm; however, peak concentrations usually occur at night, when most plants are less susceptible. A survey of air pollution effects on annual and perennial vegetation, conducted in 1984 and 1985, found no visible injury symptoms on park vegetation. However, controlled experiments indicated that *Rhus trilobata* could be injured by exposure to ozone concentrations as low as 0.15 ppm for four hours per day for four days. Other woody riparian species and summer annuals were more tolerant to O_3.

Thompson, C.R., D.M. Olszyk, G. Kats, A. Bytnerowicz, P.J. Dawson, and J.W. Wolf. 1984. Effects of Ozone or Sulfur Dioxide on Annual Plants of the Mojave Desert. *JAPCA*. 34: 1017-1022. Forty-seven annual plant species were exposed to O_3 and SO_2 in open-top field chambers to test their relative sensitivity. Exposure levels were zero, 0.05, 0.1, 0.2, 0.3, and 0.4 ppm O_3, or zero, 0.2, 0.5, 0.8, 1.0, and 1.5 ppm SO_2 for eight hours per day for four to five days. Results from the open-top chambers indicated that three species were very sensitive to both pollutants (*Camissonia claviformis*, *Camissonia hirtella*, and *Cryptantha nevadensis*), two species (*Festuca octoflora* and *Lepidium lasiocarpum*) were tolerant to both, and the rest exhibited intermediate sensitivity, with sensitivity to O_3 and SO_2 often varying. Injury symptoms from Q consisted of both flecking and large necrotic areas (color ranged from white to brown, with some species exhibiting a brownish-red necrosis. Symptoms from SO_2 often were bifacial necrotic areas, ranging in color from white to brown, with some species exhibiting a red pigmentation. In addition, 29 of the species exposed in the open-top chambers were planted in the Mojave Desert and exposed to SO_2 with a modified chamberless zonal air pollution (ZAP) system. Exposure to the ZAP system totalled 37 hours over a six day period with levels at zero, 0.4, 0.8, and 1.0 ppm SO_2. Plants exposed to SO_2 with the ZAP system experienced much less injury than plants exposed in the open-top field chambers. Only *Camissonia claviformis* was injured at 0.8 ppm SO_2 and *Oenothera californica* injured at 1 0 ppm.

Treshow, Michael, and Dennis Stewart. 1973. Ozone Sensitivity of Plants in Natural Communities. *Biological Conservation.* 5(3): 209-214. Field fumigation studies were done on grassland, oak, aspen, and conifer communities to determine the sensitivity of dominant plant species to ozone. Plants were exposed to ozone at concentrations averaging 15, 25, 30, or 40 pphm for two hours. "*Bromus tectorum*, *Quercus gambei*, and *Populus tremuloides* were injured by a single two-hour exposure to 15 pphm ozone Over half the perennial forbs and woody species studied were visibly injured at concentrations of 30 pphm or less." This suggests that lower, chronic or repeated concentrations would impair growth, affect community health and stability, and change plant composition of natural plant communities.

Wood, F.A., and J.B. Coppolino. 1972. The Response of 11 Hybrid Poplar Clones to Ozone. *Phytopathology.* 62: 501-502. (abstract) "Individuals of 11 hybrid poplar clones were exposed to 0.25 nL/mL O_3 for four hours at 24 C, 75 percent relative humidity, and 3,300 ft-c of light." The sensitivity of the clones varied over time.

Wood, F.A., and J.B. Coppolino. 1971. The Influence of Ozone on Selected Woody Ornamentals. *Phytopathology.* 61: 133. (abstract) Nine hundred plants of 24 woody ornamental species were exposed to 25 pphm ozone for eight hours with controlled temperature, light, and humidity The following species were sensitive (i.e., sustained injury from exposure): *Cercis canadensis*, *Cotoneaster divaricata*, *C. horizontalis*, *Forsythia intermedia spectabilis* "Lynwood gold," *Gleditsia triacanthos inermis*, *Rhododendron kaempheri* "Camp fire," *R. kurume* "Snow," *R. catawbiense album*, *R. nova zembla*, *R. roseum elegans*, *Sorbus aucuparia*, *Syringa vulgaris*, and *Viburnum carlesi*. The following were not sensitive (i.e., did not sustain injury from exposure). *Euonymous alatus compacta*, *Hedra helix*, *Juniperus communis depressa plumosa*, *Pachysandra terminalis*, *Pieris japonica*, *Pyracantha coccinea lalandi*, *Rhododendron caroliniana*, *R. mollis*, *Taxus cuspidata*, *T. media hicksi*, and *Vinca minor*.

Youngner, V.H., and F.J. Nudge. 1980. Air Pollution Oxidant Effects on Cool-season and Warm-season Turf Grasses. *Agronomy Journal.* 72: 169-170. Cultivars of common turf grass species were germinated in a greenhouse under charcoal filtered air. One treatment was then fumigated with 0.50 ppm ozone for three hours. There were significant variations in leaf injury among species and even between cultivars of the same species. All *Lolium perenne* (perennial ryegrass) cultivars showed severe injury, while *Poa pratense* (Kentucky bluegrass) varied from very intolerant to very tolerant *Agrostis tenuis* (creeping bentgrass) and *Festuca rubra* (creeping red fescue) had moderate injury. Warm season grasses in general were less sensitive than cool-season, only "Emerald" Zoysiagrass and "Tufgrass" Bermudagrass showed signs of injury. The article briefly reviews past work on turfgrass species. "Field observations have shown pronounced reduction in turf quality in areas subject to repeated pollution exposure."

Zwoch, I., U. Knorre and H. Schaub. 1990. Influence of SO_2 and O_3, Singly or in Combination, on Ethylene Synthesis in Sunflower. *Environmental and Experimental Botany.* 30(2): 193-205. Sunflowers (*Helianthus annus* L.) showed no visible injury after 18 days of exposure to SO_2 (100 ppb) and/or O_3 (100 ppb). SO_2 exposure reduced ethylene releases from intact plants, while O_3 and combined O_3/SO_2 exposure enhanced ethylene releases in two of five developmental stages. The ratio of ethane to ethylene production was increased in most cases. The aminocyclopropane-l-carboxylic acid (ACC) concentration was smaller than the malonyl-l-aminocyclopropane-l-carboxylic acid (MACC) concentration in most cases. Fumigation effects depended on type of tissue and plant age. In conclusion, changes in ethylene synthesis and release caused by a long-term fumigation with low doses of SO_2 and/or O_3 did not appear to represent a stress reaction.

Appendix C

Bibliography On Ozone Damage to Plants: References Not Used or Retrieved

Appendix C

Bibliography On Ozone Damage To Plants: References Not Used Or Retrieved

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Appendix D

Ozone Non-Attainment Areas and Temperature Zones

Appendix D: Table D1

Ozone Non-Attainment Areas, by Region, Class, and Temperature Zone

EPA Region	Non-Attainment Area	Ozone Class	Temp. Zone	1990 Population
1	Boston-Lawrence	4	5-7	5,786,021
1	Greater-Connect	4	5-6	2,459,471
1	Hancock & Waldo	6	5	79,966
1	Knox & Lincoln	5	5	66,667
1	Lewiston-Auburn	5	5	221,163
1	Manchester, NH	6	5	120,005
1	Portland, ME	5	5	441,257
1	Portsmouth-Dove	4	5	104,233
1	Providence-Pawt	4	6	1,003,464
1	Springfield, MA	4	5	812,322
1-2	New York-N. New	2	6-7	17,041,786
2	Albany-Schenect	6	4-5	874,304
2	Atlantic City,	5	7	319,416
2	Buffalo-Niagara	6	3-5	1,189,288
2	Essex Co. NY	6	4	37,152
2	Jefferson Co, N	6	4	110,943
2	Poughkeepsie, N	6	5-6	343,403
2-3	Philadelphia-Wi	3	6-7	6,010,338
3	Allentown-Bethl	6	5-6	595,081
3	Altoona, PA	6	6	130,542
3	Baltimore, MD	3	6-7	2,348,219
3	Charleston, WV	5	6	250,454
3	Erie, PA	6	5	275,572
3	Greenbrier Co.	6	5	34,693
3	Harrisburg-Leba	6	6	587,986
3	Johnstown, PA	6	5-6	241,247
3	Kent & Queen An	6	7	51,795
3	Lancaster, PA	6	6	422,822
3	Norfolk-Virgini	6	7-8	1,365,976
3	Parkersburg-Mar	5	6	86,915
3	Pittsburgh-Beav	5	5-6	2,468,289
3	Reading, PA	5	6	336,523
3	Richmond-Peters	5	7	738,964
3	Scranton-Wilkes	6	5-6	734,175
3	Smyth Co, VA	6	6	32,370
3	Sussex Co. DE	6	7	113,229
3	Washington, DC-	4	6-7	3,923,574
3	York, PA	6	6	417,848
3-4	Huntington-Ashl	5	6	226,355
3-5	Youngstown-Warr	6	5	613,622
4	Atlanta, GA	4	7	2,653,613
4	Birmingham, AL	6	7	750,883
4	Charlotte-Gasto	5	7	686,526
4	Cherokee @ Gree	6	7	44,506
4	Edmonson Co	6	6	10,357
4	Greensboro-Wins	5	7	767,834
4	Jacksonville, F	8	9	672,971
4	Knoxville, TN	6	6	335,749
4	Lexington-Fayet	6	6	249,233
4	Memphis, TN-AR-	6	7	826,330
4	Miami-Fort Laud	5	9-10	4,056,100
4	Nashville, TN	5	6	881,331
4	Owensboro, KY	6	6	95,053
4	Paducah, KY (No	6	6	36,267
4	Raleigh-Durham,	5	7	643,560
4	Tampa-St. Peter	6	9	1,685,713

Appendix D: Table D1

Ozone Non-Attainment Areas, by Region, Class, and Temperature Zone

EPA Region	Non-Attainment Area	Ozone Class	Temp. Zone	1990 Population
4-5	Cincinnati-Hami	5	6	1,705,289
4-5	Louisville, KY-	5	6	897,948
5	Canton, OH	6	5	367,585
5	Chicago-Gary-La	2	5	7,937,452
5	Cleveland-Akron	5	5	2,859,644
5	Clinton Co, OH	8	6	35,415
5	Columbus, OH	6	5	1,156,666
5	Dayton-Springfi	5	5-6	951,270
5	Detroit-Ann Arb	5	5	4,590,468
5	Door Co, WI	6	5	25,690
5	Evansville, IN-	6	6	165,058
5	Flint, MI	8	5	430,459
5	Grand Rapids, M	5	5	688,399
5	Indianapolis, I	6	5	797,159
5	Jersey Co	6	5	20,539
5	Kewaunee Co, WI	5	5	18,878
5	Lansing-East La	8	5	432,674
5	Manitowoc Co, W	5	5	80,421
5	Milwaukee-Racin	2	5	1,735,364
5	Muskegon, MI	5	5	158,983
5	Preble Co at Da	8	6	40,113
5	Sheboygan, WI	5	5	103,877
5	South Bend-Mish	6	5	403,250
5	Steubenville-We	8	6	80,298
5	Toledo, OH	5	5	575,630
5	Walworth @ Milw	6	5	75,000
5-7	St Louis, MO-IL	5	5-6	2,389,616
6	Baton Rouge, LA	4	8	581,853
6	Beaumont-Port A	4	8-9	361,226
6	Dallas-Fort Wor	5	7-8	3,560,474
6	El Paso, TX	4	7	591,610
6	Houston-Galvest	2	8-9	3,731,131
6	Lafayette, LA	8	8	164,762
6	Lake Charles, L	6	8	168,134
6	New Orleans, LA	8	8-9	1,054,312
7	Kansas City, MO	7	5	1,361,557
8	Denver-Boulder,	8	4-5	1,848,319
8	Salt Lake City-	5	6-7	913,897
9	Chico, CA	8	8	182,120
9	Fresno, Bak & Sur.	4	8-9	2,742,000
9	Imperial Co, CA	8	9	109,303
9	Los Angeles-LA & Orange	1	9-10	11,273,720
9	Los Angeles-San B & Rivers	2	9	2,588,793
9	Monterey Bay	5	9	622,091
9	Phoenix, AZ	5	9	2,122,101
9	Reno, NV	6	7	254,667
9	Sacramento, CA	4	8-9	1,545,517
9	San Diego, CA	3	9	2,498,016
9	San Francisco-O	5	9-10	6,023,577
9	Santa Barbara-S	5	10	369,608
9	Ventura Co	3	9	669,016
9	Yuba City, CA	8	8	58,228
10	Portland-Vancou	6	8	1,412,344
10	Seattle-Tacoma,	6	8	2,559,164

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
1	Boston-Lawrence	Massachusetts	Barnstable Co	4	7	186,605
1	Boston-Lawrence	Massachusetts	Bristol Co	4	6	506,325
1	Boston-Lawrence	Massachusetts	Dukes Co	4	6	11,639
1	Boston-Lawrence	Massachusetts	Essex Co	4	6	670,080
1	Boston-Lawrence	Massachusetts	Middlesex Co	4	6	1,398,468
1	Boston-Lawrence	Massachusetts	Nantucket Co	4	6	6,012
1	Boston-Lawrence	Massachusetts	Norfolk Co	4	6	616,087
1	Boston-Lawrence	Massachusetts	Plymouth Co	4	6	435,276
1	Boston-Lawrence	Massachusetts	Suffolk Co	4	6	663,906
1	Boston-Lawrence	Massachusetts	Worcester Co	4	5	709,705
1	Boston-Lawrence	New Hampshire	Hillsborough Co	4	5	336,073
1	Boston-Lawrence	New Hampshire	Rockingham Co	4	5	245,845
1	Greater-Connect	Connecticut	Hartford Co	4	6	851,783
1	Greater-Connect	Connecticut	Litchfield Co	4	5	174,092
1	Greater-Connect	Connecticut	Middlesex Co	4	6	143,196
1	Greater-Connect	Connecticut	New Haven Co	4	6	804,219
1	Greater-Connect	Connecticut	New London Co	4	6	254,957
1	Greater-Connect	Connecticut	Tolland Co	4	5	128,699
1	Greater-Connect	Connecticut	Windham Co	4	6	102,525
1	Hancock & Waldo	Maine	Hancock Co	6	5	46,948
1	Hancock & Waldo	Maine	Waldo Co	6	5	33,018
1	Knox & Lincoln	Maine	Knox Co	5	5	36,310
1	Knox & Lincoln	Maine	Lincoln Co	5	5	30,357
1	Lewiston-Auburn	Maine	Androscoggin Co	5	5	105,259
1	Lewiston-Auburn	Maine	Kennebec Co	5	5	115,904
1	Manchester, NH	New Hampshire	Merrimack Co	6	5	120,005
1	Portland, ME	Maine	Cumberland Co	5	5	243,135
1	Portland, ME	Maine	Sagadahoc Co	5	5	33,535
1	Portland, ME	Maine	York Co	5	5	164,587
1	Portsmouth-Dove	New Hampshire	Strafford Co	4	5	104,233
1	Providence-Pawt	Rhode Island	Bristol Co	4	6	48,859
1	Providence-Pawt	Rhode Island	Kent Co	4	6	161,135
1	Providence-Pawt	Rhode Island	Newport Co	4	6	87,194
1	Providence-Pawt	Rhode Island	Providence Co	4	6	596,270
1	Providence-Pawt	Rhode Island	Washington Co	4	6	110,006
1	Springfield, MA	Massachusetts	Berkshire Co	4	5	139,352
1	Springfield, MA	Massachusetts	Franklin Co	4	5	70,092
1	Springfield, MA	Massachusetts	Hampden Co	4	5	456,310
1	Springfield, MA	Massachusetts	Hampshire Co	4	5	146,568
1-2	New York-N. New	New Jersey	Bergen Co	2	6	825,380
1-2	New York-N. New	New Jersey	Essex Co	2	6	778,206
1-2	New York-N. New	New Jersey	Hudson Co	2	6	553,099
1-2	New York-N. New	New Jersey	Hunterdon Co	2	6	107,776
1-2	New York-N. New	New Jersey	Middlesex Co	2	6	671,780
1-2	New York-N. New	New Jersey	Monmouth Co	2	7	553,124
1-2	New York-N. New	New Jersey	Morris Co	2	6	421,353
1-2	New York-N. New	New Jersey	Ocean Co	2	7	433,203
1-2	New York-N. New	New Jersey	Passaic Co	2	6	453,060
1-2	New York-N. New	New Jersey	Somerset Co	2	6	240,279
1-2	New York-N. New	New Jersey	Sussex Co	2	6	130,943
1-2	New York-N. New	New Jersey	Union Co	2	6	493,819
1-2	New York-N. New	New York	Bronx Co	2	6	1,203,789
1-2	New York-N. New	New York	Kings Co	2	7	2,300,664
1-2	New York-N. New	New York	Nassau Co	2	7	1,287,348
1-2	New York-N. New	New York	New York Co	2	6	1,487,536
1-2	New York-N. New	New York	Orange Co	2	6	307,647
1-2	New York-N. New	New York	Queens Co	2	7	1,951,598

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
1-2	New York-N. New	New York	Richmond Co	2	6	378,977
1-2	New York-N. New	New York	Rockland Co	2	6	265,475
1-2	New York-N. New	New York	Suffolk Co	2	7	1,321,864
1-2	New York-N. New	New York	Westchester Co	2	6	874,866
2	Albany-Schenect	New York	Albany Co	6	5	292,594
2	Albany-Schenect	New York	Greene Co	6	5	44,739
2	Albany-Schenect	New York	Montgomery Co	6	5	51,981
2	Albany-Schenect	New York	Rensselaer Co	6	5	154,429
2	Albany-Schenect	New York	Saratoga Co	6	4	181,276
2	Albany-Schenect	New York	Schenectady Co	6	5	149,285
2	Allentown-Bethl	New Jersey	Warren Co	6	6	91,607
2	Atlantic City.	New Jersey	Atlantic Co	5	7	224,327
2	Atlantic City.	New Jersey	Cape May Co	5	7	95,089
2	Buffalo-Niagara	New York	Erie Co	6	5	968,532
2	Buffalo-Niagara	New York	Niagara Co	6	3	220,756
2	New York-N. New	Connecticut	Fairfield Co	2	6	827,645
2	Poughkeepsie. N	New York	Dutchess Co	6	5	259,462
2	Poughkeepsie. N	New York	Putnam Co	6	6	83,941
2	Essex Co. NY	New York	Essex Co	6	4	37,152
2	Jefferson Co. N	New York	Jefferson Co	6	4	110,943
2-3	Philadelphia-Wi	Delaware	Kent Co	3	7	110,993
2-3	Philadelphia-Wi	Delaware	New Castle Co	3	7	441,946
2-3	Philadelphia-Wi	Maryland	Cecil Co	3	7	71,347
2-3	Philadelphia-Wi	New Jersey	Burlington Co	3	6	395,066
2-3	Philadelphia-Wi	New Jersey	Camden Co	3	6	502,824
2-3	Philadelphia-Wi	New Jersey	Cumberland Co	3	7	138,053
2-3	Philadelphia-Wi	New Jersey	Gloucester Co	3	6	230,082
2-3	Philadelphia-Wi	New Jersey	Mercer Co	3	6	325,824
2-3	Philadelphia-Wi	New Jersey	Salem Co	3	7	65,294
2-3	Philadelphia-Wi	Pennsylvania	Bucks Co	3	6	541,174
2-3	Philadelphia-Wi	Pennsylvania	Chester Co	3	6	376,396
2-3	Philadelphia-Wi	Pennsylvania	Delaware Co	3	6	547,651
2-3	Philadelphia-Wi	Pennsylvania	Montgomery Co	3	6	678,111
2-3	Philadelphia-Wi	Pennsylvania	Philadelphia Co	3	6	1,585,577
3	Allentown-Bethl	Pennsylvania	Carbon Co	6	5	56,846
3	Allentown-Bethl	Pennsylvania	Lehigh Co	6	6	291,130
3	Allentown-Bethl	Pennsylvania	Northampton Co	6	6	247,105
3	Altoona. PA	Pennsylvania	Blair Co	6	6	130,542
3	Baltimore. MD	Maryland	Anne Arundel Co	3	7	427,239
3	Baltimore. MD	Maryland	Baltimore	3	6	736,014
3	Baltimore. MD	Maryland	Baltimore Co	3	6	692,134
3	Baltimore. MD	Maryland	Carroll Co	3	6	123,372
3	Baltimore. MD	Maryland	Harford Co	3	6	182,132
3	Baltimore. MD	Maryland	Howard Co	3	6	187,328
3	Charleston. WV	West Virginia	Kanawha Co	5	6	207,619
3	Charleston. WV	West Virginia	Putnam Co	5	6	42,835
3	Erie. PA	Pennsylvania	Erie Co	6	5	275,572
3	Harrisburg-Leba	Pennsylvania	Cumberland Co	6	6	195,257
3	Harrisburg-Leba	Pennsylvania	Dauphin Co	6	6	237,813
3	Harrisburg-Leba	Pennsylvania	Lebanon Co	6	6	113,744
3	Harrisburg-Leba	Pennsylvania	Perry Co	6	6	41,172
3	Johnstown. PA	Pennsylvania	Cambria Co	6	5	163,029
3	Johnstown. PA	Pennsylvania	Somerset Co	6	6	78,218
3	Kent & Queen An	Maryland	Kent Co	6	7	17,842
3	Kent & Queen An	Maryland	Queen Annes Co	6	7	33,953
3	Lancaster. PA	Pennsylvania	Lancaster Co	6	6	422,822
3	Norfolk-Virgini	Virginia	Chesapeake	6	8	151,976

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
3	Norfolk-Virgini	Virginia	Hampton	6	7	133,793
3	Norfolk-Virgini	Virginia	James City Co	6	7	34,859
3	Norfolk-Virgini	Virginia	Newport News	6	7	170,045
3	Norfolk-Virgini	Virginia	Norfolk	6	8	261,229
3	Norfolk-Virgini	Virginia	Poquoson	6	7	11,005
3	Norfolk-Virgini	Virginia	Portsmouth	6	8	103,907
3	Norfolk-Virgini	Virginia	Suffolk	6	8	52,141
3	Norfolk-Virgini	Virginia	Virginia Beach	6	8	393,069
3	Norfolk-Virgini	Virginia	Williamsburg	6	7	11,530
3	Norfolk-Virgini	Virginia	York Co	6	7	42,422
3	Parkersburg-Mar	West Virginia	Wood Co	5	6	86,915
3	Pittsburgh-Beav	Pennsylvania	Allegheny Co	5	5	1,336,449
3	Pittsburgh-Beav	Pennsylvania	Armstrong Co	5	5	73,478
3	Pittsburgh-Beav	Pennsylvania	Beaver Co	5	6	186,093
3	Pittsburgh-Beav	Pennsylvania	Butler Co	5	5	152,013
3	Pittsburgh-Beav	Pennsylvania	Fayette Co	5	5	145,351
3	Pittsburgh-Beav	Pennsylvania	Washington Co	5	6	204,584
3	Pittsburgh-Beav	Pennsylvania	Westmoreland Co	5	5	370,321
3	Reading, PA	Pennsylvania	Berks Co	5	6	336,523
3	Richmond-Peters	Virginia	Charles City Co	5	7	6,282
3	Richmond-Peters	Virginia	Chesterfield Co	5	7	209,274
3	Richmond-Peters	Virginia	Colonial Heights	5	7	16,064
3	Richmond-Peters	Virginia	Hanover Co	5	7	63,306
3	Richmond-Peters	Virginia	Henrico Co	5	7	217,881
3	Richmond-Peters	Virginia	Hopewell	5	7	23,101
3	Richmond-Peters	Virginia	Richmond	5	7	203,056
3	Scranton-Wilkes	Pennsylvania	Columbia Co	6	5	63,202
3	Scranton-Wilkes	Pennsylvania	Lackawanna Co	6	5	219,039
3	Scranton-Wilkes	Pennsylvania	Luzerne Co	6	5	328,149
3	Scranton-Wilkes	Pennsylvania	Monroe Co	6	6	95,709
3	Scranton-Wilkes	Pennsylvania	Wyoming Co	6	5	28,076
3	Washington, DC-	Dist. Columbia	Washington	4	6	606,900
3	Washington, DC-	Maryland	Calvert Co	4	7	51,372
3	Washington, DC-	Maryland	Charles Co	4	7	101,154
3	Washington, DC-	Maryland	Frederick Co	4	6	150,208
3	Washington, DC-	Maryland	Montgomery Co	4	6	757,027
3	Washington, DC-	Maryland	Prince George's Co	4	6	729,268
3	Washington, DC-	Virginia	Alexandria	4	6	111,183
3	Washington, DC-	Virginia	Arlington Co	4	6	170,936
3	Washington, DC-	Virginia	Fairfax	4	6	19,622
3	Washington, DC-	Virginia	Fairfax Co	4	6	818,584
3	Washington, DC-	Virginia	Falls Church	4	6	9,578
3	Washington, DC-	Virginia	Loudoun Co	4	6	86,129
3	Washington, DC-	Virginia	Manassas	4	6	27,957
3	Washington, DC-	Virginia	Manassas Park	4	6	6,734
3	Washington, DC-	Virginia	Prince William Co	4	7	215,686
3	Washington, DC-	Virginia	Stafford Co	4	7	61,236
3	York, PA	Pennsylvania	Adams Co	6	6	78,274
3	York, PA	Pennsylvania	York Co	6	6	339,574
3	Sussex Co, DE	Delaware	Sussex Co	6	7	113,229
3	Smyth Co, VA	Virginia	Smyth Co	6	6	32,370
3	Greenbrier Co,	West Virginia	Greenbrier Co	6	5	34,693
3-4	Huntington-Ashl	Kentucky	Boyd Co	5	6	51,150
3-4	Huntington-Ashl	Kentucky	Greenup Co	5	6	36,742
3-4	Huntington-Ashl	West Virginia	Cabell Co	5	6	96,827
3-4	Huntington-Ashl	West Virginia	Wayne Co	5	6	41,636
3-5	Youngstown-Warr	Ohio	Mahoning Co	6	5	264,806

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
3-5	Youngstown-Warr	Ohio	Trumbull Co	6	5	227,813
3-5	Youngstown-Warr	Pennsylvania	Mercer Co	6	5	121,003
4	Atlanta, GA	Georgia	Cherokee Co	4	7	90,204
4	Atlanta, GA	Georgia	Clayton Co	4	7	182,052
4	Atlanta, GA	Georgia	Cobb Co	4	7	447,745
4	Atlanta, GA	Georgia	Coweta Co	4	7	53,853
4	Atlanta, GA	Georgia	De Kalb Co	4	7	545,837
4	Atlanta, GA	Georgia	Douglas Co	4	7	71,120
4	Atlanta, GA	Georgia	Fayette Co	4	7	62,415
4	Atlanta, GA	Georgia	Forsyth Co	4	7	44,083
4	Atlanta, GA	Georgia	Fulton Co	4	7	648,951
4	Atlanta, GA	Georgia	Gwinnett Co	4	7	352,910
4	Atlanta, GA	Georgia	Henry Co	4	7	58,741
4	Atlanta, GA	Georgia	Paulding Co	4	7	41,611
4	Atlanta, GA	Georgia	Rockdale Co	4	7	54,091
4	Birmingham, AL	Alabama	Jefferson Co	6	7	651,525
4	Birmingham, AL	Alabama	Shelby Co	6	7	99,358
4	Charlotte-Gasto	North Carolina	Gaston Co	5	7	175,093
4	Charlotte-Gasto	North Carolina	Mecklenburg Co	5	7	511,433
4	Greensboro-Wins	North Carolina	Davidson Co	5	7	126,677
4	Greensboro-Wins	North Carolina	Davie Co	5	7	27,859
4	Greensboro-Wins	North Carolina	Forsyth Co	5	7	265,878
4	Greensboro-Wins	North Carolina	Guilford Co	5	7	347,420
4	Jacksonville, F	Florida	Duval Co	8	9	672,971
4	Knoxville, TN	Tennessee	Knox Co	6	6	335,749
4	Lexington-Fayet	Kentucky	Fayette Co	6	6	225,366
4	Lexington-Fayet	Kentucky	Scott Co	6	6	23,867
4	Memphis, TN-AR-	Tennessee	Shelby Co	6	7	826,330
4	Miami-Fort Laud	Florida	Broward Co	5	10	1,255,488
4	Miami-Fort Laud	Florida	Dade Co	5	10	1,937,094
4	Miami-Fort Laud	Florida	Palm Beach Co	5	9	863,518
4	Nashville, TN	Tennessee	Davidson Co	5	6	510,784
4	Nashville, TN	Tennessee	Rutherford Co	5	6	118,570
4	Nashville, TN	Tennessee	Sumner Co	5	6	103,281
4	Nashville, TN	Tennessee	Williamson Co	5	6	81,021
4	Nashville, TN	Tennessee	Wilson Co	5	6	67,675
4	Owensboro, KY	Kentucky	Daviess Co	6	6	87,189
4	Owensboro, KY	Kentucky	Hancock Co	6	6	7,864
4	Paducah, KY (No	Kentucky	Livingston Co	6	6	9,062
4	Paducah, KY (No	Kentucky	Marshall Co	6	6	27,205
4	Raleigh-Durham,	North Carolina	Durham Co	5	7	181,835
4	Raleigh-Durham,	North Carolina	Granville Co	5	7	38,345
4	Raleigh-Durham,	North Carolina	Wake Co	5	7	423,380
4	Tampa-St. Peter	Florida	Hillsborough Co	6	9	834,054
4	Tampa-St. Peter	Florida	Pinellas Co	6	9	851,659
4	Edmonson Co	Kentucky	Edmonson Co	6	6	10,357
4	Cherokee @ Gree	South Carolina	Cherokee Co	6	7	44,506
4-5	Cincinnati-Hami	Kentucky	Boone Co	5	6	57,589
4-5	Cincinnati-Hami	Kentucky	Campbell Co	5	6	83,866
4-5	Cincinnati-Hami	Kentucky	Kenton Co	5	6	142,031
4-5	Cincinnati-Hami	Ohio	Butler Co	5	6	291,479
4-5	Cincinnati-Hami	Ohio	Clermont Co	5	6	150,187
4-5	Cincinnati-Hami	Ohio	Hamilton Co	5	6	866,228
4-5	Cincinnati-Hami	Ohio	Warren Co	5	6	113,909
4-5	Louisville, KY-	Indiana	Clark Co	5	6	87,777
4-5	Louisville, KY-	Indiana	Floyd Co	5	6	64,404
4-5	Louisville, KY-	Kentucky	Bullitt Co	5	6	47,567

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
4-5	Louisville, KY-	Kentucky	Jefferson Co	5	6	664,937
4-5	Louisville, KY-	Kentucky	Oldham Co	5	6	33,263
5	Canton, OH	Ohio	Stark Co	6	5	367,585
5	Chicago-Gary-La	Illinois	Cook Co	2	5	5,105,067
5	Chicago-Gary-La	Illinois	Du Page Co	2	5	781,666
5	Chicago-Gary-La	Illinois	Grundy Co	2	5	32,337
5	Chicago-Gary-La	Illinois	Kane Co	2	5	317,471
5	Chicago-Gary-La	Illinois	Kendall Co	2	5	39,413
5	Chicago-Gary-La	Illinois	Lake Co	2	5	516,418
5	Chicago-Gary-La	Illinois	McHenry Co	2	5	183,241
5	Chicago-Gary-La	Illinois	Will Co	2	5	357,313
5	Chicago-Gary-La	Indiana	Lake Co	2	5	475,594
5	Chicago-Gary-La	Indiana	Porter Co	2	5	128,932
5	Cleveland-Akron	Ohio	Ashtabula Co	5	5	99,821
5	Cleveland-Akron	Ohio	Cuyahoga Co	5	5	1,412,140
5	Cleveland-Akron	Ohio	Geauga Co	5	5	81,129
5	Cleveland-Akron	Ohio	Lake Co	5	5	215,499
5	Cleveland-Akron	Ohio	Lorain Co	5	5	271,126
5	Cleveland-Akron	Ohio	Medina Co	5	5	122,354
5	Cleveland-Akron	Ohio	Portage Co	5	5	142,585
5	Cleveland-Akron	Ohio	Summit Co	5	5	514,990
5	Columbus, OH	Ohio	Delaware Co	6	5	66,929
5	Columbus, OH	Ohio	Franklin Co	6	5	961,437
5	Columbus, OH	Ohio	Licking Co	6	5	128,300
5	Dayton-Springfi	Ohio	Clark Co	5	5	147,548
5	Dayton-Springfi	Ohio	Greene Co	5	5	136,731
5	Dayton-Springfi	Ohio	Miami Co	5	5	93,182
5	Dayton-Springfi	Ohio	Montgomery Co	5	6	573,809
5	Detroit-Ann Arb	Michigan	Livingston Co	5	5	115,645
5	Detroit-Ann Arb	Michigan	Macomb Co	5	6	717,400
5	Detroit-Ann Arb	Michigan	Monroe Co	5	5	133,600
5	Detroit-Ann Arb	Michigan	Oakland Co	5	6	1,083,592
5	Detroit-Ann Arb	Michigan	St. Clair Co	5	5	145,607
5	Detroit-Ann Arb	Michigan	Washtenaw Co	5	5	282,937
5	Detroit-Ann Arb	Michigan	Wayne Co	5	5	2,111,687
5	Evansville, IN-	Indiana	Vanderburgh Co	6	6	165,058
5	Flint, MI	Michigan	Genesee Co	8	5	430,459
5	Grand Rapids, M	Michigan	Kent Co	5	5	500,631
5	Grand Rapids, M	Michigan	Ottawa Co	5	5	187,768
5	Indianapolis, I	Indiana	Marion Co	6	5	797,159
5	Lansing-East La	Michigan	Clinton Co	8	5	57,883
5	Lansing-East La	Michigan	Eaton Co	8	5	92,879
5	Lansing-East La	Michigan	Ingham Co	8	5	281,912
5	Milwaukee-Racin	Wisconsin	Kenosha Co	2	5	128,181
5	Milwaukee-Racin	Wisconsin	Milwaukee Co	2	5	959,275
5	Milwaukee-Racin	Wisconsin	Ozaukee Co	2	5	72,831
5	Milwaukee-Racin	Wisconsin	Racine Co	2	5	175,034
5	Milwaukee-Racin	Wisconsin	Washington Co	2	5	95,328
5	Milwaukee-Racin	Wisconsin	Waukesha Co	2	5	304,715
5	Muskegon, MI	Michigan	Muskegon Co	5	5	158,983
5	Sheboygan, WI	Wisconsin	Sheboygan Co	5	5	103,877
5	South Bend-Mish	Indiana	Elkhart Co	6	5	156,198
5	South Bend-Mish	Indiana	St. Joseph Co	6	5	247,052
5	Steubenville-We	Ohio	Jefferson Co	8	6	80,298
5	Toledo, OH	Ohio	Lucas Co	5	5	462,361
5	Toledo, OH	Ohio	Wood Co	5	5	113,269
5	Jersey Co	Illinois	Jersey Co	6	5	20,539

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
5	Clinton Co. OH	Ohio	Clinton Co	8	6	35,415
5	Preble Co at Da	Ohio	Preble Co	8	6	40,113
5	Door Co, WI	Wisconsin	Door Co	6	5	25,690
5	Kewaunee Co, WI	Wisconsin	Kewaunee Co	5	5	18,878
5	Manitowoc Co, W	Wisconsin	Manitowoc Co	5	5	80,421
5	Walworth @ Milw	Wisconsin	Walworth Co	6	5	75,000
5-7	St Louis, MO-IL	Illinois	Madison Co	5	6	249,238
5-7	St Louis, MO-IL	Illinois	Monroe Co	5	6	22,422
5-7	St Louis, MO-IL	Illinois	St. Clair Co	5	6	262,852
5-7	St Louis, MO-IL	Missouri	Franklin Co	5	5	80,603
5-7	St Louis, MO-IL	Missouri	Jefferson Co	5	5	171,380
5-7	St Louis, MO-IL	Missouri	St. Charles Co	5	5	212,907
5-7	St Louis, MO-IL	Missouri	St. Louis	5	6	396,685
5-7	St Louis, MO-IL	Missouri	St. Louis Co	5	6	993,529
6	Baton Rouge, LA	Louisiana	Ascension Par	4	8	58,214
6	Baton Rouge, LA	Louisiana	East Baton Rouge Par	4	8	380,105
6	Baton Rouge, LA	Louisiana	Iberville Par	4	8	31,049
6	Baton Rouge, LA	Louisiana	Livingston Par	4	8	70,526
6	Baton Rouge, LA	Louisiana	Pointe Coupee Par	4	8	22,540
6	Baton Rouge, LA	Louisiana	West Baton Rouge Par	4	8	19,419
6	Beaumont-Port A	Texas	Hardin Co	4	8	41,320
6	Beaumont-Port A	Texas	Jefferson Co	4	9	239,397
6	Beaumont-Port A	Texas	Orange Co	4	9	80,509
6	Dallas-Fort Wor	Texas	Collin Co	5	7	264,036
6	Dallas-Fort Wor	Texas	Dallas Co	5	8	1,852,810
6	Dallas-Fort Wor	Texas	Denton Co	5	7	273,525
6	Dallas-Fort Wor	Texas	Tarrant Co	5	8	1,170,103
6	El Paso, TX	Texas	El Paso Co	4	7	591,610
6	Houston-Galvest	Texas	Brazoria Co	2	9	191,707
6	Houston-Galvest	Texas	Chambers Co	2	9	20,088
6	Houston-Galvest	Texas	Fort Bend Co	2	8	225,421
6	Houston-Galvest	Texas	Galveston Co	2	9	217,399
6	Houston-Galvest	Texas	Harris Co	2	8	2,818,199
6	Houston-Galvest	Texas	Liberty Co	2	8	52,726
6	Houston-Galvest	Texas	Montgomery Co	2	8	182,201
6	Houston-Galvest	Texas	Waller Co	2	8	23,390
6	Lafayette, LA	Louisiana	Lafayette Par	8	8	164,762
6	Lake Charles, L	Louisiana	Calcasieu Par	6	8	168,134
6	New Orleans, LA	Louisiana	Jefferson Par	8	8	448,306
6	New Orleans, LA	Louisiana	Orleans Par	8	8	496,938
6	New Orleans, LA	Louisiana	St. Bernard Par	8	9	66,631
6	New Orleans, LA	Louisiana	St. Charles Par	8	8	42,437
7	Kansas City, MO	Kansas	Johnson Co	7	5	355,054
7	Kansas City, MO	Kansas	Wyandotte Co	7	5	161,993
7	Kansas City, MO	Missouri	Clay Co	7	5	153,411
7	Kansas City, MO	Missouri	Jackson Co	7	5	633,232
7	Kansas City, MO	Missouri	Platte Co	7	5	57,867
8	Denver-Boulder,	Colorado	Adams Co	8	5	265,038
8	Denver-Boulder,	Colorado	Arapahoe Co	8	5	391,511
8	Denver-Boulder,	Colorado	Boulder Co	8	4	225,339
8	Denver-Boulder,	Colorado	Denver Co	8	5	467,610
8	Denver-Boulder,	Colorado	Douglas Co	8	5	60,391
8	Denver-Boulder,	Colorado	Jefferson Co	8	5	438,430
8	Salt Lake City-	Utah	Davis Co	5	6	187,941
8	Salt Lake City-	Utah	Salt Lake Co	5	7	725,956
9	Chico, CA	California	Butte Co	8	8	182,120
9	Los Angeles-Ana	California	Los Angeles Co	1	9	8,863,164

Appendix D: Table D2

Ozone Non-Attainment Areas, by County, Class, and Temperature Zone

EPA Region	Non-Attainment Area	State	County	Ozone Desig.	Temp. Zone	1990 Population
9	Los Angeles-Ana	California	Orange Co	1	10	2,410,556
9	Monterey Bay	California	Monterey Co	5	9	355,660
9	Monterey Bay	California	San Benito Co	5	9	36,697
9	Monterey Bay	California	Santa Cruz Co	5	9	229,734
9	Imperial Co, CA	California	Imperial Co	8	9	109,303
9	Ventura Co	California	Ventura Co	3	9	669,016
9	Phoenix, AZ	Arizona	Maricopa Co	5	9	2,122,101
9	Reno, NV	Nevada	Washoe Co	6	7	254,667
9	Sacramento, CA	California	El Dorado Co	4	8	125,995
9	Sacramento, CA	California	Placer Co	4	8	172,796
9	Sacramento, CA	California	Sacramento Co	4	9	1,041,219
9	Yuba City, CA	California	Sutter Co	4	9	64,415
9	Sacramento, CA	California	Yolo Co	4	9	141,092
9	San Diego, CA	California	San Diego Co	3	9	2,498,016
9	San Francisco-O	California	Alameda Co	5	9	1,279,182
9	San Francisco-O	California	Contra Costa Co	5	9	803,732
9	San Francisco-O	California	Marin Co	5	10	230,096
9	San Francisco-O	California	Napa Co	5	9	110,765
9	San Francisco-O	California	San Francisco Co	5	10	723,959
9	San Francisco-O	California	San Mateo Co	5	10	649,623
9	San Francisco-O	California	Santa Clara Co	5	9	1,497,577
9	San Francisco-O	California	Solano Co	5	9	340,421
9	San Francisco-O	California	Sonoma Co	5	9	388,222
9	Fresno, CA	California	Fresno Co	4	9	667,490
9	Bakersfield, CA	California	Kern Co	4	9	543,477
9	Fresno, CA	California	Kings Co	4	9	101,469
9	Madera Co, CA	California	Madera Co	4	8	88,090
9	Merced, CA	California	Merced Co	4	9	178,403
9	Stockton, CA	California	San Joaquin Co	4	9	480,628
9	Modesto, CA	California	Stanislaus Co	4	9	370,522
9	Visalia-Tulare-	California	Tulare Co	4	9	311,921
9	Santa Barbara-S	California	Santa Barbara Co	5	10	369,608
9	Los Angeles-Ana	California	Riverside Co	2	9	1,170,413
9	Los Angeles-Ana	California	San Bernardino Co	2	9	1,418,380
9	Yuba City, CA	California	Yuba Co	8	8	58,228
10	Portland-Vancou	Oregon	Clackamas Co	6	8	278,850
10	Portland-Vancou	Oregon	Multnomah Co	6	8	583,887
10	Portland-Vancou	Oregon	Washington Co	6	8	311,554
10	Portland-Vancou	Washington	Clark Co	6	8	238,053
10	Seattle-Tacoma.	Washington	King Co	6	8	1,507,319
10	Seattle-Tacoma.	Washington	Pierce Co	6	8	586,203
10	Seattle-Tacoma.	Washington	Snohomish Co	6	8	465,642
	Total:					146,423,413