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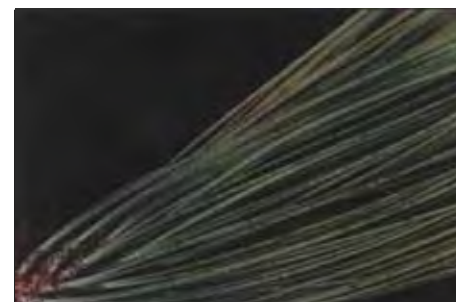
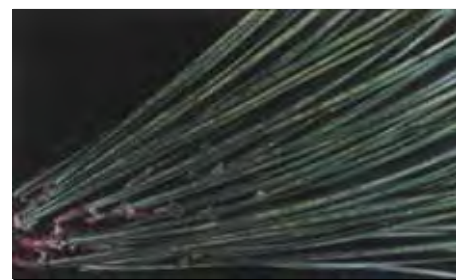
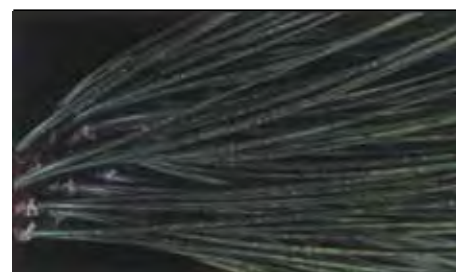
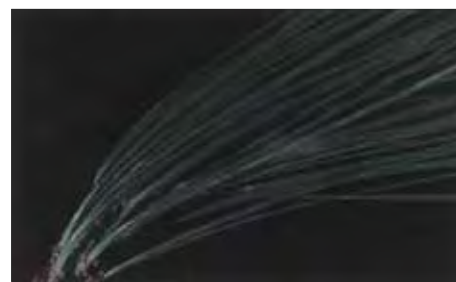


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Evaluating Ozone Air Pollution Effects on Pines in the Western United States

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Abstract

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Historical and technical background is provided about ozone air pollution effects on ponderosa (*Pinus ponderosa* Dougl. ex Laws) and Jeffrey (*P. jeffreyi* Grev. and Balf.) pines in forests of the western United States. The principal aim is to document the development of field survey methods to be applied to assessment of chronic ozone injury by government agencies responsible for management of forest and air resources, primarily in the Sierra Nevada and mountains of southern California. Detailed procedures are supplied for the selection of sample plots, collection of plot and tree data, computation of an injury index for each tree and execution of quality assurance procedures. The methods have been field tested in California National Forests and National Parks during 4 consecutive years.

Retrieval terms: ozone, injury, ponderosa, Jeffrey, pines, methods

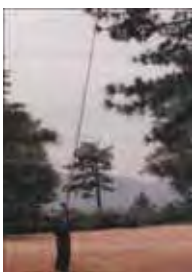
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A standard method is needed to evaluate the effects of chronic ozone air pollution on the health of ponderosa and Jeffrey pines in California and other western States. These species are ideal bioindicators of ozone damage because they are ozone sensitive, widely distributed, and an important element of the forest ecosystem. The first two papers of this report describe the current knowledge of extent and severity of ozone injury to conifer forests in the West and present the reasons why government agencies need a continuing assessment of this problem for the implementation of sound ecosystem management. The next three papers describe the biological mechanism of ozone injury, review the development and application of early methods for assessing injury to pines, and present the statistical criteria for plot design and sampling procedures. These papers provide the basis for the design of a recommended standard procedure. The last three papers present detailed instructions for establishing sample plots, collecting data, processing data, and applying quality assurance procedures. The appendix provides very precise detail for tasks relating to data gathering, data processing and expressing injury in the form of an injury index. The method has been field tested by collecting data from 1,700 trees at 33 plots in California from 1991 to 1994. Although this report provides a fully workable method for measurement and description of chronic ozone injury to pines, the authors encourage further development of methods for data collection and interpretation.

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Preface

The high rate of fossil fuel consumption needed to sustain the economies of western States, coupled with ever-increasing population densities, result in air pollution. The climate and topography in California are particularly conducive to the accumulation of ozone in urbanized air basins and the subsequent long-range transport to forested mountains downwind. Ozone damages many plant species including ponderosa and Jeffrey pines. The natural range of these species in the Sierra Nevada and southern California mountains is extensive. Chronic ozone exposure damages the foliage, reduces growth and makes trees more vulnerable to natural pests like the pine bark beetle. Protection of this forest resource requires knowledge about the extent of ozone damage and its change in severity over time.

The purposes of this report are to (1) examine the current effects of ozone air pollution on mixed conifer forests in the western United States; (2) review the mechanisms by which ozone injures leaf tissue and diminishes tree health; (3) describe and evaluate the historical methods used by different groups to evaluate ozone injury to pines and to assign a numerical index of injury for the purpose of tracking injury trends; (4) prescribe the statistical principles that must be applied for sampling; (5) propose an improved method for measurement and evaluation of ozone response variables to develop an injury index for ponderosa and Jeffrey pines; (6) provide detailed instructions for establishing monitoring plots, measuring ozone injury and other essential plot and tree variables; and (7) outline the procedures for handling the data set derived from annual measurements, including the computation of the current injury index.

Representatives of Federal land management agencies, and the California Air Resources Board began the process of implementing these objectives at a meeting held in 1989 at the USDA Forest Service's Pacific Southwest Research Station, Riverside, California. Preliminary drafts of this report have been prepared and circulated within a small interagency committee of workers with responsibilities to assess the prevalence and severity of ozone injury to conifer forests using ponderosa and Jeffrey pines as bioindicators. Agreement on basic methods was available by 1991 so that monitoring plots were established and tree injury data collected at approximately 33 locations in the Sierra Nevada and San Bernardino Mountains. This activity was named the Forest Ozone REsponse Study (FOREST). Each year from 1991 to 1994 summer training sessions were held to certify data gatherers and winter debriefing sessions were implemented to evaluate methods and examine data summaries from the preceding summer. These iterations have led to standardization and refinement of the procedures included in the data collection and analysis portions of this document.

The guiding principle of this effort has been to establish a methodology leading to the computation of a single injury index on the basis of a diverse data base of plot, tree, branch, and needle data that will facilitate exploration of other methods for describing and assessing chronic ozone injury. Some measured attributes must serve as common denominators allowing interpretation between different numerical expressions of chronic tree injury. The index proposed by the authors represents the current state-of-the-science; future modifications and improvements may result from further analysis of the data.

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