Does Long-term Crown Injury from Ozone Affect Bole Growth of Pines in the Southern Sierra Nevada?

Forest Pest Management Ozone Survey Plots (FPM)

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Introduction

Injury to the mixed conifer forest from tropospheric ozone has been occurring in southern California since the 1950's and in the Sierra Nevada since the 1970's (Miller and Millecan 1971, Pronos et al. 1978). Research by Miller et al. (1963) identified the unique injury symptomology, foliar chlorotic mottle (*see picture below*), associated with ozone exposure. In recent years federal and state land management agencies have initiated programs to develop monitoring methodologies to assess oxidant injury to ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) and Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.), the two most affected tree species of the mixed conifer forest ecosystem.

Although crown injury has been well documented in the Sierra Nevada, association of crown injury with bole growth changes has been less successful. Past studies have indicated that site averaged changes in growth that could be attributed to ozone injury to may occur at a few locations for Jeffrey pine (Peterson et al. 1987), but neither locally or regionally for Ponderosa pine (Peterson and Arbaugh 1988, Peterson et al. 1989) even though foliar sensitivity to ozone is equal for both species (Miller et al 1997).

Recent studies indicate that some individual pines have endogenously (genetically) higher conductance of ozone relative to the population (Grulke 1999). This may partially explain the lack of clear connection between foliar and bole diameter changes over the region. Small numbers of injured crowns may influence averaged site scores, but growth changes in these trees may be obscured by averaging across the site (by including larger amounts of growth variation due to age, stand dynamics, etc.).

In this study an alternative comparison approach will be investigated using a series of plots that were established in the Sequoia and Sierra National Forests by Forest Pest Management in 1977, then re-evaluated every two years through 2000. Cores were evaluated for paired trees from each site selected for comparable crown dominance position (only co-dominant trees were used in this analysis), comparable tree age/dbh, but different averaged historical FPM scores. Several comparisons of basal area growth between pre-pollution (prior to 1956) and pollution periods (after 1955) within trees, between paired trees, and between sites were conducted to examine whether individual trees with severe crown injury had detectable growth changes when compared to trees with slight or no crown injury.

Mounted tree cores

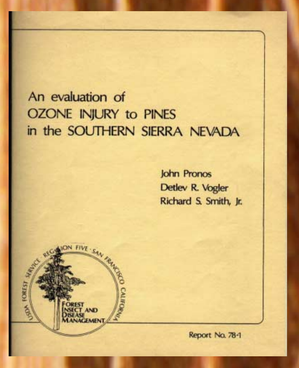
Site and Study Design

In 1977 a large scale survey of ozone crown injury was conducted in the Southern Sierra Nevada. Potential plot sites were systematically located on topographic maps wherever roads or trails intersected 4000, 5000, 6000, 7000, and 8000 foot (1220, 1525, 1830, 2135, and 2440 meter) contour lines. These elevational limits were used because the majority of commercial pine stands in the southern Sierra Nevada are found between 4000 and 8000 feet. Plot sites were then visited on the ground and considered valid if ten ponderosa and/or Jeffrey pines were found within an area one chain (20 meters) by six chains (121 meters) on each side of and parallel to the road or trail. The near edge of each plot was separated from the roadside influence by one-half chain (10 meters). Four hundred seventy-four sites were visited, and from these, 242 valid plots were established and evaluated. Subsequently 44 of these plots were chosen to be re-evaluated on the Sequoia and Sierra National Forests. These re-evaluations were conducted between 1978 and 2000 by the same person, one forest per year. In 2000 a subset of these plots was visited and two cores were taken from all surviving, and recently deceased trees.

Within each plot various site and tree characteristics were observed or measured. Some of the important data collected included the level of ozone injury, the other pests present on each of the ten trees, the distance from the plot to the suspected metropolitan pollution source, and the plot elevation. Pest data were collected to avoid confusing other abiotic or biotic symptoms with ozone injury.

FPM Survey Methodology

The FPM index was developed by the USDA Forest Service's Forest Pest Management staff (Pronos et al. 1978) and uses a five point nominal rating scale that identifies injury based upon the most recent whorl of needles that show chlorotic mottle symptoms from ozone. The FPM index provides a means for making repeated estimates of ozone injury on the same trees at the end of each summer season. Data from hands-on inspection of unpruned branches of small trees or pruned branches from the lower crowns of large trees was used for index calculation. Ozone injury is quantified by noting the youngest whorl of needles showing chlorotic mottle symptoms from ozone. The index has a range from 0 to 4 for each tree; if there is injury on the current year then the score is 0, if there is no injury to the current year's needles but there is injury on the 1-year old needles, then the score is 1; if there is no injury on 0 or 1 year old needles but there is injury on 2-year old needles then the score is 2. This proceeds through 4-year old needles, where if no injury is found the score is 4, and the tree is considered uninjured by ozone.



Analysis Approach

The choice of paired trees has great potential to influence the analysis results. Growth rates were not used to determine pair members, which were chosen prior to mounting the tree cores. Pairs were determined based upon only the historical and present crown position of the tree, present dbh, and average 20-year crown injury. Each pair used in this preliminary analysis was chosen to be a stand co-dominant and have comparable dbh's (to reduce comparisons between trees with greatly different ages or histories). One member of the pair had average FPM < 2.0, and the other had FPM > 3.0. If multiple candidate trees were present at a site, then the sample tree was selected randomly. Core ages were subsequently examined to confirm general age comparability. Fifteen pairs of trees at 14 different sites were identified using this approach from among the 200+ trees cored in this study.

Tree growth was divided into two periods – 1911 through 1955, and 1956 through 1999. This division has been determined by prior studies (Peterson et al. 1987, Peterson and Arbaugh 1988, Peterson et al. 1989) to be reasonable for determining bole growth that might be influenced by urban transported pollution in the Sierra Nevada.

Observational studies have many sources of variability due to the lack of control that is present in true experimental designs. Increasing the number and type of comparisons conducted is one way to compensate for this problem. Thus instead of a single comparison, we will rely on several different comparisons that must yield consistent results before we conclude that a significant effect is present. We have chosen four comparisons of growth to determine if severely injured trees also have growth reductions. All comparisons were conducted using total basal area growth in the pre-pollution period (BA_{ikt1}) and pollution period basal area growth (BA_{ikt2}) for each tree, where basal area (BA) is the basal area growth for tree i (severely crown injury) or j (slight to no crown injury), site k, and time periods (t1 – pre-pollution period, and t2-pollution period).

The four measures used in the analysis are:

$\Delta BA_{ik} = (BA_{ikt2} - BA_{ikt1})/(BA_{ikt1}+BA_{ikt2})$, (1)

$\Delta BA_{kt2} = (BA_{jkt2} - BA_{ikt2})/(BA_{jkt2}+BA_{ikt2})$, (2)

$\Delta BA_{kt1} = (BA_{jkt1} - BA_{ikt1})/(BA_{jkt1}+BA_{ikt1})$, (3)

$\Delta BA_{k} = (\Delta BA_{jk} - \Delta BA_{ik})$, (4)

The first measure (1) compares time period differences in growth within the same tree, (2) the difference in growth in the pre-pollution period between paired trees, (3) the difference in growth during the pollution period between paired trees, and (4) changes in growth between pre- and pollution periods between paired trees at a site. Relative measures were chosen to reduce the influence of intrinsic site factors that result in faster or slower growth.

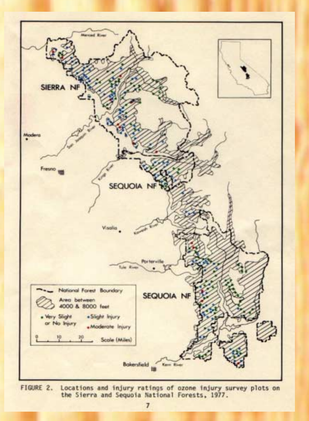


FIGURE 2. Locations and injury ratings of ozone injury survey plots on the Sierra and Sequoia National Forests, 1977.
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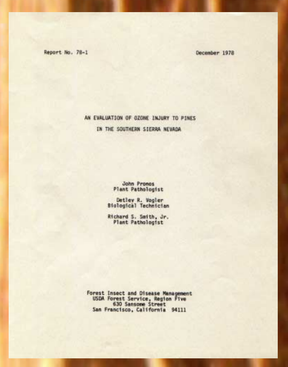
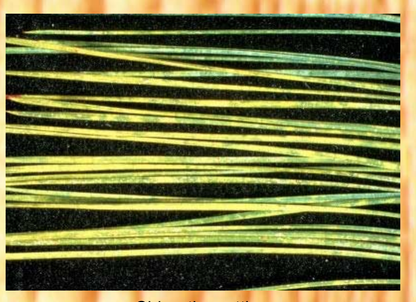
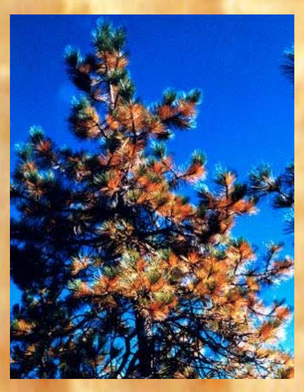




Chlorotic mottle

Results and Future Analyses:

Results are still being analyzed for pairs of trees, and we anticipate results will be presented orally at this meeting (Wed. 7:00 pm). It is possible that these preliminary analysis results may be dependent on the choice of paired trees at a site. In future analyses will use the same approach listed in the methods section, but with alternate pairings of trees. These pairings will be based on alternative criteria, such as random selection from severe and low-injury trees, inclusion of other crown dominance classes, dbh alone, and other groupings. If results of theses alternative pairings are consistent with the preliminary analysis then we will have more confidence that the study results are not due to the groupings chosen.



Ozone damaged tree crown

Chlorotic mottle and abiotic winter fleck

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