Current conditions and trends in ozone injury to pines in the Southern Sierra Nevada

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- **How are our forests responding to severe and prolonged ozone pollution?**
- **What is the current status of ozone injury to Jeffrey and ponderosa pines?**
- **As this stressor interacts with others in the changing ecosystem, what management and planning questions will these trends raise ?**

Project Overview

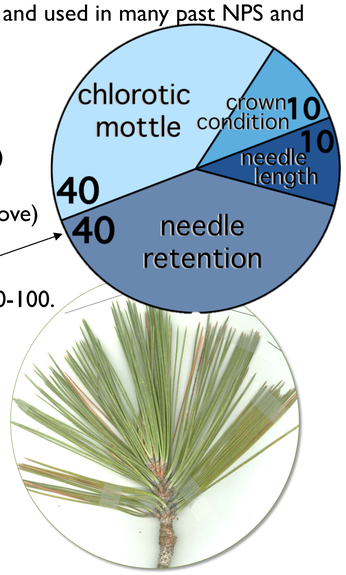
Our study addresses these questions by tracking ozone injury and growth in tagged ponderosa and Jeffrey pines. Surveys using the Ozone Injury Index method were conducted at eight sites in Sequoia and Kings Canyon National Parks and Sierra National Forest in 2011-2012. We have observed that over the course of twenty years, trees in polluted sites in the Southern Sierra continue to exhibit substantial injury from exposure to ozone; injury at lower exposure sites remains minimal. Our study extends the monitoring initiated by the interagency Forest Ozone Response Study in 1991, which aimed to understand how ambient ozone and tree injury were distributed on the western slope of the Sierra Nevada. Today, by examining these same trees and expanding the network to additional sites, we can understand forest response to chronic pollution and the resultant impacts on the ecosystem.

How to judge a tree by its color

Each tree is given an injury score using the Ozone Injury Index, or OII (Miller et al 1996). This technique, developed in California and used in many past NPS and USFS surveys, is very hands-on:

- Find the tag, check diameter
- Assess the percentage live crown
- Grab an extendable pole pruner
- Sample & label 5 branchlets (see lower right)
- *For each branchlet x whorl*:
  - Examine for mottled surface area (see above)
  - Classify retention
  - Measure typical length

Weighting the measures gives an **OII score** of 0-100.

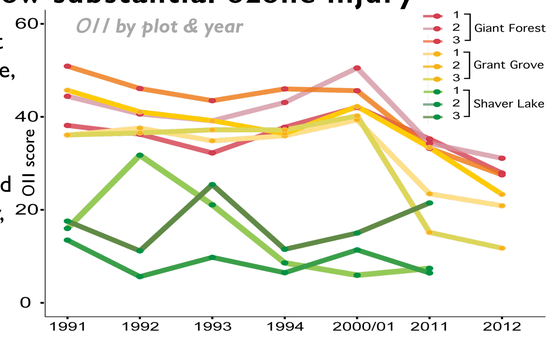


Our survey includes 494 trees in 8 sites. Giant Forest, Grant Grove and Shaver Lake locations (273 trees in 9 plots) have been surveyed eight times since 1991. The remaining 5 sites, all in Sierra National Forest and Sequoia and Kings Canyon National Parks (221 trees in 9 plots) were newly surveyed in 2011-12 to extend the monitoring network into less polluted parts of the region.

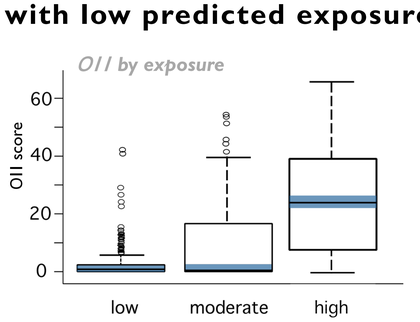
Ozone injury 1991-2012

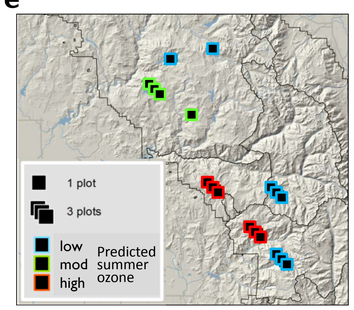
Jeffrey and ponderosa pines in polluted sites continue to show substantial ozone injury

At Giant Forest, Grant Grove, and Shaver Lake, ozone injury surveys now span 20+ years. In the 1990s the plots at Giant Forest showed the most severe injury, with OII scores of 35-50. Plot GF3, less than a mile from General Sherman, showed the highest overall: 50.5, sampled in summer 2000. Today, all trees in SEKI plots show a slight decline in injury severity. The largest shifts are seen in the Grant Grove area, at GG1 and GG3, both near Panoramic Point. At about 2200m, these plots are higher in elevation than any others in the monitoring network. Shaver Lake continues to have minor to moderate injury; ambient ozone exposure at this site is considerably lower than that farther south. The injury scores presented include all trees sampled six or more times; when possible, scores are averaged over two years.



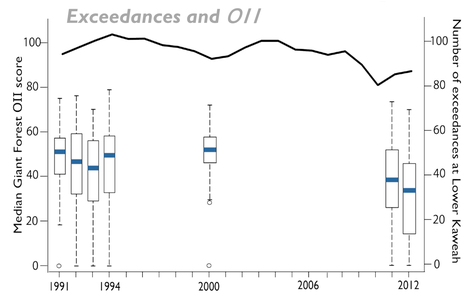
Injury in high ozone sites differs from that in sites with low predicted exposure





Survey sites added in 2011-2012 complement the study of more polluted areas by examining the condition of forests less exposed to damaging ozone. These locations have comparable forest composition and climatic water deficit, but regional ozone models built using 2006-2008 data predict summer average concentrations of 30 parts per billion by volume or less (Flint et al 2011; Panek, Saah, and Esperanza 2012). We found that injury in these "unpolluted" sites (see map) was significantly lower than that in the polluted sites (p=0.00). A few trees in unpolluted areas showed minor mottle. Exceptions like these serve as warning signs and also have the potential to help improve models of ozone distribution in the region.

Low within-site variability over 20 years



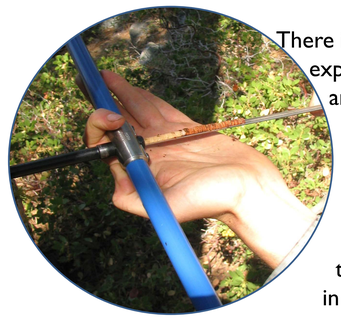
As seen in records of OII score across three plots at Giant Forest, severity of ozone injury to trees has remained fairly stable over the last 20 years. Exposure within sites is also stable, though exceedances of the EPA's 8 hour standard for ozone have dipped slightly in recent years.

Discussion

How might we manage chronically stressed ecosystems today and in the future? Up to date and accurate descriptions of the damage incurred are a first step. Observations over the past two decades show that ozone injury to pines continues in polluted sites. However, injury has not worsened through time, and we find little evidence of foliar damage in unexpected locations.

But should we expect trees and forests exposed to decades of pollution to be more vulnerable to environmental risks like bark beetle attack or catastrophic fire? Does pollution damage slow growth or overall forest productivity? In planning for long term ecosystem management, the interactions of multiple stressors represent a very complex range of possibilities. Quantification of the tree response to one stressor can provide a window into underlying ecological processes. Thus, a detailed account of forest condition will be helpful in describing the vulnerability of Southern Sierra ecosystems to changing environmental and anthropogenic risks.

Connected questions



There is reason to suspect that prolonged ozone exposure might slow tree growth: foliage is badly damaged, and since needles are the site of photosynthesis, it follows that tree growth would be negatively impacted. But trees that suffer water shortages close their stomata to further gas exchange, ending uptake of ozone. Using growth (tree ring) data from these same trees, our further work will investigate the interactions of ozone, drought, and tree growth in Southern Sierra Nevada forests.

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