ASSESSMENT OF OZONE-INDUCED FOLIAR INJURY ACROSS THE SOUTH FROM 1997 - 2002

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~ ABSTRACT ~

Ambient ozone (O_3) concentrations can cause visible foliar injury on a number of plant species. Currently, the USDA Forest Service is monitoring for O_3-induced foliar injury across the United States. The occurrence and severity of foliar injury, throughout 11 southern states, on O_3-sensitive species was determined on a total of 876 plots, 252 of which had some evidence of O_3 injury. On these plots, a total of 57,029 plants were examined, of which 2,589 had some degree of injury. A biosite index was derived from the amount and severity of injury recorded at each plot. Biosite index varied both spatially and temporally. For GA and VA (N_{yr}=6), 1998 had the highest average index (23.4 ±9.6 S.E.M. and 22.1 ±9.7 S.E.M., respectively). Biosite indices varied significantly (ANOVA) by year for: GA (N_{yr}=6, N_{plot}=148) (p=0.0925), LA (N_{yr}=2, N_{plot}=43) (p=0.0576), SC (N_{yr}=4, N_{plot}=92) (p<0.0001), and VA (N_{yr}=6, N_{plot}=130) (p=0.0286); state was significant for: 1999 (N_{states}=5, N_{plot}=90) (p<0.0001), 2000 (N_{states}=6, N_{plot}=178) (p=0.0084), and 2002 (N_{states}=11, N_{plot}=316) (p=0.0009). Blackberry (*Rubus allegheniensis*, Porter) and Sweetgum (*Liquidambar styraciflua*, L.) had the highest species indices (9.6 ±1.3 S.E.M. and 6.2 ±1.0 S.E.M., respectively), and were the most frequently tallied (N=19,325 and 13,659, respectively). Sensitivity to O_3 varied by species (p<0.0001), indicating that the distribution, selection, and evaluation of individual species could have an effect on the calculation of biosite indices.

~ INTRODUCTION ~

Ozone has been identified by the EPA as the most significant air pollutant affecting vegetation (U.S. EPA, 1996).

Figure 1. Yellow Poplar leaf showing ozone-induced injury.

Research has shown that ozone can cause foliar injury on a number of plant species (fig. 1).

Ozone injury varies according to a complex set of factors including, exposure, rates of stomatal uptake and sensitivity to ozone.

Ozone is formed when volatile organic compounds (VOCs) mix and react with nitrogen oxides (NOx) (fig. 2).

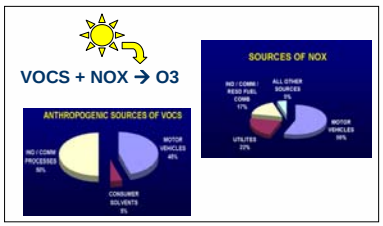

Figure 2. Ozone formation and sources of pre-cursors.

~ METHODS ~

➢O_3 injury was tallied on open areas (Biosites), at least 1 acre in size, within or alongside forested areas (USDA Forest Service, 2000).

➢At each biosite 30 plants of 2 indicator spp. were inspected for amount and severity of ozone injury

Amount= % of leaves on plant with injury (all leaves)
Severity = % of leaf area with injury (injured leaves)

➢Biosite Index (B. I.) (Smith et al. 2003) (table 1) was calculated as:

B. I. = avg. score (amount * severity) for each species, averaged across all species on site.

Table 1. Categories of injury for B. I.

Biosite Index	Bioindicator response
0 to 4.9	Little or no injury
5.0 to 14.9	Light to moderate injury
15.0 to 24.9	Moderate to sever injury
> 25	Severe foliar injury

~ RESULTS ~

•States varied in the amount of available data

•Yearly avg. B. I. ranged from 2.6 (2002) to 20.7 (1998) (table 2)

Table 2. Average B. I. by year.

YEAR	STATES WITH DATA	NUM PLOTS EVAL'D	NUM PLOTS WITH INJ	NUM PLANTS EVAL'D	NUM PLANTS WITH INJ	AVG BIOSITE INDEX
1997	GA, VA	19	8	697	101	7.0 ± 3.3
1998	AL, GA, VA	25	12	1419	260	20.7 ± 6.2
1999	AL, GA, NC, SC, VA	90	33	4409	405	12.0 ± 3.9
2000	NC, SC, TN, AR, GA, KY, VA	178	62	8937	529	5.5 ± 1.7
2001	KY, LA, NC, SC, TN, VA	248	76	14563	660	4.4 ± 1.0
2002	AL, AR, FL, GA, KY, LA, NC, SC, TN, TX, VA	316	61	26335	628	2.5 ± 0.5

•O_3 injury varied both spatially and temporally (fig. 3)

•1999 was a high year for NC and SC, but not for GA and VA (no data for other states)

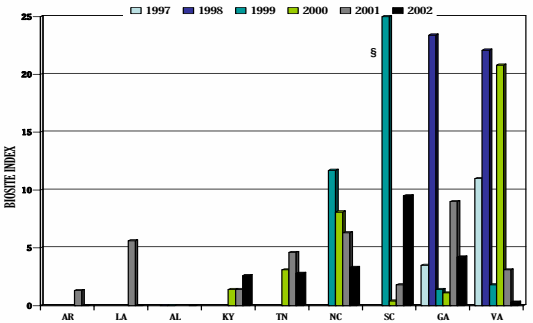

Figure 3. Average B. I. for each state and year. TX and FL not included.

§ Actual value for SC, 1999 was 56.8

•Species varied in their sensitivity to O_3 (fig. 4)

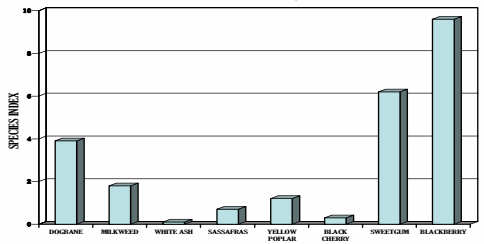

Figure 4. Average species index across all years and states.

•Species were not tallied equally – the 2 most sensitive species were tallied most frequently (fig. 5).

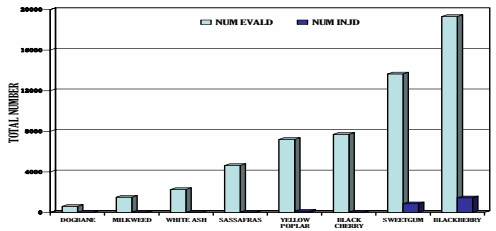

Figure 5. Number of times each species was tallied vs. number of times tallied with injury.

•O_3 injury was sometimes correlated with O_3 exposure, but not always, as in the case of 1999 (fig. 6).

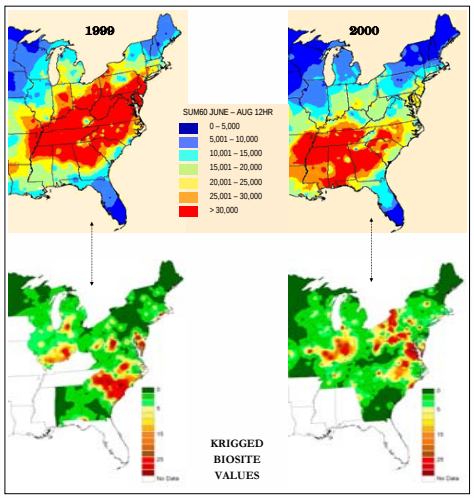

Figure 6. SUM60 O_3 exposures (top), based on monitoring data, and krigged Biosite Indices (bottom), based on plot-level data.

~ CONCLUSIONS ~

❖O_3-induced foliar injury was detected in all 11 states included in this time period, with the exception of AL, and was highly variable spatially and temporally.

❖The average biosite index was very low for GA and VA in 1999, a year of high O_3 exposure. This finding agrees well with Smith et al. (2003) who found that for 1999, average biosite indices were low across the northeastern U.S., corresponding to mild to severe drought conditions across much of this region.

❖An analysis of variance showed a statistically significant affect of both year and state on biosite indices at the $p < 0.10$ level, illustrating the high degree of temporal and spatial variability that exists in this measurement. However, the effect of the small sample size (small number of plots per year of data) is unknown.

❖Bioindicator species were not equally sampled and showed significantly different sensitivities to O_3 injury. Ultimately, this could mean that the distribution and selection of species could affect the resulting Biosite Index.

❖At present, the effect of ozone on forest health is still poorly understood. Few studies exist that show a direct relation between foliar injury and physiological response to elevated levels of ozone. More importantly, is the uncertainty that exists in extrapolating from controlled seedling studies to large forest trees (Samuelson and Kelly 2001).

❖The high degree of injury noted in some areas of some states may be cause for more intensive evaluation and monitoring. Further research is therefore needed in order to scale this foliar injury to individual species, ecosystem, and / or regional level response.

~ LITERATURE CITED ~

Samuelson L., Kelly J.M. 2001. Scaling ozone effects from seedlings to forest trees. New Phytologist, Volume 149, Issue 1, Pages 21-41

Smith G., Coulston J., Jepsen E., Prichard T. 2003. A national ozone biomonitoring program - Results from field surveys of ozone sensitive plants in northeastern forests (1994-2000). Environmental Monitoring and Assessment, Volume 87, Issue 3, Pages 271-291.

USDA Forest Service: 2000, 'Forest Inventory and Analysis, National Core Field Guide, Volume I: Field Data Collection Procedures for Phase 2 & 3 Plots, Section 9 – Ozone Bioindicator Plants', Northeast Forest Experiment Station, New Town Square, PA and Pacific Northwest Research Station, Portland, OR.

U.S. Environmental Protection Agency: 1996, 'Air Quality Criteria for Ozone and Related Photochemical Oxidants, Vol I of III, Section 4.0, Environmental concentrations, patterns, and exposure estimates', EPA/600/P-93/004aF. Office of Research and Development, Washington, DC 20460.