EVALUATION OF OZONE DAMAGE TO VEGETATION ON THE LYE BROOK WILDERNESS IN 1992

SURVEY REPORT
APRIL 1993

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HIGHLIGHTS

* Ozone concentrations in the vicinity of Lye Brook Wilderness were low, on the average, during 1992. The second highest hourly average concentration - the value used for PSD (Prevention of Significant Deterioration) purposes - was 103 ppb (at high elevations), reached in May. Later, periods of high concentrations occurred in June (at both high and low elevations) and in August (at high elevations only). Concentrations were unusually low in July, normally a month of high concentrations, at both high and low elevations. The red line value for PSD purposes, a second highest hourly average concentration of 120 ppb, was not reached in 1992.

* At Bennington, VT (low elevation) in the 1992 growing season, ozone concentrations reached or exceeded 80 ppb during only 28 hours, the fewest recorded since full-season monitoring began in 1987. On Mt. Equinox (high elevation) concentrations reached or exceeded 80 ppb during 71 hours, compared to 121 in 1991.

* Symptoms of ozone injury to plants on the Wilderness reflected the low concentrations. Injury was found on only one of the 14 white ashes sampled, and on none of the 26 black cherries. Blackberries on only one of the five blackberry plots were injured.

* The low ozone concentrations recorded are attributed primarily to the cool, wet weather that prevailed in the summer of 1992, rather than to economic conditions or to legal restraints on pollution sources.

* Continuation of both the ozone concentration monitoring and the vegetation surveys is recommended.

INTRODUCTION

Under provisions of the Clean Air Act amendments of 1977, the Forest Service is responsible for the protection of "Class I" wilderness areas from the adverse effects of air pollution. In 1987, personnel of the National Forest System requested assistance from Forest Health Protection in evaluating the effect of ozone on the vegetation of the Lye Brook Wilderness in Vermont. Since then the Wilderness has been surveyed annually for symptoms of ozone injury. Herein is a report of the 1992 findings, and comparisons with the findings of previous years.

OBJECTIVES

The objectives of the 1992 evaluation were, as in previous years, (1) to determine if symptoms of ozone injury were present on ozone sensitive species on Lye Brook Wilderness, and if so, to quantify the extent and intensity of the injury, and (2) to relate the occurrence of symptoms found in the Wilderness to ozone concentrations recorded nearby.

SURVEY METHODS

Tree group and plot establishment

In 1992, the species of ozone-sensitive plants that were closely examined for symptoms of ozone injury were white ash (*Fraximus americana* L.), black cherry (*Prunus serotina* Ehrh.), and blackberry (mostly *Rubus vermontanus* Blanch.). Usually the same trees or clones (blackberries) were examined in 1988 through 1992. If symptoms were noted on other plant species in passing, the observations were recorded.

Data were collected from 14 white ash and 11 black cherry trees (in 5 groups located about .5 km apart) along the jeep road on the northern border of the Wilderness. Samples were 10 (5 previous to 1991) midcrown or upper branch tips (45 cm long) taken from each tree by a professional tree climber. Beginning in 1991, 15 additional smaller black cherry trees were sampled with pole pruners, at the opening at the east end of the jeep road (3 trees), near the north end of the Lye Brook Trail (3 trees), and near Kelly Stand at the southernmost part of the Wilderness (9 trees).

For blackberries, five plots containing 10 canes each - 5 first year canes (primocanes) and 5 second year canes (floricanes) - were established in the eastern portion of the Wilderness, where blackberries growing in the open can be found. The plots were square or rectangular, and were for the purpose of location only - their sizes varied according to the area necessary to enclose 10 canes.

In 1992, height growth by year, 1987-1991, of 30 white pines growing on The Burning (Figure 1) was measured for later correlation with annual ozone concentrations.

The locations of the blackberry plots and tree groups are indicated in Figure 1.

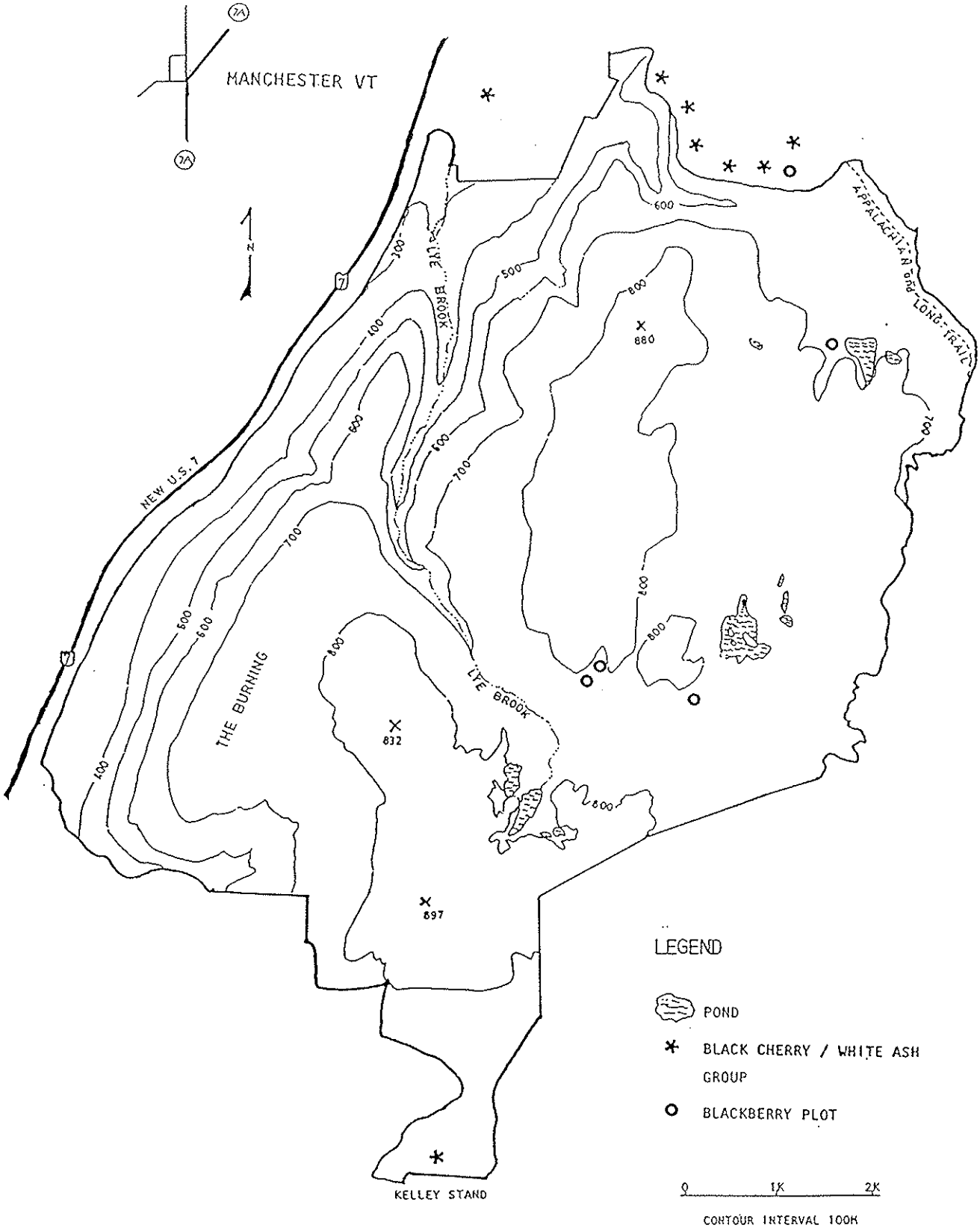

Figure 1. Map of Lye Brook Wilderness, Green Mountain National Forest (Scale 1:62800)

Injury ratings

From 1988 to 1992, nearly all the injury found on the plants examined consisted of a purple stippling or discoloration of the leaves. Very little dead tissue was found.

The method of rating injured foliage, in order to quantify the injury and permit comparisons from year to year, is described in the previous report, that for 1991. It is not repeated here because so little injury was found in 1992. Ratings of any kind would not have been of much significance.

Ozone concentrations

Computer printouts of ozone one-hour average concentrations recorded April through October in 1988 through 1992, at Bennington, Vermont (elevation 244 m), were obtained from Richard Poirot of the Vermont Air Pollution Control Agency. Records from the monitor on Mt. Equinox (elevation 625 m), which operated June through August, 1989 - 1992 (from May 22 in 1992), were compared with the Bennington data, and both sources of information were used to estimate the ozone levels to which the vegetation on Lye Brook Wilderness was subjected. Dr. William Manning of the University of Massachusetts, cooperating with the Forest Service, oversaw activities at the Mt. Equinox site.[1]

RESULTS AND DISCUSSION

Symptoms on black cherry and white ash

Table 1 compares symptom expression on black cherry and white ash for 1988, 1989, 1990, 1991, and 1992. Most investigations, in which both species were involved, indicate that black cherry is somewhat more sensitive than white ash. The surveys don't reveal any great difference in the sensitivity of the two species (though they are apparently not necessarily equally sensitive in the same year). In 1992, only the foliage of a single sample tree was injured, and it was an ash.

Trees with symptoms over the last 5 years are as follows:

1988: 6 of 8 (75%) black cherries examined; 3 of 5 (60%) white ashes.

1989: 5 of 11 (45%) black cherries examined; 2 of 14 (14%) white ashes.

1990: 4 of 11 (36%) black cherries examined; 5 of 14 (36%) white ashes.

1991: 2 of 10 (20%) black cherries examined; 9 of 14 (64%) white ashes.

1992: 0 of 10 (0%) black cherries examined; 1 of 14 (7%) white ashes.

Of the 15 black cherry trees added in 1991 (not included in Tables 1), none had symptoms in 1992.

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[1] A third cooperator was the Carthusian Foundation of Arlington, VT. The Foundation provided the site and access to electric power.

Table 1. Black cherry and white ash trees and branches with ozone symptoms in Lye Brook Wilderness in 1988, 1989, 1990, 1991, and 1992.

Group Number	Total Trees[1]	Trees with symptoms					Branches with symptoms				
		1988	1989	1990	1991	1992	1988	1989	1990	1991	1992
1	5	3	1	0[2]	0	0	5	1	0[2]	0	0
2	5(4)	2	1	1	3	0	6	5	1	6	0
3	5(2)	2	2	4	2	1	10	10	11	10	6
4	5(1)	1	2	2	2	0	4	8	8	11	0
5	5(1)	1	1	1	4	0	3	5	1	20	0
Percent of total		69	28	32	46	4	47	23	17	39	2

[1]Number in parenthesis refers to trees examined in 1988, when many crowns could not be reached with the pole pruners used (a tree climber was employed in subsequent years). In 1991, only 4 trees could be examined in group 1.

[2]One tree exhibited signs of early senescence on 4 of 5 branches; another on 2 branches.

Symptoms on blackberry

Blackberries on only one of the five plots had symptoms in 1992. The blackberries on that plot appear to be of a different species or variety than those on the other four plots. Nevertheless, a second factor may be more important in plot differences. The overstory of the trees surrounding the openings in which several plots are located are beginning to shade the blackberry plants. Only plants in sunlight are likely to show symptoms of ozone, so these plots are losing their usefulness. One replacement plot was established in 1992 (no injury found), and two more are planned.

Correlation of white pine internodes with ozone concentrations

A good correlation was found between average internode height of white pine 1987-91 and number of hours when concentrations were above 50 ppb, but only if the year 1987 is omitted. Moreover, cool moist growing seasons result in both good tree height growth and low ozone concentrations. The effects of high moisture and low pollutant levels are not readily distinguished. Clearly, another way of determining the effect of ozone on tree growth is needed.

Symptoms on other plant species

No symptoms were noted in 1992 on those plant species that in previous years were noted in passing as having typical ozone symptoms but were not evaluated quantitatively. These species have included *Spirea latifolia* (Ait.) Borkh. and *S. tomentosa* L., witherod or northern wild raisin (*Viburnum cassinoides* L.), white woodland aster (*Aster divaricatus* L.), and marsh grass (Spartina, probably *S. petinata* Link).

Ozone concentrations in 1992

Table 2 shows that for most of the parameters computed, ozone concentrations recorded at Bennington, in 1992, were the lowest recorded since 1988, when the first survey was completed. We can expand this statement to include 1987, the first full year in which monitoring was completed by the State of Vermont.

The number of hours during which concentrations were 80 ppb or higher was only 28 at Bennington in 1992 (Table 2). Because concentrations were much higher on Mt. Equinox in May and August, the number for Mt. Equinox in 1992 was 71 hours. Even so, this is lower than the concentrations on Mt. Equinox in 1991, when the number of hours at 80 ppb or higher was 121. This was true even though the monitoring period was shorter in 1991 (There were no May data).

Table 2. Comparison of 1988, 1989, 1990, 1991, and 1992 data on high concentrations from the ozone monitor at Bennington, Vermont

		APR	MAY	JUN	JUL	AUG	SEP	OCT	7 MONTH MEAN/TOTAL	MAY-AUG MEAN/TOTAL
Average daily peaks (ppb)	1988	49	63	66	71	64	47	38	57	66
	1989	55	63	56	59	48	47	45	53	56
	1990	51	53	61	55	50	49	39	51	55
	1991	57	60	59	56	53	45	40	53	57
	1992	61	55	58	47	44	46	38	50	51
Number hours >50 ppb	1988	55	218	161	207	197	61	43	942	783
	1989	170	268	131	148	66	69	56	908	613
	1990	109	145	150	137	96	84	42	763	528
	1991	160	176	117	108	99	66	49	775	500
	1992	214	142	180	42	43	26	11	658	407
Percent hours >50 ppb	1988	9	37	31	32	29	9	6	21	32
	1989	25	39	19	21	10	10	8	19	23
	1990	17	20	23	19	15	12	6	16	20
	1991	23	25	17	16	14	10	7	16	18
	1992	32	20	26	6	6	4	2	14	15
Number hours ≥80 ppb[1]	1988	2	26	59	65	42	2	0	196	192
	1989	0	13	13	13	0	1	0	40	39
	1990	12	4	33	17	5	1	0	72	59
	1991	0	12	47	28	18	0	0	105	105
	1992	21	4	24	0	0	0	0	49	28
Percent hours ≥80 ppb	1988	0.3[2]	4.4	10.8	9.4	6.1	0.3	0.0	4.4	7.7
	1989	0.0	1.9	1.9	1.9	0.0	0.2	0.0	0.9	1.4
	1990	1.9	0.6	5.1	2.4	0.8	0.2	0.0	1.5	2.2
	1991	0.0	1.7	6.8	4.1	2.6	0.0	0.0	2.2	3.8
	1992	3.2	0.6	3.6	0.0	0.0	0.0	0.0	1.0	1.0

[1]Levels ≥80 ppb occurred on 35 days in 1988; 9 in 1989; 14 in 1990; 19 in 1991; and 8 in 1992.
[2]Erroneously recorded as 3.4 in the reports for 1990 and 1991.

The second highest one-hour average concentration has been chosen as the ozone parameter relevant to the Forest Service's PSD (Prevention of Significant Deterioration) process for the wildernesses of Region 9 (Adams and others, 1991). The "green line" (concentrations sufficiently low that impacts on wilderness values are not expected) was set at 80 ppb; the "red line" (concentrations sufficiently high that impacts on wilderness values are predicted) at 120 ppb (The "yellow zone" - effects uncertain - is between 80 ppb and 120 ppb). As metered at Bennington, the second highest one-hour average concentrations for 1987 through 1992 are as follows:

	1987	1988	1989	1990	1991	1992
Bennington	95 ppb	125 ppb	101 ppb	107 ppb	118 ppb	94 ppb
Mt. Equinox	------	-------	100 ppb	96 ppb	123 ppb	103 ppb

The monitors on Mt. Equinox and at Bennington usually record peak concentrations on the same day. In 1992, however, the second highest value on Mt. Equinox (103 ppb) occurred on May 23. The comparable value at Bennington on that date was 84 ppb. At Bennington, the second highest value during the growing season (91 ppb) occurred on June 14. The comparable value on Mt. Equinox on June 14 was 98 ppb - the second highest for June, but not for the season. Atmospheric conditions were unusual in another respect in 1992. Normally, average peak concentrations are only slightly higher at the higher elevation site, but in 1992 peak concentrations averaged 10-12 ppb higher on Mt. Equinox than at Bennington during May and August of that year (Appendix Table 1).

CONCLUSIONS

(1) In May and June 1992, Lye Brook Wilderness was subjected to ozone concentrations well within the yellow zone (though below the red line). Little injury to vegetation occurred, either because foliage tissue was not yet mature when high concentrations occurred, or because the concentrations were not high for a long enough period of time.

(2) The low concentrations of ozone in 1992 is reflected in the slight amount of injury to vegetation, just as high concentrations in 1988 and 1991 were reflected in correspondingly higher indices of injury. However, the relationship holds up consistently only if, with regard to concentrations, the higher parameters (number of hours at 80 ppb or above, average daily peaks, second highest hourly average, etc.) are used. The annual average appears to be of little value in assessing injury to vegetation, a finding in accord with the literature (Lefohn and Foley 1993). To maintain the record, the annual averages are presented, but only in the appendix (Appendix Table 2). In addition, as might be expected, the parameters computed for May - August show a better relationship than those for the entire seven month monitoring season.

(3) The concentrations of ozone were low after June in 1992 because weather conditions were not suitable for the formation of ozone in the atmosphere. Warm temperatures are conducive to ozone formation and in Vermont, July 1992 was the coldest July on record. Of course, economic activity was lower in 1992 than in the years immediately preceding it, because the economy was in recession. Moreover, for the United States as a whole, ozone concentrations can be expected to decline as newer, cleaner industrial processes come on line and old ones are phased out, and as older automobiles are replaced with newer ones[2]. However, neither reduced economic activity nor lower emissions of the precursors of ozone could have such immediate, dramatic effects on concentrations as occurred in 1992.

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[2]Concentrations are expected to increase again in the more distant future, as people drive more.

RECOMMENDATIONS

(1) To discern long term trends in ozone concentrations, the ozone concentration monitoring should be continued indefinitely. The Forest Service monitor on Mt. Equinox is more relevant to the Wilderness than the State monitor at Bennington because it is closer, both geographically and in elevation. In 1992, the Mt. Equinox monitor was more indicative of the higher concentrations to which most of the Wilderness was exposed. Apparently, in some years, the differences in elevation between the locations of the monitors leads to marked differences in concentrations. Nevertheless, the Bennington monitor is of considerable value, particularly for May data, as the weather may make it difficult to install the Mt. Equinox monitor in May.

(2) The vegetation surveys too should be continued, at least for several more years. Most of what insight we have as to the effect of ozone on the plants came only after several years of surveying.

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APPENDIX

Appendix Table 1. Comparison of average daily peak ozone concentrations (ppb) recorded by the Bennington and Mt. Equinox monitors. Days in which there were no or incomplete recordiings at either monitor were omitted for both monitors.

Year	Location	May (21-31)	June	July	August	Average
1989	Bennington	--	60	63	48	57
	Mt. Equinox	--	57	61	49	56
1990	Bennington	--	60	55	49	55
	Mt. Equinox	--	63	55	48	55
1991	Bennington	--	59	56	53	56
	Mt. Equinox	--	61	61	60	61
1992	Bennnington	50	58	46	46	50
	Mt. Equinox	62	61	48	56	57

Appendix Table 2. Comparison of 1988-92 overall and 7-hour (0900-1600) average ozone concentrations at Bennington, Vermont

		APR	MAY	JUN	JUL	AUG	SEP	OCT	7 MONTH MEAN/TOTAL	MAY-AUG MEAN/TOTAL
Overall average (ppb)	1988	38	43	44	44	38	27	26	37	42
	1989	43	46	37	35	30	27	28	35	37
	1990	39	40	41	34	30	28	25	34	36
	1991	42	38	35	35	30	25	26	33	34
	1992	47	41	43	35	32	35	27	37	38
7 hr ave (0900-1600) (ppb)	1988	42	55	59	61	51	39	32	48	56
	1989	50	55	45	47	43	37	37	45	48
	1990	45	47	50	47	44	42	33	44	47
	1991	50	47	47	45	42	35	32	43	45
	1992	54	46	48	36	36	36	31	41	42