EVALUATION OF OZONE DAMAGE TO VEGETATION ON THE LYE BROOK WILDERNESS IN 1991

SURVEY REPORT
APRIL 1992

Prepared by:
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UNITED STATES DEPARTMENT
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HIGHLIGHTS

* In 1991, ozone concentrations near Lye Brook Wilderness exceeded the PSD "red line" of 120 ppb on August 17. Concentrations reached or exceeded 100 ppb on five days, and were 80 ppb or higher during 105 hours (low elevations) and 119 hours (high elevations), the most since 1988.

* In 1991, injury to white ash and blackberry was more widespread and intensive than in 1989 or 1990 and was comparable to injury in 1988. For reasons that are not known, black cherry was not as severely injured in 1991 as in previous years.

* Apparently ozone concentrations are high enough every year to injure some plants on the Wilderness. The visible injuries are slight, but their chronic nature suggests that plant succession may be altered by the pollutant.

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

INTRODUCTION

Under provisions of the Clean Air Act 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 1991 findings, and comparisons with the findings of previous years.

OBJECTIVES

The objectives of the 1991 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 1991, 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, 1989, 1990, and 1991.[1] 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 in previous years) midcrown or upper branch tips (45 cm long) taken from each tree by a professional tree climber. In 1991, additional black cherry trees were sampled from the opening at the east end of the jeep road, near the north end of the Lye Brook Trail, and near Kelly Stand, at the south end of the Wilderness.

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.

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

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[1] Injury to white pine was evaluated each year 1988-90, but not in 1991. The symptoms were not distinctive and, in addition, little difference in injury from one year to the next was found, regardless of ozone concentrations.

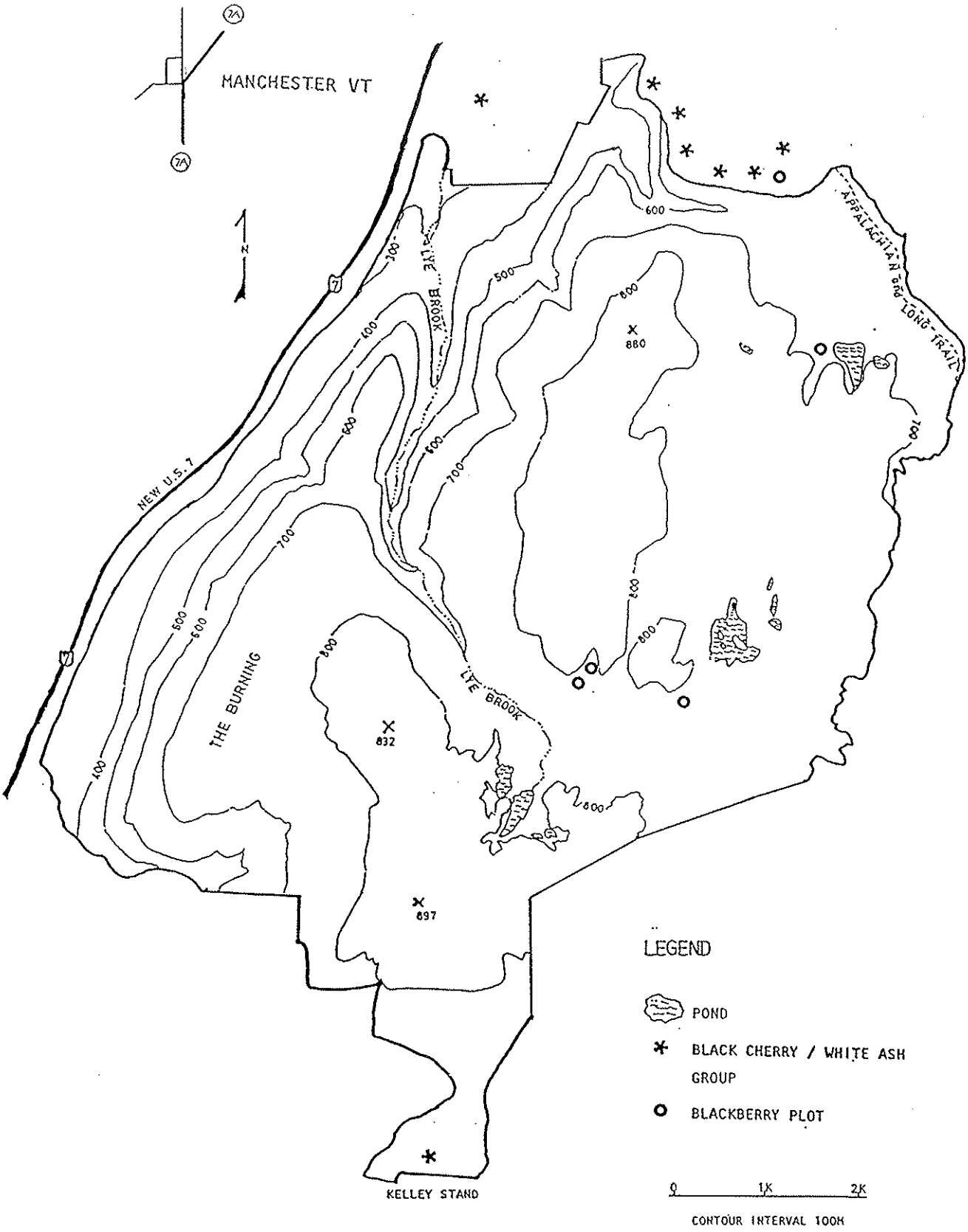

Figure 1. Map of Lye Brook Wilderness, Green Mountain National Forest (Scale 1:62800)

Injury ratings

To compare the extent of damage to sensitive vegetation from year to year, or among species, the injury must be quantified. To quantify the ozone injury found in the surveys, entire plants (blackberries) or branches from sample trees (black cherry or white ash) were examined and rated. From 1988 to 1991, nearly all the injury found on these species consisted of a purple stippling or discoloration of the leaves. Very little dead tissue was found.

The ratings combined the percentage of injured leaves on the plant or branch and the intensity of damage on the 10 most severely injured leaves. Both of these were on a scale of 0 to 4 as follows:

0 = no injury
1 = trace (1 to 5 percent)
2 = light (6 to 25 percent)
3 = moderate (26 to 50 percent)
4 = heavy (greater than 50 percent)

The classes were multiplied for the index rating. For example, a plant with 20 percent of its leaves injured, the heaviest 10 of which averaged 4 percent, would be rated 2 (2 x 1). The most severe injury possible would be 16 (4 x 4).

Ozone concentrations

Computer printouts of ozone one-hour average concentrations recorded April through October in 1988, 1989, 1990, and 1991 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, 1990, and 1991, 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. William Manning of the University of Massachusetts, cooperating with the Forest Service, oversaw activities at the Mt. Equinox site.[2]

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

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, and 1991. 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). Trees with symptoms over the last 4 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.

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

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

[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.

The average frequency/intensity indices for both species are grouped in Table 2.

Table 2. Frequency x intensity indices of ozone symptoms on black cherry and white ash foliage on the Lye Brook Wilderness 1988 through 1991.

Group Number	Total trees[1]		Average injury index			
	Cherry	Ash	1988	1989	1990	1991
1	5	0	1.0	2.0	0.0	0.0
2	0	5(4)	2.6	8.0	0.0	2.4
3	3(1)	2(1)	7.0	3.0	2.3	7.8
4	1(1)	4(0)	1.2	5.1	3.6	5.6
5	2(1)	3(0)	1.0	6.6	2.4	5.2
Total/Ave.	11(8)	14(5)	2.6	4.9	2.5	4.2

[1]Number in parenthesis refers to number of trees examined in 1988.

Of the 15 black cherry trees added in 1991 (not included in Tables 1 and 2), 4 (27 percent) of the trees and 25 (17 percent) of the branches had symptoms. The injury indices averaged 4.0.

The method by which these trees are rated must be considered a crude one. Only a few branches, rather than the entire tree, could be examined. Even these branches were usually parts of a single large branch. The intention was to obtain branches exposed to sunlight, otherwise the choice of branches was arbitrary. Still, when averaged, the evaluations are probably an accurate, albeit rough, reflection of the extent of the injury that actually occurred. Thus, the apparent differences between years are real.

Symptoms on blackberry

A valid comparison of the blackberry plots over the four years (Table 3) is difficult because in 1989 a fungal disease of the foliage masked any symptoms that might have been present on all but one plot. Nevertheless, we do see the probable effect of several days of high concentrations in late July (in 1991) or early August (in 1988) (Figure 2) on maturing primocanes. The primocanes were still immature when high concentrations occurred in 1989 and 1990.

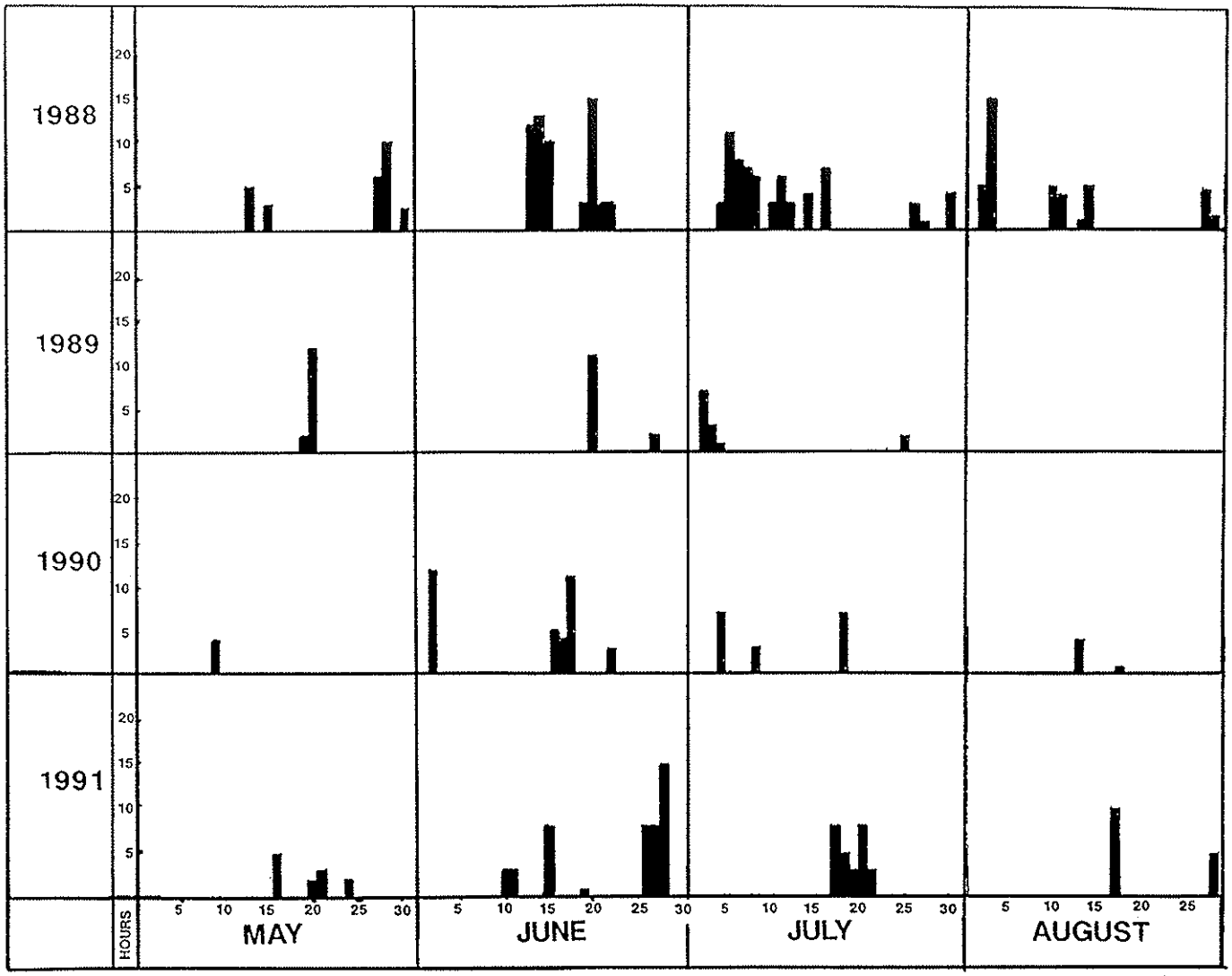

Figure 2. Hours during which ozone concentrations reached or exceeded 80 ppb as measured at Bennington, VT, in the years 1988-91.

Table 3. Frequency and intensity ratings of ozone symptoms found on blackberry in 1988, 1989, and 1990 in the Lye Brook Wilderness.

Plot	Cane Type	Average Frequency/Intensity Index 1988	1989	1990	1991
1	Primo-	0.6	-	0.0	0.0
	Flori-	2.5	-	1.2	0.0
2	Primo-	2.2	-	0.6	2.4
	Flori-	9.0	-	12.0	10.0
3	Primo-	12.0	-	0.8	5.0
	Flori-	9.8	-	15.2	10.6
4	Primo-	9.2	2.5	1.2	8.8
	Flori-	7.2	12.0	1.2	12.8
5	Primo-	-	-	0.0	0.0
	Flori-	-	-	8.8	0.0
Average	Primo-	6.0	-	0.5	3.2
	Flori-	7.1	-	7.4	6.7

Symptoms on other plant species

Plant species that were not part of the evaluation, but that were noted in passing as having typical ozone symptoms in 1991, were *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 (if correctly identified, a species of Spartina, probably *S. petinata* Link).

Ozone concentrations in 1991

Table 4 shows that for most of the parameters computed, ozone concentrations recorded at Bennington in 1991, were about the same as in 1990 and 1989, and lower than in 1988. For the season as a whole, only in the parameter "hours during which concentrations equalled or exceeded 80 ppb", did 1991 values greatly exceed those of 1990 and 1989. Here, 1991 values were about 1.5 x 1990 values and about 2.5 x 1989 values. The 1991 values were half those of 1988. On Mt. Equinox, concentrations were 80 ppb or higher for a total of 119 hours, considerably more than the 105 hours recorded at Bennington.

Table 4. Comparison of 1988, 1989, 1990, and 1991 data from the ozone monitor at Bennington, Vermont

		APR	MAY	JUN	JUL	AUG	SEP	OCT	7 MONTH MEAN/TOTAL	MAY-AUG MEAN/TOTAL
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
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
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
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
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
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
Percent hours ≥80 ppb	1988	3.4	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

[1]Levels ≥80 ppb occurred on 35 days in 1988; 9 in 1989; 14 in 1990; and 19 in 1991.

The "80 ppb +" parameter is considered a meaningful one by many authorities, but any evidence for it was lacking in our previous surveys. Now, the differences in the extent of symptoms on the plants (Table 1) do seem to be a reflection of the "80 ppb +" parameter but not their intensity (Table 2). Apparently, more plants are injured when concentrations are high, but the average severity is lower.

The maximum one-hour average concentrations recorded by the Bennington meter for the years 1987 through 1991 are as follows:

1987 - 100 ppb	1989 - 106 ppb	1991 - 126 ppb
1988 - 125 ppb	1990 - 114 ppb	

The highest concentration in 1991 (as well as the second highest, shown below) was reached on August 17. Concentrations above 100 ppb occurred on 4 other days.

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. As metered at Bennington, the second highest one-hour average concentrations for 1987 through 1991 are as follows:

1987 - 95 ppb	1989 - 101 ppb	1991 - 118 ppb
1988 - 125 ppb	1990 - 107 ppb	

The corresponding second highest values on Mt. Equinox for 1989, 1990, and 1991 are 100 ppb, 96 ppb, and 123 ppb, respectively. By referring to Table 1, the reader can note that the second highest one-hour average also correlates well with the number of plants injured.

CONCLUSIONS

(1) Most of Lye Brook Wilderness is at high elevations (62 percent is at 600 meters above sea level or higher). The high elevation monitor, the one on Mt. Equinox, recorded ozone concentrations above the red line on August 17, 1991. Therefore, we know that concentrations on the Wilderness almost certainly exceeded the red line on that date.

(2) Indications are that the parameter chosen for the PDS process was appropriate. The number of hours in the growing season during which concentrations reach or exceed 80 ppb could also be used, as the vegetation data gathered so far indicate that more plants are injured in those years in which the most hours of concentrations above 80 ppb occur. The average severity of injury is lower, but presumably that is because some of the more resistant plants are affected when the concentrations are especially high, while concentrations are high enough every year to affect the sensitive genotypes. Unfortunately, nothing in the data appears to explain why black cherry was not injured as severely in 1991 as in previous years.

(3) Precisely what the injuries described here mean to the plants is not yet known. As injuries to individual plants, they appear no more significant than infections by leaf spot fungi or feeding by minor herbivorous insects. However, ozone may affect plants in ways that are not visible. Ozone has been shown to retard the growth of some plants. Flowering, and thus regeneration, may also be affected. If the growth or regeneration of some species, or genotypes, in the Wilderness is retarded, ecological succession will tend to eliminate those plants. There is considerable evidence that ozone has eliminated certain clones of aspen from highly polluted areas of the United States (Berrang and others 1991).

The alteration of plant succession by ozone on Lye Brook Wilderness would be a human-caused change in a wilderness, and is therefore undesirable (and, if the change is a significant one, not in compliance with the law). However, if such a change is occurring, a study much more elaborate than a survey would be needed to quantify it. Some insight might be gained by a simple comparison of the growth rates of visibly sensitive vs. tolerant trees of the same species, but the effect on species vs. species competition would be a much more complex matter.

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.

(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. For 1992, a more precise method for discerning differences in injury between years is planned, along with a search for, and examination of, rare or endangered plants.

REFERENCES

Adams, Mary Beth; Nichols, Dale S.; Federer, C. Anthony; Jensen, Keith F.; Parrott, Harry. 1991. Screening Procedure to Evaluate Effects of Air Pollution on Eastern Region Wildernesses Cited as Class I Air Quality Areas. Gen. Tech. Rep. NE-151. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 33 p.

Berrang, P.; Karnosky, D.F.; Bennett, J.P. 1991. Natural selection for ozone tolerance in *Populus tremuloides*: an evaluation of nationwide trends. Can. J. For. Res. 21: 1091-1097.