

EVALUATION OF OZONE DAMAGE TO VEGETATION  
ON THE LYE BROOK WILDERNESS

IN 1993

Survey Report

June 1994

SURVEY REPORT

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UNITED STATES DEPARTMENT  
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Evaluation of Ozone Damage  
to Vegetation on the Lye Brook  
Wilderness in 1993

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Northeastern Area

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#### ABSTRACT

An evaluation of ozone damage to vegetation in Lye Brook Wilderness is conducted annually to help the Green Mountain National Forest meet the requirements of the Clean Air Act. The objectives of the evaluations are (1) to determine if symptoms of ozone injury are 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. To these ends, sensitive vegetation within the Wilderness, primarily black cherry and white ash trees and blackberry brambles, have been examined for ozone injury since 1988. Ozone data have been obtained from the State monitor at Bennington (low elevation) and, since 1989, the Forest Service monitor on Mount Equinox (high elevation).

In 1993, ozone concentrations in the vicinity of the Wilderness were generally moderate; the "average daily peak concentration" during the growing season was, at both elevations, 56 ppb - close to the 1988-92 mean. The second highest hourly average concentration - the value used for PSD (Prevention of Significant Deterioration) purposes - was 110 ppb at Bennington and 102 ppb on Mt. Equinox. The "red line" value, a second highest hourly average concentration of 120 ppb, was not reached in 1993.

In 1993, symptoms of ozone injury to plants on the Wilderness were not often found and not pronounced when they were found. No injury was found on either of the 2 white ash trees sampled, and injury was found on only 3 of the 18 black cherry trees. None of the blackberry canes on the six blackberry plots examined was injured, making 1993 the first year since the surveys were begun in 1988 that no blackberry plants were injured.

In the evaluations so far, plant injury and ozone concentrations have been fairly well correlated, though not as closely as might be expected. In 1993, for example, it is believed that the dry weather of that summer prevented much of the injury by causing the plants' stomata to close. The plants did not absorb the dose they would have if there had been no drought.

## 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, and the injury related to ozone concentrations recorded at nearby monitors. Herein is a report of the 1993 findings, and comparisons with the findings of previous years.

## OBJECTIVES

The objectives of the 1993 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.

## METHODS

### *Ozone concentrations*

In the same manner as for the reports of previous years, computer printouts of one-hour average ozone concentrations recorded April through October 1993 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 1993, 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.<sup>1</sup>

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 protection of the air quality of 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 and 120 ppb.

### *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 (*Fraxinus 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.

<sup>1</sup> A third cooperator was the Carthusian Foundation of Arlington, VT. The Foundation provided the site and access to electric power.

In 1993, only 2 white ash and 18 black cherry trees were sampled, compared to 14 ash and 25 cherry trees in 1991 and 1992. A tree climber could not be used to collect samples from tall trees, as was done in previous years, because of rain. Thus it was necessary to use pole pruners to obtain all tree samples, and the crowns of most tall trees could not be reached. The white ashes and two of the black cherries that were sampled are located along the jeep road on the northern edge of the Wilderness. The 16 smaller black cherry trees, in Groups 6, 7, and 8, are located at the opening at the east end of the jeep road (4 trees), near Kelley Stand at the southernmost part of the Wilderness (9 trees), and near the north end of the Lye Brook Trail (3 trees).

Six blackberry clones in the eastern portion of the Wilderness, where blackberry canes growing in the open can be found, were sampled in 1993. To prevent sampling a plant twice, temporary plots containing 10 canes each - 5 first year canes (primocanes) and 5 second year canes (floricanes) - were established in each clone.

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

### *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. Thus it was this purple discoloration that was searched for and, when found, rated in 1993.

Two methods of classifying and rating injured foliage, in order to quantify the injury and permit comparisons from year to year, were used in 1993: (1) A five class system - the way foliage was classified and rated in surveys of the Wilderness since 1988. This was to allow comparison of 1993 injury with that of previous years. (2) An eight class system - the way samples are classified in National Park Service surveys. The latter method standardizes procedures in the eastern United States.

The five class system combines 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 are 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 of which averaged 4 percent, would be rated 2 ( $2 \times 1$ ). The most severe injury possible would be 16 ( $4 \times 4$ ).

The eight class system is the modified Horsfall-Barrett system, a system that takes advantage of the fact that an observer can discern small differences when injury is light, but gradually loses this ability as injury approaches 50 percent. The observer rates 30 leaves on each of three terminal shoots from near the top of a tree, or the oldest 30 leaves on a smaller plant. The injury on each leaf is classified thusly: 0 (0), 1 (1-3 percent), 2 (4-6 percent), 3 (7-12 percent), 4 (13-25 percent), 5 (26-50 percent), 6 (51-75 percent), and 7 (76 percent or greater). The classes are averaged for a rating of the plant.

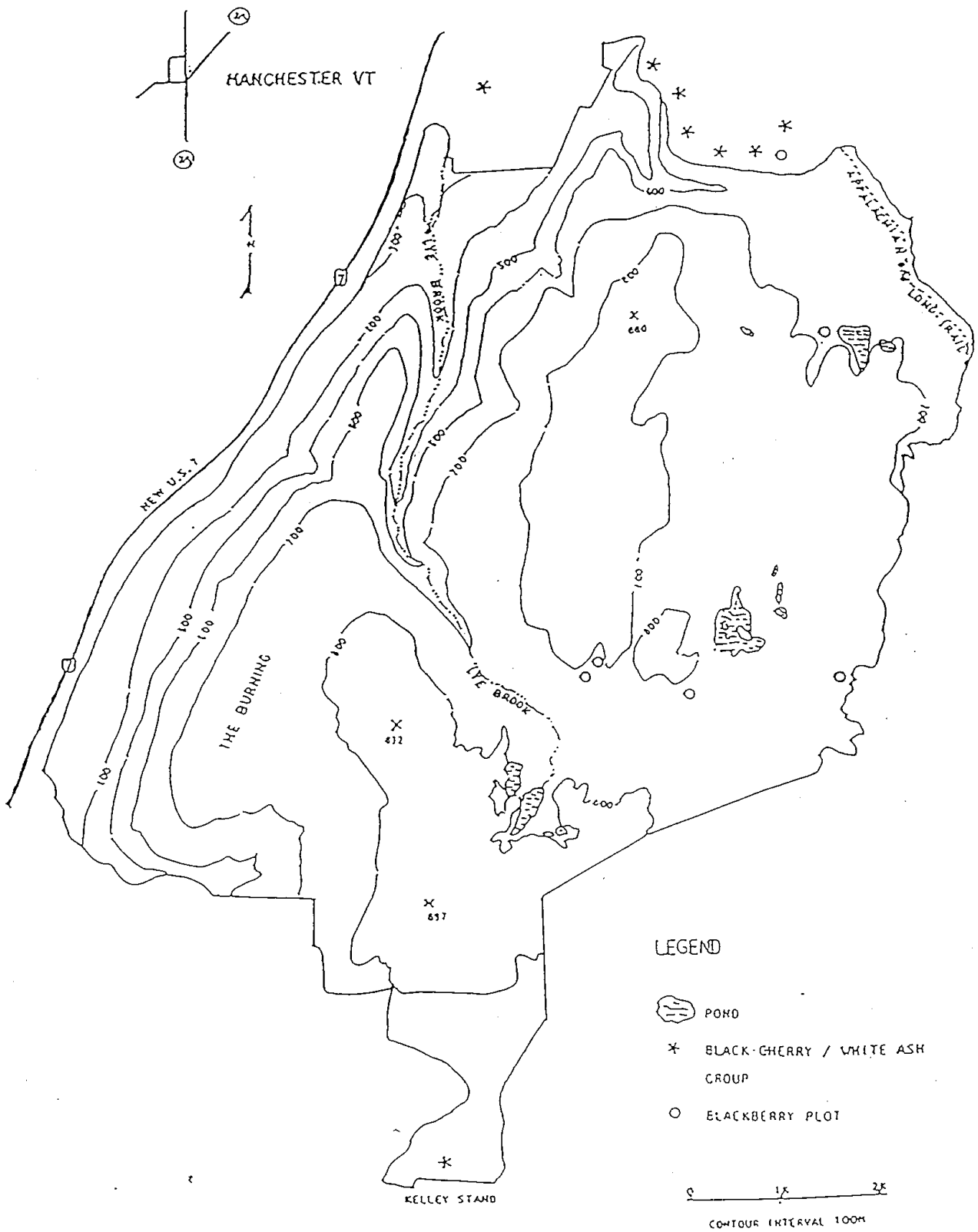


Figure 1. Map of Lye Brook Wilderness, Green Mountain National Forest, Vermont, showing locations of vegetation examined for ozone injury. (Scale 1:62800).

## RESULTS

### *Ozone concentrations in 1993*

Table 1 shows that for most of the parameters computed, ozone concentrations recorded at Bennington, in 1993, were in the low to moderate range when compared to previous years. (Overall and 7 hour averages, because they are not significant with regard to plant injury, are presented in Appendix Table 1.)

The "average daily peak concentrations" for 1993 was 56 ppb - about the mean of the years 1988 through 1992. The number of hours during which May-August concentrations were 80 ppb or higher was 51 at Bennington in 1993 (Table 1), which is the third lowest of the years 1988-93.

On Mt. Equinox, the number of hours during which June-August concentrations were 80 ppb or higher was 40 in 1993, compared to 54 in 1992, 121 in 1991, and about 46 in 1990. The count for 1989 was only 17, but concentrations were high in May of that year. The Mt. Equinox monitor is usually not in operation in May.

As in most years, in 1993 the number of hours, June-August, during which concentrations exceeded 50 ppb was greater on Mt. Equinox than at Bennington - 428 vs. 348 (owing to the nighttime "scavaging" of ozone at low elevations, Bennington averages about 100 hours fewer than Mt. Equinox). For Mt. Equinox 428 is a low total, compared with 484 in 1992, 614 in 1991, and 446 in 1990.

The second highest one-hour average concentrations (in ppb) for 1987 through 1993 are as follows:

	1987	1988	1989	1990	1991	1992	1993
Bennington	95	125	101	107	118	94	110
Mt. Equinox	--	--	100	96	123	103	102

### *Symptoms on black cherry and white ash*

Symptoms of ozone injury were found on the two black cherry trees examined along the jeep road. One of these, tree 1 of group 3, when rated by the five class system, had an injury index of 4.7; by the eight class system, 1.8. Symptoms on the other black cherry along the jeep road, tree 1 of group 4, were found on a single leaf and were very faint, so no rating was possible. No symptoms were found on the two white ashes examined. Of the 16 black cherries in groups not along the jeep road (groups 6-8), only one, tree 3 (PB 347) of group 6, had symptoms. Oddly, only the foliage of a single lower branch was affected. That branch was rated 8 by the five class system and 1.2 by the eight class system.

### *Symptoms on blackberry*

None of the 60 blackberry canes examined in the six clones surveyed had symptoms of ozone injury in 1993.

Table 2. Comparison of 1988 through 1993 data on high concentrations from the ozone monitor at Bennington, Vermont.  
(Missing data 6/26-7/2/93 filled in with Mt. Equinox data.)

		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
	1993	47	55	55	52	60	46	53	53	56
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
	1993	83	126	114	89	145	57	122	736	474
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
	1993	12	18	17	12	20	8	17	15	17
Number hours $\geq$ 80 ppb <sup>1</sup>	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
	1993	7	0	29	9	13	0	0	58	51
Percent hours $\geq$ 80 ppb	1988	0.3	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
	1993	1.0	0.0	4.2	1.3	1.8	0.0	0.0	1.2	1.8

<sup>1</sup>Levels  $\geq$  80 ppb occurred on 35 days in 1988; 9 in 1989; 14 in 1990; 19 in 1991; 8 in 1992; and 11 in 1993.

## DISCUSSION

The ozone concentrations that occurred in 1993 appear to be those for a typical or average year - or perhaps below average (Table 1 and Appendix Table 1). The 'red line', a second-highest concentration of 120 ppb was not reached; in fact that concentration has been reached in only 2 of the 7 years in which monitoring was conducted. Nevertheless, some injury to vegetation has occurred each year and 1993 was no exception. The ratings given both the trees that were rated reflect the fact that many of the leaves were affected but they were only lightly injured. One of these, tree 1 of group 3, is known to be quite sensitive, having shown injury every year since 1988 except 1992.

That injury was slight was indicated also by the absence of injury to blackberry plants. At least some blackberries were injured every previous year since 1988, even in 1992, a year of low concentrations. It was because of the low concentrations that injury to vegetation was light in 1992. In 1993, in contrast, concentrations were high enough to cause injury, but even less injury occurred. Dr. Manning, who examined vegetation near the monitor throughout the summer of 1993, thinks the hot, dry weather conditions that occurred during that summer protected the plants by causing the stomata to close. The closing of the stomata is the means by which a plant limits water loss through transpiration, and inadvertently the plant shuts out ozone at the same time.

#### *FUTURE PLANS*

Plans are to continue the ozone concentration monitoring indefinitely, in order to discern long term trends in ozone concentrations. Though presently the Forest Service monitor on Mt. Equinox cannot be available for the entire growing season, it should be more relevant to the Wilderness than the State monitor at Bennington because it is closer, both geographically and in elevation. Perhaps eventually the Mt. Equinox monitor can be replaced with a solar-powered unit at EPA's recently installed CASTNET (Clean Air Status and Trends NETwork) site about 700 m SW of Kelley Stand at an elevation of about 700 m. That site is even closer to the Wilderness.

Another vegetation survey is planned for 1994, and perhaps surveys should be continued one or two years beyond that. By that time, we should have enough information to estimate what concentration level should "trigger" a survey. That is, a survey would be conducted only when concentrations, and meteorological conditions, are such that significant injury is likely. At this writing, the May concentrations look as if they may indicate the later appearance of symptoms. In the years 1988, 1989, and 1991 symptoms were widespread and intensive, and those are the years when May concentrations were highest. That correlation may be only a coincidence, but the matter bears watching in future years.

#### *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.



## APPENDIX

Appendix Table 1. Comparison of 1988-93 overall and 7-hour (0900-1600) average ozone concentrations at Bennington, VT (Missing data 6/26-7/2/93 filled in with Mt. Equinox data).

		APR	MAY	JUN	JUL	AUG	SEP	OCT	7 MONTH MEAN	MAY-AUG MEAN
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
	1993	35	37	37	32	35	33	41	36	35
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
	1993	46	45	46	42	49	37	48	45	46