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Forest Service

Northeastern Area

Evaluation of Ozone Damage to Vegetation on the Lye Brook Wilderness in 1989

Survey Report

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ABSTRACT

The Lye Brook Wilderness on the Green Mountain Forest in Vermont is one of the "Class I" areas given special protection under the Clean Air Act. Surveys in both 1988 and 1989 revealed symptoms of ozone injury on several species of plants in the Wilderness. The high concentrations recorded at the ozone meters nearest the Wilderness easily account for the symptoms. Moreover, at a site near the Wilderness, ozone symptoms appeared on potted plants, of the same species as those found in the Wilderness, within unfiltered growth chambers. Plants in adjacent filtered chambers remained symptomless.

Ozone concentrations were, for most of the growing season, not as high in 1989 as in 1988. The extent of the injuries was correspondingly less in 1989 than in 1988, but the difference was not as great as the difference in concentrations might lead us to expect. Thus, the threshold for injury may be lower than the concentrations experienced in a typical year.

INTRODUCTION

About 14,600 acres (5910 h) of the 16,000 acre Lye Brook Wilderness on the Green Mountain National Forest has been designated a "Class I" area under the Clean Air Act Amendments of 1977. The intent of the Amendments is to safeguard the air quality of Wildernesses and National Parks by insuring that air pollutant concentrations do not rise above 1977 levels. The legislation gives land managing agencies an active role in the granting of permits by EPA or state pollution control agencies for the construction of new facilities that emit pollutants.

Thus the Forest Service is responsible for the protection of the Lye Brook Wilderness from the adverse effects of air pollution. Accordingly, in 1987 personnel of Region 9 of the National Forest System requested the technical assistance of Forest Pest Management in assessing pollution-caused injury to vegetation in the Wilderness.

The oxidant ozone (O_3) causes injury to plants throughout the eastern United States and is the pollutant most likely to damage plants on the Lye Brook Wilderness. Therefore, a survey of those plant species known to be sensitive to ozone was conducted in 1988 (O'Brien 1989) and, reported herein, in 1989. A second part of the evaluation consists of an ozone monitor (meter) and two pairs of filtered/unfiltered plant growth chambers located near the Wilderness. The purpose of this equipment is to definitely relate symptoms found in the Wilderness to ozone concentrations. The results are, for the most part, reported separately by Drs. Gretchen Smith and William Manning of the University of Massachusetts.

OBJECTIVES

The objectives of the 1989 survey were: (1) As in 1988, to determine if symptoms of ozone injury were present on ozone sensitive species on Lye Brook Wilderness, and if symptoms were found, to evaluate the distribution and intensity of the damage. (2) To relate the occurrence of symptoms in the Wilderness to ozone levels recorded nearby and to symptoms found in the growth chambers established near the Wilderness.

METHODS

In order to note any change in the foliage of particular plants that would indicate cumulative ozone injury, the same survey was conducted twice during the summer of 1989. The first survey was conducted July 10-20 and the second August 14-24.

Quality assurance

To assure the quality of the results, the field crew was trained in recognition of the symptoms of ozone injury by experienced personnel at the University of Massachusetts (Drs. Gretchen Smith and William Manning). In addition, I accompanied the crew for several days of each survey. As an aid to the estimation of damage intensity, the crew referred to photographs, such as those from Bennett and Stolte (1985), and to diagrams provided.

Tree group and plot establishment

The species of ozone-sensitive plants that were closely examined were white ash (*Fraximus americana* L.), black cherry (*Prunus serotina* Ehrh.), white pine (*Pinus strobus* L.), and blackberry (mostly *Rubus vermontanus* Blanch.). A few others, such as *Aster* spp. and elderberry (*Sambucus canadensis* L.), were examined in passing.

Data were collected from 13 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 5 midcrown or upper branch tips (45 cm long) taken from each tree by a professional tree climber (using a ladder and rope, rather than the usual climbing spikes, and a pole pruner). The foliage of one black cherry tree, in the opening at the union of the Appalachian and Branch Pond Trails, could be sampled non-destructively.

Four plots (two in addition to the two established in 1988), each containing 10 white pines with foliage accessible from the ground, were established on The Burning[1].

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.

All plots were square or rectangular, and were for the purpose of relocation only - their sizes varied according to the area necessary to enclose 10 trees or canes. The location of each plot and tree group was indicated on a 1:24,000 scale topographic map and a sketch was drawn to insure that it could be relocated. The locations of the plots and groups are indicated in Figure I.

Injury ratings

To quantify the injury to sensitive broadleaf vegetation in the Wilderness, entire plants (blackberries) or branches from sample trees (black cherry or white ash) were examined and rated. The ratings combined percentage of injured leaves on the plant or branch and intensity of damage on the 10 most severely injured leaves. Both of these were on a scale of 0 to 4 [0 = no injury; 1 = 1 to 5 percent (trace); 2 = 6 to 25 percent (light); 3 = 26 to 50 percent (moderate); 4 = greater than 50 percent (heavy)]. 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).

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[1]*The Burning is a ridgetop in the southwestern quarter of the Wilderness, burned so severely in 1917 that the original vegetation has not yet fully regenerated.*

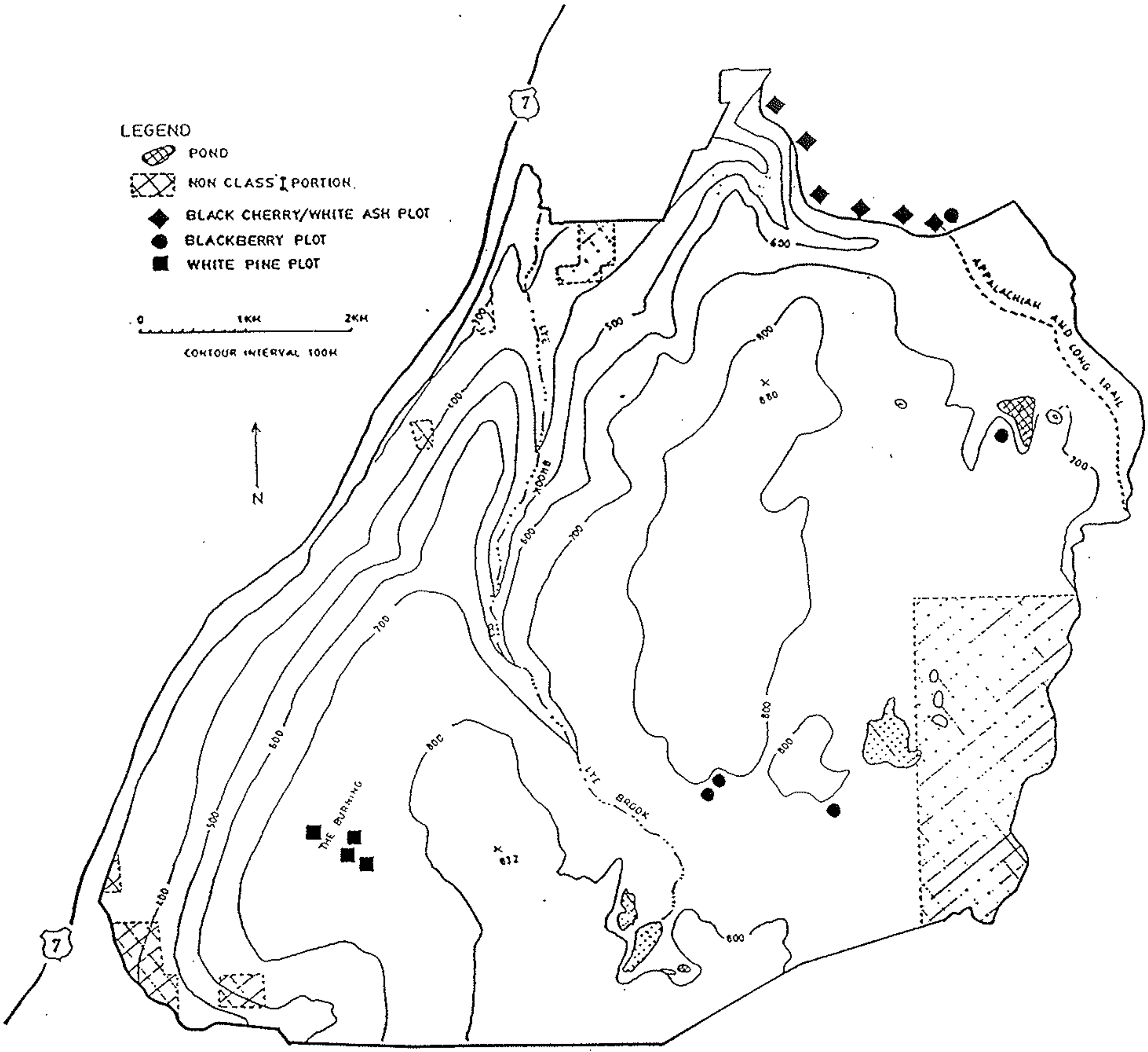

Figure 1. Map of the Lye Brook Wilderness, Green Mountain National Forest (Scale 1:60000).

White pine was evaluated on both a whole tree and a single branch basis. For the tree, annual height growth (internodal distances) was measured for the years 1980-88, along with needle length, needle retention (current needles only, current and 1 year old needles, or current, 1 year old and 2 year old needles present) and distribution of any foliage injury over the tree. For a selected branch on each tree, the current years and previous years foliage were evaluated separately for chlorosis (discoloring) and necrosis (dead tissue), and the percent fascicles affected and the average number of needles affected per fascicle were estimated.

1989 Ozone levels

Computer printouts of ozone levels recorded April through October 1989 at Bennington, Vermont were obtained from Richard Poirot of the Vermont Air Pollution Control Agency. Records from the monitor on Mt. Equinox, which had been installed in 1989, 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. The Mt. Equinox monitor, located about 5 km from the Wilderness, was operated from mid-June until late September. Personnel of the University of Massachusetts, cooperating with the Forest Service, oversee activities at the Mt. Equinox site[2].

To relate the growth of white pine to ozone concentrations, the records of the State's Burlington monitor, some 270 km to the north, were used because only these records go back for a reasonable period. Relatively, differences in concentrations between one year and another should be similar on the Wilderness and at Burlington.

RESULTS AND DISCUSSION

Injury to vegetation in 1989

Injury to the foliage of black cherry and white ash in 1989 was less common than in 1988, affecting only 28 percent of the trees vs. 69 percent in 1988 (It should be noted, however, that more trees were examined in 1989). The overall intensity rating was somewhat higher in 1989 than in 1988 (4.9 vs. 2.3) (Table 1). In contrast to 1988, a few black cherry and white ash trees displayed symptoms of ozone injury (a purplish coloration or stippling on the upper surfaces of the leaves) at the time of the first survey, July 18-19. Only a slight blanching of portions of some leaves had been found at this time in 1988. Both the intensity and the extent of the earlier 1989 injury had increased by the time of the second survey, August 22-23.

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[2]*A third cooperator is the Carthusian Foundation of Arlington, VT. The Foundation provided the site as well as access to electric power.*

Another difference was found in the symptoms themselves. The 1989 symptoms were often not "classic", as they had been in 1988. On some leaves, the stippling was on both upper and lower surfaces rather than on the upper surface only. As in 1988, injury was classified light.

The blackberry plots showed some symptoms of ozone injury, but the ratings were confused by a fungal foliage disease. Only one plot displayed definite and unmixed ozone symptoms. Here, injury to primocanes was rated lower than in 1988 (3.2 vs. 9.2), but injury to floricanes higher (12.0 vs. 7.2).

Table 1. Frequency and intensity ratings of ozone symptoms on black cherry and white ash on the Lye Brook Wilderness in 1988.

Group Number	Total trees Cherry	Total trees Ash	Trees w/ Symptoms	Total Branches	Branches w/symptoms	Average Branch Intensity Rating
1	5	0	1	25	1	2.0
2	0	5	1	25	5	8.0
3	3	2	2	25	10	3.0
4	1	4	2	25	8	5.1
5	2	3	1	25	5	6.6

For white pine, the rating scheme was changed in 1989, so no numerical comparison is possible. Subjectively, the trees were a darker green than in 1988, when some trees had displayed a pronounced yellowed foliage, particularly on their west sides.

The evaluation scheme used in 1989 for white pine was better than that used in 1988, but was still not satisfactory. The multiplicity of symptoms created difficulties with the numerical ratings. The symptoms were primarily mottling of the needles and necrosis of portions of some needles, but other abnormalities were found as well.

The internodal growth of the white pine did not correlate well with average ozone concentrations recorded at Burlington during the past 8 years. Nor could the growth of individual trees be correlated with the intensity of symptoms appearing on those trees.

No symptoms of ozone injury were found on any species other than the four mentioned above.

Ozone concentrations in 1988 and 1989

Two ozone "episodes" (levels of 80 parts per billion (ppb) or higher for two hours on two consecutive days) occurred during the 1989 growing season - May 18-19 and July 2-4. The July episode, as well as some other incidences of high concentrations that were of shorter duration, was recorded by both the Bennington and Mt. Equinox monitors, and ozone symptoms were soon found on black cherry in the unfiltered chambers and ambient air plots at the Mt. Equinox site. No symptoms appeared in the filtered chambers. Thus, there is little doubt that at least some of the injuries found within the Wilderness were ozone-caused.

Air pollution workers have often disagreed about which ozone parameters are biologically meaningful. Most of the parameters that have appeared in the literature are presented, for the Bennington site, in Table 2. All have weaknesses, so all are presented in the hopes that in the future the more meaningful parameters will become apparent.

By all parameters measured (Table 2), ozone concentrations in 1989 were lower than in 1988. May-August average concentrations, average daily peaks, the number of episodes, and percent of hours > 80 ppb in 1988 exceeded those of 1989 by considerable margins. The damage observed in the field does not adequately reflect these differences. Certain environmental factors, such as relative humidity and soil moisture, affect injury to plants by ozone and these may be as important as the concentrations. In any case, if we assume the concentrations in 1989 were those of a typical year (and concentrations in 1987 were similar in important respects[3]), the threshold for injury appears to be lower than the concentrations experienced in a typical year. In short, the plants may be injured every year.

The cumulative total of one hour average ozone concentrations (total "dose") for 1988 and 1989 is presented in Figure 2. This is a graphic comparison of the ozone concentrations in the two years, but again its value in assessing damage to the vegetation on the Wilderness is not yet apparent.

A Comparison of the Bennington and Mt. Equinox Monitors

Personnel are not available to service the Mt. Equinox monitor until June. Thus, for the period before June, the Bennington monitor provides the only ozone data available in the area near the Lye Brook Wilderness.

Ozone concentrations can be expected to be similar over large geographical areas, and the Bennington monitor is located only about 29 km from the Wilderness. Therefore, we might expect its data to be an accurate reflection of the concentrations that occurred on the Wilderness. However, the elevation where the Bennington monitor is located, 244 m, is considerably lower than most of the Wilderness. Nearly two thirds of the Wilderness is above 700 m.

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[3]*The overall average concentrations were lower in 1987 (32 ppb vs. 35 ppb), the May-August average was lower (34 ppb vs. 37 ppb), and no episodes occurred in 1987. However, concentrations equaled or exceeded 80 ppb on 8 days (44 hours), a figure not very different from that of 1989 when such concentrations occurred on 9 days (40 hours). Unfortunately we have no vegetation data for 1987.*

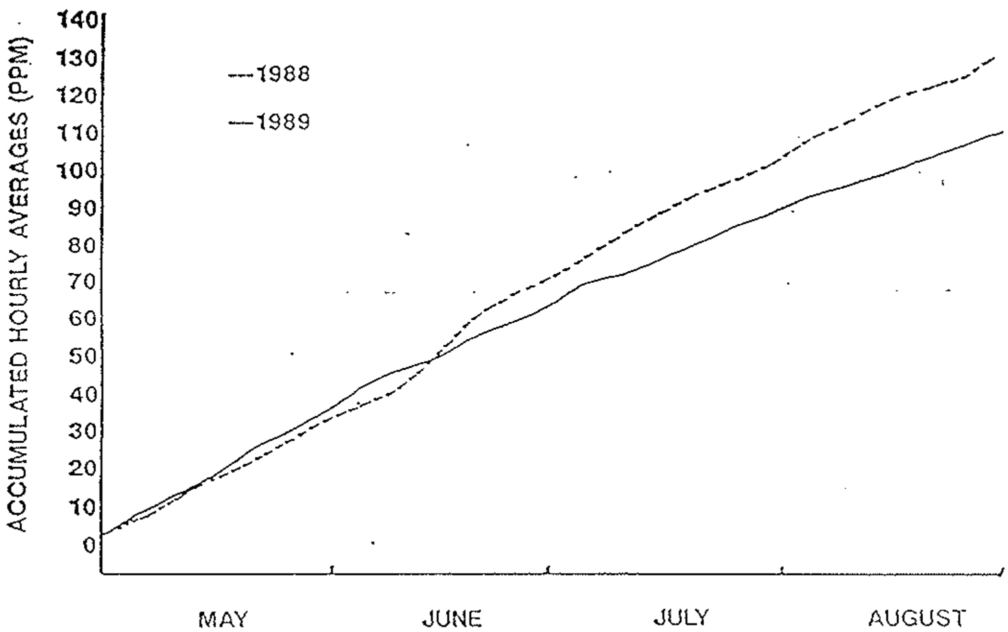

Figure 2. Cumulative hourly ozone concentrations in southern Vermont as recorded by the Bennington monitor in 1988 and 1989.

With regard to ozone concentrations, elevation is important. Wolff and his coworkers (1987) discovered that peak concentrations may be similar at high and low elevations, but the duration of high levels is longer at high elevations. At night, ozone accumulated during the daylight hours is rapidly depleted below the nocturnal inversion layer but not above it. Hence, the vegetation at the higher elevations is exposed to high concentrations for longer periods.

Figure 3 compares the data from the Mt. Equinox (elevation 625 m) and Bennington monitors for 12 of the days in 1989 during which both monitors were operated at least 22 hours per day. The pattern follows that described by Wolff and his coworkers very well. If we compare all of the days of June- August 1989 during which both monitors were operated 22 hours or more, the intervals between daily high and low values averaged 44 ppb at Bennington and 31 ppb on Mt. Equinox (the difference is statistically significant). For the same period, the average daily **peak** values were the same at Bennington and on Mt. Equinox - 54 ppb.

Consequently, we should consider the Bennington monitor indicative of conditions on the Wilderness for only the higher value parameters, such as average daily peak concentrations, number of episodes, or number of hours above 80 ppb.[4]

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[4]*The intent is to use the Mt. Equinox meter to monitor ozone concentrations* ***inside*** *the growth chambers as well as in the ambient air. Thus, the Bennington meter could not completely substitute for the Mt. Equinox meter even if these higher value parameters prove more appropriate than the lower value parameters.*

LITERATURE CITED

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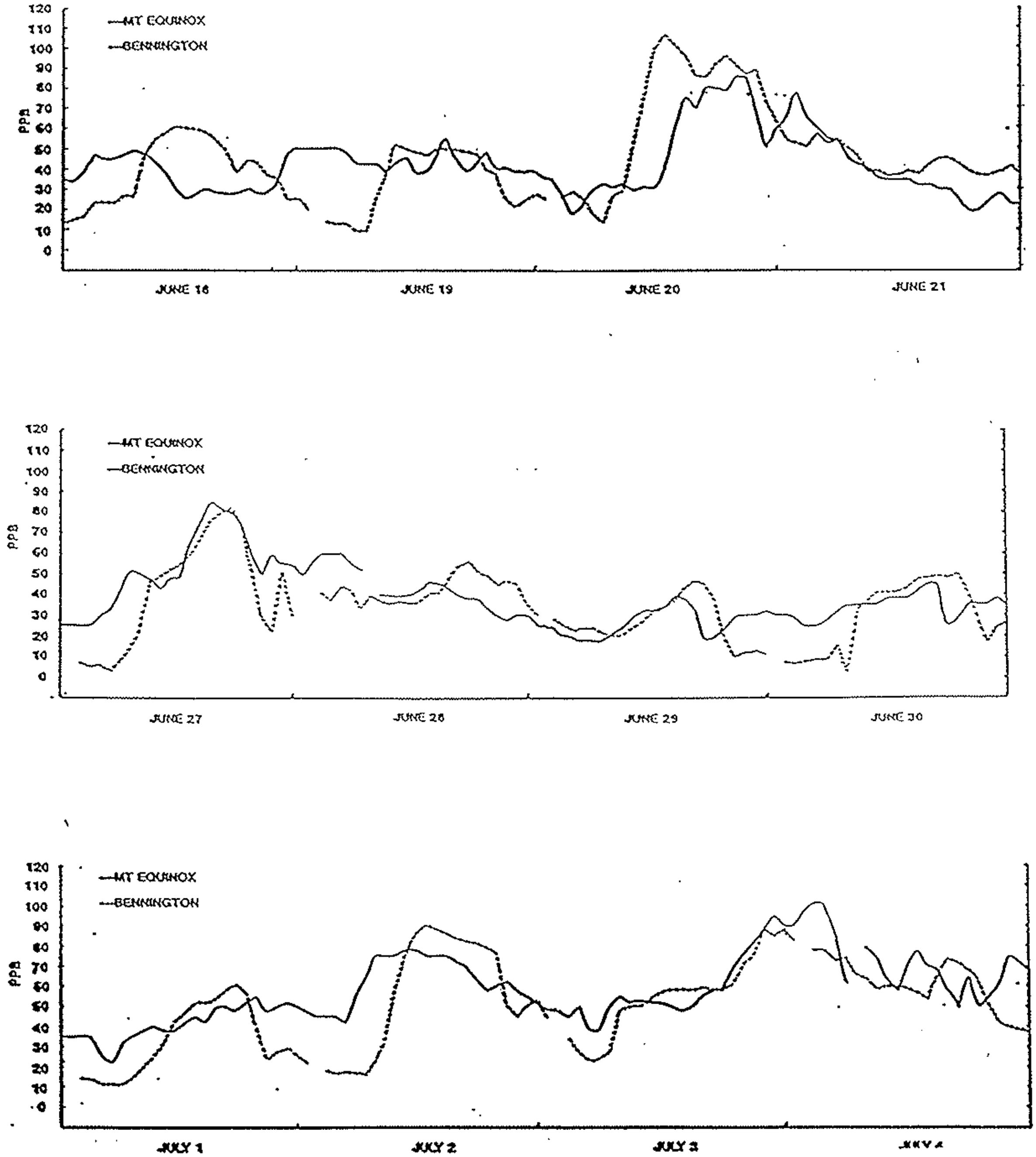

Figure 3. Graphic comparison of the ozone concentrations recorded by the Bennington and Mt. Equinox monitors during 12 days in 1989.