

EVALUATION OF OZONE SENSITIVE SPECIES WITHIN BIOINDICATOR PLOTS ASSOCIATED WITH THE USDA-FOREST SERVICE, FOREST HEALTH MONITORING PROGRAM IN PENNSYLVANIA AND PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF AIR QUALITY AND THE US EPA SITES

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Introduction

Bioindicator plots of plant species known sensitive to tropospheric ozone air pollution were established during 1998, 1999, 2000, and 2001 as part of our participation within the USDA - Forest Service Forest Health Monitoring Program (Table 1). During each of the four years, additional bioindicator plots were established proximal to numerous air quality monitoring stations operated by the Pennsylvania Department of Environmental Protection, Bureau of Air Quality and the US EPA (Table 1). Field crews were trained in recognition of ozone-induced foliar symptoms and in the use of Forest Health evaluation system for quantifying amounts of ozone-induced foliar injury. Black cherry, yellow poplar, white ash, sassafras, blackberry, common milkweed, and spreading dogbane were observed within the plots across the Commonwealth. In 1998, 1999, 2000, and 2001, 3,182, 9,709, 11,271 plants and 15,135 plants, respectively, were evaluated by the field crews (Table 2). Black cherry, blackberry, common milkweed, and dogbane were the most frequently observed species across all plots and years. Overall the symptoms observed and recorded at the Forest Health Monitoring plots, and the PA DEP Bureau of Air Quality and USEPA Air Quality Monitoring sites were similar in species responses to ozone induced injury within each year. However there were major differences in the percent of plants showing injury when comparing the four years of observations with foliar symptoms most frequently observed in 1998 > 2000 > 2001 > 1999 (Table 3). In 1998, black cherry and black berry appeared to be most symptomatic with 61% and 40% showing injury less injury was on white ash 31%, yellow poplar 25% and common milkweed 15%; no symptom on dogbane or sassafras were observed. As further evidenced in Table 3, far fewer symptoms were observed in 1999, 2000 and 2001 with the very least amount of symptoms found across all species and plots in 1999. The amounts of foliar injury were also noted to be different between the four years of observations with injury in 1998 and 2000 having more plants within the higher injury score classes. Blackberry and black cherry especially showed this trend of increased injury recorded in 1998. All species combined showed this similar trend following the 1998 survey (Tables 4, 5) with numbers of plants per injury class being more evenly distributed into the greater injury classes. Comparisons of injury incidence and severity of the bioindicators to various ozone exposure statistics is underway at each of the PA DEP, BAQ air quality monitoring sites; GIS and Kriging techniques will be utilized within a current MS thesis project to project these findings into the more uniformly distributed bioindicator plots associated with the Forest Health Monitoring plots throughout the Commonwealth.

Materials and methods

Procedures for the selection of the bioindicator plots with plant species known to be sensitive to ozone were developed by the USDA Forest Service and the National Forest Health Monitoring Program. Bioindicator plots were located within open areas of no less than .5 acres and greater. Plots were within a three miles radius and an elevation difference not greater than 300' +/- from the plot center of the main FHM plot. The evaluation window was from August 1 to August 20. Within each plot a voucher specimen was collected from one plant of each bioindicator species at each plot with ozone like symptoms. Vouchers were mailed to the Quality Assurance office led by Dr. G. Smith to be verified for the presence or absence of ozone symptoms. Field crews are required to attend a one-day course on the protocols to be employed in the collection and recognition of ozone induced foliar injury; crews were audited in the field to reaffirm the sampling protocol used within each annual survey.

Results.

Table 1. Total number of sites surveyed for bio-indicators of ozone induced foliar symptoms observed during the first four years of the Pennsylvania surveys. Plots visited included USDA-FS Forest Health Monitoring Plots, PA Bureau of Air Quality and USEPA Air Quality Monitoring sites.

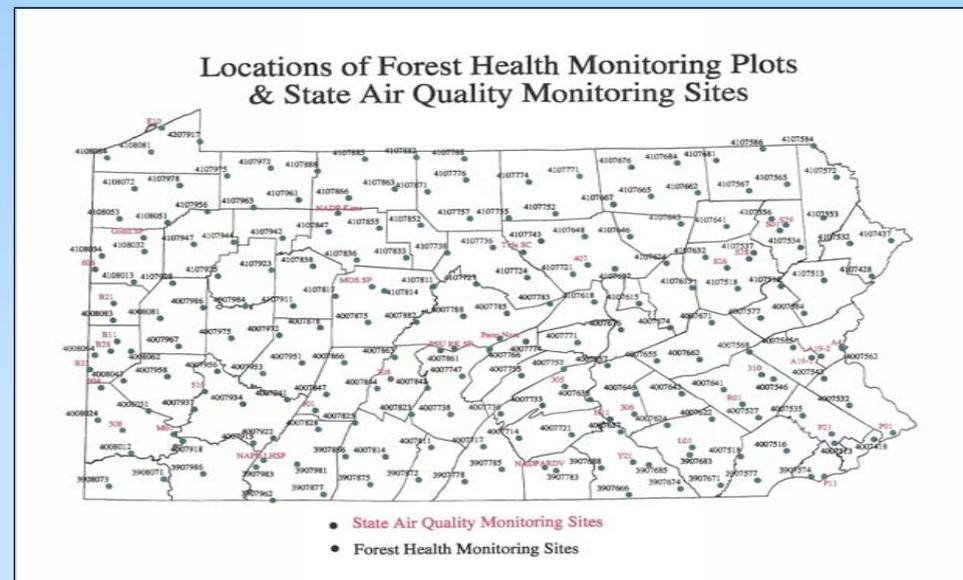
Year	FHM	State	US EPA	Total Plots
1998	96	24	5	125
1999	122	37	5	163
2000	95	37	5	137
2001	97	39	5	141

Table 2. Total plant species surveyed as bio-indicators of ozone exposure and numbers and percent of plants with ozone induced foliar symptoms observed during the four years of the survey. Plots visited included USDA-FS Forest Health Monitoring Plots, PA Bureau of Air Quality and US EPA Air Quality Monitoring sites.

Year	Total Plants	Number of Symptomatic Plants	Percent of Symptomatic Plants	² Injury Index
1998	3182	987	31.0%	14.24
1999	9709	231	2.4%	.14
2000	11271	1307	11.6%	5.03
2001	15135	929	6.14%	3.24

Table 3. Plant species surveyed as bioindicators of ozone exposure and numbers and percent of plants with ozone induced foliar symptoms observed during the four years of the survey. Plots visited included USDA-FS Forest Health Monitoring Plots, PA Bureau of Air Quality and US EPA Air Quality Monitoring sites.

Species	Total No. Plants Obs.				Percent of Total Plants Obs.			Number of Plants With Symptoms				Percents of Plants With Symptoms				
	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001
Blackberry	878	1255	2098	2480	28	13	19	16	533	150	738	676	61	12	35	27
Black cherry	544	1822	1979	2981	17	19	18	20	220	40	124	92	40	2	6	3
Milkweed	1106	2407	2509	3007	35	25	22	20	168	23	167	40	15	1	7	1
Dogbane	380	2115	1834	2810	12	22	16	19	10	15	35	9	0	1	2	0.3
White ash	113	1041	1392	1883	4	11	12	12	35	1	158	100	31	1	12	5
Yellow-poplar	83	125	428	487	3	1	4	3	21	1	27	1	25	1	6	0.2
Sassafras	39	596	928	1477	1	0	8	10	0	1	58	11	0	1	6	0.8



White ash (*Fraxinus americana* L.)



Sassafras (*Sassafras albidum* Nutt.)



Blackberry (*Rubus allegheniensis* Porter.)



Yellow-poplar (*Liriodendron tulipifera*)



Black cherry (*Prunus serotina* Ehrh.)



Milkweed (*Apocynum androsaemifolium* L.)

Continued Results

Table 4. Plant species surveyed as bioindicators of ozone injury and numbers of plants per injury class surveyed for incidence of foliar injury and severity of symptoms observed during the four years of the survey. Plots visited included USDA-FS Forest Health Monitoring Plots, PA Bureau of Air Quality and US EPA Air Quality Monitoring sites.

Species	Total No. Plants Obs.	¹ Number of Plants Per Injury Class					² Injury Index
		0	1	2	3	4	
Blackberry							
1998	879	345	214	268	263	168	135
1999	1255	1105	81	87	65	46	24
2000	2098	1360	303	345	409	312	107
2001	2490	1814	283	357	388	209	135
Black cherry							
1998	544	324	158	110	74	46	52
1999	1822	1782	32	23	14	6	5
2000	1979	1851	116	76	26	24	10
2001	2981	2889	101	48	22	9	4
Milkweed							
1998	1106	938	171	73	42	22	28
1999	2407	2386	23	11	6	4	0
2000	2509	2339	159	111	42	20	5
2001	3007	2967	30	25	16	8	1
Dogbane							
1998	380	370	20	0	0	0	0
1999	2115	2100	10	15	4	1	0
2000	2509	1788	25	32	6	6	1
2001	2810	2801	8	4	2	2	2
White ash							
1998	113	78	11	11	14	11	23
1999	1041	1040	0	0	1	1	0
2000	1392	1233	48	95	81	58	35
2001	1883	1783	42	43	48	26	41
Yellow-poplar							
1998	83	62	26	8	6	2	0
1999	125	124	0	0	1	1	0
2000	428	401	32	11	10	1	0
2001	487	486	2	0	0	0	0
Sassafras							
1998	39	39	0	0	0	0	0
1999	596	595	0	2	0	0	0
2000	928	870	56	51	8	0	1
2001	1477	1466	8	6	5	3	0

Table 5. Number of all plants combined per injury class surveyed for foliar injury and severity of the average severity-index injury, for species during the four years. Plots visited included USDA-FS Forest Health Monitoring Plots, PA Bureau of Air Quality and US EPA Air Quality Monitoring sites.

All Species	Total No. Plants Obs.	¹ Numbers of Plants Per Injury Class					² Injury Index
		0	1	2	3	4	
1998	3182	2195	600	470	399	249	256
1999	9709	9480	146	138	91	56	29
2000	11271	9959	739	721	582	421	159
2001	15135	14206	454	483	481	257	183

Key

¹ Rating Scale: Injury Severity (The average percent leaf area on individual plants showing ozone-induced foliar injury for the injured leaves only).

- 0 = No injury
- 1 = 1 to 6 percent of leaf area of injured leaves symptomatic.
- 2 = 7 to 25 percent of leaf area of injured leaves symptomatic.
- 3 = 26 to 50 percent of leaf area of injured leaves symptomatic.
- 4 = 51 to 75 percent of leaf area of injured leaves symptomatic.
- 5 = > 76 percent of leaf area of injured leaves symptomatic.

² (No. of plants x class 1 + Class 2...Class 5) / Total Number of Injured Plants.

