

APPALACHIAN HIGHLANDS NETWORK

APHN – 03 ASSESS

BIG SOUTH FORK NATIONAL RIVER AND RECREATION AREA (BISO)

Plant Species Sensitive to Ozone

<i>Latin Name</i>	<i>Common Name</i>	<i>Family</i>
<i>Ailanthus altissima</i>	Tree-of-heaven	Simaroubaceae
<i>Asclepias exaltata</i>	Tall milkweed	Asclepiadaceae
<i>Asclepias syriaca</i>	Common milkweed	Asclepiadaceae
<i>Aster macrophyllus</i>	Big-leaf aster	Asteraceae
<i>Aster umbellatus</i>	Flat-topped aster	Asteraceae
<i>Cercis canadensis</i>	Redbud	Fabaceae
<i>Fraxinus americana</i>	White ash	Oleaceae
<i>Fraxinus pennsylvanica</i>	Green ash	Oleaceae
<i>Liquidambar styraciflua</i>	Sweetgum	Hamamelidaceae
<i>Liriodendron tulipifera</i>	Yellow-poplar	Magnoliaceae
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Vitaceae
<i>Pinus rigida</i>	Pitch pine	Pinaceae
<i>Pinus taeda</i>	Loblolly pine	Pinaceae
<i>Pinus virginiana</i>	Virginia pine	Pinaceae
<i>Platanus occidentalis</i>	American sycamore	Platanaceae
<i>Prunus serotina</i>	Black cherry	Rosaceae
<i>Rhus copallina</i>	Flameleaf sumac	Anacardiaceae
<i>Robinia pseudoacacia</i>	Black locust	Fabaceae
<i>Rubus allegheniensis</i>	Allegheny blackberry	Rosaceae
<i>Rudbeckia laciniata</i>	Cut-leaf coneflower	Asteraceae
<i>Sambucus canadensis</i>	American elder	Caprifoliaceae
<i>Sassafras albidum</i>	Sassafras	Lauraceae
<i>Verbesina occidentalis</i>	Crownbeard	Asteraceae
<i>Vitis labrusca</i>	Northern fox grape	Vitaceae

Representative Ozone Injury Thresholds

Sum06 -- The running 90-day maximum sum of the 0800-2000 hourly ozone concentrations of ozone equal to or greater than 0.06 ppm. Index is in cumulative ppm-hr.

Natural Ecosystems	8 - 12 ppm-hr (foliar injury)
Tree Seedlings	10 - 16 ppm-hr (1-2% reduction in growth)
Crops	15 - 20 ppm-hr (10% reduction in 25-35% of crops)

W126 -- A cumulative index of exposure that uses a sigmoidal weighting function to give added significance to higher concentrations of ozone while retaining and giving less weight to mid and lower concentrations. The number of hours over 100 ppb (N100) is

also considered in assessing the possible impact of the exposure. The W126 index is in cumulative ppm-hr.

	<u>W126</u>	<u>N100</u>
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

Ozone Exposure Data

Ambient concentrations of ozone were not monitored on-site, but were estimated by Krieger, a statistical interpolation process. The estimated hourly concentrations of ozone were then used to generate annual exposure values for the site. The exposure values include the Sum06 and W126 exposure indices in ppm-hr and the annual number of hours above 60, 80 and 100 ppb (N60, N80 and N100, respectively).

<u>Ozone air quality data for BISO</u>					
	1995	1996	1997	1998	1999
Sum06	4	4	3	14	8
W126	6.8	6.7	8.5	16.3	10.3
N60	98	86	109	272	158
N80	13	9	18	44	24
N100	1	1	2	5	2

Soil Moisture Status

The uptake of ambient ozone by a plant is highly dependent upon the environmental conditions under which the exposure takes place. The level of soil moisture is an important environmental variable controlling the uptake of ozone. Understanding the soil moisture status can provide insight to how effective the exposure may have been in leading to foliar injury. The Palmer Z Index was used to indicate soil moisture status since it represents the short-term departure of soil moisture from the average for that time period for the site. The objectives of the assessment were to examine the relationship between high annual levels of ozone and soil moisture status, and to consider the impact reduced soil moisture status would have on the effectiveness of exposure.

Palmer Z data were compiled for the site for both the months used to calculate the Sum06 index and for the April through October period for the W126 index for 1995 through 1999. The index ranges from approximately +4.0 (extreme wetness) to -4.0 (extreme drought) with ± 0.9 representing normal soil moisture.

Soil moisture status for the Sum06 index period.

Palmer Z Index data for 3-month Sum06 period at BISO					
	1995	1996	1997	1998	1999
Month 1	1.05	-0.16	-3.06	0.23	3.52
Month 2	-1.28	0.98	-0.75	0.33	0.07
Month 3	-0.50	0.82	0.66	-2.51	-1.87

Soil moisture status for the April through October period for the W126 index.

Palmer Z Index data for the 7-month W126 period at BISO					
	1995	1996	1997	1998	1999
April	-1.05	0.28	0.06	4.35	-1.14
May	2.31	0.46	2.10	-0.31	0.18
June	1.05	-0.16	5.90	6.93	3.52
July	-1.28	0.98	-3.06	0.23	0.07
August	-0.50	0.82	-0.75	0.33	-1.87
September	0.81	2.45	0.66	-2.51	-2.48
October	3.77	-0.93	0.25	-1.30	-1.25

Risk Analysis

- There are numerous ozone-sensitive species at the site, some of which are bioindicators for ozone.
- The Sum06 index is generally below the threshold for injury to vegetation. While the W126 accumulative value is above the threshold, the N100 count is below the required number and thus the criteria for injury are not satisfied. The Sum06 and W126 indices are generally below the levels considered necessary for injury to vegetation.
- The N-values for the site show concentrations frequently exceeded 60 ppb and exceeded 80 ppb for a few hours each year. No year had more than 5 hours in which the concentration exceeded 100 ppb. These levels of exposure are not likely to injure vegetation.
- Relationships between the 90-day Sum06 accumulation periods and soil moisture are difficult to assess because ozone exposure was low and similar in four of the five years. There appears to be no relationship between the 90-day Sum06 accumulation of ozone and soil moisture conditions. In the five-year assessment period, months of mild to severe drought were scattered throughout and without regard to the level of ozone exposure. There is some indication the soil moisture levels associated with the seasonal W126 index are inversely related to ozone

concentrations: when ozone is high, soil moisture is low. This relationship reduces the uptake of ozone and the effectiveness of the exposure in producing foliar injury. In the highest overall ozone years, 1998 and 1999, soil moisture conditions were at mild to moderate drought levels for consecutive months and would have significantly reduced the uptake of ozone. In the other years when the ozone exposure was lower, 1995, 1996, and 1997, soil moisture conditions showed several months of mild drought, were favorable, and at a month of severe drought, respectively.

The risk of foliar ozone injury at Big South Fork National River and Recreation Area is low. The threshold levels for injury are not consistently satisfied by either the Sum06 or W126 indices of exposure. The N-value counts indicate there are occasional exposures to concentrations of ozone greater than 80 ppb, and rare exposure to 100 ppb. Soil moisture levels suggest months of mild to severe drought occur at scattered intervals. These drought levels can cause minor to major reductions in the uptake of ozone.

If the level of risk increases in the future, a program to assess the incidence of foliar ozone injury on plants at the site could use one or more of the following bioindicator species: tree-of-heaven, tall milkweed, common milkweed, big-leaf aster, redbud, white ash, yellow-poplar, American sycamore, black cherry, cut-leaf coneflower, American elder, crownbeard and northern fox grape.

BLUE RIDGE PARKWAY (BLRI)

Plant Species Sensitive to Ozone

<i>Latin Name</i>	<i>Common Name</i>	<i>Family</i>
<i>Ailanthus altissima</i>	Tree-of-heaven	Simaroubaceae
<i>Apocynum androsaemifolium</i>	Spreading dogbane	Apocynaceae
<i>Asclepias exaltata</i>	Tall milkweed	Asclepiadaceae
<i>Asclepias syriaca</i>	Common milkweed	Asclepiadaceae
<i>Aster acuminatus</i>	Whorled aster	Asteraceae
<i>Aster macrophyllus</i>	Big-leaf aster	Asteraceae
<i>Aster umbellatus</i>	Flat-topped aster	Asteraceae
<i>Cercis canadensis</i>	Redbud	Fabaceae
<i>Fraxinus americana</i>	White ash	Oleaceae
<i>Fraxinus pennsylvanica</i>	Green ash	Oleaceae
<i>Krigia montana</i>	Mountain dandelion	Asteraceae
<i>Liquidambar styraciflua</i>	Sweetgum	Hamamelidaceae
<i>Liriodendron tulipifera</i>	Yellow-poplar	Magnoliaceae
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Vitaceae
<i>Pinus banksiana</i>	Jack pine	Pinaceae
<i>Pinus rigida</i>	Pitch pine	Pinaceae
<i>Pinus virginiana</i>	Virginia pine	Pinaceae
<i>Platanus occidentalis</i>	American sycamore	Platanaceae
<i>Populus tremuloides</i>	Quaking aspen	Salicaceae
<i>Prunus serotina</i>	Black cherry	Rosaceae
<i>Rhus copallina</i>	Flameleaf sumac	Anacardiaceae
<i>Robinia pseudoacacia</i>	Black locust	Fabaceae
<i>Rubus allegheniensis</i>	Allegheny blackberry	Rosaceae
<i>Symphoricarpos albus</i>	Common snowberry	Caprifoliaceae
<i>Verbesina occidentalis</i>	Crownbeard	Asteraceae

Representative Ozone Injury Thresholds

Sum06 -- The running 90-day maximum sum of the 0800-2000 hourly ozone concentrations of ozone equal to or greater than 0.06 ppm. Index is in cumulative ppm-hr.

Natural Ecosystems	8 - 12 ppm-hr (foliar injury)
Tree Seedlings	10 - 16 ppm-hr (1-2% reduction in growth)
Crops	15 - 20 ppm-hr (10% reduction in 25-35% of crops)

W126 -- A cumulative index of exposure that uses a sigmoidal weighting function to give added significance to higher concentrations of ozone while retaining and giving less

weight to mid and lower concentrations. The number of hours over 100 ppb (N100) is also considered in assessing the possible impact of the exposure. The W126 index is in cumulative ppm-hr.

	<u>W126</u>	<u>N100</u>
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

Ozone Exposure Data

Ambient concentrations of ozone were not monitored on-site, but were estimated by Kriegering, a statistical interpolation process. The estimated hourly concentrations of ozone were then used to generate annual exposure values for the site. The exposure values include the Sum06 and W126 exposure indices in ppm-hr and the annual number of hours above 60, 80 and 100 ppb (N60, N80 and N100, respectively).

Ozone air quality data for BLRI					
	1995	1996	1997	1998	1999
Sum06	7	18	12	20	19
W126	22.6	33.7	23.9	38.9	33.9
N60	235	544	340	736	576
N80	8	20	5	21	16
N100	0	0	0	3	0

Soil Moisture Status

The uptake of ambient ozone by a plant is highly dependent upon the environmental conditions under which the exposure takes place. The level of soil moisture is an important environmental variable controlling the uptake of ozone. Understanding the soil moisture status can provide insight to how effective the exposure may have been in leading to foliar injury. The Palmer Z Index was used to indicate soil moisture status since it represents the short-term departure of soil moisture from the average for that time period for the site. The objectives of the assessment were to examine the relationship between high annual levels of ozone and soil moisture status, and to consider the impact reduced soil moisture status would have on the effectiveness of exposure.

Palmer Z data were compiled for the site for both the months used to calculate the Sum06 index and for the April through October period for the W126 index for 1995 through 1999. The index ranges from approximately +4.0 (extreme wetness) to -4.0 (extreme drought) with ± 0.9 representing normal soil moisture.

Soil moisture status for the Sum06 index period.

Palmer Z Index data for 3-month Sum06 period at BLRI					
	1995	1996	1997	1998	1999
Month 1	-0.22	-0.70	2.84	-2.57	1.24
Month 2	3.12	0.26	-1.17	-2.52	-0.91
Month 3	-1.62	-0.32	-3.35	-3.01	-2.64

Soil moisture status for the April through October period for the W126 index.

Palmer Z Index data for the 7-month W126 period at BLRI					
	1995	1996	1997	1998	1999
April	-2.81	0.22	2.05	3.84	-0.96
May	-0.22	-0.70	-0.13	-1.65	-0.39
June	3.12	0.26	2.84	0.73	1.24
July	-1.62	-0.32	-1.17	-2.57	-0.91
August	1.98	1.36	-3.35	-2.52	-2.64
September	-0.16	2.86	1.59	-3.01	-1.75
October	3.09	-1.80	0.65	-1.32	-0.37

Risk Analysis

- There are numerous ozone-sensitive species at the site, some of which are bioindicators for ozone.
- The Sum06 index generally exceeds the threshold for injury to vegetation. While the W126 accumulative value exceeds the threshold, the N100 count shows that the one-hour concentration of ozone reached 100 ppb in only one year, and thus the criteria for injury under the W126 exposure index are not satisfied.
- The N-values for the site show only a few hours in which concentrations exceeded 80 ppb, and only one year in which the concentration reached 100 ppb. These levels of exposure are not likely to injure vegetation.
- There are no associations between the levels of ozone and soil moisture conditions for either the Sum06 or W126 indices of exposure. Soil moisture levels during the years with the highest 90-day Sum06 accumulation period values, 1996, 1998, and 1999, showed well-watered conditions, moderate to severe drought, and moderate drought, respectively. The two years with the lowest ozone exposures showed mild to severe drought. Soil moisture levels associated with the seasonal W126 index are similarly mixed, with a diversity of mild, moderate and severe, and mild and moderate drought conditions, respectively, occurring among 1996, 1998, and 1999, the three highest exposure

years. The two lower years of exposure had months of mild and moderate and mild and severe drought conditions. Soil moisture conditions for both indices in most years could significantly constrain the uptake of ozone and reduce the probability of foliar injury.

The low levels of ozone exposure at Blue Ridge Parkway make the risk of foliar ozone injury to plants low. The Sum06 exposure threshold is generally satisfied, but the W126 criteria are not. While there were some hours with concentrations of ozone above 80 ppb, the numbers were not high and concentrations of 100 ppb are rare. Soil moisture conditions and ozone exposure levels are not related, and conditions unfavorable for uptake can occur at any level of ozone exposure. The level of risk can be expected to be greater in a year in which favorable levels of soil moisture coincide with higher levels of ambient ozone.

If a program to assess the incidence of foliar ozone injury on plants at the site was initiated at some point in the future, one or more of the following bioindicator species could be used: tree-of-heaven, spreading dogbane, tall milkweed, common milkweed, big-leaf aster, redbud, white ash, yellow-poplar, American sycamore, quaking aspen, black cherry, common snowberry and crownbeard.

GREAT SMOKY MOUNTAINS NATIONAL PARK (GRSM)

Plant Species Sensitive to Ozone

<i>Latin Name</i>	<i>Common Name</i>	<i>Family</i>
<i>Ailanthus altissima</i>	Tree-of-heaven	Simaroubaceae
<i>Apocynum androsaemifolium</i>	Spreading dogbane	Apocynaceae
<i>Asclepias exaltata</i>	Tall milkweed	Asclepiadaceae
<i>Asclepias syriaca</i>	Common milkweed	Asclepiadaceae
<i>Aster acuminatus</i>	Whorled aster	Asteraceae
<i>Aster macrophyllus</i>	Big-leaf aster	Asteraceae
<i>Aster umbellatus</i>	Flat-topped aster	Asteraceae
<i>Cercis canadensis</i>	Redbud	Fabaceae
<i>Fraxinus americana</i>	White ash	Oleaceae
<i>Fraxinus pennsylvanica</i>	Green ash	Oleaceae
<i>Krigia montana</i>	Mountain dandelion	Asteraceae
<i>Liquidambar styraciflua</i>	Sweetgum	Hamamelidaceae
<i>Liriodendron tulipifera</i>	Yellow-poplar	Magnoliaceae
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Vitaceae
<i>Pinus rigida</i>	Pitch pine	Pinaceae
<i>Pinus taeda</i>	Loblolly pine	Pinaceae
<i>Pinus virginiana</i>	Virginia pine	Pinaceae
<i>Platanus occidentalis</i>	American sycamore	Platanaceae
<i>Prunus serotina</i>	Black cherry	Rosaceae
<i>Robinia pseudoacacia</i>	Black locust	Fabaceae
<i>Rubus allegheniensis</i>	Allegheny blackberry	Rosaceae
<i>Rudbeckia laciniata</i>	Cut-leaf coneflower	Asteraceae
<i>Sambucus canadensis</i>	American elder	Caprifoliaceae
<i>Verbesina occidentalis</i>	Crownbeard	Asteraceae

Representative Ozone Injury Thresholds

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Natural Ecosystems	8 - 12 ppm-hr (foliar injury)
Tree Seedlings	10 - 16 ppm-hr (1-2% reduction in growth)
Crops	15 - 20 ppm-hr (10% reduction in 25-35% of crops)

W126 -- A cumulative index of exposure that uses a sigmoidal weighting function to give added significance to higher concentrations of ozone while retaining and giving less

weight to mid and lower concentrations. The number of hours over 100 ppb (N100) is also considered in assessing the possible impact of the exposure. The W126 index is in cumulative ppm-hr.

	<u>W126</u>	<u>N100</u>
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

Ozone Exposure Data

Ambient concentrations of ozone monitored on-site were analyzed to generate annual exposure values. The values include the Sum06 and W126 exposure indices in ppm-hr and the annual number of hours above 60, 80 and 100 ppb (N60, N80 and N100, respectively).

Lookout Rock

Ozone air quality data for GRSM – Lookout Rock					
	1995	1996	1997	1998	1999
Sum06	33	35	47	46	54
W126	66.9	76.6	92.8	120.6	128.8
N60	1270	1490	1686	2102	2240
N80	218	175	374	558	617
N100	24	5	42	105	82

Cade's Cove

Ozone air quality data for GRSM – Cade's Cove					
	1995	1996	1997	1998	1999
Sum06	16	18	22	27	36
W126	23.6	24.3	30.6	42.2	47.4
N60	410	452	570	742	877
N80	33	21	56	131	159
N100	4	0	1	5	8

Cove Mountain

Ozone air quality data for GRSM – Cove Mountain					
	1995	1996	1997	1998	1999
Sum06	36	38	44	55	57
W126	95.7	98.7	106.2	142.6	141.3
N60	1856	1990	2019	2566	2511
N80	247	248	368	680	680
N100	18	8	15	107	54

Clingman's Dome

Ozone air quality data for GRSM – Clingman's Dome					
	1995	1996	1997	1998	1999
Sum06	18	31	35	51	51
W126	65.9	74.2	90.0	136.2	133.9
N60	1300	1489	1786	2577	2568
N80	127	124	188	617	510
N100	5	3	5	57	29

Soil Moisture Status

The uptake of ambient ozone by a plant is highly dependent upon the environmental conditions under which the exposure takes place, and the level of soil moisture is an important environmental variable controlling the process. Understanding the soil moisture status can provide insight to how effective an exposure may be in leading to foliar injury. The Palmer Z Index was selected to indicate soil moisture status since it represents the short-term departure of soil moisture from the average for each month for the site. The objectives of the assessment were to examine the relationship between high annual levels of ozone and soil moisture status, and to consider the impact reduced soil moisture status would have on the effectiveness of exposure.

The Palmer Z Index is calculated for up to 10 regions within a state and therefore is not a site-specific index. Without site-specific data, ozone/soil moisture relationships can only be estimated. Site-specific criteria such as aspect, elevation, and soil type can alter soil moisture conditions such that they depart from those determined for the region. However, in lieu of site-specific data, the Palmer Z Index is the best estimate of short-term soil moisture status and its change throughout the growing season.

Palmer Z data were compiled for the site for both the months used to calculate the Sum06 index and for the April through October period for the W126 index for 1995 through 1999. The Palmer Z index ranges from approximately +4.0 (extreme wetness) to -4.0 (extreme drought) with ± 0.9 representing normal soil moisture.

Soil moisture status for the Sum06 index period.

Palmer Z Index data for 3-month Sum06 period at GRSM					
	1995	1996	1997	1998	1999
Month 1	1.37	-0.09	-0.80	-0.89	1.52
Month 2	-2.96	1.38	-1.53	-1.71	-2.38
Month 3	-1.51	1.32	1.39	-2.87	-1.82

Soil moisture status for the April through October period for the W126 index.

Palmer Z Index data for the 7-month W126 period at GRSM					
	1995	1996	1997	1998	1999
April	-2.42	0.78	1.59	7.53	-0.78
May	2.15	1.14	2.08	-0.33	0.42
June	1.37	-0.09	3.01	3.96	2.45
July	-2.96	1.38	-0.80	-0.89	1.52
August	-1.51	1.32	-1.53	-1.71	-2.38
September	0.24	2.32	1.39	-2.87	-1.82
October	1.38	-0.86	0.51	-2.35	-0.58

Risk Analysis

- There are numerous ozone-sensitive species at the site, some of which are bioindicators for ozone.
- The Sum06 index significantly exceeds the threshold for foliar injury at each of the sites. The W126 accumulative value significantly exceeds the threshold at each site, however the N100 count is highly variable both among sites and years. The number of hours above 100ppb ozone often, but not consistently, meets the threshold for injury under the W126 criterion for injury to vegetation.
- The N-values for concentrations of 60 and 80 ppb are very high and demonstrate that there are a significant numbers of hours during which plants are exposed to potentially harmful levels of ozone. While the N100 index is highly variable, site-years with 10 hours of concentrations greater than 100 ppb are common and there are five site-years with over 50 hours of ozone greater than 100 ppb.
- Soil moisture levels during the 90-day Sum06 accumulation periods with the highest values show moderate levels of drought. These conditions would reduce the uptake of ozone and decrease the effectiveness of the exposures. Soil moisture levels associated with the seasonal W126 index appear inversely related to ozone concentrations: when ozone is high, soil moisture is low. This relationship reduces the uptake of ozone and the effectiveness of the seasonal exposure in producing foliar injury. However, high levels of ozone exposure in which both the Sum06 and W126 indices exceed the threshold for injury also occur in years when soil moisture conditions favor ozone uptake.

The risk of foliar ozone injury to plants at Great Smoky Mountains National Park is high. While the levels of ozone exposure consistently create the potential for injury, dry soil conditions may reduce the likelihood of injury developing in any particular year. Due to the high level of exposure, it is possible that even with the reduced uptake the physiological threshold for injury may be surpassed. Since the site is subject to potentially harmful levels of ozone annually, the probability of foliar injury developing may be greatest during years in which ozone levels are somewhat reduced but still exceed the thresholds, and soil moisture levels are normal or under mild drought and do not significantly constrain the uptake of ozone. While all four Smoky Mountain sites have a high risk for ozone injury, the Cade's Cove site shows levels of ozone distinctly lower than those at the other three sites. Exposure trends among the four sites are similar with the highest exposures occurring in the same years at all sites and the lowest exposures in the same years. Thus it is likely that the level of risk of ozone injury will be similar among all four sites in any given year.

A program to assess the incidence of foliar ozone injury on plants at the site could use one or more of the following bioindicator species: tree-of-heaven, spreading dogbane, tall milkweed, common milkweed, big-leaf aster, redbud, white ash, yellow-poplar, American sycamore, black cherry, cut-leaf coneflower, American elder and crownbeard.

OBED WILD AND SCENIC RIVER (OBRI)

Plant Species Sensitive to Ozone

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<i>Ailanthus altissima</i>	Tree-of-heaven	Simaroubaceae
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<i>Liquidambar styraciflua</i>	Sweetgum	Hamamelidaceae
<i>Liriodendron tulipifera</i>	Yellow-poplar	Magnoliaceae
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Vitaceae
<i>Pinus taeda</i>	Loblolly pine	Pinaceae
<i>Pinus virginiana</i>	Virginia pine	Pinaceae
<i>Platanus occidentalis</i>	American sycamore	Platanaceae
<i>Prunus serotina</i>	Black cherry	Rosaceae
<i>Robinia pseudoacacia</i>	Black locust	Fabaceae
<i>Rubus allegheniensis</i>	Allegheny blackberry	Rosaceae
<i>Rudbeckia laciniata</i>	Cut-leaf coneflower	Asteraceae
<i>Sambucus canadensis</i>	American elder	Caprifoliaceae
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Ozone Exposure Data

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Ozone air quality data for OBRI					
	1995	1996	1997	1998	1999
Sum06	17	17	15	18	24
W126	40.9	41.1	47.0	63.6	63.6
N60	727	750	845	1118	1147
N80	140	129	154	270	267
N100	22	11	13	42	31

Soil Moisture Status

The uptake of ambient ozone by a plant is highly dependent upon the environmental conditions under which the exposure takes place. The level of soil moisture is an important environmental variable controlling the uptake of ozone. Understanding the soil moisture status can provide insight to how effective the exposure may have been in leading to foliar injury. The Palmer Z Index was used to indicate soil moisture status since it represents the short-term departure of soil moisture from the average for that time period for the site. The objectives of the assessment were to examine the relationship between high annual levels of ozone and soil moisture status, and to consider the impact reduced soil moisture status would have on the effectiveness of exposure.

Palmer Z data were compiled for the site for both the months used to calculate the Sum06 index and for the April through October period for the W126 index for 1995 through 1999. The index ranges from approximately +4.0 (extreme wetness) to -4.0 (extreme drought) with ± 0.9 representing normal soil moisture.

Soil moisture status for the Sum06 index period.

Palmer Z Index data for 3-month Sum06 period at OBRI					
	1995	1996	1997	1998	1999
Month 1	1.05	-0.16	-3.06	6.93	0.07
Month 2	-1.28	0.98	-0.75	0.23	-1.87
Month 3	-0.50	0.82	0.66	0.33	-2.48

Soil moisture status for the April through October period for the W126 index.

Palmer Z Index data for the 7-month W126 period at OBRI					
	1995	1996	1997	1998	1999
April	-1.05	0.28	0.06	4.35	-1.14
May	2.31	0.46	2.10	-0.31	0.18
June	1.05	-0.16	5.90	6.93	3.52
July	-1.28	0.98	-3.06	0.23	0.07
August	-0.50	0.82	-0.75	0.33	-1.87
September	0.81	2.45	0.66	-2.51	-2.48
October	3.77	-0.93	0.25	-1.30	-1.25

Risk Analysis

- There are numerous ozone-sensitive species at the site, some of which are bioindicators for ozone.
- The Sum06 index exceeds the threshold for injury to vegetation. The W126 accumulative value and the N100 count are greater than their threshold values, thus the criteria for injury under the W126 index are satisfied. The Sum06 and W126 indices both exceed the levels considered necessary for injury to vegetation.
- The N-values for concentrations of 60, 80, and 100 ppb are all elevated and show there are a significant numbers of hours during which plants are exposed to levels of ozone likely to produce foliar injury.
- Relationships between the 90-day Sum06 accumulation period index of ozone and soil moisture conditions can best be described as mixed. Soil moisture levels in the lowest and highest ozone years, 1997 and 1999 respectively, include periods of severe and moderate drought that would significantly reduce the uptake of ozone. Soil moisture conditions in the remaining three years were generally favorable with only one month of mild drought. Soil moisture levels associated with the seasonal W126 index appear inversely related to ozone concentrations: when ozone is high, soil moisture is low. This relationship reduces the uptake of

ozone and the effectiveness of the seasonal exposure in producing foliar injury. In the highest ozone years, 1998 and 1999, soil moisture conditions were at moderate drought levels and would have significantly reduced the uptake of ozone. In the years when ozone exposures were lower, soil moisture conditions ranged from being favorable for the uptake of ozone, to months of mild and severe levels of drought.

The risk of foliar ozone injury to plants at Obed Wild and Scenic River is high. The levels of ozone exposure consistently create the potential for injury, however dry soil conditions may reduce the likelihood of injury, particularly in a high exposure year. Levels of exposure capable of producing foliar injury also occur under conditions of minor drought and normal soil moisture. The probability of foliar injury developing may be greatest during years in which ozone levels are somewhat reduced but still exceed the thresholds, and soil moisture levels are normal or under mild drought and do not significantly constrain the uptake of ozone.

A program to assess the incidence of foliar ozone injury on plants at the site could use one or more of the following bioindicator species: tree-of-heaven, tall milkweed, common milkweed, redbud, white ash, yellow-poplar, American sycamore, black cherry, cut-leaf coneflower, American elder, crownbeard and northern fox grape.