



Cumberland Piedmont Network Ozone and Foliar Injury Report – Carl Sandburg Home NHS, Guilford Courthouse NMP and Mammoth Cave NP

Annual Report 2012

Natural Resource Data Series NPS/CUPN/NRDS—2014/676



ON THE COVER

(Clockwise starting at top-left) Milkweed patch at CARL, ozone injury on common milkweed at CARL, POMS at CARL and the lead author during a foliar injury survey at GUCO and POMS at GUCO.

NPS photographs by: Top images by Irene Van Hoff, bottom-center by Shepard McAninch and all others by Johnathan Jernigan.

Cumberland Piedmont Network Ozone and Foliar Injury Report – Carl Sandburg Home NHS, Guilford Courthouse NMP and Mammoth Cave NP

Annual Report 2012

Natural Resource Data Series NPS/CUPN/NRDS—2014/676

Johnathan Jernigan and Bobby C. Carson

National Park Service
P.O. Box 7
Mammoth Cave, KY 42259

Teresa Leibfreid

National Park Service
P.O. Box 8
Mammoth Cave, KY 42259

July 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Cumberland Piedmont Network's intranet site (<http://www1.nrintra.nps.gov/im/units/cupn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Jernigan, J. W., B. Carson, and T. Leibfreid. 2014. Cumberland Piedmont Network ozone and foliar Injury report – Carl Sandburg Home NHS, Guilford Courthouse NMP and Mammoth Cave NP: Annual report 2012. Natural Resource Data Series NPS/CUPN/NRDS—2014/676. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	iv
Abstract.....	v
Acknowledgments.....	vi
Introduction.....	1
Sampling Sites	3
CARL Sandburg Home Pasture (CARL0001-OC/FoIn).....	3
GUCO Francisco Monument (GUCO0001-FoIn).....	4
GUCO Kotis Tract (GUCO0002-FoIn).....	5
GUCO Library POMS (GUCO0003-OC).....	6
MACA Great Onyx Job Corps (MACA0001-FoIn).....	7
MACA Air Quality Station (MACA0002-OC).....	8
Results.....	9
Ozone Concentration	9
Foliar Injury.....	14
The Interrelationship of Ozone Concentration and Drought Severity with Foliar Injury	18
Ozone Concentration Near the Remaining CUPN Parks.....	20
General Ozone and Foliar Injury Status.....	21
Future Ozone and Foliar Injury Monitoring Recommendations.....	21
Literature Cited	22

Figures

	Page
Figure 1 – Voucher specimen from ozone-injured milkweed plant at CARL in 2012	2
Figure 2 – CARL Sandburg Home Pasture (CARL0001) site photographs and map	3
Figure 3 – GUCO Francisco Monument (GUCO0001) site photographs and map	4
Figure 4 – GUCO Kotis Tract (GUCO0002) site photographs and map	5
Figure 5 – GUCO Library POMS (GUCO0003) site photographs and map	6
Figure 6 – MACA Great Onyx Job Corps site photograph and map	7
Figure 7 – MACA Air Quality Station site photograph and map	8
Figure 8 – MACA hourly ozone concentration graphs.	10
Figure 9 – CARL and GUCO POMS hourly ozone concentration graphs.	11
Figure 11 – Drought severity for the week of August 14, 2012	19
Figure 12 – Drought severity for the week of August 21, 2012	19

Tables

	Page
Table 1 – 2012 SUM06 and W126 values for CARL, CUGA, GUCO and MAC	14
Table 2 – List of plants with confirmed and unconfirmed foliar injury.....	15
Table 3 – Total number of plants inspected at each of the CUPN parks.	16
Table 4 – Total number of plants per species inspected at each park.	17
Table 5 – Plant counts with and without injury sorted by park location and species.	17
Table 6 – 2012 seasonal SUM060 and W126 values for state-operated sites near CUPN parks	20
Table 7 – CUPN sampling schedule of on-park POMS ozone concentration (OC) monitoring and foliar injury (FoIn) assessments	21

Abstract

This is the Cumberland Piedmont Network's (CUPN) fifth annual report on ozone concentration and associated foliar injury. Data were collected during 2012 at Carl Sandburg Home National Historic Site (CARL), Guilford Courthouse National Military Park (GUCO) and Mammoth Cave NP (MACA). Ozone concentration/foliar injury data and associated analyses are presented for each of these three parks. Both CARL and GUCO had generally low ozone concentrations that might be expected to produce minimal foliar injury while MACA had higher concentrations that would be expected to result in injury. However, the reality was the opposite: foliar injury was confirmed at CARL and GUCO while none was confirmed at MACA. This outcome could be explained by MACA's being in a drought while CARL and GUCO were not. Also included in this report are summary statistics for ozone data from off-park state-operated monitors located around CARL, GUCO, MACA and the remaining CUPN parks.

Acknowledgments

The investigators would like to thank park staff at CARL and GUCO for their assistance. In particular, thanks to Irene Van Hoff at CARL for her assistance with the installation/removal of the Portable Ozone Monitoring Stations at that park. Also, we would like to thank Irene and Ernesto Alcantar for maintaining that POMS throughout the season. Further thanks to Irene for assisting with foliar injury surveys at CARL. At GUCO, Stephen Ware assisted with POMS site installation and maintenance throughout the season (as well as some troubleshooting with a satellite communication problem that developed during the season). Thanks to Stephen for his help. Stephen was assisted with maintenance visits by the following people: Hannah Eitelberg, Max Feldman and Andrew Thiele. Thanks to them for their assistance as well. When assessing foliar injury at GUCO, the lead author was assisted by Shepard McAninch (CUPN). Thanks to “Shep” for his help. During MACA’s foliar injury assessment, we were aided by Sammi Jo Doyle (CUPN), Ayaka Matsuo (MACA intern) and Laura Schultz (MACA intern). Thanks to them for their assistance.

We would also like to thank CUPN staff at the MACA office (Brenda Wells, Lillian Scoggins and Sammi Jo Doyle) for their assistance with various office-based tasks. Brenda processes and maintains the voucher specimens, Lillian made the maps contained in this report and Sammi Jo keeps all of the paperwork straight. Thanks for all of their support. Thanks to all parks (CARL, GUCO and MACA) for allowing us to sample in their parks.

Lastly, thanks to Howie Neufeld and Art Chappelka for inspecting our foliar injury voucher specimens. In years past, this inspection has been completed by Gretchen Smith through the USFS Forest Inventory and Analysis program. We would like to extend a retroactive tip-of-the-hat and thanks to Gretchen and the USFS for their assistance in the past.

Introduction

This is the fifth report on the Cumberland Piedmont Network's (CUPN's) efforts to monitor both ozone and ozone's associated foliar injury. This report includes data collected in calendar year (CY) 2012, displays results in tabular and graphic form (accompanied by a brief interpretation) and concludes with a summary of the key results and recommendations. The CUPN's ozone and foliar injury efforts in CY2012 focused on three parks: Carl Sandburg Home National Historic Site (CARL), Guilford Courthouse National Military Park (GUCO) and Mammoth Cave National Park (MACA). Since these parks were where efforts were focused in CY2012, they will be hereafter referred to as the "focus parks". Results presented in this report are primarily based on data collected at these three parks.

The CUPN collected ozone concentration data at only two of the three focus parks in CY2012. A Portable Ozone Monitoring Station (POMS) was used for nearly the entire ozone season at CARL and GUCO. The CARL and GUCO POMS were maintained by park personnel. This report contains results from the analyses of data from those two sites. Additionally, MACA, working cooperatively with National Park Service – Air Resources Division (NPS-ARD), serviced and maintained its own ozone monitoring site, and analyses of those data are presented in this report.

It should be noted that the ozone analyzer used by both CUPN POMS is the Model 202 by 2B Technologies, Inc., Federal Equivalent Method EQOA-0410-190 (April 27, 2010 Federal Register Notice). However, the CUPN units are not equipped with ozone generators. As such, the data collected by CUPN POMS are not EPA equivalent.

For the eleven remaining CUPN parks, indices of ozone exposure from nearby, state-operated sites are presented for each park. These indices apply only to the state-operated site from which they were collected, and not directly to the park with which they are paired. These analyses are presented only in order to provide these remaining CUPN parks with a general indication of the severity of their ozone exposure by considering ozone exposure indices in their vicinity. These data are also provided for the three focus parks.

Foliar injury data were collected at CARL, GUCO and MACA. At CARL and MACA, one site each was surveyed for foliar injury. At GUCO, two sites were surveyed. An example of an injured (by ozone and other causes) leaf is shown in Figure 1.



Figure 1 – Voucher specimen from ozone-injured milkweed plant at CARL in 2012. NPS photograph by Brenda Wells.

Sampling Sites

CARL Sandburg Home Pasture (CARL0001-OC/FolIn)

The Sandburg Pasture site is located in the pasture that surrounds the Carl Sandburg home and barn. Ozone concentration and foliar injury data were collected at this site. The POMS was located roughly on the northern edge of the foliar injury sampling area. For the foliar injury survey, plants were sampled throughout the pasture. The site elevation is about 2,194 feet but varies since the terrain at the site is uneven. The elevation at the POMS is about 2,224 feet.

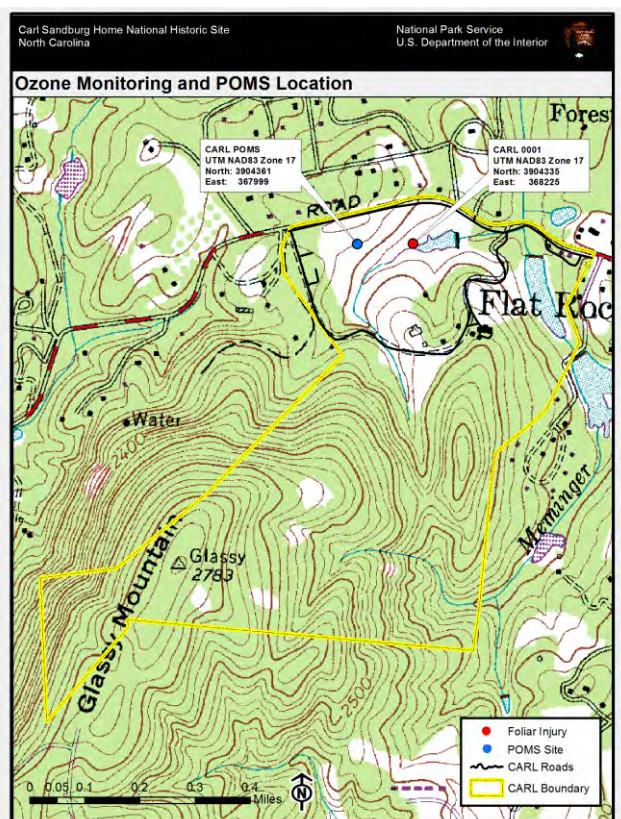


Figure 2 – CARL Sandburg Home Pasture (CARL0001) site photographs and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

GUCO Francisco Monument (GUCO0001-Foln)

GUCO's Francisco Monument site is adjacent to the park's Francisco Monument which is located along the self-guiding auto/bicycle tour. The site slopes gently downward away from the monument and is essentially a rectangular field. Plants that were examined were distributed fairly uniformly throughout the field, down to a stream near its lowest point. Site photographs and its map are shown in Figure 3. The elevation of the site is about 854 feet.

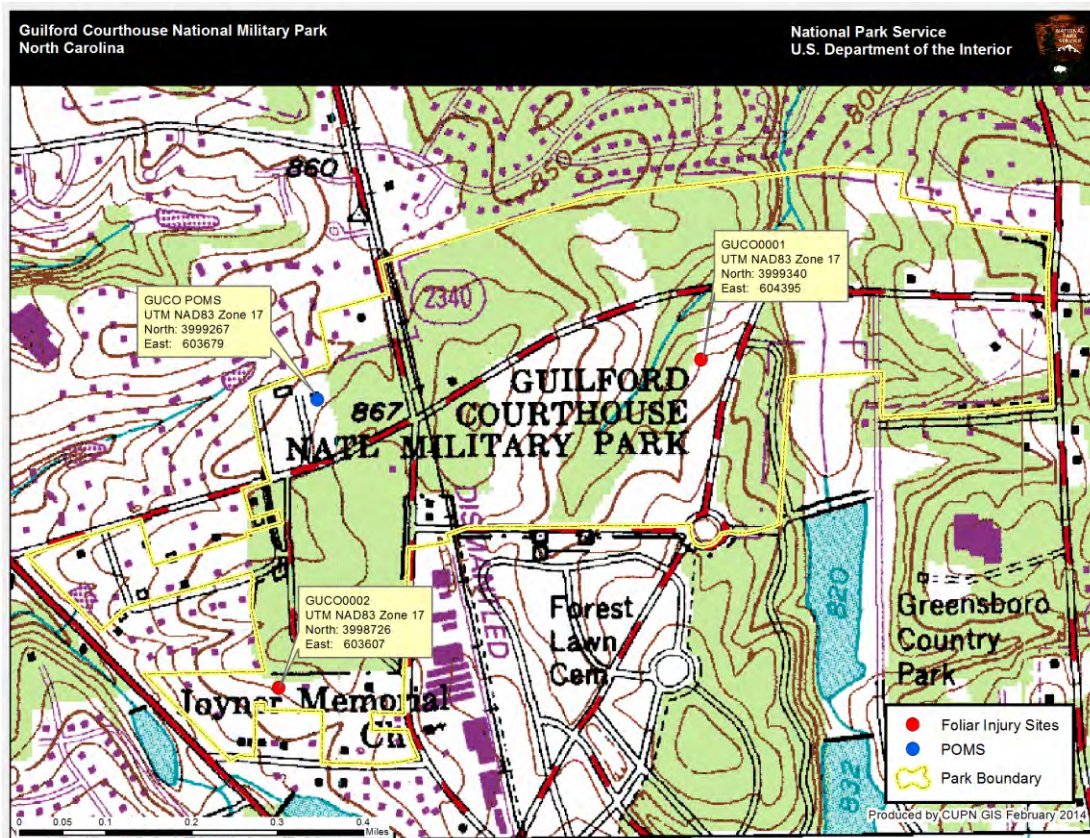


Figure 3 – GUCO Francisco Monument (GUCO0001) site photographs and map. NPS photographs by Shepard McAninch. NPS map by Lillian Scoggins (CUPN GIS specialist).

GUCO Kotis Tract (GUCO0002-FolIn)

GUCO's Kotis Tract site is land recently acquired by GUCO. Site photographs and its map are shown in Figure 4. Plants were examined from within the higher vegetation shown directly behind the primary author in the leftmost image. The elevation of the site is about 882 feet.

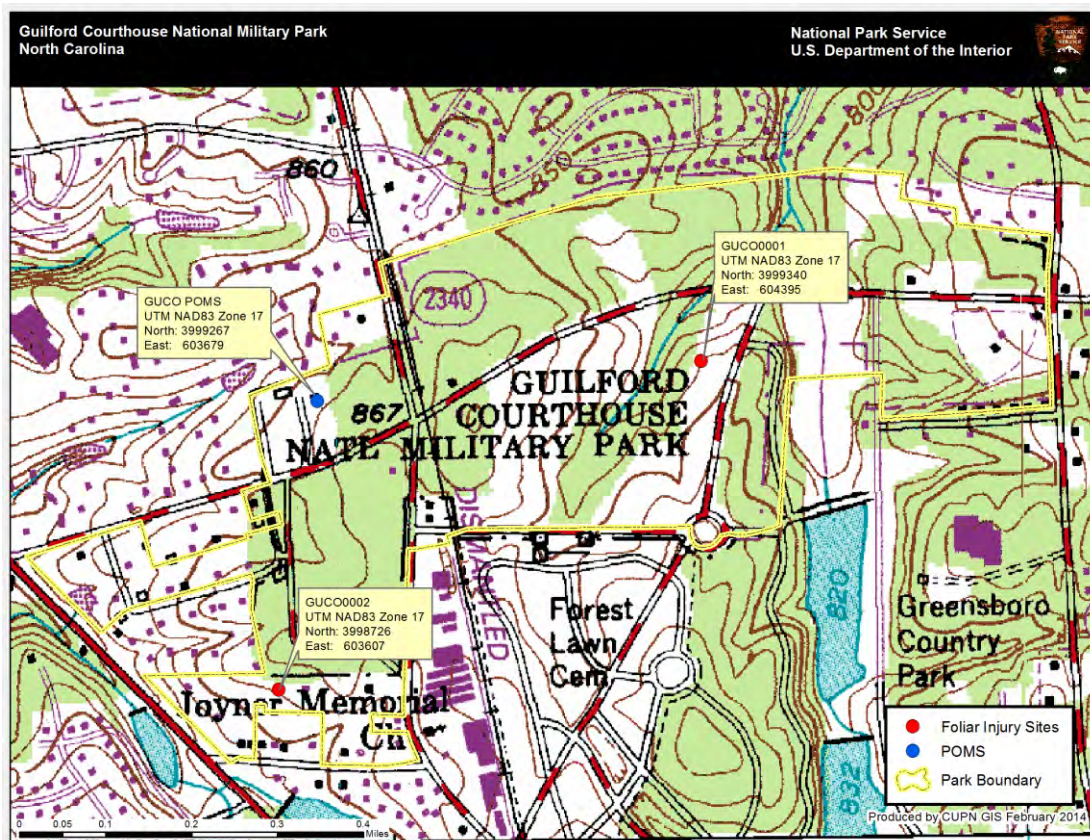


Figure 4 – GUCO Kotis Tract (GUCO0002) site photographs and map. NPS photographs by Shepard McAninch. NPS map by Lillian Scoggins (CUPN GIS specialist).

GUCO Library POMS (GUCO0003-OC)

The POMS was located in a yard adjacent to GUCO's maintenance area which is near its Visitor Center (Figure 5). Foliar injury data were not collected at this site. The elevation at the POMS site is about 855 feet.

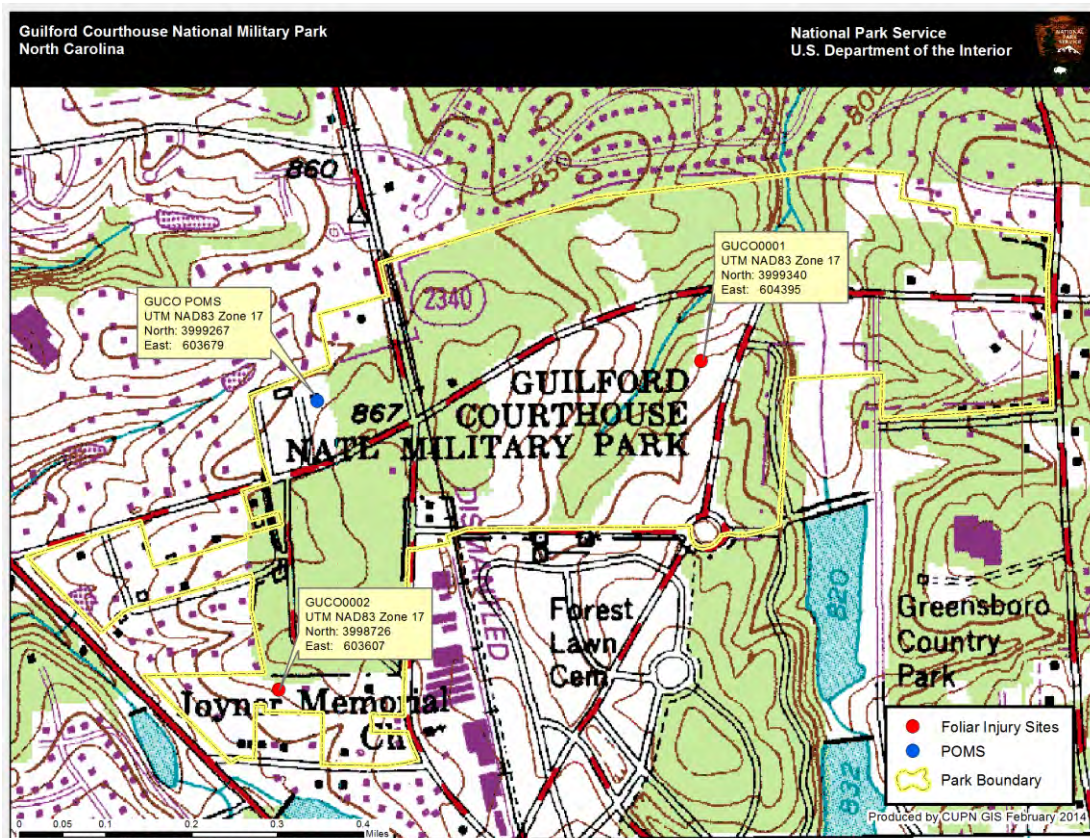


Figure 5 – GUCO Library POMS (GUCO0003) site photographs and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

MACA Great Onyx Job Corps (MACA0001-Foln)

MACA's Great Onyx Job Corps site lies on the northwest corner of the park. Plants were sampled from the edge within the tall grassy area shown in Figure 6. The elevation of the site is about 650 feet.

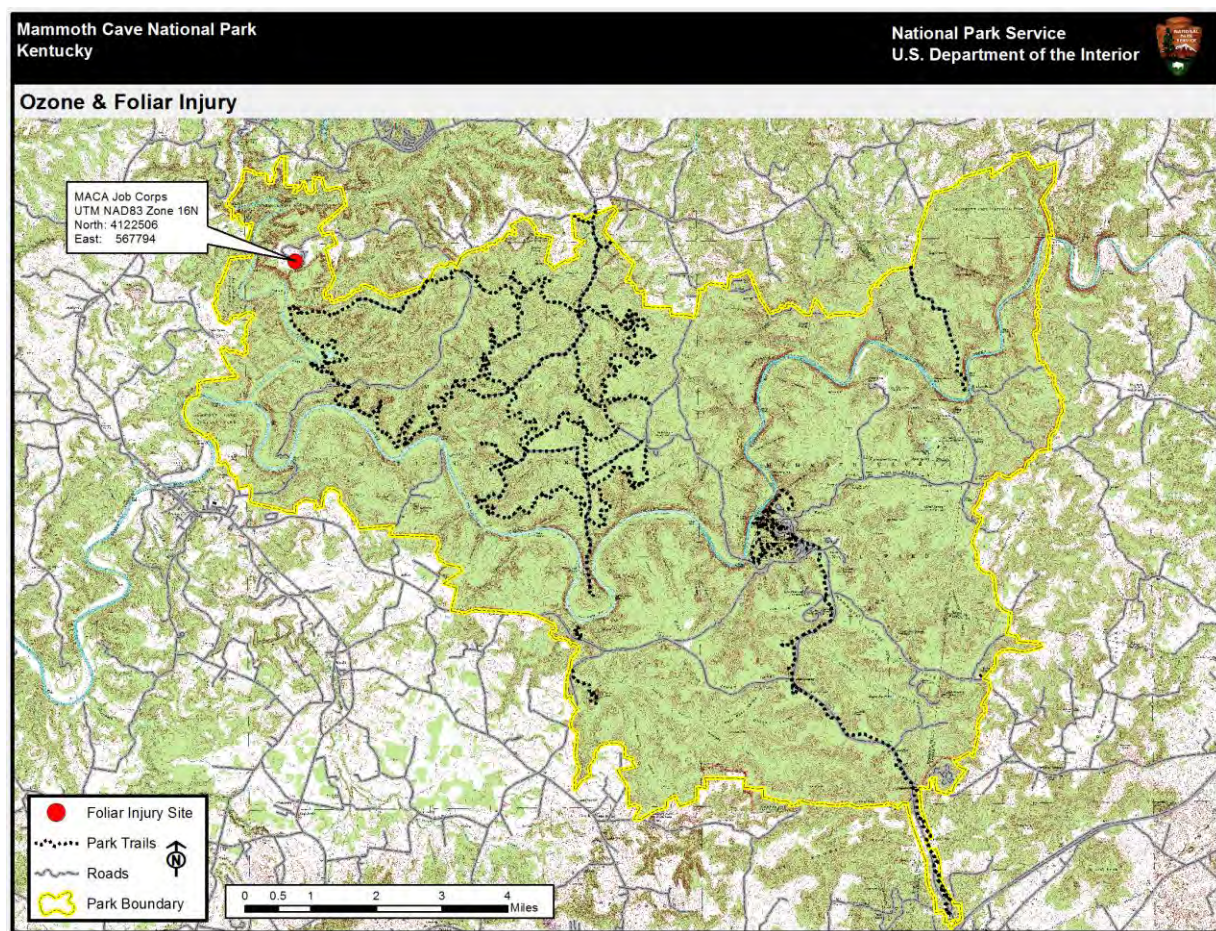


Figure 6 – MACA Great Onyx Job Corps site photograph and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

MACA Air Quality Station (MACA0002-OC)

MACA's air quality station lies on the western boundary of the park. This report utilizes only ozone data from this site. No foliar injury sampling was completed at this location. The site's ozone analyzer is an EPA-equivalent method (EQOA-0880-047) and the site's data are of sufficient quality to be used for permit review. The analyzer is housed in the leftmost and largest building, near the center of the photograph (Figure 7). At the rear of that building is a 10 meter tower and at the top of that tower is an inlet through which air is drawn for the analyzer. There are three towers in the photograph; the tower mentioned is the middle tower. The elevation of the site is 774 ft.

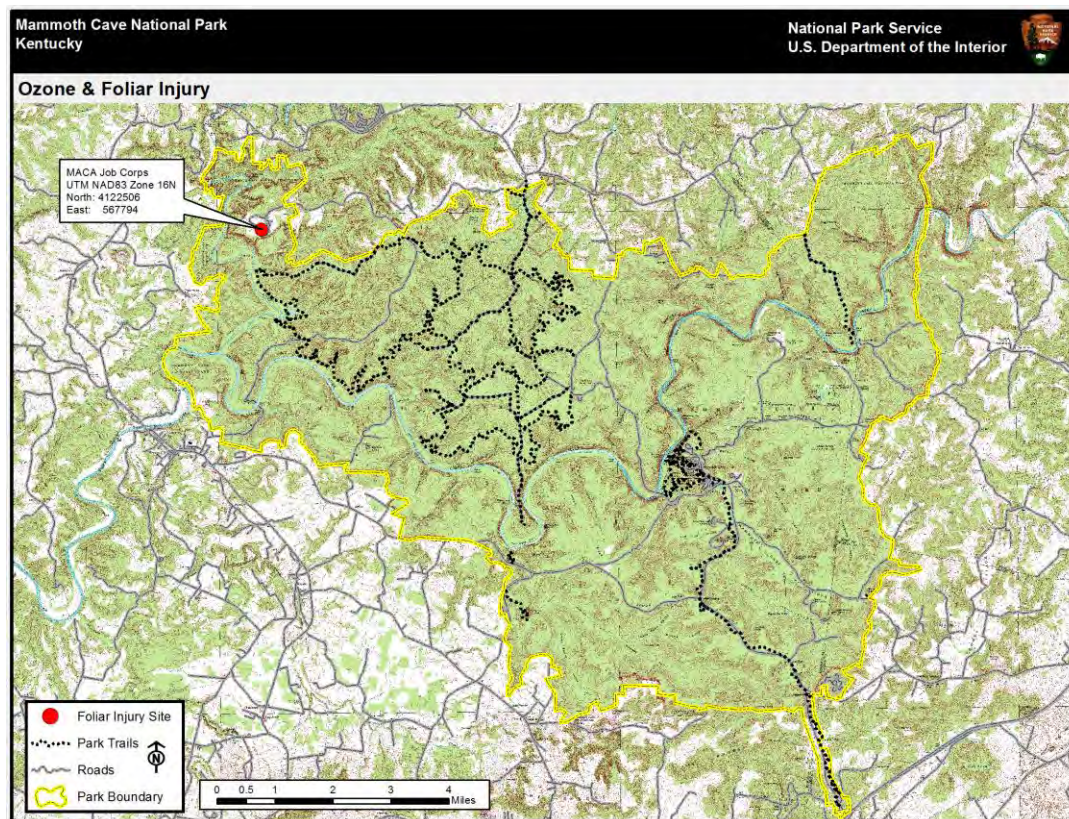


Figure 7 – MACA Air Quality Station site photograph and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

Results

In addition to operating two POMS units (one at CARL and one at GUCO), the CUPN mined ozone concentration data from external sources for the other park (MACA) at which foliar injury sampling was conducted. The three parks and their ozone data sources are:

- CARL – Ozone data are from a POMS located in the Sandburg Pasture, near the Sandburg home. The POMS was in place from 5 April 2012 to 1 November 2012.
- GUCO – Ozone data are from a POMS located very near the park's Visitor Center. The POMS was in place from 6 April 2012 to 1 November 2012.
- MACA – Ozone data are from the park's air quality station located along the park's boundary. Data cover the entire growing season.

Also, CUGA continued their operation of a POMS at the Hensley Settlement. The data presented here for CUGA were collected at that site. In 2012, the site was maintained by CUGA staff and joint funded by the CUPN and the National Park Service – Air Resources Division (NPS-ARD).

Additionally, ozone data were retrieved for nearby state-operated sites near all CUPN parks. These data are used to provide insight into the magnitude of the ozone exposure at each of these parks (especially those that were not focus parks in 2012). SUM060 and W126 indices are listed for all parks (see tables 1 and 6 in subsequent sections) using the indicated data sources.

Foliar injury assessments were conducted by the CUPN at a total of four sites spread across three parks in CY2012.

Ozone Concentration

Ozone data from focus parks (CARL, GUCO and MACA) are displayed in time series graphs and one scatterplot. Two time series plots are shown for hourly data at each site along with one scatterplot (figures 8 and 9). The first plot shows all available hourly ozone concentration data for the entire ozone season. The second time series plot is a subset of the previous plot, showing only seven days of hourly data around the time of the foliar injury assessment at that park. To explore diurnal patterns, a scatterplot is also shown in which the entire season's available hourly ozone data are plotted against the hour during which they were collected.

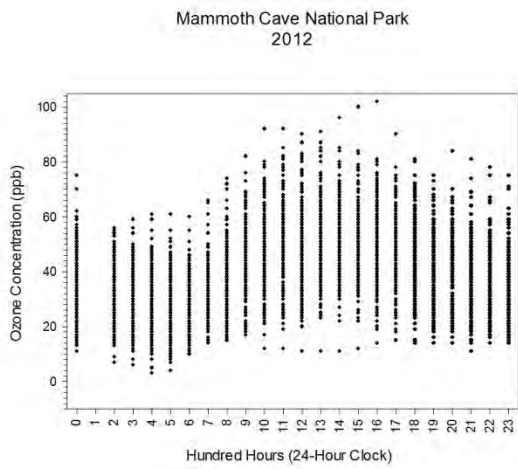
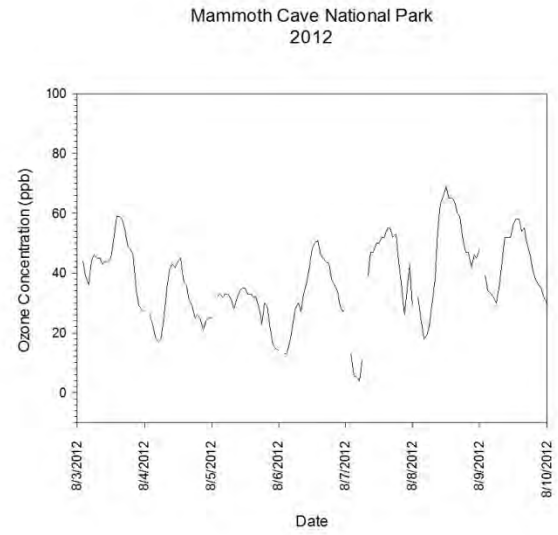
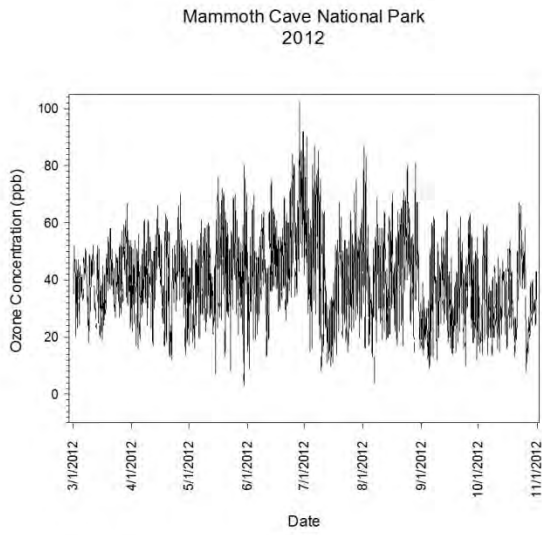


Figure 8 – MACA hourly ozone concentration graphs.

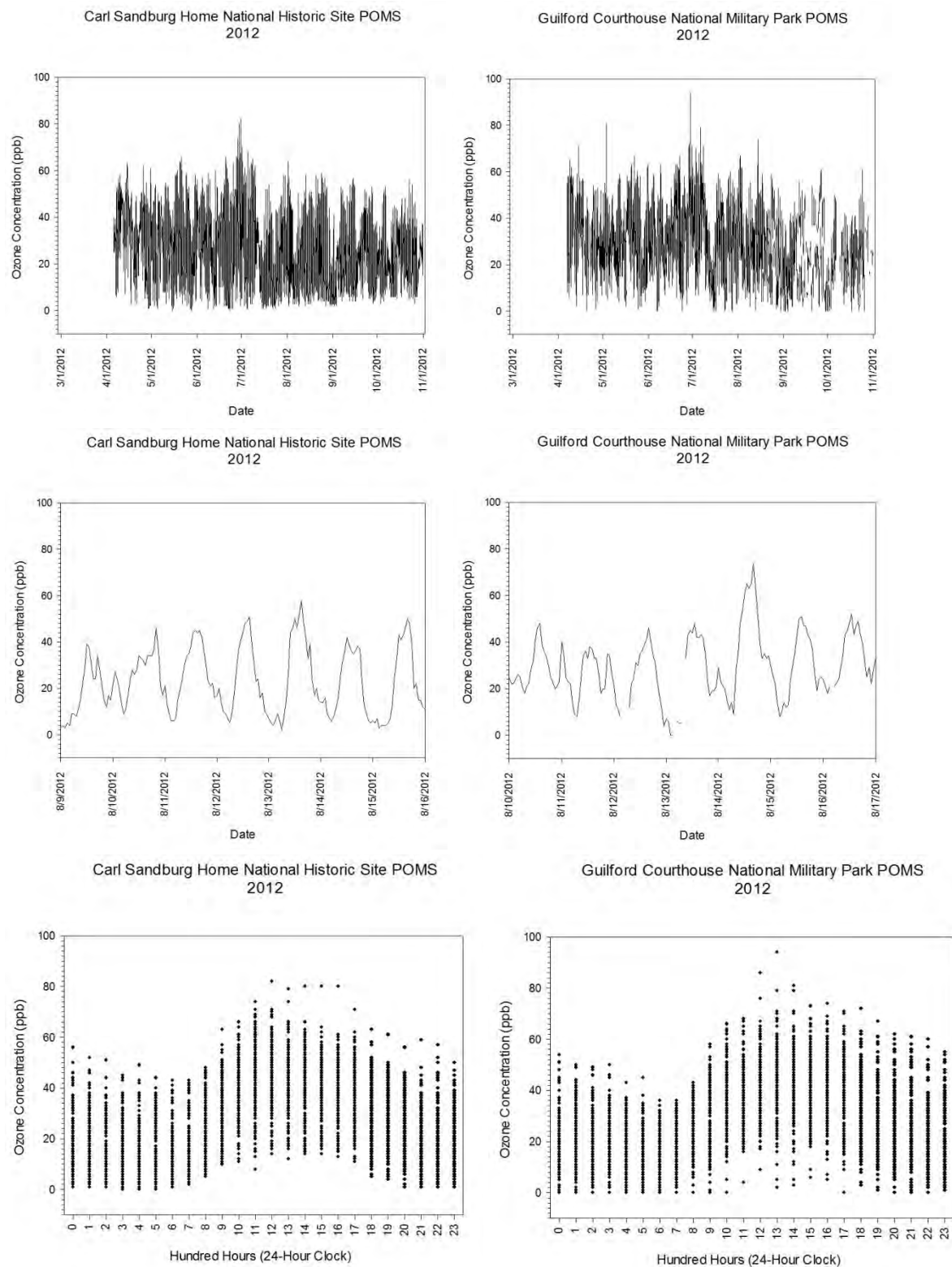


Figure 9 – CARL and GUCO POMS hourly ozone concentration graphs.

There are several metrics available to ascertain whether the ozone concentrations seen in Figure 8 and Figure 9 are considered to be too high. The current National Ambient Air Quality Standard (NAAQS) for ozone, as set by the Environmental Protection Agency, is 0.075 parts per million averaged over eight hours. This average is shown plotted in Figure 10 for CARL, CUGA, GUCO and MACA. The data shown in Figures 8 through 10 were downloaded from the NPS-ARD website that is maintained by the NPS-ARD Monitoring Support Contractor.

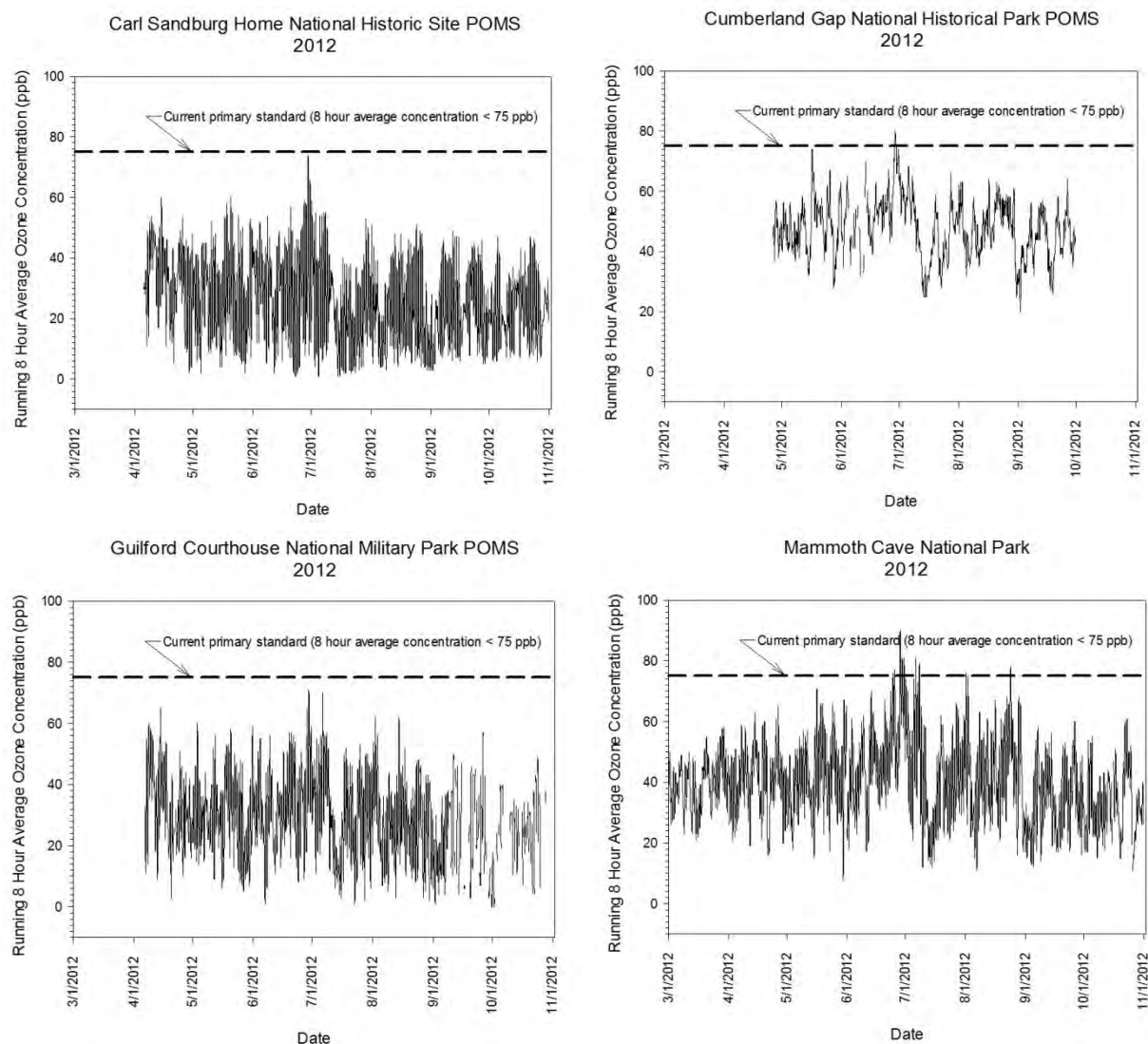


Figure 10 – Running 8 hour average ozone concentration at CARL, CUGA, GUCO and MACA.

Currently, the eight-hour average of 0.075 ppm is the primary (public health) standard and the secondary (public welfare) standard. Scientific studies have suggested that the public health standard is not protective of plant health. One of two alternative statistics is generally used to evaluate potential impacts to plant health (even though they are not used for regulatory purposes): the SUM06 or the W126. These indices are preferred because they are cumulative and emphasize the effects of higher ozone concentrations.

The SUM06 is the seasonal sum of all hourly ozone concentration measurements above 60 ppb. The W126 is the weighted sum of all hourly ozone measurements, with greater weighting placed on higher ozone values since those values have the most dramatic impact on plants. The W126 is defined by the equation

$$W126 = \sum_{i=1}^n \frac{c_i}{1 + 4403 \exp(-0.126 c_i)}$$

where c_i is the hourly ozone concentration expressed in ppb and n is the number of hours with valid ozone measurements.

A couple of options are available when computing the SUM06 and the W126. Firstly, either all 24 hourly measurements available for the day may be used or only those from 8 AM to 7 PM, inclusively, may be used. In this report, 8 AM to 7 PM (known as 8 – to – 8) measurements are presented. We prefer that time period since gas exchange in plants is highest during that time and plants are, therefore, more impacted by ozone concentrations at that time. Secondly, the indices may be computed using the chosen hourly values, either through the entire growing season or for each possible 3 consecutive month period in the growing season (with the largest of those values being taken as the W126 for the season). Both options are used here as a matter of convenience. The 3-month highest value is preferred, though, since a separate secondary standard recently proposed by EPA was based upon the 3-month value (and the NPS Air Resources Division has a calculator available online for use with POMS and NPS site data). However, for the state sites shown in Table 6, indices were computed using a calculator developed by the US Forest Service, and that calculator cannot compute the highest 3-month value, and so, in Table 6, cumulative growing season values are shown.

Sensitivity to ozone varies amongst species. Generally, though, Ray (2004) states that SUM06 values in the 8-12 ppm-hrs range are the values that can produce foliar injury in natural ecosystems. Similarly, Ray (2004) states that W126 threshold values are 5.9 ppm-hours for highly sensitive species and 23.8 ppm-hours for moderately sensitive species. All thresholds are 8 – to – 8, three month maxima.

The SUM06 and W126 values for CARL, GUCO and MACA (and CUGA as well) are given in Table 1. These indices were computed using the “data products” utility available at NPS-ARD’s “Access to Gaseous Pollutant and Meteorological Data” website (<http://ard-request.air-resource.com/DataProducts.aspx>).

Table 1 – 2012 SUM06 and W126 values for CARL, CUGA, GUCO and MACA. Values are calculated using data from 0800 to 1900. Indices presented are 3-month maxima (realized during the indicated period) in 2012. Also listed is the number of violations of the primary standard.

Park Name	Data Source	Percent Valid	SUM06 (ppm-hrs)	W126 (ppm-hrs)	Period	Between March 1 and October 31, number of 8 hour periods whose average exceeded 0.075 ppm
CARL	POMS (5 April to 31 Oct)	98.0	3.6	4.2	Apr-Jun	0
CUGA	POMS	83.0	10.1	9.7	May-Jul	17
GUCO	POMS (6 April to 31 Oct)	85.0	4.5	4.8	May-Jul	0
MACA	Houchins' Meadow Site	95.0	25.9	18.6	Jun-Aug	43

Foliar Injury

In CY2012, foliar injury assessments were completed at three parks on the following dates:

Carl Sandburg Home National Historic Site – August 16, 2012

Guilford Courthouse National Military Park – August 17, 2012

Mammoth Cave National Park – August 10, 2012

Foliar injury assessments were conducted by visually inspecting plant leaves for ozone injury and noting presence/absence of the injury on a field form. A summary of the findings in 2012 are shown in Table 2. An explanation for a few of the fields in Table 2 follows.

Starting with the rightmost column, the plant number is simply an identifier for each individual plant inspected. So, a value of “3” means that the plant was the 3rd one inspected. Near that column are the amount and severity columns. The amount is an index that refers to the proportion of the leaves on the plant that show any kind of ozone injury. The severity is an index that refers to the proportion of the leaf surface (for a leaf showing typical or average injury amongst all the plant’s injured leaves) that is covered by ozone injury. Rather than list actual percentages for these proportions, integer values are assigned that correspond to percentage ranges. The integer values that are assigned to given ranges are the same for both amount and severity indices. Those assignments are:

<u>Amount/Severity Percentage Range</u>	<u>Amount/Severity Code</u>
No injury	0
1-6%	1
7-25%	2
26-50%	3
51-75%	4
>75%	5

In those cases where injury was found, three injured leaves were collected for each species. These injured leaves (referred to as voucher specimens) were preserved and later sent to members of academia who have extensive experience with ozone foliar injury. These experts provided a second and authoritative opinion on the injury seen on the voucher specimens. If the injury is not confirmed by the regional expert, the CUPN does not consider plants from that park/site/species to be positive for ozone injury.

In past years, it should be noted, the investigators have been able to participate in the US Forest Service's program and have submitted voucher specimens to that program for inspection. In 2012, the USFS program was not operational and so voucher specimen inspection was performed by the aforementioned members of academia. Please note that the opinions forwarded to the investigators for the voucher specimens were not definitive for all location/species. So, in Table 2, the "Injury Confirmed (Y/N)" field is based upon the investigators' interpretation of the opinions offered by the academics.

Table 2 – List of plants with confirmed and unconfirmed foliar injury.

Park Name	Injury Confirmed (Y/N)	Date	Site Name	Species	Amount	Severity	Plant Number
CARL	Y	8/16/2012	Sandburg Pasture	Blackberry	1	2	3
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	1
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	3
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	4
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	5
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	6
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	7
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	11
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	13
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	14
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	1	30
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	2	2
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	1	2	17
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	2	1	8
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	2	1	9
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	3	1	29
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	3	2	28
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	3	3	23
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	4	1	27
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	4	2	26
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	4	3	20
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	2	21
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	2	24
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	2	25
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	3	18
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	3	19
CARL	Y	8/16/2012	Sandburg Pasture	Common Milkweed	5	3	22
CARL	Y	8/16/2012	Sandburg Pasture	Elderberry	1	2	2
CARL	Y	8/16/2012	Sandburg Pasture	Elderberry	1	4	1
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	19
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	21
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	22
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	23
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	27
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	28
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	29
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	1	1	30
GUCO	Y	8/17/2012	Francisco Monument	Spreading dogbane	4	1	18
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	1	1	12
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	1	1	17

Park Name	Injury Confirmed (Y/N)	Date	Site Name	Species	Amount	Severity	Plant Number
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	1	1	19
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	3	2	30
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	4	2	3
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	4	2	4
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	4	2	9
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	5	3	14
CARL	N	8/16/2012	Sandburg Pasture	Ironweed	5	3	15
MACA	N	8/10/2012	Job Corps	Common Milkweed	2	1	24
MACA	N	8/10/2012	Job Corps	Common Milkweed	2	1	26
MACA	N	8/10/2012	Job Corps	Common Milkweed	2	1	27
MACA	N	8/10/2012	Job Corps	Common Milkweed	2	1	28
MACA	N	8/10/2012	Job Corps	Common Milkweed	2	2	29
MACA	N	8/10/2012	Job Corps	Common Milkweed	3	1	21
MACA	N	8/10/2012	Job Corps	Common Milkweed	3	1	23
MACA	N	8/10/2012	Job Corps	Common Milkweed	3	2	22
MACA	N	8/10/2012	Job Corps	Common Milkweed	4	2	25

Foliar injury was confirmed at CARL and GUCO (38 plants total from confirmed park/site/species), but not at MACA. There were 9 plants with unconfirmed injury from CARL and 9 from MACA. Table 2 summarizes these results.

Table 3 – Total number of plants inspected at each of the CUPN parks.

Park Name	Number of Plants Inspected
CARL	139
GUCO	167
MACA	96
Total	402

In 2012, 402 plants at three CUPN parks were inspected for foliar injury. Of those 402 plants, there were 38 plants from confirmed park/site/species. Table 3 shows the total number of plants inspected at each park. Table 4 expands upon the information in Table 3 by showing the number of plants inspected in each park by each species. From Table 4, the number of species inspected at each of the four parks may be summed (CARL had 8 species, GUCO had 4 species and MACA had 5 species).

Table 4 – Total number of plants per species inspected at each park.

Park Name	Species	Number of Plants Inspected
CARL	Black Cherry	7
CARL	Blackberry	30
CARL	Common groundnut	2
CARL	Common Milkweed	30
CARL	Elderberry	4
CARL	Ironweed	30
CARL	Winged Sumac	30
CARL	Tulip Poplar	6
GUCO	Blackberry	60
GUCO	Spreading dogbane	30
GUCO	Sweet Gum	60
GUCO	Tulip Poplar	17
MACA	Blackberry	30
MACA	Common Milkweed	30
MACA	Spreading dogbane	5
MACA	Sweet Gum	30
MACA	Winged Sumac	1

Table 5 – Plant counts with and without injury sorted by park location and species.

Park Name	Site Name	Species	Number of Plants Inspected	Confirmed Injury (Y/N) [Number of Plants with Observed Injury]
CARL	Sandburg Pasture	Black Cherry	7	N
CARL	Sandburg Pasture	Blackberry	30	Y[1]
CARL	Sandburg Pasture	Common groundnut	2	N
CARL	Sandburg Pasture	Common Milkweed	30	Y[26]
CARL	Sandburg Pasture	Elderberry	4	Y[2]
CARL	Sandburg Pasture	Ironweed	30	N
CARL	Sandburg Pasture	Sumac	30	N
CARL	Sandburg Pasture	Tulip Poplar	6	N
GUCO	Kotis Tract	Blackberry	30	N
GUCO	Kotis Tract	Sweet Gum	30	N
GUCO	Francisco Monument	Blackberry	30	N
GUCO	Francisco Monument	Spreading dogbane	30	Y[9]
GUCO	Francisco Monument	Sweet Gum	30	N
GUCO	Francisco Monument	Tulip Poplar	17	N
MACA	Job Corps	Blackberry	30	N
MACA	Job Corps	Common Milkweed	30	N
MACA	Job Corps	Spreading dogbane	5	N
MACA	Job Corps	Sweet Gum	30	N
MACA	Job Corps	Winged Sumac	1	N

Table 5 shows the number of plants from each species inspected at each site. The rightmost column shows whether plants observed to have ozone injury in the field were verified as having ozone injury by members of academia. If the field-observed injury was verified by these experts, the number of plants observed in the field to have ozone-induced foliar injury is shown in square brackets.

The Interrelationship of Ozone Concentration and Drought Severity with Foliar Injury

Excessively dry conditions can cause plants to reduce their level of activity. This reduction results in less gas exchange across the plant's leaf surface through its stomata. Plants are therefore less susceptible to high ozone during times of drought because reduced quantities of ozone are entering the leaf.

The plots in Figures 11 and 12 show the drought severity at the time of the foliar injury assessment for each of the parks sampled. Figure 11 is the drought severity map that applies to the MACA assessment while Figure 12 applies to the CARL and GUCO assessments. Notice that neither CARL nor GUCO was in a drought, but that MACA was between abnormally dry and a severe drought.

Ozone concentrations at CARL were rather on the low side (the 3-month maximum W126 was 4.2 ppm-hrs) and a moderate amount of mild injury was observed. CARL's adequate rainfall (CARL was under no drought at the time its surveys) may explain its having a moderate amount of injury under low ozone exposure.

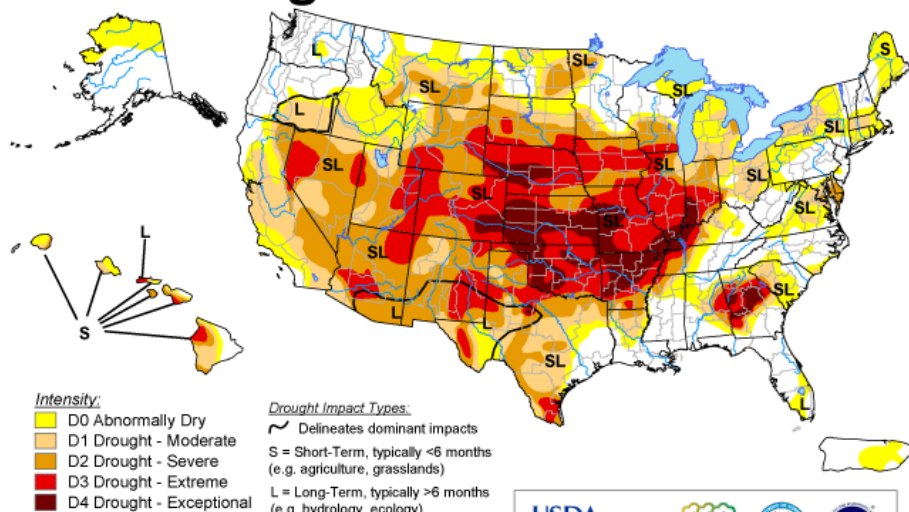
MACA's was in a drought, so lack of moisture could have limited ozone injury. Recall that no confirmed ozone injury was found at MACA (see tables 2 and 5) despite its rather high 3-month maximum W126 of 18.6 ppm-hrs. That level of exposure to ozone is sufficient to cause ozone injury to the plants that were examined.

Injury at GUCO was much more limited than that found at CARL. Most of CARL's injury, though, was found on common milkweed of which there was none examined at GUCO. The pasture at CARL also forms a larger size opening than the GUCO sites. Therefore, plants at GUCO may have spent less time exposed to the sun and therefore were less impacted by ozone. Otherwise, GUCO was much like CARL, in that GUCO, also, was in no drought and it had a similar 3-month maximum W126 (GUCO's was 4.8 ppm-hrs).

U.S. Drought Monitor

August 14, 2012

Valid 7 a.m. EDT



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://droughtmonitor.unl.edu/>

Released Thursday, August 16, 2012
Author: Michael Brewer/Liz Love-Brotak, NOAA/NESDIS/NCDC

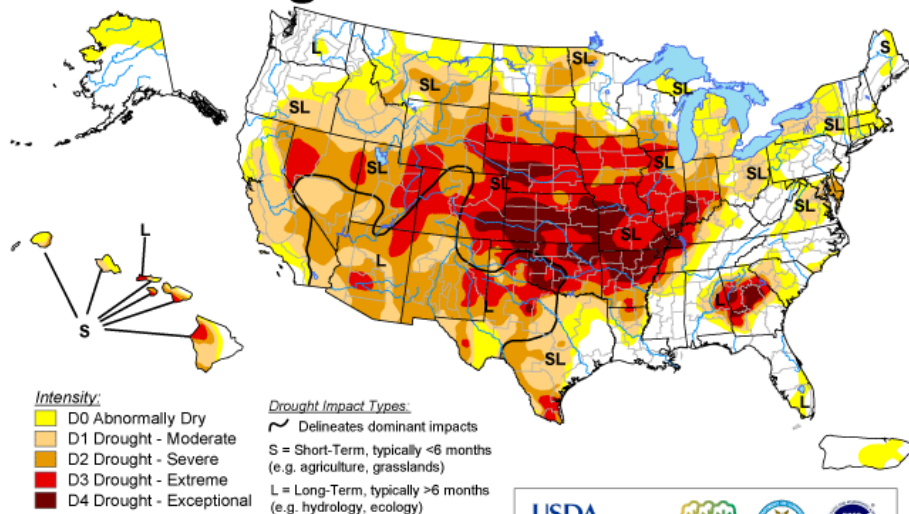
Figure 11 – Drought severity for the week of August 14, 2012.

<http://www.drought.unl.edu/dm/archive.html>.

U.S. Drought Monitor

August 21, 2012

Valid 7 a.m. EDT



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://droughtmonitor.unl.edu/>

Released Thursday, August 23, 2012
Author: Michael Brewer/Liz Love-Brotak, NOAA/NESDIS/NCDC

Figure 12 – Drought severity for the week of August 21, 2012.

<http://www.drought.unl.edu/dm/archive.html>.

Ozone Concentration Near the Remaining CUPN Parks

The CUPN conducted no ozone or foliar injury monitoring at the eleven remaining CUPN parks. Instead, Table 6 presents the SUM06 and W126 indices from non-CUPN ozone monitoring sites located near each of CUPN's parks (data from sites near the three focus parks are also included). Since the data were not collected within each park's boundaries, the data in Table 6 are presented only as an ozone risk assessment tool. The data in Table 6 were provided by National Park Service – Air Resources Division (NPS-ARD).

Table 6 – 2012 seasonal SUM060 and W126 values for state-operated sites near CUPN parks. Data are 3-month maxima from 0800 to 1900 (inclusively) and April through October (inclusively). Data from the CUGA POMS are available in Table 1. (**) indicates insufficient data to correctly compute indices. Computation of indices courtesy of NPS-ARD.

Park Name	AQS Site ID of Nearby Site	County, State of Nearby Site	SUM060 (ppm-hrs)	W126 (ppm-hrs)
ABLI	210930006	Hardin County, KY	13.04	16
CARL	370210030	Buncombe County, NC	7.40	7
	370870035	Haywood County, NC	9.19	11
CHCH	130550001	Chattooga County, GA	7.79	10
	132130003	Murray County, GA	5.37	5
	470651011	Hamilton County, TN	13.0	17
	470654003	Hamilton County, TN	14.67	20
	471210104	Meigs County, TN	13.67	19
COWP	450210002	Cherokee County, SC	7.72	8
CUGA	210130002	Bell County, KY	7.01	7
	211930003	Perry County, KY	8.02	10
	211950002	Pike County, KY	8.16	10
FODO	212219991	Trigg County, KY	15.98	21
GUCO	371570099	Rockingham County, NC	11.43	14
KIMO	371090004	Lincoln County, NC	12.78	16
	371191005	Mecklenburg County, NC	13.08	17
	450910006	York County, SC	5.57	6
LIRI	130550001	Chattooga County, GA	7.79	10
MACA	212270008	Warren County, KY	**	2
NISI	450010001	Abbeville County, SC	6.64	6
	450370001	Edgefield County, SC	3.88	3
RUCA	470654003	Hamilton County, TN	14.67	20
SHIL	010331002	Colbert County, AL	9.83	12
	280810005	Lee County, MS	8.44	10
STRI	470370011	Davidson County, TN	13.86	18
	470370026	Davidson County, TN	15.68	20
	471490101	Rutherford County, TN	12.64	17
	471890103	Wilson County, TN	16.80	23

General Ozone and Foliar Injury Status

At the three focus parks in 2012, confirmed foliar injury was limited and mild (with no injury found at MACA). CARL and GUCO had low ozone exposure indices and were not in any level of drought. These conditions may be consistent with the injury observed at those two parks. MACA had higher exposure indices than either CARL or GUCO, but MACA was in a drought. MACA's dry conditions could have helped reduce the amount of injury from ozone.

Future Ozone and Foliar Injury Monitoring Recommendations

The CUPN monitors ozone and foliar injury according to the schedule established in its ozone and foliar injury monitoring protocol (Jernigan et al 2012). The monitoring schedule is presented in Table 7. According to that schedule, CUPN will resample ozone concentration and foliar injury at CARL and GUCO in 2018.

MACA maintains its own ozone monitor, so ozone concentration will be monitored by MACA staff each year. Also, since the CUPN main office is at MACA, it is convenient to monitor for foliar injury at MACA each year.

Since around 2006, CUGA has had a POMS at the Hensley Settlement that is being provided by NPS-ARD with financial assistance from CUPN (since 2010) and is being serviced by CUGA staff. That monitoring will continue as long as the CUPN, NPS-ARD staff and CUGA staff are willing to dedicate the resources necessary to maintain the site.

Table 7 – CUPN sampling schedule of on-park POMS ozone concentration (OC) monitoring and foliar injury (Foln) assessments. (*) next to a park abbreviation indicates that ozone concentration data are collected by an organization other than the CUPN. CUPN does provide financial assistance with the CUGA site.

	Year 1 (2008)	Year 2 (2009)	Year 3 (2010)	Year 4 (2011)	Year 5 (2012)	Year 6 (2013)
ABLI	OC, Foln	--	--	--	--	--
CUGA*	Foln	--	OC	OC	OC	OC
MACA*	Foln	Foln	Foln	Foln	Foln	Foln
FODO	--	OC, Foln	--	--	--	--
SHIL	--	OC, Foln	--	--	--	--
COWP*	--	Foln	--	--	--	--
CHCH	--	--	OC, Foln	--	--	--
STRI	--	--	OC, Foln	--	--	--
LIRI	--	--	--	OC, Foln	--	--
RUCA	--	--	--	OC, Foln	--	--
CARL	--	--	--	--	OC, Foln	--
GUCO	--	--	--	--	OC, Foln	--
KIMO	--	--	--	--	--	OC, Foln
NISI	--	--	--	--	--	OC, Foln

Literature Cited

- Jernigan, J. W., B .C. Carson and T. Leibfreid. 2012. A protocol for monitoring ozone and foliar injury throughout the Cumberland Piedmont Network. Natural Resource Report NPS/CUPN/NRR—2012/559. National Park Service, Fort Collins, Colorado.
- Ray, J.D. 2004. Ozone Monitoring Protocol: Guidance on Selecting and Conducting Ozone Monitoring. National Park Service Air Resources Division Research and Monitoring Branch, Lakewood, Colorado.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 445/125048, 316/125048, 135/125048, July 2014

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™