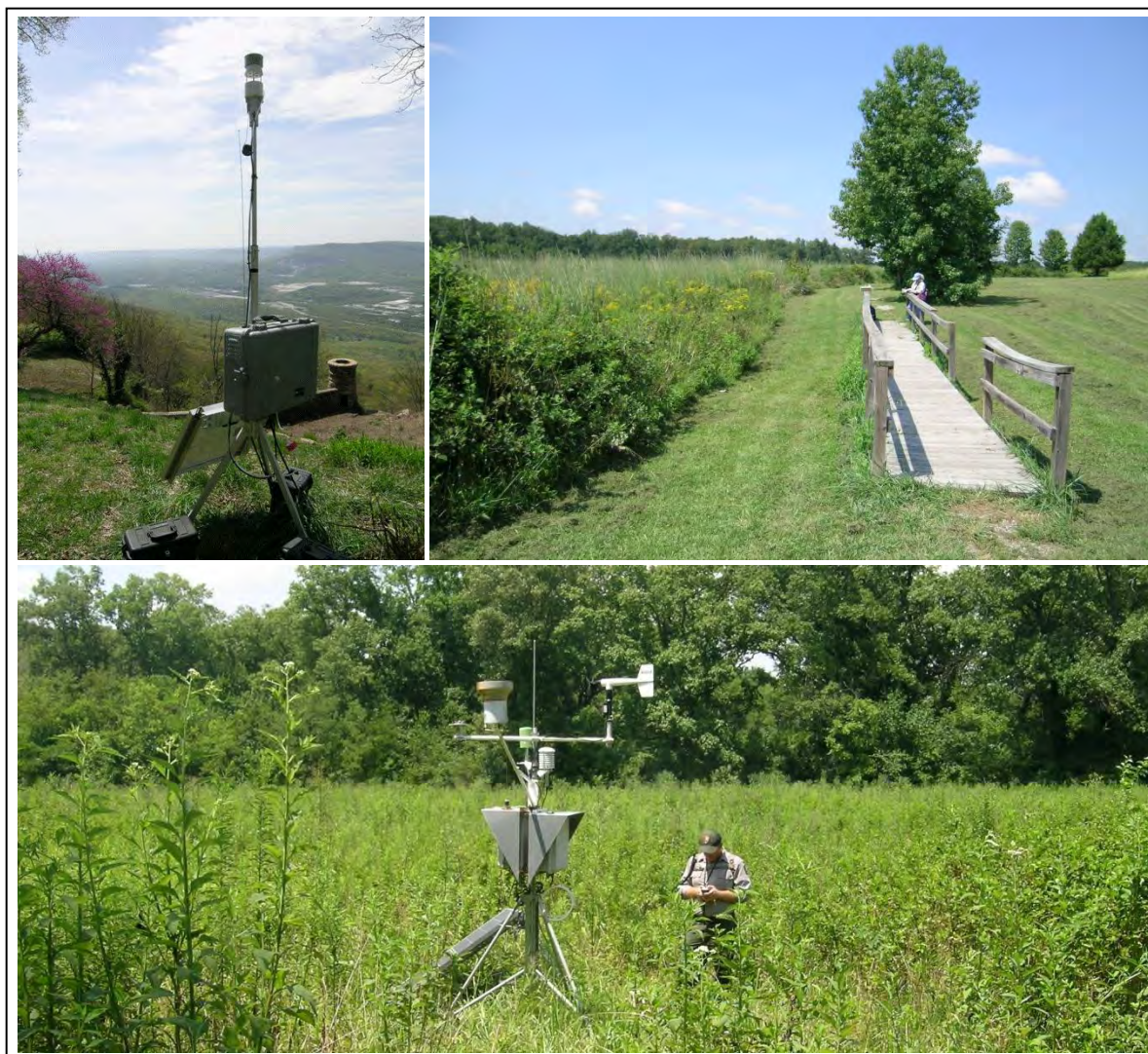




Cumberland Piedmont Network Ozone and Foliar Injury Report – Chickamauga and Chattanooga NMP, Mammoth Cave NP and Stones River NB

Annual Report 2010

Natural Resource Data Series NPS/CUPN/NRDS—2011/219



ON THE COVER

(Clockwise starting at top-left) The Portable Ozone Monitoring Station at CHCH, Sammi Jo Doyle (CUPN staff) during foliar injury sampling at MACA and STRI staff with the Portable Ozone Monitoring Station at STRI.

NPS photographs by: Johnathan Jernigan (top two photographs) and STRI staff (bottom photograph)

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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 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>).

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Abstract

This is the Cumberland Piedmont Network's (CUPN) third annual report on ozone concentration and associated foliar injury. Data were collected during 2010 at Chickamauga and Chattanooga National Military Park (CHCH), Mammoth Cave NP (MACA) and Stones River National Battlefield (STRI). Ozone concentration/foliar injury data and associated analyses are presented for each of these three parks. Both CHCH and MACA had ozone concentrations that are theoretically high enough to cause foliar injury to sensitive plants. Foliar injury was confirmed only at MACA. Also included in this report are summary statistics for ozone data from off-park state-operated monitors located around the remaining CUPN parks.

Acknowledgments

The investigators would like to thank park staff at CHCH and STRI for their assistance. In particular, thanks to Jim Szykowski at CHCH for his assistance with the installation of the Portable Ozone Monitoring Station and his cooperation throughout the ozone season. Thanks also to Joe Meiman and Bill Moore (both are CUPN staff) for maintaining the POMS at CHCH. Thanks to Terri Hogan at STRI for her assistance with installation of the Portable Ozone Monitoring Station and further assistance throughout the ozone season. Thanks to David Adams and Brian Huber at STRI for maintaining their Portable Ozone Monitoring Station and David for his help during the unit's uninstallation. Thanks to the Gulf Coast Network for allowing us to use the Portable Ozone Monitoring Station that was in their possession at the beginning of this year's ozone season. Thanks to CUPN intern John Hutcherson for helping throughout the ozone season with everything from retrieval of that Portable Ozone Monitoring Station to participating in foliar injury surveys at both CHCH and STRI. Thanks to the following STRI staff for their assistance with foliar injury surveys: David Adams, Brett Baker, Wesley Branch, Rebecca Houser, Brian Huber and Billy Plant. We would also like to thank CUPN staff at the MACA office (Sammi Jo Doyle, Lillian Scoggins and Brenda Wells) for their assistance with various office-based tasks. In particular, thanks to Lillian for making the maps contained in this report. Thanks to Sammi Jo for her assistance with foliar injury assessments at MACA. Thanks to all parks (CHCH, MACA and STRI) for allowing us to sample in their parks.

Introduction

This is the third report on the Cumberland Piedmont Network's (CUPN's) efforts to monitor both ozone and ozone's associated foliar injury generated by the CUPN. This report includes data collected in calendar year (CY) 2010, 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 CY2010 focused on three parks: Chickamauga and Chattanooga National Military Park (CHCH), Mammoth Cave National Park (MACA) and Stones River National Battlefield (STRI). Since these parks were where efforts were focused on in CY2010, 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 CY2010. A Portable Ozone Monitoring Station (POMS) was used for nearly the entire ozone season at CHCH and for much of the season at STRI. The STRI POMS was 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 severity of their ozone exposure.

Foliar injury data were collected at CHCH, MACA and STRI. At CHCH and MACA, one site each was surveyed for foliar injury. At STRI, two areas were combined to form one larger site. An example of injured (by ozone and other causes) leaves is shown in Figure 1.



Figure 1 – Voucher specimens from ozone-injured milkweed plants at MACA. NPS photograph by Brenda Wells.

Sampling Sites

CHCH Lookout Mountain (CHCH0001-OC/FoIn)

The Lookout Mountain site overlooks the city of Chattanooga, TN. The site is located a short distance and north of the Lookout Mountain Battlefield Visitor Center. Ozone concentration and foliar injury data were collected at this site. The POMS was located on the west side of the area and may have been affected by air masses coming up from Chattanooga. For the foliar injury survey, plants were sampled from amongst those plants that could be reached safely along the slope shown in the top-right image in Figure 2. The paved path is a walkway; it is not used by automobiles. The site elevation is about 1,780 feet.

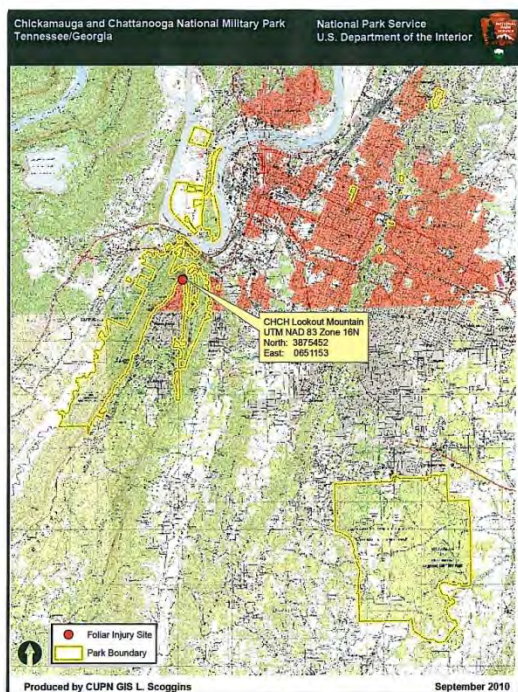


Figure 2 – CHCH Lookout Mountain site photographs and map. NPS photographs by John Hutcherson (CUPN intern). NPS map by Lillian Scoggins (CUPN GIS specialist).

STRI Beasley Field Split Plot 1 (STRI0001-OC/FolIn)

Beasley Field Split Plot 1 is located a short distance and west of the STRI Visitor Center. Ozone concentration and foliar injury data were collected in this field. Plants were sampled within the field in the area adjacent to the POMS (Figure 3). There are too few species (only blackberry) for Beasley Field to serve as its own site, so the USFS split plot approach is used. A second nearby site (Blansett Field) is paired with the Beasley Field. Plants from both fields are pooled to form one site. The elevation of Beasley Field is about 570 feet.

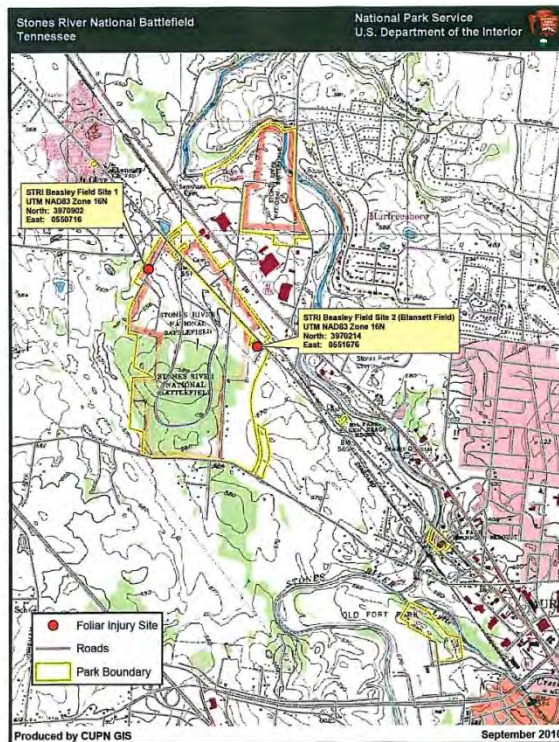


Figure 3 – STRI Beasley Field Split Plot 1 site photographs and map. NPS photographs by STRI staff. NPS map by Lillian Scoggins (CUPN GIS specialist).

STRI Beasley Field Split Plot 2 (STRI0001-FoIn)

Beasley Field Split Plot 2 is located in Blansett Field, a short distance from and southeast of the STRI Visitor Center. The field serves as part of a split plot together with Beasley Field. Plants from the two fields are pooled to form one site. Plants at Blansett Field (primarily common milkweed) were sampled from deep within the field as shown in Figure 4. The elevation of the site is about 580 feet.

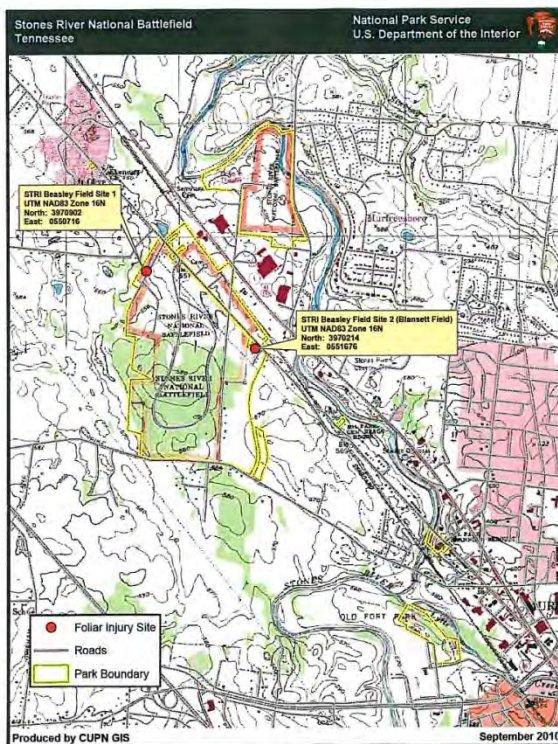


Figure 4 – STRI Beasley Field Split Plot 2 site photographs and maps. NPS photographs by STRI staff. NPS map by Lillian Scoggins (CUPN GIS specialist).

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 5. The elevation of the site is about 650 feet.

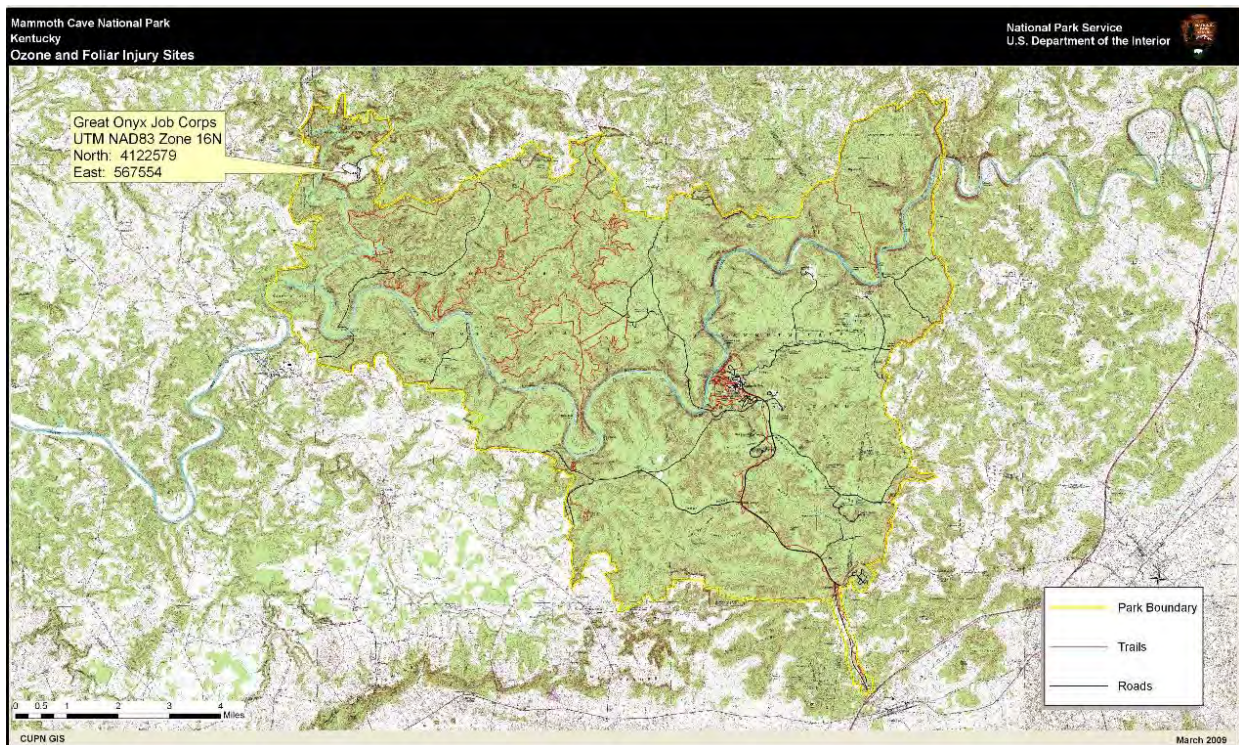


Figure 5 – MACA Great Onyx Job Corps site photograph and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

MACA Air Quality Station (MACA0002-OL)

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 6). 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.

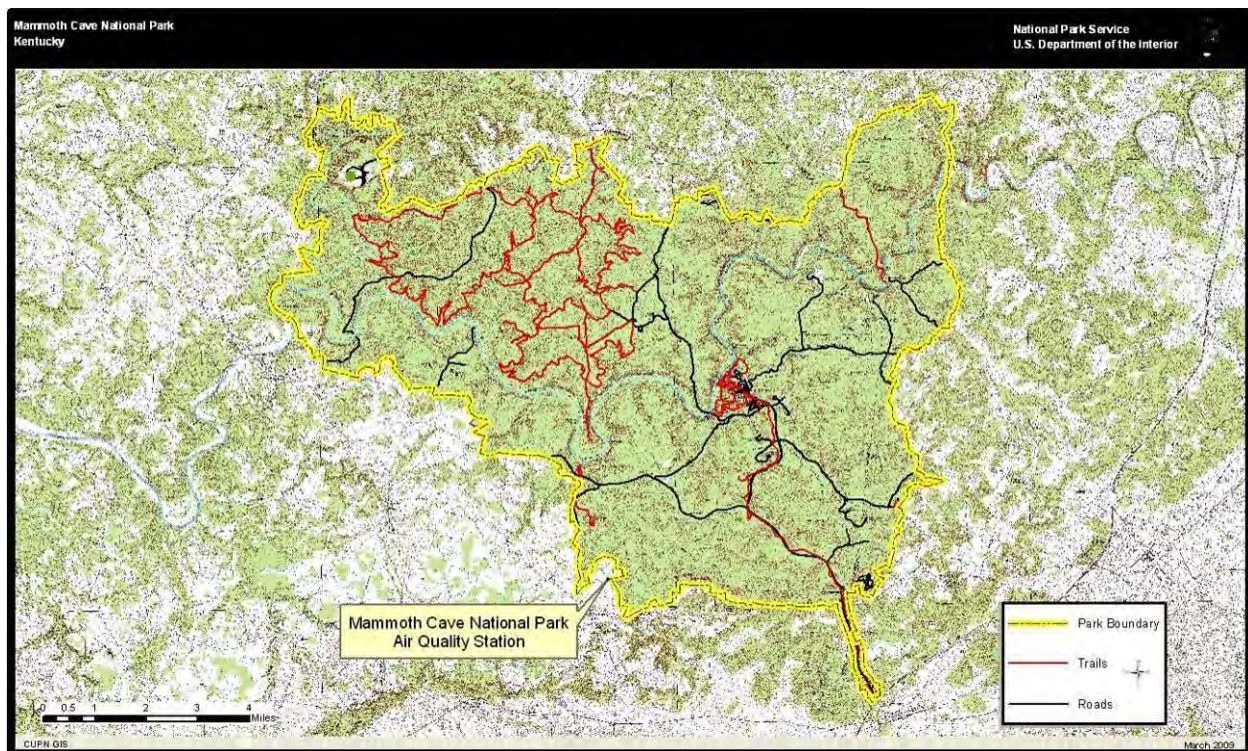


Figure 6 – MACA Air Quality Station site photograph and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

Results

In addition to operating a POMS at CHCH and STRI, the CUPN mined ozone concentration data from external sources for the other park (MACA) at which foliar injury sampling was conducted. Foliar injury assessments were conducted by the CUPN at a total of four sites spread across three parks in CY2010. The three parks and their ozone data sources are:

- CHCH – Ozone data are from a POMS located on Lookout Mountain. The POMS was in place from 7 April 2010 to 3 November 2010.
- MACA – Ozone data are from the park's air quality station located along the park's boundary.
- STRI – Ozone data are from a POMS located in a field (Beasley Field) near the park's Visitor Center. The POMS was in place from 4 June 2010 to 4 November 2010.

Also, CUGA was installed with a POMS at the Hensley Settlement. The data presented here for CUGA were collected at that site. In 2010, 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 from nearby state-operated sites for eleven of the remaining CUPN parks. These data are used to provide insight into the magnitude of the ozone exposure at each of these parks.

W126 indices are listed for all fourteen CUPN parks (see tables 1 and 6 in subsequent sections) using the indicated data sources.

Ozone Concentration

Ozone data from focus parks (CHCH, MACA and STRI) are displayed in time series graphs and one scatterplot. Two time series plots are shown for each site along with one scatterplot (figures 7 and 8). The first plot shows all available 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 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 ozone data are plotted against the hour during which they were collected.

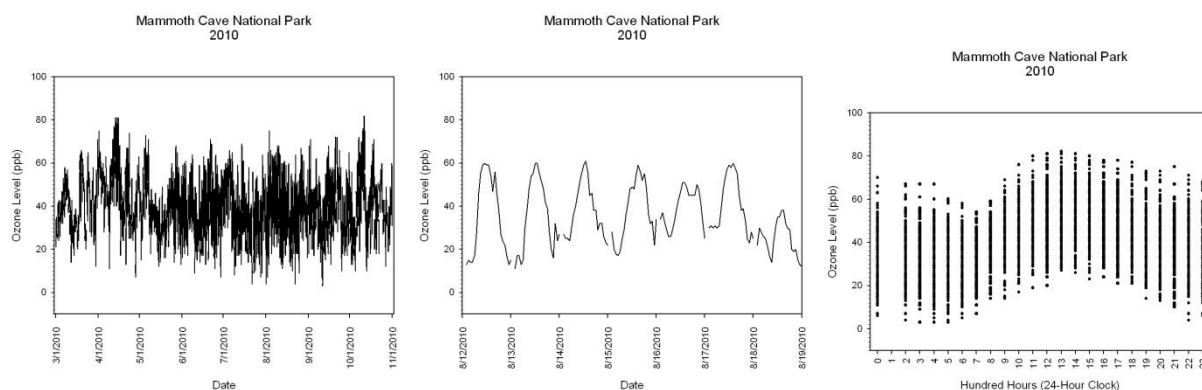


Figure 7 – MACA ozone concentration plots.

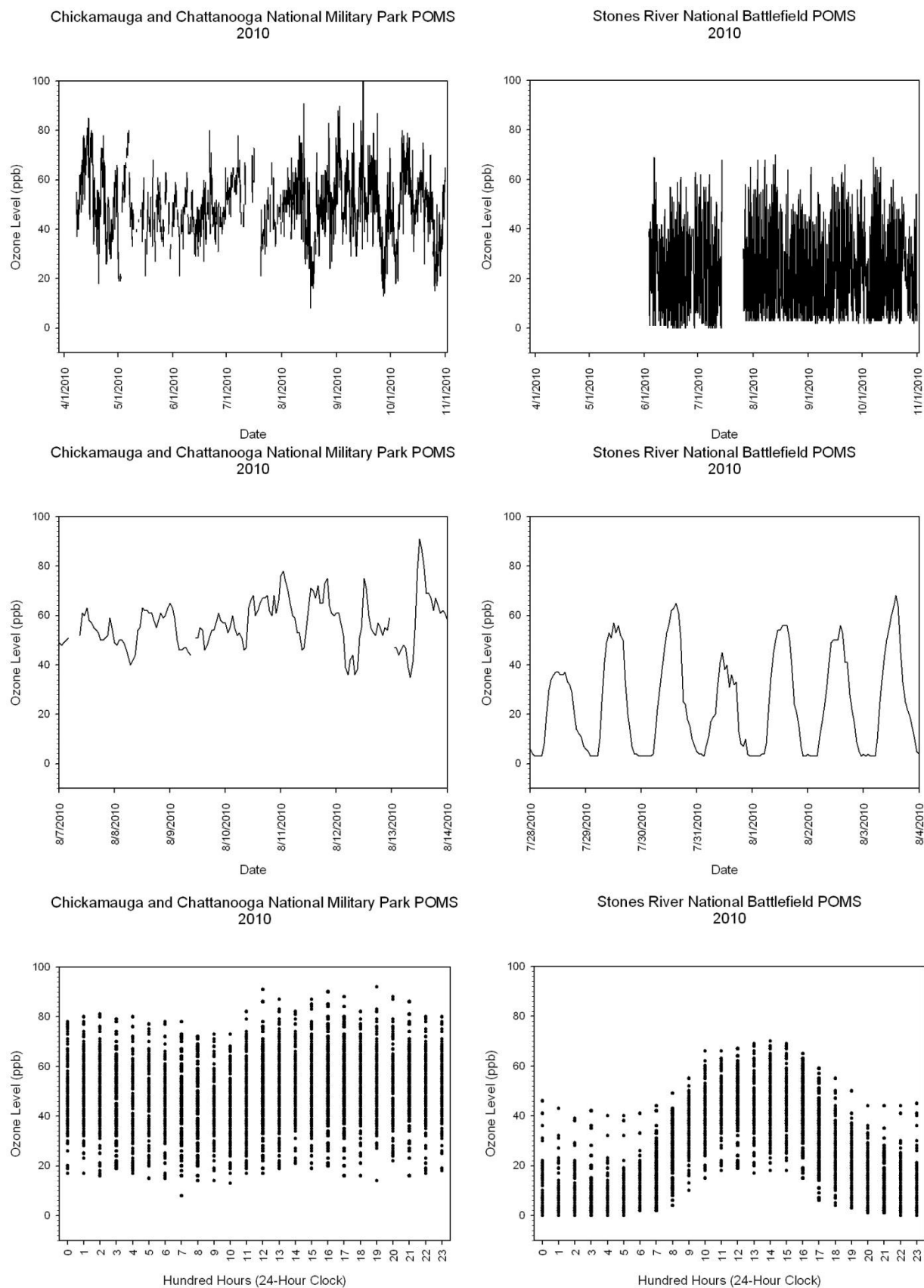


Figure 8 – CHCH and STRI POMS ozone concentration plots.

The POMS data from STRI are not available for the entire growing season. The POMS used at STRI is on loan from the Gulf Coast Network (GULN) and the CUPN did not obtain the unit until later in the season. Also of note is the significant suppression of diurnal cycling at CHCH when compared to that at MACA and STRI. This suppression at CHCH is as expected since CHCH is at a higher elevation than MACA and STRI. High elevation sites tend to exhibit little or no diurnal cycling.

There are several metrics available to ascertain whether the ozone concentrations seen in Figure 7 and Figure 8 are considered to be too high. The current National Ambient Air Quality Standard 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 9 for CHCH, CUGA, MACA and STRI. Currently, that value is the primary (public health) standard and the secondary (public welfare) standard. That is, the public health standard is applied to non-human health issues such as ozone sensitive plants. The EPA has set such standards to allow the determination of whether current concentrations are having detrimental effects on the targeted group.

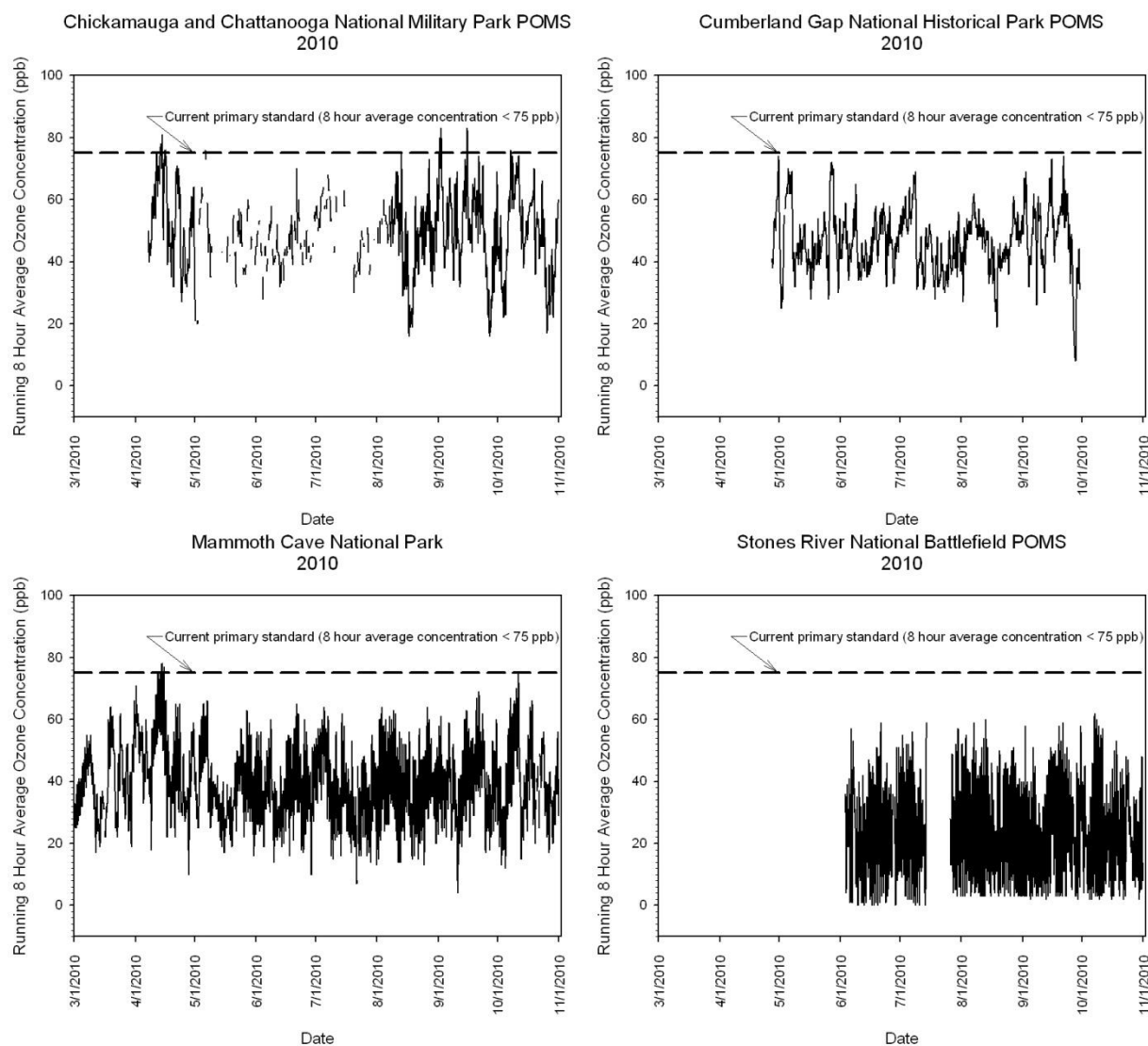


Figure 9 – Running 8 hour average ozone concentration at CHCH, CUGA, MACA and STRI.

In the case of plant welfare, scientists generally agree that the public health standard is not the best measure. One of two alternative statistics is generally used amongst scientists (even though they are not used for regulatory purposes): the SUM06 or the W126. The SUM06 is the seasonal sum of all hourly ozone concentration measurements (it is frequently computed using only values that are between 8 AM and 8 PM) above 60 ppb, expressed as ppm-hours. The W126 is also frequently computed using only values from 8 AM to 8 PM. It 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

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

where c_i is the hourly ozone concentration expressed in ppb and n is the number of hours with valid ozone measurements. Frequently, the W126 (as well as the SUM06) is computed for each possible 3 consecutive month period in the growing season and the largest of those values is taken as the W126 for the season. These values are presented in this report for each of the CUPN parks.

The SUM06 and W126 are considered better statistics than the eight hour average for plant welfare because they are cumulative and emphasize the effects of higher ozone concentrations over more extended periods of time (when compared to the eight hour average).

Sensitivity to ozone varies amongst species. 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. The SUM06 and W126 values for CHCH, MACA and STRI 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 – 2010 SUM06 and W126 values for CHCH, CUGA, MACA and STRI. Values are calculated using data from 0800 to 2000. Indices presented are 3-month maximum during 2010. 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
CHCH	POMS (7 April 2010 to 31 October 2010)	72.0	20.9	15.0	Aug-Oct	70
CUGA	POMS	85.0	6.6	6.4	May-Jul	0
MACA	Houchins' Meadow Site	94.0	13.3	10.4	Apr-Jun	7
STRI	POMS (3 June 2010 to 31 Oct 2010)	77.0	3.3	3.5	Aug-Oct	0

Foliar Injury

In FY2010, foliar injury assessments were completed at three parks on the following dates:

Chickamauga and Chattanooga National Military Park – August 5, 2010
Mammoth Cave National Park – August 19, 2010
Stones River National Battlefield – August 4, 2010

Foliar injury assessments were conducted by visually inspecting plant leaves for ozone injury and noting presence/absence of the injury on a field form. 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 a US Forest Service regional expert on

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
MACA	Y	8/19/2010	Job Corps	Common Milkweed	1	1	9
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	2	7
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	2	8
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	2	14
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	2	16
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	3	4
MACA	Y	8/19/2010	Job Corps	Common Milkweed	2	3	11
MACA	Y	8/19/2010	Job Corps	Common Milkweed	3	1	12
MACA	Y	8/19/2010	Job Corps	Common Milkweed	5	3	15
MACA	Y	8/19/2010	Job Corps	Sweet Gum	1	3	1
MACA	Y	8/19/2010	Job Corps	Sweet Gum	1	3	27
MACA	Y	8/19/2010	Job Corps	Sweet Gum	1	4	9
MACA	Y	8/19/2010	Job Corps	Sweet Gum	2	3	7
MACA	Y	8/19/2010	Job Corps	Sweet Gum	2	5	6
MACA	Y	8/19/2010	Job Corps	Sweet Gum	2	5	13
MACA	Y	8/19/2010	Job Corps	Sweet Gum	3	5	12
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	1	3	3
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	1	4	16
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	2	2	1
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	2	3	2
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	2	3	10
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	2	3	14
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	2	3	15
STRI	N	8/4/2010	Beasley Field - Site 1	Blackberry	5	2	18

ozone injury. The regional expert provides a second and authoritative opinion on the injury seen on the voucher specimens. The injury will either be confirmed or not confirmed by the regional expert. 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.

Foliar injury was confirmed at MACA (16 plants total from confirmed park/site/species), but not at STRI. There were 8 plants with unconfirmed injury from STRI. At CHCH, no plants showed even possible injury. Table 2 summarizes these results; note the absence of any CHCH plants.

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

Park Name	Number of Plants Inspected
CHCH	19
MACA	100
STRI	62
Total	181

In FY2010, 181 plants at three CUPN parks were inspected for foliar injury. Of those 181 plants, there were 16 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 (CHCH had 3 species, MACA had 4 species and STRI had 3 species).

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

Park Name	Species	Number of Plants Inspected
CHCH	Redbud	5
CHCH	Sycamore	1
CHCH	Winged Sumac	13
MACA	Blackberry	30
MACA	Common Milkweed	30
MACA	Indian Hemp	10
MACA	Sweet Gum	30
STRI	Black Cherry	2
STRI	Blackberry	30
STRI	Common Milkweed	30

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]
CHCH	Lookout Mountain	Redbud	5	N
CHCH	Lookout Mountain	Sycamore	1	N
CHCH	Lookout Mountain	Winged Sumac	13	N
MACA	Job Corps	Blackberry	30	N
MACA	Job Corps	Common Milkweed	30	Y[9]
MACA	Job Corps	Indian Hemp	10	N
MACA	Job Corps	Sweet Gum	30	Y[7]
STRI	Beasley Field - Site 1	Blackberry	30	N
STRI	Beasley Field - Site 2	Black Cherry	2	N
STRI	Beasley Field - Site 2	Common Milkweed	30	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 the USFS regional expert. If the field-observed injury was verified by the regional expert, 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 10 and 11 show the drought severity at the time of the foliar injury assessment for each of the parks sampled. Figure 10 is the drought severity map that applies to the CHCH and STRI assessments while Figure 11 applies to the MACA assessment. Notice that no park was in a drought.

Ozone concentrations at CHCH were high enough to cause ozone injury (the W126 was 15.0). However, no injury was observed at CHCH. This may have been, in part, due to the limited number of suitable sites/plants that were available. Nevertheless, it is still noteworthy that those plants examined had no injury.

There was no confirmed ozone injury at STRI (not unexpected given that the W126 at STRI was the very low value of 3.5). Consider, for example, that STRI contained significant stands of common milkweed that were generally very healthy with little to no visible injury (ozone or otherwise) on them. Not included in the list of sites at STRI was a field not far from the Visitor Center that contained very large (between 1.5 and 2 meters tall) common milkweed plants. These plants also had little injury of any kind and no ozone injury was observed.

MACA was not in a drought, so lack of moisture should not have been a factor that would limit ozone injury. Nine common milkweed plants and seven sweet gum trees showed confirmed ozone injury (tables 2 and 5). The W126 for MACA's growing season was only 10.4. That level of exposure to ozone is sufficient to cause ozone injury to the plants that were examined.

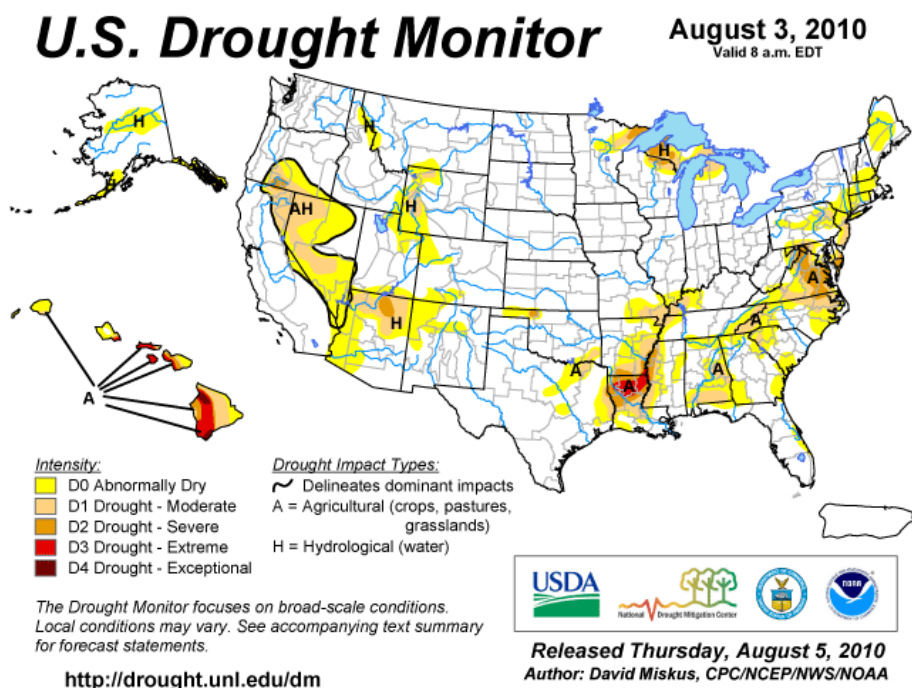


Figure 10 – Drought severity for the week of August 3, 2010.
<http://www.drought.unl.edu/dm/archive.html>.

U.S. Drought Monitor

August 17, 2010
Valid 8 a.m. EDT

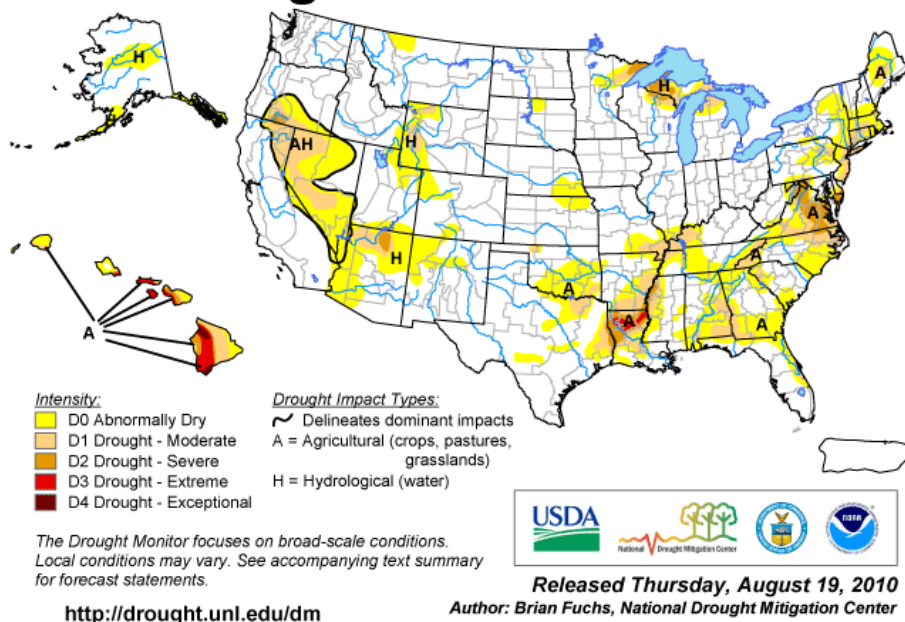


Figure 11 – Drought severity for the week of August 17, 2010.
<http://www.drought.unl.edu/dm/archive.html>.

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 W126 from non-CUPN ozone monitoring sites located near each of these and the other three parks (except FODO which has no nearby monitor). All data were calculated using EPA's "Query W126 Index Values" Internet site at http://www.epa.gov/cgi-bin/htSQL/mxplorer/query_w126.hsrl?msaorcountyName=1&msaorcountyValue=1&poll=44201. Since the data were not collected within each park's boundaries, the data in Table 6 are presented only to suggest the ozone concentrations to which a park may have been exposed in 2010.

Table 6 –W126 values for state-operated sites near CUPN parks. Data from CUGA POMS are available in Table 1.

Park Name	AQS Site ID of Nearby Site	County, State of Nearby Site	2010 Max 3-Month Sum W126 (ppm-hrs)	2008-2010 3-Year Average W126 (ppm-hrs)
ABLI	210930006	Hardin County, KY	8.58	9
CARL	370210030	Buncombe County, NC	8.40	8
	370870035	Haywood County, NC	9.88	9
CHCH	130550001	Chattooga County, GA	6.94	7
	132130003	Murray County, GA	9.31	8
	470651011	Hamilton County, TN	12.84	11
	470654003	Hamilton County, TN	12.50	13
	471210104	Meigs County, TN	12.04	11
COWP	450210002	Cherokee County, SC	8.86	9
CUGA	210130002	Bell County, KY	7.25	7
	211930003	Perry County, KY	7.81	8
	211950002	Pike County, KY	7.22	6
FODO	N/A	N/A	N/A	N/A
GUCO	371570099	Rockingham County, NC	13.28	13
KIMO	371090004	Lincoln County, NC	11.22	11
	371191005	Mecklenburg County, NC	11.50	11
	450910006	York County, SC	4.20	7
LIRI	130550001	Chattooga County, GA	6.94	7
MACA	212270008	Warren County, KY	7.51	7
NISI	450010001	Abbeville County, SC	7.41	8
	450370001	Edgefield County, SC	5.03	6
RUCA	470654003	Hamilton County, TN	12.50	13
SHIL	010331002	Colbert County, AL	6.88	6
	280810005	Lee County, MS	6.52	6
STRI	470370011	Davidson County, TN	5.28	5
	470370026	Davidson County, TN	8.87	7
	471490101	Rutherford County, TN	9.91	9
	471890103	Wilson County, TN	11.90	12

General Ozone and Foliar Injury Status

At the three focus parks in 2010, confirmed foliar injury was extremely limited and moderate. These findings are consistent with the moderate ozone levels measured under normal drought severity (except at CHCH where the W126 was slightly more elevated but no injury was observed).

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 2008). The monitoring schedule is presented in Table 7. According to that schedule, CHCH and STRI will not have CUPN-sponsored ozone concentration monitoring and foliar injury assessments again until 2016.

MACA maintains its own ozone monitor, so ozone concentration will be monitored by MACA staff during that park's off-years. Also, since the CUPN main office is at MACA, it is convenient to monitor for foliar injury at MACA each year.

As of July 2011, CUGA has 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 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	--	--
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.L. Leibfreid. 2008. A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network. Unpublished protocol draft, Mammoth Cave, KY.
- 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.