



Cumberland Piedmont Network Ozone and Foliar Injury Report – Kings Mountain NMP, Mammoth Cave NP and Ninety Six NHS

Annual Report 2013

Natural Resource Report NPS/CUPN/NRR—2015/1044



ON THE COVER

(Clockwise starting at top-left) POMS at NISI, green treefrog (*Hyla cinerea*) on ozone sensitive yellow crownbeard (*Verbesina spp.*) at NISI, monitoring site KIMO0001 at KIMO and monitoring site KIMO0002 at KIMO.
NPS photographs by: Shepard McAninch and Johnathan Jernigan.

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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.

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Abstract

This is the Cumberland Piedmont Network's (CUPN) sixth annual report on ozone concentration and associated foliar injury. Data were collected during 2013 at Kings Mountain National Military Park (KIMO), Mammoth Cave National Park (MACA) and Ninety Six National Historic Site (NISI). Ozone concentration/foliar injury data and associated analyses are presented for each of these three parks. All parks had generally low ozone concentrations that might be expected to produce minimal-to-no foliar injury. These low concentrations could explain why no ozone injury was found at any of these CUPN parks. Also included in this report are summary statistics for ozone data from off-park state-operated monitors located around KIMO, MACA, NISI and the remaining CUPN parks.

Acknowledgments

The investigators would like to thank park staff at NISI for their assistance. In particular, thanks to Tim Cruze and Gray Wood at NISI for their assistance with the installation/removal of the Portable Ozone Monitoring Stations at that park. Also, we would like to thank both Tim and Gray for maintaining that POMS throughout the season. Further thanks to Tim for assisting with foliar injury surveys at CARL. When assessing foliar injury at KIMO and NISI, 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), Courtney Van Stolk (MACA intern), Haruka Suzuki (MACA intern) and Michael Lee (University of North Carolina at Chapel Hill). 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 normally processes and maintains the voucher specimens, but there were none this year. Still, thanks for being there had we needed the help. Lillian made the maps contained in this report and Sammi Jo keeps all of the paperwork straight. Thanks for all of their support. We would also like to offer our thanks to all parks (KIMO, MACA and NISI) for allowing us to sample in their parks.

Introduction

This is the sixth 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) 2013, 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 CY2013 focused on three parks: Kings Mountain National Military Park (KIMO), Mammoth Cave National Park (MACA) and Ninety Six National Historic Site. Since these parks were where efforts were focused in CY2013, 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 one of the three focus parks in CY2013. A Portable Ozone Monitoring Station (POMS) was used for nearly the entire ozone season at NISI. The NISI POMS was maintained by park personnel. This report contains results from the analyses of data from that site. 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. KIMO, similarly, has its own POMS that is cooperatively maintained with the assistance of Shepard McAninch (CUPN) and NPS-ARD.

It should be noted that the ozone analyzer used by the CUPN and KIMO POMS is the Model 202 by 2B Technologies, Inc., Federal Equivalent Method EQOA-0410-190 (April 27, 2010 Federal Register Notice). However, these 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 KIMO, MACA and NISI. At MACA, one site was surveyed for foliar injury. At KIMO and NISI, two sites were surveyed at each park. An example of an injured leaf is shown in Figure 1. The injury shown is by ozone and other causes, and the leaf is from the 2012 sampling season (not the 2013 season that is covered by this report).



Figure 1 – In 2012, (unlike the current year, 2013) injury was confirmed at a focus park. A voucher specimen from ozone-injured milkweed plant at CARL in 2012 is shown. There are no such photographs for 2013 plants since no injury was found in 2013. NPS photograph by Brenda Wells.

Sampling Sites

KIMO Fire Tower Road Power Line (KIMO0001-Foln)

The Fire Tower Road Power Line site is located within about one mile of the non-CUPN POMS that was operated in KIMO during 2013. Only foliar injury data were collected at KIMO0001. Plants were sampled in the open area of the site shown to the right of the power line and not under the power line. No herbicides are used to keep plants low under the power lines. Instead, plants are periodically masticated. The site elevation is about 837 feet.

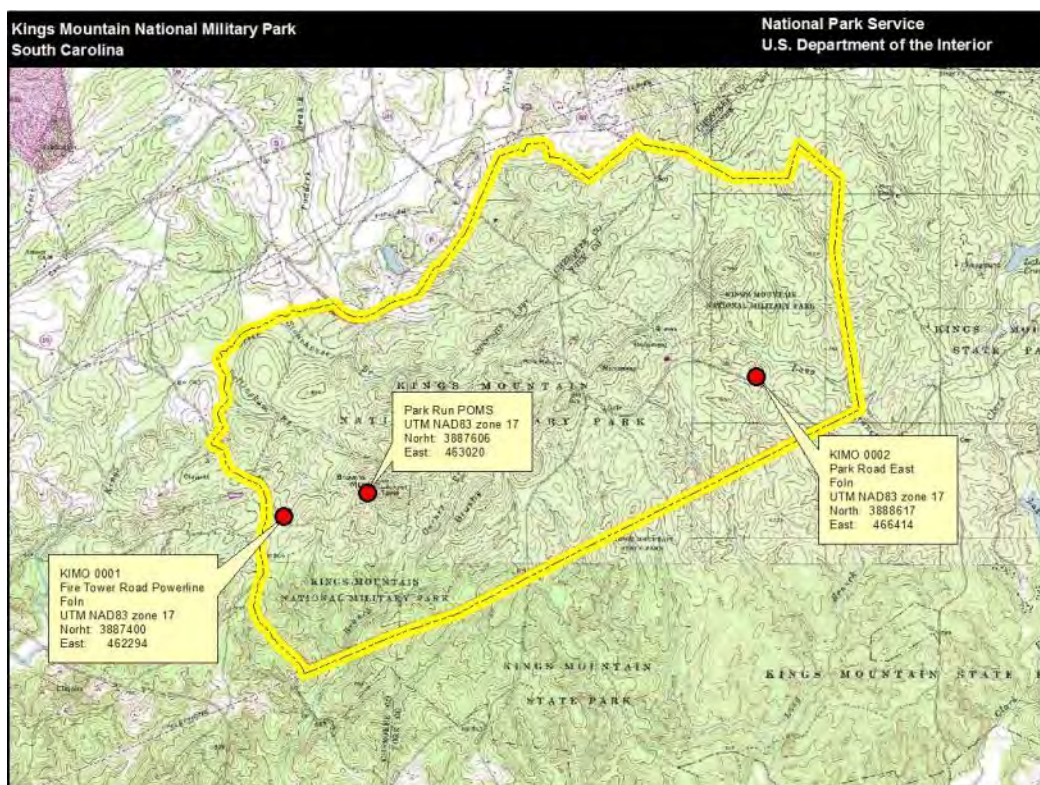


Figure 2 – KIMO Fire Tower Road Power Line (KIMO0001) site photographs and map. NPS photographs by Shepard McAninch (CUPN Ecologist). NPS map by Lillian Scoggins (CUPN GIS specialist).

KIMO Park Road East (KIMO0002-Foln)

The Park Road East site is adjacent to the park's main entrance road, within a few miles of the park's visitor center. Only foliar injury data were collected at KIMO0002. As may be seen in Figure 3, plants at the site are periodically masticated. The site's map is also shown in Figure 3. The elevation of the site is about 817 feet.

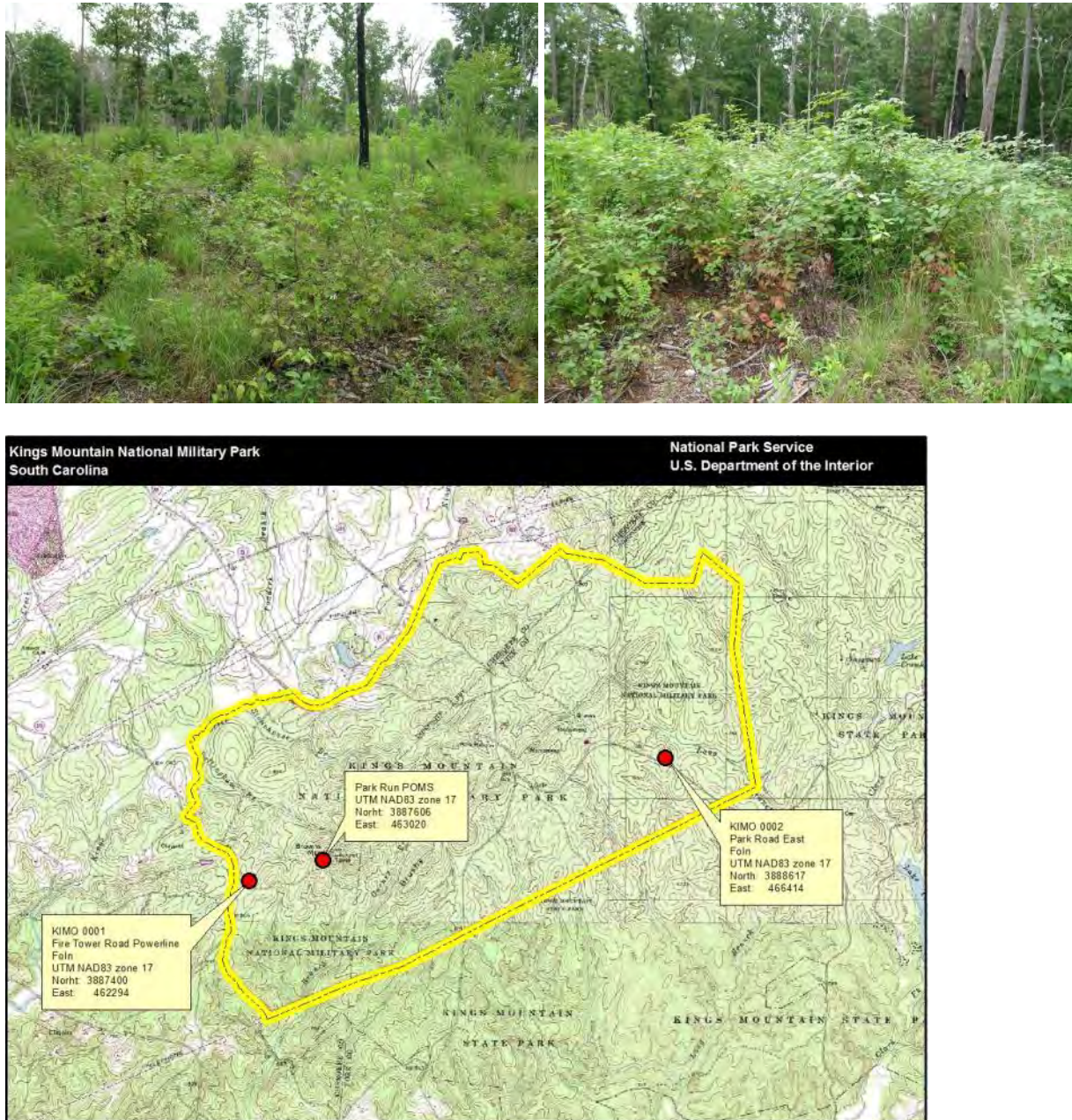


Figure 3 – KIMO Park Road East (KIMO0002) site photographs and map. NPS photographs by Shepard McAninch (CUPN ecologist). NPS map by Lillian Scoggins (CUPN GIS specialist).

NISI Bumble Bee Hill (NISI0001-OC/FoIn)

Bumble Bee Hill at NISI overlooks the Star Fort Pond (the pond is located on the east side of the park). Site photographs and its map are shown in Figure 4. Plants were examined primarily along the forest edge shown behind and left of the POMS. Some additional plants were examined farther down the slope and behind the photographer of the POMS image. The elevation of the site at the POMS is about 476 feet.

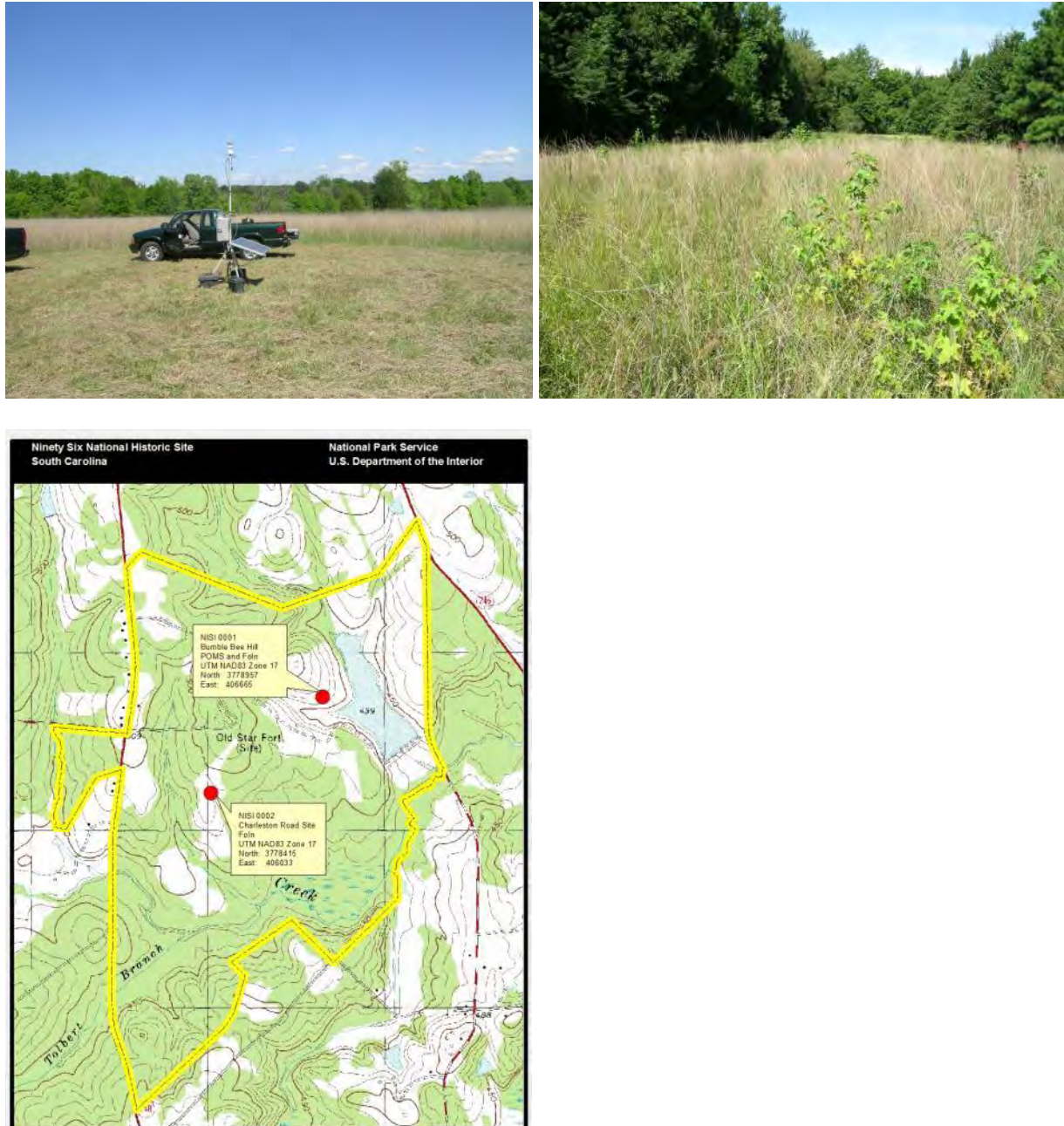


Figure 4 – NISI Bumble Bee Hill (NISI0001) site photographs and map. Rightmost NPS photograph by Shepard McAninch (CUPN ecologist). NPS map by Lillian Scoggins (CUPN GIS specialist).

NISI Charleston Road (NISI0002-Foln)

The Charleston Road site at NISI is located at the intersection of Charleston Road and Fire Road #4. Site photographs and its map are shown in Figure 5. Plants were examined primarily in the opening to the west of the intersection, but a patch of yellow crownbeard was also examined several meters to the east of Charleston Road (and adjacent to Fire Road #4). The elevation of the site is about 495 feet.

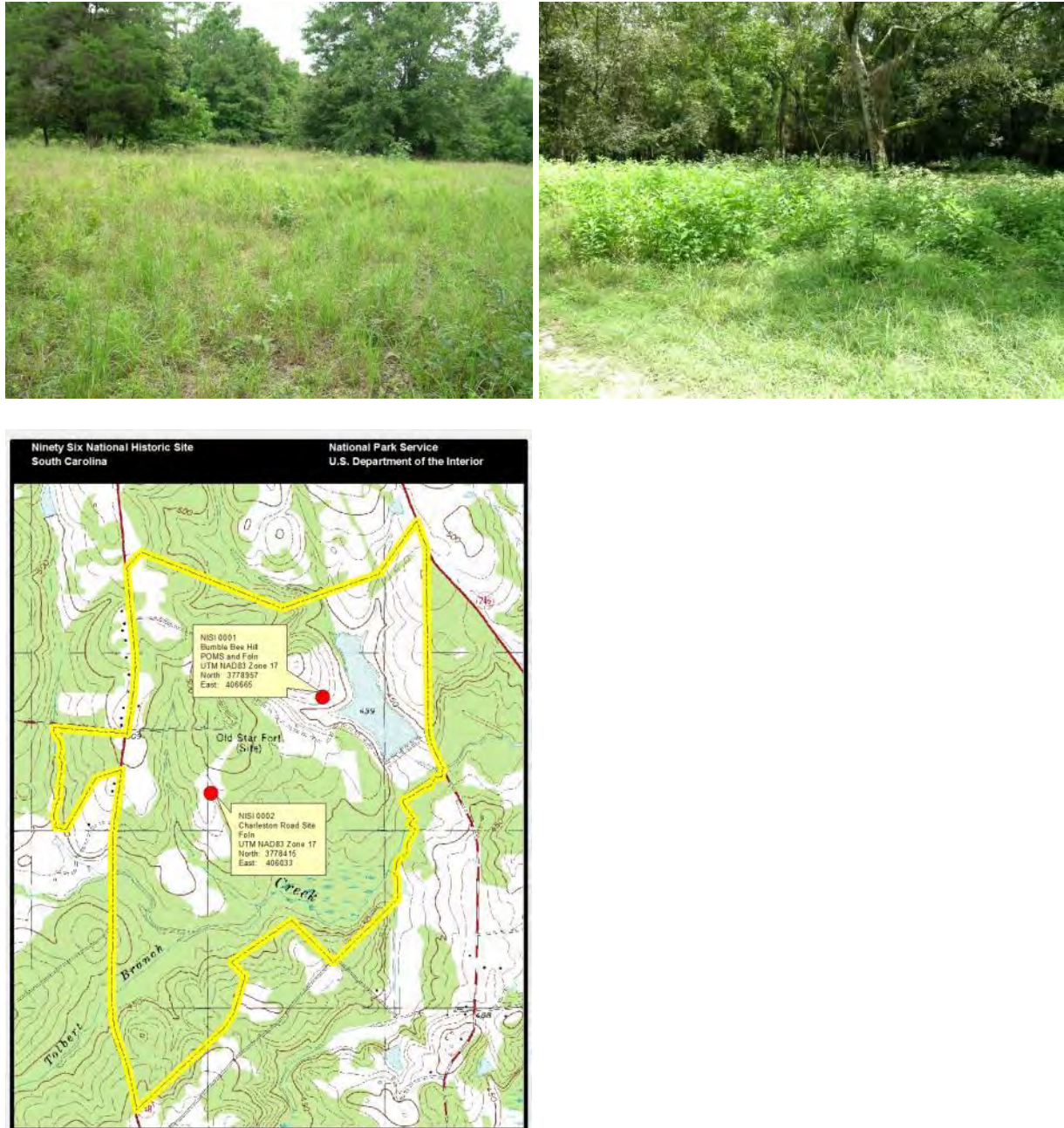


Figure 5 – NISI Charleston Road (NISI0002) site photographs and map. Leftmost image by Shepard McAninch (CUPN ecologist). NPS map by Lillian Scoggins (CUPN GIS specialist).

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.

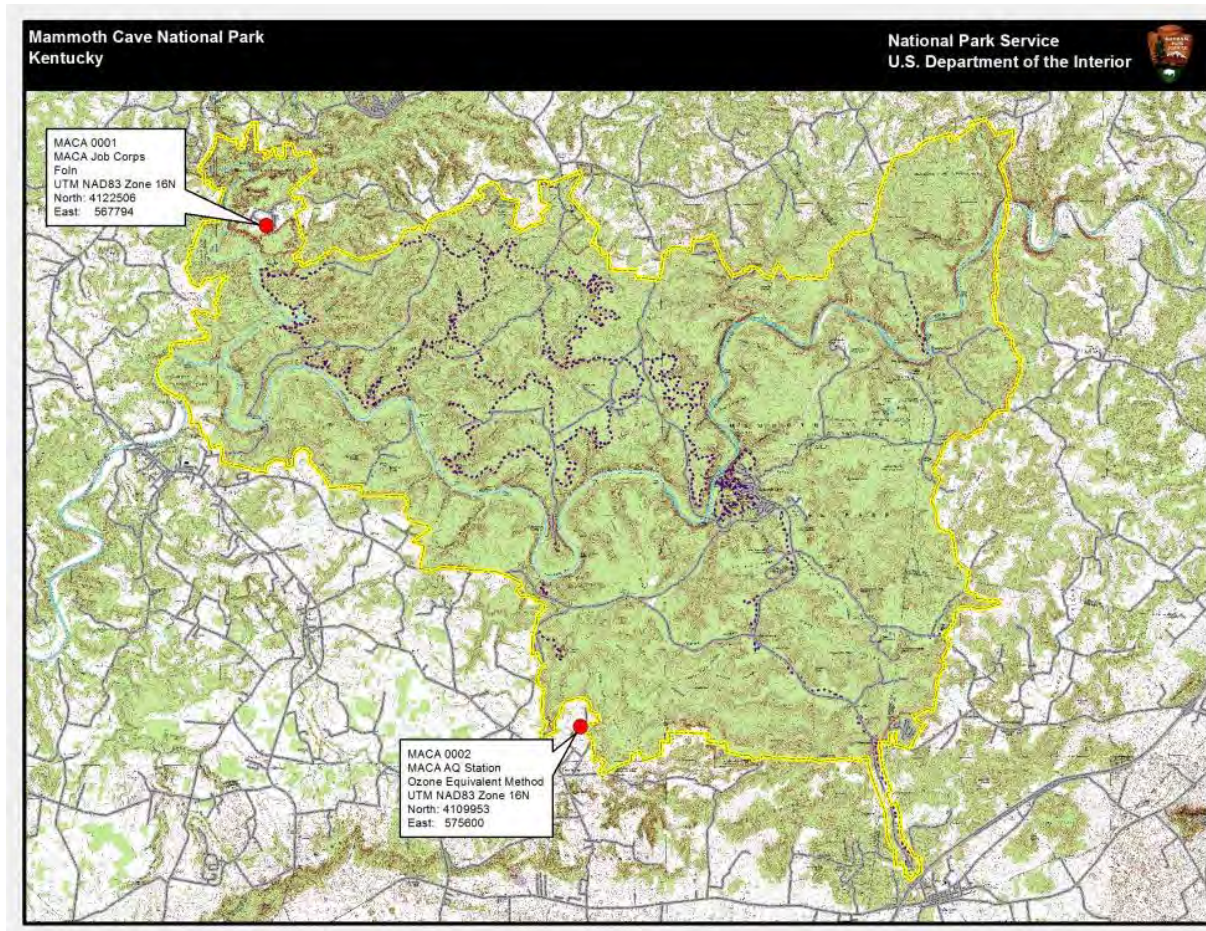


Figure 6 – MACA Great Onyx Job Corps site photograph and map. Site photographs by Michael Lee (NPS cooperators). NPS map by Lillian Scoggins (CUPN GIS specialist).

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.

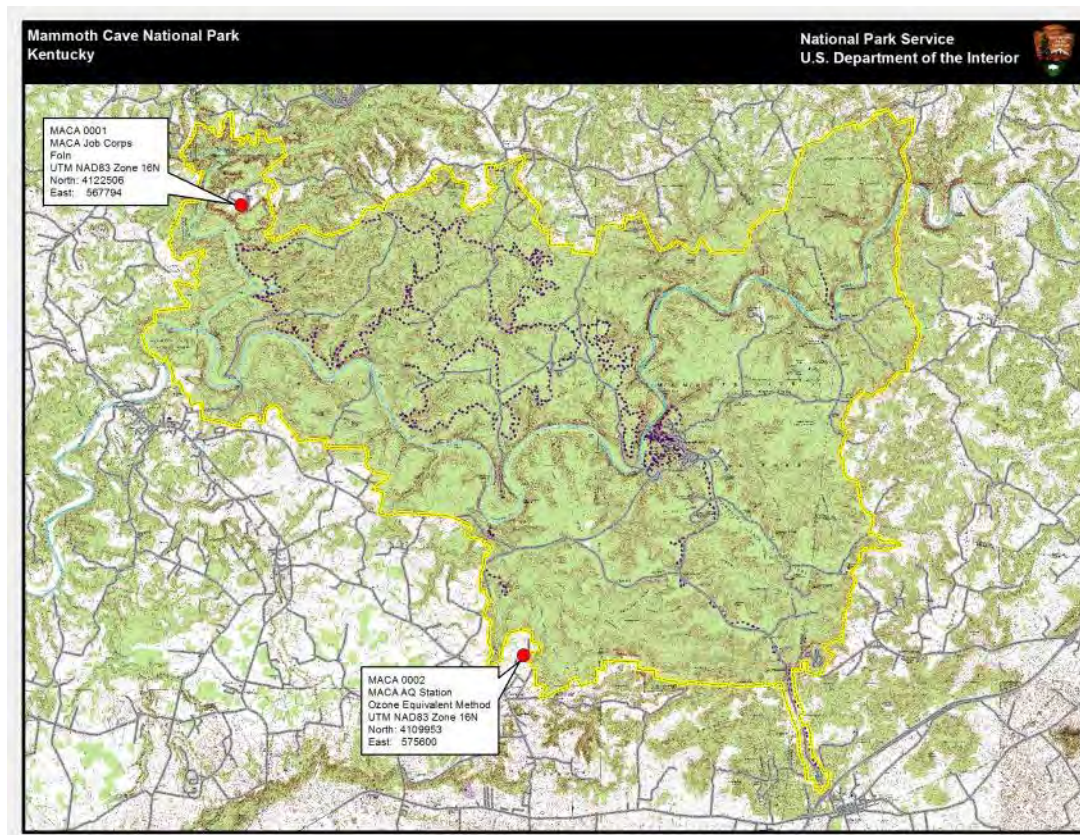


Figure 7 – MACA Air Quality Station site photograph and map. NPS map by Lillian Scoggins (CUPN GIS specialist).

Results

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

- KIMO – Ozone data are from a POMS located on Brown’s Mountain. The POMS was operational from 18 April 2013 to 10 October 2013.
- MACA – Ozone data are from the park’s air quality station located along the park’s boundary. Data cover the entire growing season.
- NISI – Ozone data are from a POMS located at Bumble Bee Hill, overlooking Star Fort Pond. The POMS was in place from 25 April 2013 to 7 November 2013.

Also, CUGA was installed with a POMS at the Hensley Settlement. The data presented here for CUGA were collected at that site. In 2013, 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 2013). 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 five sites spread across three parks in CY2013.

Ozone Concentration

Ozone data from focus parks (KIMO, MACA and NISI) 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.

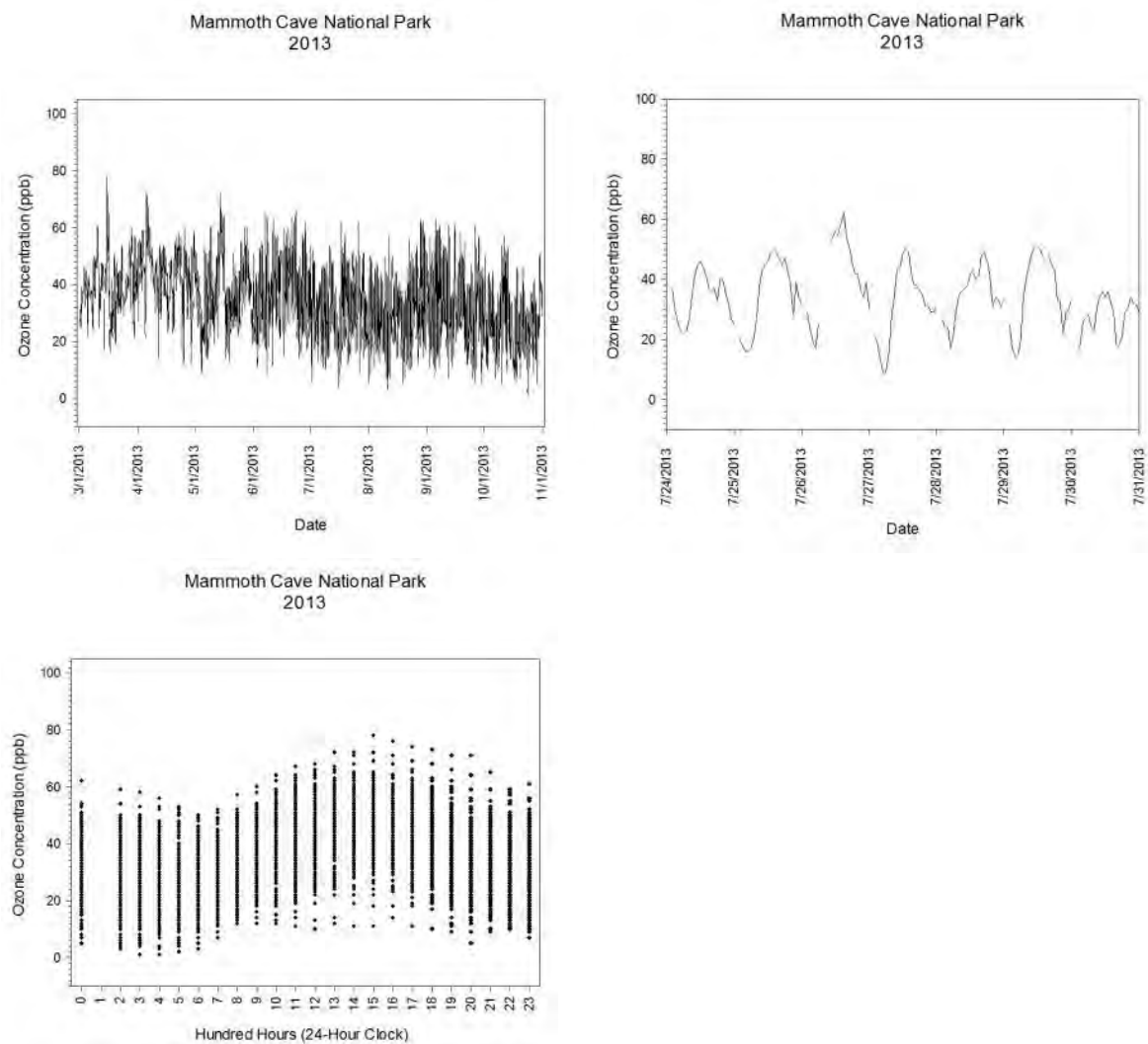


Figure 8 – MACA hourly ozone concentration plots.

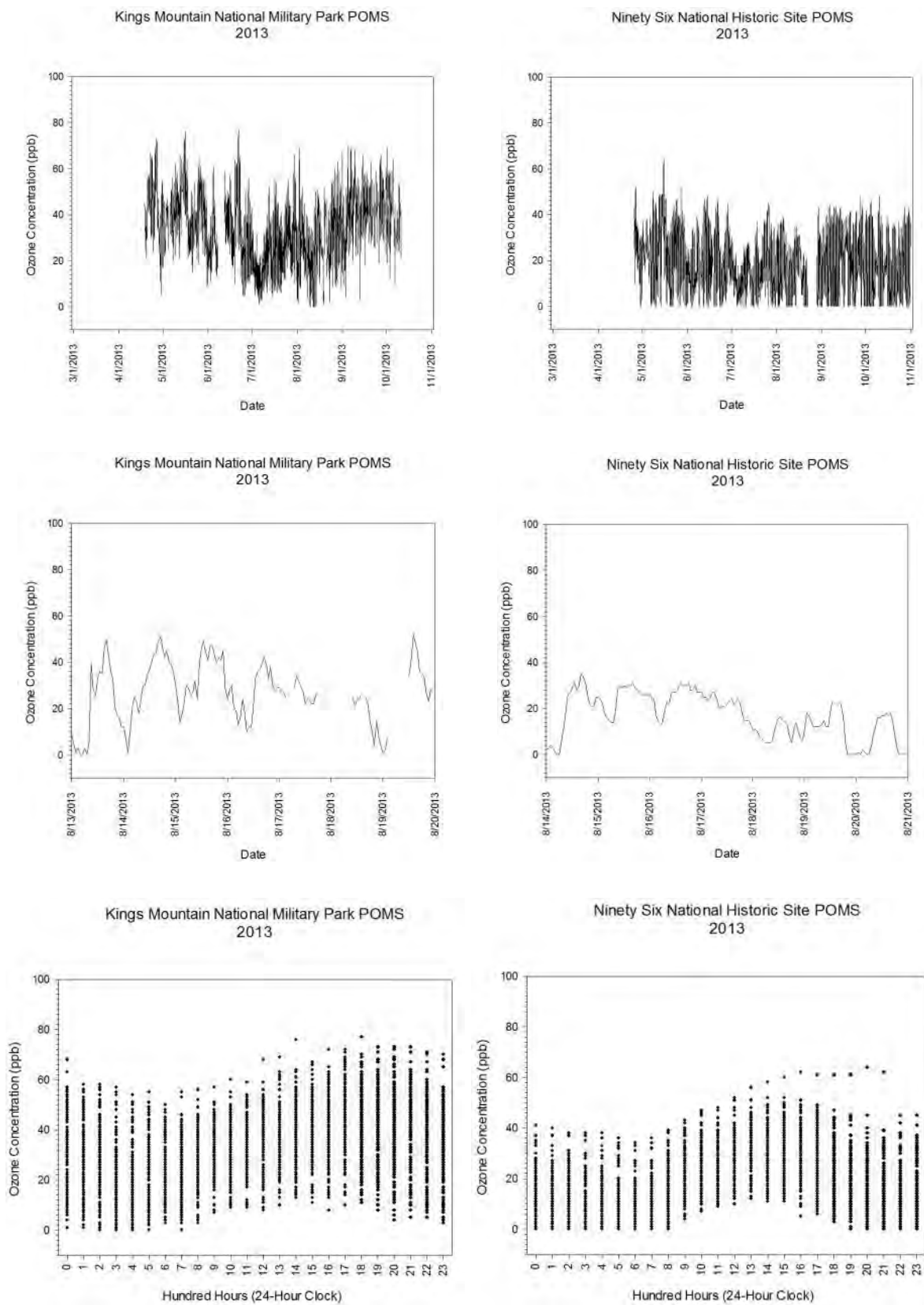


Figure 9 – KIMO and NISI POMS hourly ozone concentration plots.

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 CUGA, KIMO, MACA and NISI. 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.

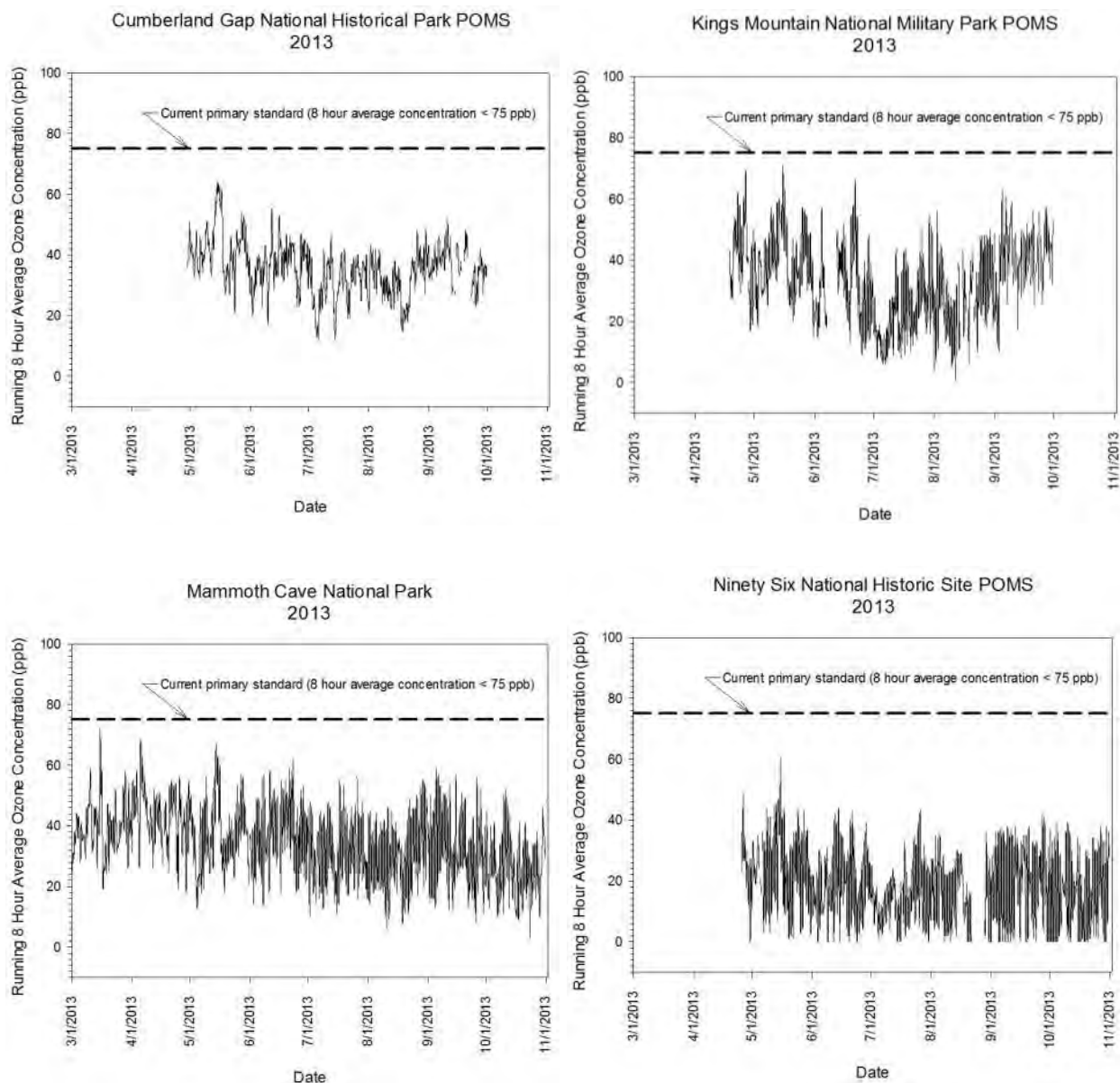


Figure 10 – Running 8 hour average ozone concentration at CUGA, KIMO, MACA and NISI.

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

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

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 (generally referred to 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). The 3-month highest value is preferred since a separate secondary standard recently proposed by EPA was based upon the 3-month value (and the NPS Air Resources Division’s Monitoring Support Contractor has a calculator available online for use with POMS and NPS site data wherein 3-month values are computed).

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 KIMO, MACA and NISI (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 – 2013 SUM06 and W126 values for CUGA, KIMO, MACA and NISI. Values are calculated using data from 0800 to 1900. Indices presented are 3-month maximum (realized during the indicated period) in 2013. 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
CUGA	POMS	75.0	1.3	1.9	May-Jul	0
KIMO	POMS	57.0	3.1	2.9	May-Jul	0
MACA	Houchins' Meadow Site	95.0	4.8	5.8	Apr-Jun	0
NISI	POMS (25 April to 31 Oct)	82.0	0.3	0.4	May-Jul	0

Foliar Injury

In CY2013, foliar injury assessments were completed at three parks on the following dates:

Kings Mountain National Military Park – August 20, 2013

Mammoth Cave National Park – July 31, 2013

Ninety Six National Historic Site – August 21, 2013

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 plants with suspected injury in 2013 is 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 is found (and recall that no injury was found in 2013), three injured leaves are collected for each species. These injured leaves (referred to as voucher specimens) are 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 2013, the USFS program was not operational and so voucher specimen inspection would have been performed by the aforementioned members of academia.

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
None	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Foliar injury was not found at any of the focus parks (KIMO, MACA or NISI) in 2013. Table 2 summarizes these results.

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

Park Name	Number of Plants Inspected
KIMO	255
MACA	99
NISI	210
Total	564

In 2013, 564 plants at three CUPN parks were inspected for foliar injury. Of those 564 plants, no plants were suspected to have foliar injury. 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 3, the number of species inspected at each of the three parks may be summed (KIMO had 6 species, MACA had 4 species and NISI had 4 species).

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

Park Name	Species	Number of Plants Inspected
KIMO	Black cherry	44
KIMO	Blackberry	60
KIMO	Flameleaf sumac	60
KIMO	Sourwood	30
KIMO	Sweetgum	31
KIMO	Yellow poplar	30
MACA	Blackberry	30
MACA	Milkweed	30
MACA	Spreading dogbane	9
MACA	Sweetgum	30
NISI	Blackberry	60
NISI	Flameleaf sumac	60
NISI	Sweetgum	60
NISI	Yellow crownbeard	30

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

Park Name	Site Name	Species	Number of Plants Inspected	Injury Confirmed	Number Of Plants with Observed Injury
KIMO	Fire Tower Road Powerline	Black cherry	30	N	0
KIMO	Fire Tower Road Powerline	Blackberry	30	N	0
KIMO	Fire Tower Road Powerline	Flameleaf sumac	30	N	0
KIMO	Fire Tower Road Powerline	Sweetgum	30	N	0
KIMO	Fire Tower Road Powerline	Yellow poplar	30	N	0
KIMO	Park Road East	Black cherry	14	N	0
KIMO	Park Road East	Blackberry	30	N	0
KIMO	Park Road East	Flameleaf sumac	30	N	0
KIMO	Park Road East	Sourwood	30	N	0
KIMO	Park Road East	Sweetgum	1	N	0
MACA	Great Onyx Job Corps	Blackberry	30	N	0
MACA	Great Onyx Job Corps	Milkweed	30	N	0
MACA	Great Onyx Job Corps	Spreading dogbane	9	N	0
MACA	Great Onyx Job Corps	Sweetgum	30	N	0
NISI	Bumble Bee Hill	Blackberry	30	N	0
NISI	Bumble Bee Hill	Flameleaf sumac	30	N	0
NISI	Bumble Bee Hill	Sweetgum	30	N	0
NISI	Charleston Road Site	Blackberry	30	N	0
NISI	Charleston Road Site	Flameleaf sumac	30	N	0
NISI	Charleston Road Site	Sweetgum	30	N	0
NISI	Charleston Road Site	Yellow crownbeard	30	N	0

Table 5 shows the number of plants from each species inspected at each site. The “Injury Confirmed” column shows whether the species the indicated site was verified to have injury by the ozone injury experts. The rightmost column shows the number of plants observed to have ozone injury (regardless of whether that injury was expert-confirmed).

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 KIMO and NISI assessments. Notice that all of the focus parks were experiencing neither a drought nor abnormally wet conditions.

Further, as shown in Table 1, ozone exposure indices at all the focus parks in 2013 were low. It is, therefore, not surprising that no injury was found at the focus parks.

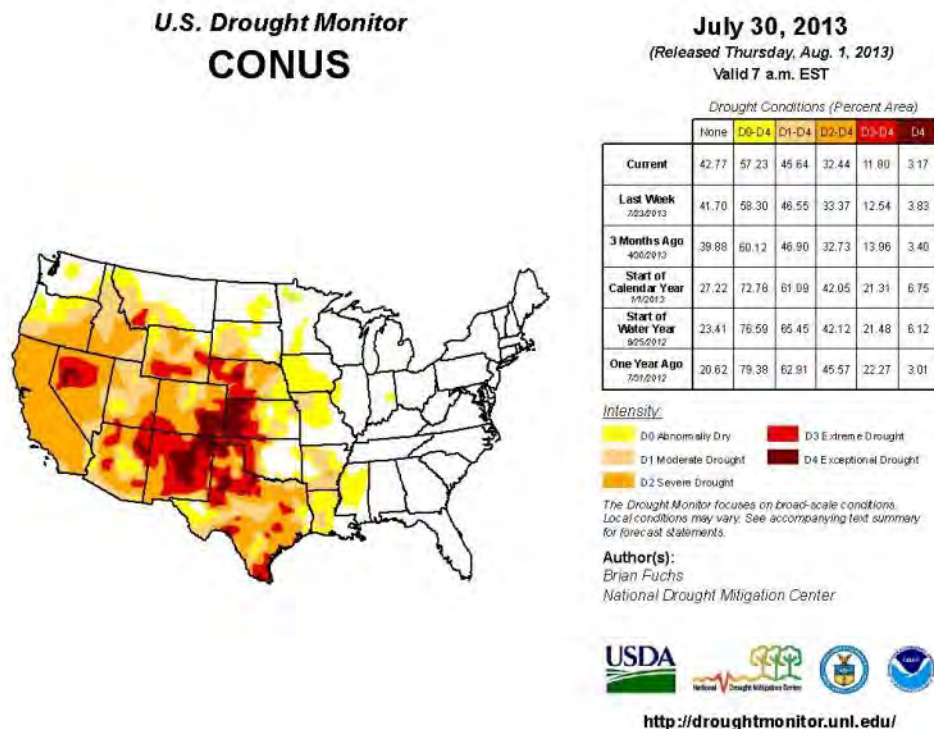


Figure 11 – Drought severity for the week of July 30, 2013.

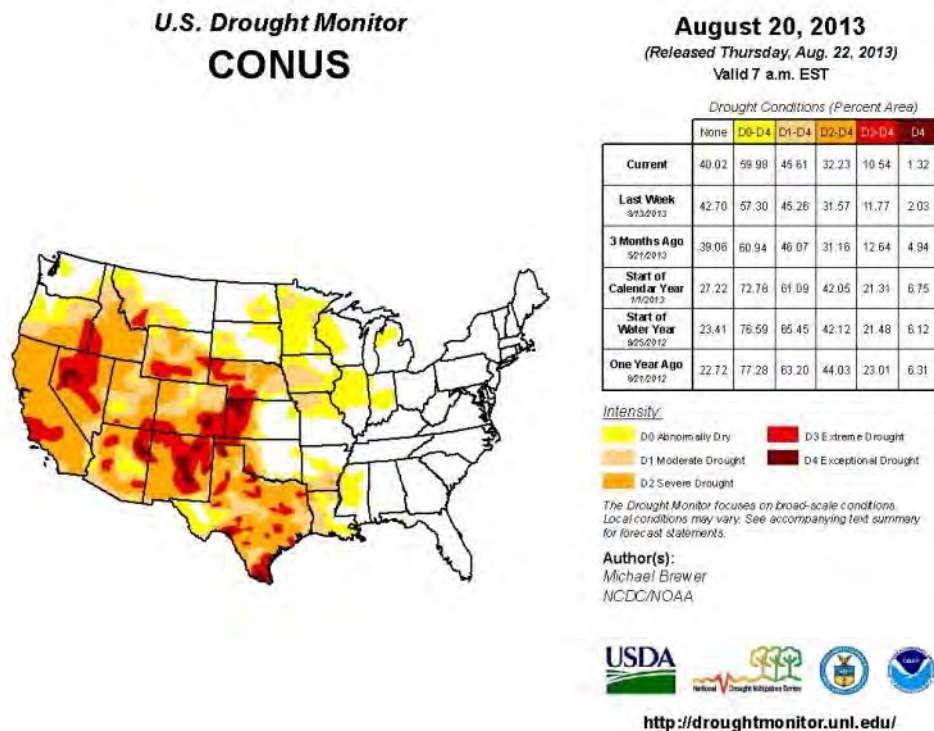


Figure 12 – Drought severity for the week of August 20, 2013.

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. These summary statistics were courtesy of the National Park Service – Air Resources Division.

Table 6 – 2013 seasonal SUM060 and W126 values for state-operated sites near CUPN parks. Data are from 0800 to 1900 (inclusively) and are 3 month maxima from a rolling 3 month sum (June, for example, would mean the data are from April, May and June). Data from CUGA POMS are available in Table 1. Summary statistics are courtesy of the National Park Service – Air Resources Division. * - Indicates that 2013 data were unavailable.

Park Name	AQS Site ID of Nearby Site	County, State of Nearby Site	SUM060 (ppm-hrs) / End Month of Max	W126 (ppm-hrs) / End Month of Max	Percent Valid (percent)	Number of Days Sampled
ABLI	210930006	Hardin County, KY	3.2 / Jul	3.8 / Jun	99.1	245
CARL	370210030	Buncombe County, NC	3.1 / Jun	4.5 / Jun	98.1	214
	370870035	Haywood County, NC	4.5 / Jun	6.1 / Jun	94.4	214
CHCH	130550001	Chattooga County, GA	2.4 / May	3.4 / May	99.6	245
	132130003	Murray County, GA	2.4 / May	3.8 / May	98.8	245
	470651011	Hamilton County, TN	3.0 / Jun	4.3 / May	97.1	245
	470654003	Hamilton County, TN	3.9 / Jun	4.9 / Jun	98.4	245
	471210104	Meigs County, TN	1.9 / May	3.1 / May	93.9	245
COWP	450210002	Cherokee County, SC	1.9 / Jun	3.1 / Jun	96.3	246
CUGA	210130002	Bell County, KY	2.1 / May	3.6 / May	99.6	245
	211930003	Perry County, KY	1.3 / May	3.1 / May	100.0	245
	211950002	Pike County, KY	1.2 / May	2.8 / May	99.2	245
FODO	212219991	Trigg County, KY	3.2 / May	4.8 / Jun	92.1	365
GUCO	371570099	Rockingham County, NC	5.0 / Jun	5.3 / Jun	98.1	214
KIMO	371090004	Lincoln County, NC	3.8 / Jun	5.0 / Jun	100.0	214
	371191005	Mecklenburg County, NC	3.5 / Sep	3.1 / Sep	100.0	214
	450910006	York County, SC	1.9 / May	3.3 / May	99.0	244
LIRI	130550001	Chattooga County, GA	2.4 / May	3.4 / May	99.6	245
MACA	212270008	Warren County, KY	*	*	*	*
NISI	450010001	Abbeville County, SC	1.1 / Jun	2.3 / Jun	94.8	231
	450370001	Edgefield County, SC	0.3 / Jun	0.6 / Jun	84.3	229
RUCA	470654003	Hamilton County, TN	3.9 / Jun	4.9 / Jun	98.4	245
SHIL	010331002	Colbert County, AL	1.6 / May	2.8 / May	100.0	245
	280810005	Lee County, MS	2.0 / May	3.5 / May	98.8	245
STRI	470370011	Davidson County, TN	1.6 / Aug	2.4 / Jun	94.3	245
	470370026	Davidson County, TN	2.1 / Jun	3.7 / Jun	98.8	245
	471490101	Rutherford County, TN	*	*	*	*
	471890103	Wilson County, TN	3.7 / Jun	4.4 / Jun	96.7	245

General Ozone and Foliar Injury Status

At the three focus parks in 2013, no injury was found. All focus parks (KIMO, MACA and NISI) had low ozone exposure indices and were not in any level of drought. These conditions may be consistent with the absence of injury observed at those parks.

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 KIMO and NISI in 2019.

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.

As of December 2014, CUGA had a POMS at the Hensley Settlement that was being provided by NPS-ARD with financial assistance from CUPN (2010 – 2014). The site was serviced by CUGA staff. Monitoring at that site was not resumed in 2015.

For logistical reasons, monitoring at COWP is being moved to coincide with monitoring at KIMO and NISI. To bridge the time gap until 2019, when monitoring is once again due for KIMO and NISI, COWP will be monitored for foliar injury in 2016.

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 provided financial assistance with the CUGA site from 2010 through 2014.

	Year 1 (2014)	Year 2 (2015)	Year 3 (2016)	Year 4 (2017)	Year 5 (2018)	Year 6 (2019)
ABLI	OC, Foln	--	--	--	--	--
CUGA*	OC, Foln	--	--	--	--	--
MACA*	Foln	Foln	Foln	Foln	Foln	Foln
FODO	--	OC, Foln	--	--	--	--
SHIL	--	OC, Foln	--	--	--	--
COWP*	--	Foln	Foln	--	--	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.
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