Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition

Sonoran Desert Network (SODN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/379
ON THE COVER

Some ecosystems and vegetation types, such as remote high-elevation lakes, sugar maple trees, headwater streams, and red spruce trees, are sensitive to the effects of acidification from atmospheric nitrogen and sulfur deposition.

Photograph by: National Park Service
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This report received peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. 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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This report is available from Air Resources Division of the NPS (http://www.nature.nps.gov/air/Permits/ARIS/networks/acidification-eval.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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National maps of atmospheric S and N emissions and deposition are provided in Maps A through D as context for subsequent network data presentations. Maps A and B show county level emissions of total S and total N for the year 2002. Maps C and D show total S and total N deposition, again for the year 2002.

There are 11 parks in the Sonoran Desert Network. Two of them are larger than 100 square miles: Organ Pipe Cactus (ORPI) and Saguaro (SAGU).

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Sonoran Desert Network. Annual county-level S emissions were generally less than 1 ton per square mile per year, with one area having emissions between 1 and 5 tons per square mile. County-level N emissions within the network were higher, ranging from less than 1 ton per square mile to between 5 and 20 tons per square mile. In general, annual county N emissions were less than 5 tons per square mile throughout most of the network. There were relatively few point source emissions of SO2 in the network. Most were centered around Phoenix and emitted less than 5,000 tons of S per year (Map G). Point source emissions of oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N are shown in Map H. There were few point sources of any magnitude (i.e., larger than about 500 tons per square mile) in this network. Of the point sources that did occur, the larger ones were sources of oxidized, rather than reduced, N.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. Most of the population centers of any magnitude (i.e., larger than 50,000 people) are located in and around Phoenix and Tucson. Los Angeles and San Diego fall within the 300-mile buffer.

Total deposition of S and N in and around the network are shown in Maps J and K, respectively. Included in this analysis are both wet and dry forms of deposition and both the oxidized and reduced N species. Total S deposition in the network was uniformly less than 2 kg S/ha/yr (Map J). Total N deposition within the network was generally between 2 and 5 kg N per year, though there were areas of both lower and higher deposition (Map K). Estimated deposition was less than 5 kg N/ha/yr throughout most of the network, including all of the areas that contain I&M parks.

Land cover in and around the network is shown in Map L. The predominant cover type within this network is shrubland. There are also smaller areas of developed land, row crops, forest, and grassland/herbaceous vegetation scattered throughout the network.

Land slope within the parks in this network is shown in Map M. The slope varies considerably, from less than 10° in some parks to over 40° in portions of SAGU.

Park lands requiring special protection against potential adverse impacts associated with acidic deposition are shown on Map N. Also shown on Map N are all federal lands designated as wilderness, both lands managed by NPS and lands managed by other federal agencies. The land designations used to identify this heightened protection included Class I designation under the
Clean Air Act Amendments and wilderness designation. SAGU is a Class I area. ORPI is a
designated wilderness. There are many other wilderness areas in this network that are outside
NPS jurisdiction.

Network rankings are given in Figures A through C as the average ranking of the Pollutant
Exposure, Ecosystem Sensitivity, and Park Protection metrics, respectively. Figure D shows the
overall network Summary Risk ranking. In each figure, the rank for this particular network is
highlighted to show its relative position compared with the ranks of the other 31 networks.

The Sonoran Desert Network ranked in the second lowest quintile among networks in Pollutant
Exposure (Figure A). Nitrogen and S emissions and deposition within the network were
relatively low. The network Ecosystem Sensitivity was also ranked in the second lowest quintile
(Figure B). This network ranked in the second highest quintile in Park Protection, having fairly
substantial amounts of protected lands (Figure C).

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park
Protection yielded an overall Network Risk ranking that is below the middle of the distribution
among networks (Figure D). The overall level of concern for acidification effects on I&M parks
within this network is considered Moderate.

Similarly, park rankings are given in Figures E through H for the same metrics. In the case of the
park rankings, we only show in the figures the parks that are larger than 100 square miles.
Relative ranks for all parks, including the smaller parks, are given in Table A and Appendix A.
As for the network ranking figures, the park ranking figures highlight those parks that occur in
this network to show their relative position compared with parks in the other 31 networks. Note
that the rankings shown in Figures E through H reflect the rank of a given park compared with
all other parks, irrespective of size.

Two parks in the Sonoran Desert Network were ranked in the middle quintile in Pollutant
Exposure (Table A). The Pollutant Exposure rankings for the other parks were lower, with four
parks (including SAGU) ranked Low and five parks (including ORPI) ranked Very Low.
Ecosystem Sensitivity for the parks in this network varied from Very Low to High (Table A).
Rankings for Park Protection tended to be higher, with three parks (including the two larger
parks, SAGU and ORPI) ranked Very High for this theme. Two of the smaller parks (Coronado
[CORO] and Gila Cliff Dwellings [GICL] were ranked High and the remaining six parks were
ranked Moderate.

In combination, the Summary Risk ranked SAGU as High (Figure H). ORPI and three of the
smaller parks (Chiricahua [CHIR], GICL, and Tonto [TONT]) were ranked Moderate. The
overall acidification risk to the remaining parks is considered Low (Table A).
### Table A. Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and overall Summary Risk from acidic deposition.

<table>
<thead>
<tr>
<th>I&amp;M Parks² in Network</th>
<th>Pollutant Exposure</th>
<th>Ecosystem Sensitivity</th>
<th>Park Protection</th>
<th>Summary Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casa Grande Ruins</td>
<td>Moderate</td>
<td>Very Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Chiricahua</td>
<td>Very Low</td>
<td>High</td>
<td>Very High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Coronado</td>
<td>Very Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Fort Bowie</td>
<td>Very Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Gila Cliff Dwellings</td>
<td>Very Low</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Montezuma Castle</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Organ Pipe Cactus</strong></td>
<td>Very Low</td>
<td>Moderate</td>
<td>Very High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Saguaro</td>
<td>Low</td>
<td>High</td>
<td>Very High</td>
<td>High</td>
</tr>
<tr>
<td>Tonto</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tumacacori</td>
<td>Low</td>
<td>Very Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Tuzigoot</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

¹ Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (very low risk) to the highest quintile (very high risk).

² Park name is printed in bold italic for parks larger than 100 square miles.

Map A. National map of total S emissions by county for the year 2002, in units of tons of S per square mile per year. (Source of data: EPA National Emissions Inventory, [http://www.epa.gov/ttn/chief/net/2002inventory.html](http://www.epa.gov/ttn/chief/net/2002inventory.html))

Map B. National map of total N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) forms of N are included. The total is expressed in tons per square mile per year. (Source of data: EPA National Emissions Inventory, [http://www.epa.gov/ttn/chief/net/2002inventory.html](http://www.epa.gov/ttn/chief/net/2002inventory.html))

Map C. Total S deposition for the conterminous United States for the year 2002, expressed in units of kilograms of S deposited from the atmosphere to the Earth surface per hectare per year. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP (three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.

Map D. Total N deposition for the conterminous United States for the year 2002, expressed in units of kilograms of N deposited from the atmosphere to the Earth surface per hectare per year. Wet and dry forms of both oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N are included. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP.
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(three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.

Map E. Total S emissions by county for lands surrounding the network, expressed as tons of S emitted into the atmosphere per square mile per year. (Source of data: EPA National Emissions Inventory, [http://www.epa.gov/ttn/chief/net/2002inventory.html](http://www.epa.gov/ttn/chief/net/2002inventory.html))

Map F. Total N emissions by county for lands surrounding the network, expressed as tons of N emitted into the atmosphere per square mile per year. The total includes both oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N. (Source of data: EPA National Emissions Inventory, [http://www.epa.gov/ttn/chief/net/2002inventory.html](http://www.epa.gov/ttn/chief/net/2002inventory.html))


Map H. Major point source emissions of oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N in and around the network. The base of each vertical bar is positioned in the map at the approximate location of the source. The height of the bar is proportional to the magnitude of the source. (Source of data: EPA National Emissions Inventory, [http://www.epa.gov/ttn/chief/net/2002inventory.html](http://www.epa.gov/ttn/chief/net/2002inventory.html))

Map I. Urban centers having more than 10,000 people within the network and within a 300-mile buffer around the perimeter of the network. (Source of data: U.S. Census 2000)

Map J. Total S deposition in and around the network. Values are expressed as kilograms of S deposited per hectare per year. (Source of data: CMAQ Model wet and dry deposition data for 2002; see information for Map C above for details)

Map K. Total N deposition in and around the network. Included in the total are wet plus dry forms of both oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N. Values are expressed as kilograms of N deposited per hectare per year. (Source of data: CMAQ Model wet and dry deposition data for 2002; see information for Map D above for details)

Map L. Land cover types in and around the network, based on the National Land Cover dataset. (Source of data: National Land Cover Dataset, [http://www.mrlc.gov/nlcd_multizone_map.php](http://www.mrlc.gov/nlcd_multizone_map.php))

Map N. Lands within the network that are classified as Class I or wilderness area. (Source of data: USGS 2005 [National Atlas; http://nationalatlas.gov] and NPS)

Figure A. Network rankings for Pollutant Exposure, calculated as the average of scores for all Pollutant Exposure variables.

Figure B. Network rankings for Ecosystem Sensitivity, calculated as the average of scores for all Ecosystem Sensitivity variables.

Figure C. Network rankings for Park Protection, calculated as the average of scores for all Park Protection variables.

Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.

Figure E. Park rankings for Pollutant Exposure for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Pollutant Exposure variables.

Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.

Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.
Total Sulfur Emissions by County
Conterminous U.S.
(tons per square mile per year)

Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
Total Sulfur Deposition
Conterminous U.S.
(kg/ha/yr)

Data Source: Interpolated NADP Wet and CMAC Model Dry Deposition for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

Map C
Total Sulfur Emissions by County
Sonoran Desert Network
(tons per square mile per year)

Locator Map

Map E
Figure A
Figure C
Acidification Risk Assessment
Summary Risk Ranking

Networks:
- Mid-Atlantic
- North Coast and Cascades
- Sierra Nevada
- Appalachian Highlands
- Cumberland Piedmont
- Eastern Rivers and Mountains
- Great Lakes
- Greater Yellowstone
- Rocky Mountain
- Heartland
- Klamath
- South Florida / Caribbean
- Arctic
- Central Alaska
- Mojave Desert
- Northern Temperate
- Northeastern Plateau
- Western Alaska
- Mediterranean Coast
- National Capital Region
- Northern Great Plains
- Pacific Island
- San Francisco Bay Area
- Sonoran Desert
- Southern Colorado Plateau
- Chihuahuan Desert
- Southeastern Plateau
- Southeast Coast
- Gulf Coast
- Southern Plains
- Upper Columbia Basin

Average of Network Ranking

Figure D
Acidification Risk Assessment
Sonoran Desert Network - Pollutant Exposure Ranking

Figure E
Acidification Risk Assessment
Sonoran Desert Network - Ecosystem Sensitivity Ranking

Figure F
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.

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