Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition

*Upper Columbia Basin Network (UCBN)*

Natural Resource Report NPS/NRPC/ARD/NRR—2011/334
ON THE COVER
Some ecosystems, such as arid shrublands, subalpine meadows, remote high elevation lakes, and wetlands, are sensitive to the effects of nutrient enrichment from atmospheric nitrogen deposition.
Photograph by: National Park Service
Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition

*Upper Columbia Basin Network (UCBN)*

Natural Resource Report NPS/NRPC/ARD/NRR—2011/334

T. J. Sullivan  
T. C. McDonnell  
G. T. McPherson  
S. D. Mackey  
D. Moore

E&S Environmental Chemistry, Inc.  
P.O. Box 609  
Corvallis, OR 97339

February 2011

U.S. Department of the Interior  
National Park Service  
Natural Resource Program Center  
Denver, Colorado
The National Park Service, Natural Resource Program Center 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 Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

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.

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.

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 Air Resources Division of the NPS (http://www.nature.nps.gov/air/Permits/ARIS/networks/n-sensitivity.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:


NPS 960/106716, February 2011
Upper Columbia Basin Network (UCBN)

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

There are eight parks in the Upper Columbia Basin Network. Two of them are larger than 100 square miles: Craters of the Moon (CRMO) and Lake Roosevelt (LARO).

Total annual N emissions, by county, are shown in Map C for lands in and surrounding the Upper Columbia Basin Network. County-level emissions within the network ranged from less than 1 ton per square mile to more than 5 tons per square mile. In general, annual county N emissions were less than 5 tons per square mile. Point source emissions of oxidized (nitrogen oxides, NOx) and reduced (ammonia, NH3) N are shown in Map D. There are few N point sources of any magnitude in this network. Urban centers within the network and within a 300 mile buffer around the network are shown in Map E. There are only two human population centers larger than 100,000 people and none larger than 500,000 people.

Total N deposition in and around the network is shown in Map F. Included in this analysis are both wet and dry forms of N deposition and both the oxidized and reduced N species. Total N deposition within the network ranged from less than 2 kg N/ha/yr to as high as 2 to 5 kg N/ha/yr across much of the northern portion of the network, with pockets of estimated deposition higher than that. In general, total N deposition was in the range of 2 to 5 kg N/ha/yr at the locations of most of the parks in this network.

Land cover in and around the network is shown in Map G. The predominant cover types within this network are generally quite varied. They include mainly forest and row crops in the north, and shrubland and grassland/herbaceous in the south.

Map H shows the distribution within the only park that is large enough to see at the network scale of the five vegetation types thought to be most responsive to nutrient N enrichment effects (arctic, alpine, grassland and meadow, wetland, and arid and semi-arid). In general, the predominant sensitive vegetation type is arid and semi-arid vegetation.

Park lands requiring special protection against potential adverse impacts associated with nutrient N enrichment from atmospheric N deposition are shown in Map I. Also shown on Map I are all federal lands designated as wilderness, both lands managed by NPS and also lands managed by other federal agencies. The land designations used to identify this heightened protection included Class I designation under the CAAA and wilderness designation. There is very limited Class I or wilderness area managed by NPS in this network. There is, however, substantial wilderness 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 Upper Columbia Basin Network ranks in the second lowest quintile, among networks, in N pollutant Exposure (Figure A). Nitrogen emissions and N deposition within the network are both low. The network Ecosystem Sensitivity ranking is also relatively low, within the second lowest quintile among networks (Figure B). This is because there is limited vegetation coverage in the I&M parks that occur in this network that includes vegetation types expected to be especially sensitive to nutrient enrichment effects from N deposition, and there are no high elevation lakes. This network also ranks in the second lowest quintile in Park Protection, having limited amounts of protected lands (Figure C).

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yield an overall Network Risk ranking that is the lowest of all networks (Figure D). The overall level of concern for nutrient N enrichment effects on I&M parks within this network is considered Very Low.

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 B. 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.

There are two parks in the Upper Columbia Basin Network that are ranked in the middle quintile for Pollutant Exposure: Hagerman Fossil Beds (HAFO) and Whitman Mission (WHMI); neither is large. Other parks in the network are ranked in the lowest (four parks including LARO) or second lowest (two parks including CRMO) quintile ranking for this theme. Ecosystem Sensitivity rankings are generally much higher, in the highest quintile for HAFO and John Day Fossil Beds (JODA), and in the second highest quintile for three other parks. All of the parks except CRMO are ranked in the middle quintile for Park Protection; CRMO is ranked High, in the second highest quintile.

The Summary Risk ranking places CRMO and HAFO in the middle quintile (Moderate). Other parks are ranked in the second lowest or lowest quintile, suggesting Low or Very Low risk of nutrient N enrichment effects.
### Table A. Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and Summary Risk from atmospheric nutrient N enrichment.

<table>
<thead>
<tr>
<th>I&amp;M Parks(^2) in Network</th>
<th>Pollutant Exposure</th>
<th>Ecosystem Sensitivity</th>
<th>Park Protection</th>
<th>Summary Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Hole</td>
<td>Very Low</td>
<td>High</td>
<td>Moderate</td>
<td>Very Low</td>
</tr>
<tr>
<td>City of Rocks</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td><em>Craters of the Moon</em></td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Hagerman Fossil Beds</td>
<td>Moderate</td>
<td>Very High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>John Day Fossil Beds</td>
<td>Very Low</td>
<td>Very High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Lake Roosevelt</td>
<td>Very Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Very Low</td>
</tr>
<tr>
<td>Nez Perce</td>
<td>Very Low</td>
<td>High</td>
<td>Moderate</td>
<td>Very Low</td>
</tr>
<tr>
<td>Whitman Mission</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Very 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 N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NO\(_x\)) and reduced (ammonia, NH\(_3\)) 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 B.** 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, NO\(_x\)) and reduced (ammonia, NH\(_3\)) N are included. 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 C.** 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, NO\(_x\)) and reduced (ammonia, NH\(_3\)) 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 D.** Major point source emissions of oxidized (nitrogen oxides, NO\(_x\)) and reduced (ammonia, NH\(_3\)) 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 E. 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 F. 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 B above for details)

Map G. 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)

Map H. Distribution within the larger parks that occur in this network of the five terrestrial vegetation types thought to be most sensitive to N-nutrient enrichment effects: arctic, alpine, meadow, wetland, and arid and semi-arid. (Source of data: See Appendix A)

Map I. 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 ranking, calculated as the sum of the averages of the scores for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection.

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 scores for all Summary Risk variables.
Total Nitrogen Emissions by County
Upper Columbia Basin Network
(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

Map C
Map D

NO₃ (Nitrogen Oxides) and NH₃ (Ammonia) Point Sources
Upper Columbia Basin Network (tons N 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
Map F
2001 Land Cover
Upper Columbia Basin Network
(National Land Cover Data)

Data Source: National Land Cover Data (NLCD, 2001)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

Map G
Map H
Figure A

Nitrogen Enrichment Risk Assessment
Pollutant Exposure Ranking

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

Average of Network Ranking

Figures:
1. Nitrogen Enrichment Risk Assessment
2. Pollutant Exposure Ranking

Figure A
Figure B

Nitrogen Enrichment Risk Assessment
Ecosystem Sensitivity Ranking

Network

Average of Network Ranking
Figure C
Figure D
Figure E

Average of Park Ranking

Upper Columbia Basin Network - Pollutant Exposure Ranking

Nitrogen Enrichment Risk Assessment
Nitrogen Enrichment Risk Assessment

Upper Columbia Basin Network - Park Protection Ranking

Average of Park Ranking

Park

Yosemite, Sequoia, Everglades, Yellowstone, Glacier, Kings Canyon, Bly Royal, North Cascades, Big Bend, Petrified Forest, Olympic, Grand Canyon, Noatak, Voyageurs, Gates of the Arctic, Theodore Roosevelt, Mount Rainier, Rocky Mountain, Canyonlands, Katmai, Wrangell-St. Elias, Denali, Death Valley, Grand Teton, Glacier Bay, Great Smoky Mountains, Joshua Tree, Capitol Reef, Lake Clark, Arches, Lassen Volcanic, Shenandoah, Crater Lake, Guadalupe Mountains, Hawaii Volcanoes, Zion, Organ Pipe Cactus, Mojave, Redwood, Saguaro, Lake Mead, Great Sand Dunes, Kobuk Valley, Badlands, Buffalo, Point Reyes, Craters of the Moon, Gulf Islands, Blue Ridge, El Malpais, Big Cypress, Golden Gate, Kenai Fjords, Glen Canyon, Aniakchak, Apostle Islands, Bering Land Bridge, Bighorn Canyon, Biscayne, Big South Fork, Big Thicket, Canyon de Chelly, Cape Krusenstern, Channel Islands, Delaware Water Gap, Dinosaur, Dry Tortugas, Great Basin, Lake Roosevelt, Missouri, New River Gorge, Ozark, Padre Island, Pictured Rocks, Saint Croix, Santa Monica Mountains, Sleeping Bear Dunes, White Sands, Yukon-Charley Rivers.
Figure H
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 960/106716, February 2011