National Park Service
U.S. Department of the Interior

Natural Resource Program Center

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

Mid-Atlantic Network (MIDN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/362

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

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

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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.

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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NPS 962/107398, April 2011

Mid-Atlantic Network (MIDN)

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 is only one park in the Mid-Atlantic Network that is larger than 100 square miles: Shenandoah (SHEN). There are nine smaller parks.

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Mid-Atlantic Network. County-level S emissions within the network ranged from less than 1 to greater than 100 tons per square mile per year (Map E). In general, S emissions were less than 20 tons per square mile per year, with only a few counties exceeding this amount. County-level N emissions within the network ranged from less than 1 ton per square mile to more than 100 tons per square mile (Map F). In general, N emissions were less than 20 tons per square mile, but there were several areas with higher N emissions, most in the range of 20 to 50 tons per square mile. Individual point sources of S are displayed on Map G. Point sources of S within the network were mostly less than 5,000 tons per year. However, there were several sources of greater magnitude, with one source emitting more than 40,000 tons per year (Map G). There were also numerous large S point sources to the northwest of the network. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map H. There were relatively few substantial (larger than 1,000 tons per year) N point sources within this network, and all except one of these emitted NO_x. There were, however, a number of point sources of oxidized N that were larger than 5,000 tons per year just to the west of the network boundary.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. Baltimore is the only urban center within the network that is larger than 500,000 people. However, there are many large cities within the 300-mile buffer around the network boundary, some very close to the network boundary (Washington, DC, New York, and Philadelphia).

Total S and N deposition in and around the network are shown on Maps J and K, respectively. Included in this analysis are both wet and dry forms of acidic deposition and both the oxidized and reduced N species. Total S deposition within the network ranged from as low as 5 to 10 kg S/ha/yr to greater than 30 kg S/ha/yr (Map J). SHEN is located in a zone that receives less than 15 kg S/ha/yr. The highest S deposition values within the network occur to the north. Total N deposition within the network ranged from as low as 5 to 10 kg N/ha/yr to 20 to 30 kg N/ha/yr (Map K). Estimated total N deposition throughout much of the network, including most of SHEN, was in the range of 10 to 15 kg N/ha/yr.

Land cover in and around the network is shown in Map L. The predominant cover types within this network are highly variable. SHEN is largely forested, but the surrounding land is a mix of pasture/hay, forest, and developed land. Elsewhere within the network, land cover types consist mainly of a varied mix of pasture/hay, forest, row crops, and developed areas.

Land slope tends to be fairly steep in SHEN, which is situated along the ridge of the Appalachian Mountains. The HUCs throughout the entire park have average slope in the 30° to 40º range. All other parks within the network are much less steep, with average slope less than 10º in all but one park (Hopewell Furnace [HOFU]), which has average slope in the 10° to 20º range.

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. SHEN is classified as Class I. Large portions of SHEN, along with two small areas outside NPS jurisdiction, are designated as wilderness.

Maps P-1 through P-3 are park-specific maps for SHEN, which show sensitive vegetation (Map P-1), high-elevation lakes and streams (Map P-2) and low-order streams (Map P-3). Nearly the entire park is covered by vegetation types likely to contain sugar maple (Map P-1). Sugar maple is known to be especially sensitive to acidification effects from atmospheric S and N inputs.

High-elevation lakes are absent from the park but there is considerable length of high-elevation streams (Map P-2). Higher-elevation streams are considered potentially more susceptible to acidification from atmospheric S and N input than lower-elevation streams. All streams in the park are first or second order.

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 Mid-Atlantic Network ranked among the highest of all of the networks in Pollutant Exposure (Figure A). Sulfur and N emissions and deposition within the network were very high. Network Ecosystem Sensitivity ranking was also in the highest quintile among networks (Figure B). This was because there is extensive vegetation coverage in the I&M parks in this network that includes sugar maple, and there is considerable length of high-elevation and low-order streams. Surface waters and geology within this network are also known to be highly sensitive to acidification effects. This network ranked near the median among networks in Park Protection (Figure C), having moderate amounts of protected lands. In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yielded an overall Network Risk ranking that is the highest among networks (Figure D).

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 rankings, the park rankings 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.

SHEN, the only park larger than 100 square miles, ranked near the top among parks in Pollutant Exposure (Figure E) and Ecosystem Sensitivity (Figure F), having substantial coverage of sensitive resources and high risk from nearby pollution sources. The Park Protection ranking for SHEN was also in the highest quintile among parks (Figure G).

Most of the smaller historical parks in this network were ranked Very High in Pollutant Exposure; Appomattox Court House (APCO) and for Booker T. Washington (BOWA) were ranked High. The smaller parks were variable in Ecosystem Sensitivity, from Very Low in BOWA to Moderate in Valley Forge (VAFO), HOFU, and Gettysburg (GETT). All of the smaller parks were ranked in the middle quintile in Park Protection.

Overall, the park Summary Risk ranking placed SHEN at the top among parks (Figure H). Concern for acidification effects in SHEN is considered Very High. For the park Summary Risk ranking for the smaller parks, three were ranked High (GETT, HOFU, and VAFO), and the rest were ranked Moderate.

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.

	Relative Ranking of Individual Parks[1]			
I&M Parks[2] in Network	**Pollutant Exposure**	**Ecosystem Sensitivity**	**Park Protection**	**Summary Risk**
Appomattox Court House	High	Low	Moderate	Moderate
Booker T. Washington	High	Very Low	Moderate	Moderate
Eisenhower	Very High	Low	Moderate	Moderate
Fredericksburg and Spotsylvania	Very High	Low	Moderate	Moderate
Gettysburg	Very High	Moderate	Moderate	High
Hopewell Furnace	Very High	Moderate	Moderate	High
Petersburg	Very High	Low	Moderate	Moderate
Richmond	Very High	Low	Moderate	Moderate
Shenandoah	Very High	Very High	Very High	Very High
Valley Forge	Very High	Moderate	Moderate	High

[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)

Map B. 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)

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, 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 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)

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, NO_x) and reduced (ammonia, NH_3) N. (Source of data: EPA National Emissions Inventory, http://www.epa.gov/ttn/chief/net/2002inventory.html)

Map G. Major point source emissions of SO_2 for lands surrounding the network. (Source of data: EPA National Emissions Inventory, http://www.epa.gov/ttn/chief/net/2002inventory.html)

Map H. 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)

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: Interpolated NADP wet and CMAQ Model 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, NO_x) and reduced (ammonia, NH_3) N. Values are expressed as kilograms of N deposited per hectare per year. (Source of data: Interpolated NADP wet and CMAQ Model 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)

Map M. Average land slope within park units that occur within the network, by 10-digit HUC. (Source of data: U.S. EPA National Elevation Dataset [http://ned.usgs.gov/])

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)

Map P-1. Park-specific map: sensitive vegetation types in SHEN. (Source of data: Landfire [http://www.landfire.gov/] and NPS Vegetation Survey)

Map P-2. Park-specific map: high-elevation lakes and streams in SHEN. (Source of data: U.S. EPA National Elevation Dataset [http://ned.usgs.gov/] and U.S. EPA/USGS National Hydrography Dataset Plus [http://www.horizon-systems.com/nhdplus/])

Map P-3. Park-specific map: low-order streams in SHEN. (Source of data: U.S. EPA/USGS National Hydrography Dataset Plus [http://www.horizon-systems.com/nhdplus/])

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.

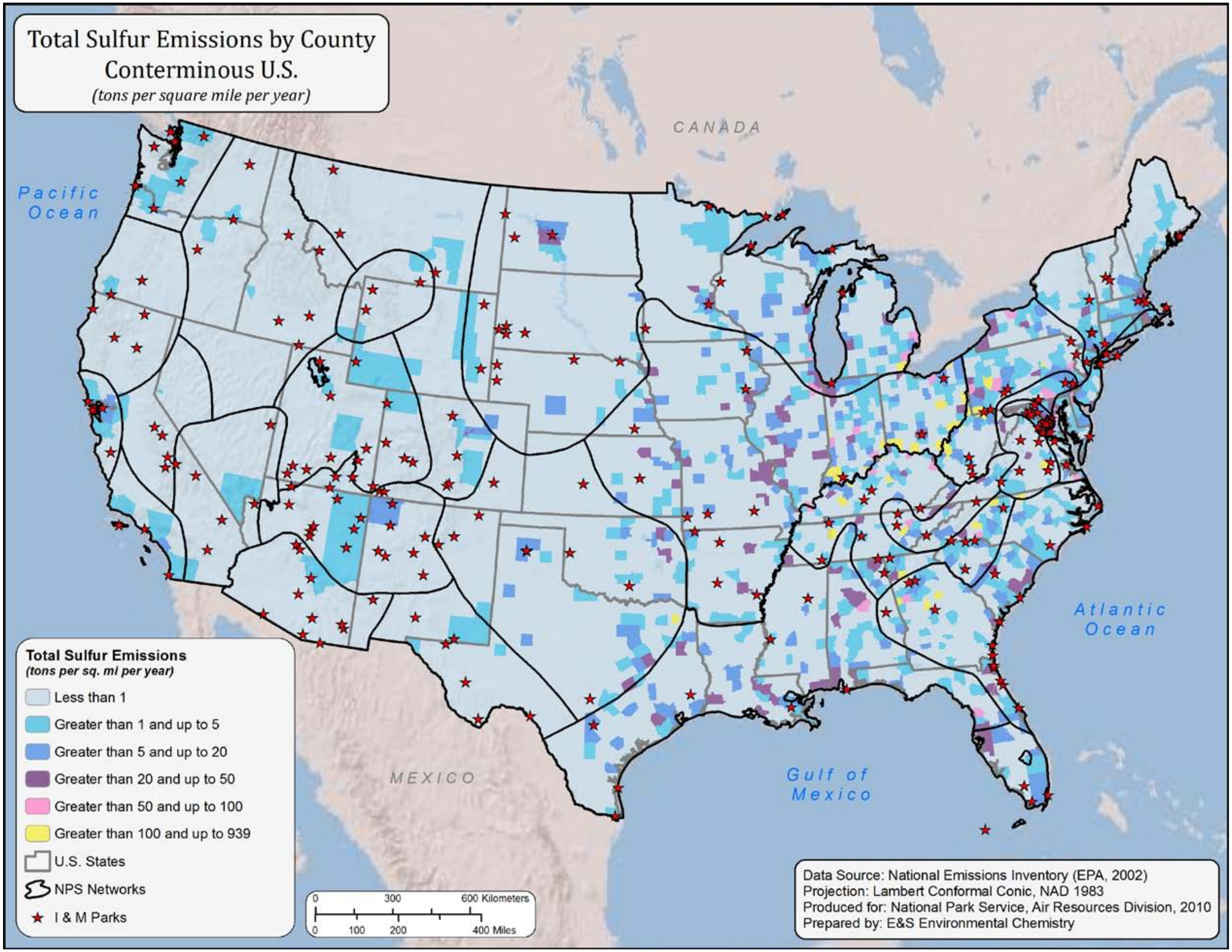
Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.

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.

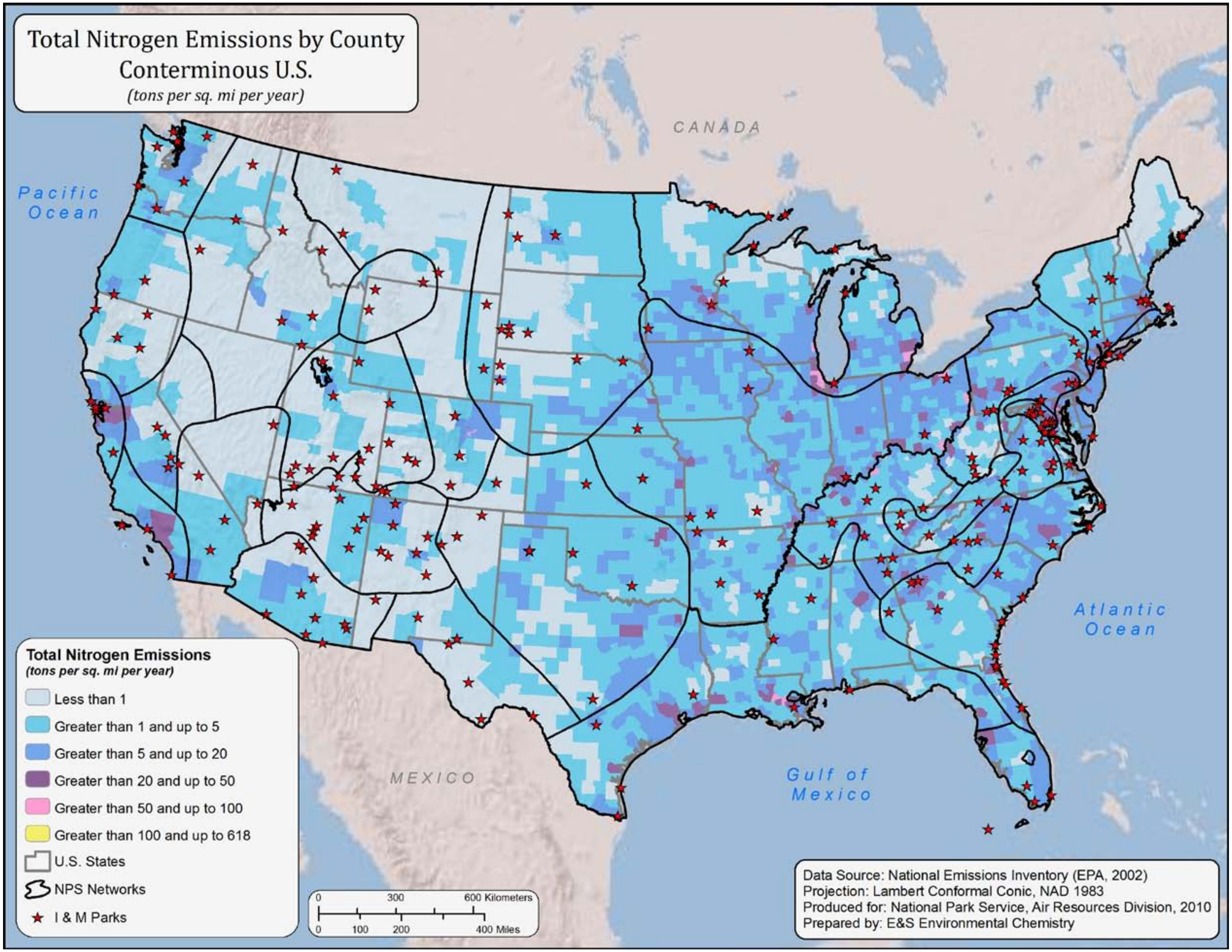
Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.

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.

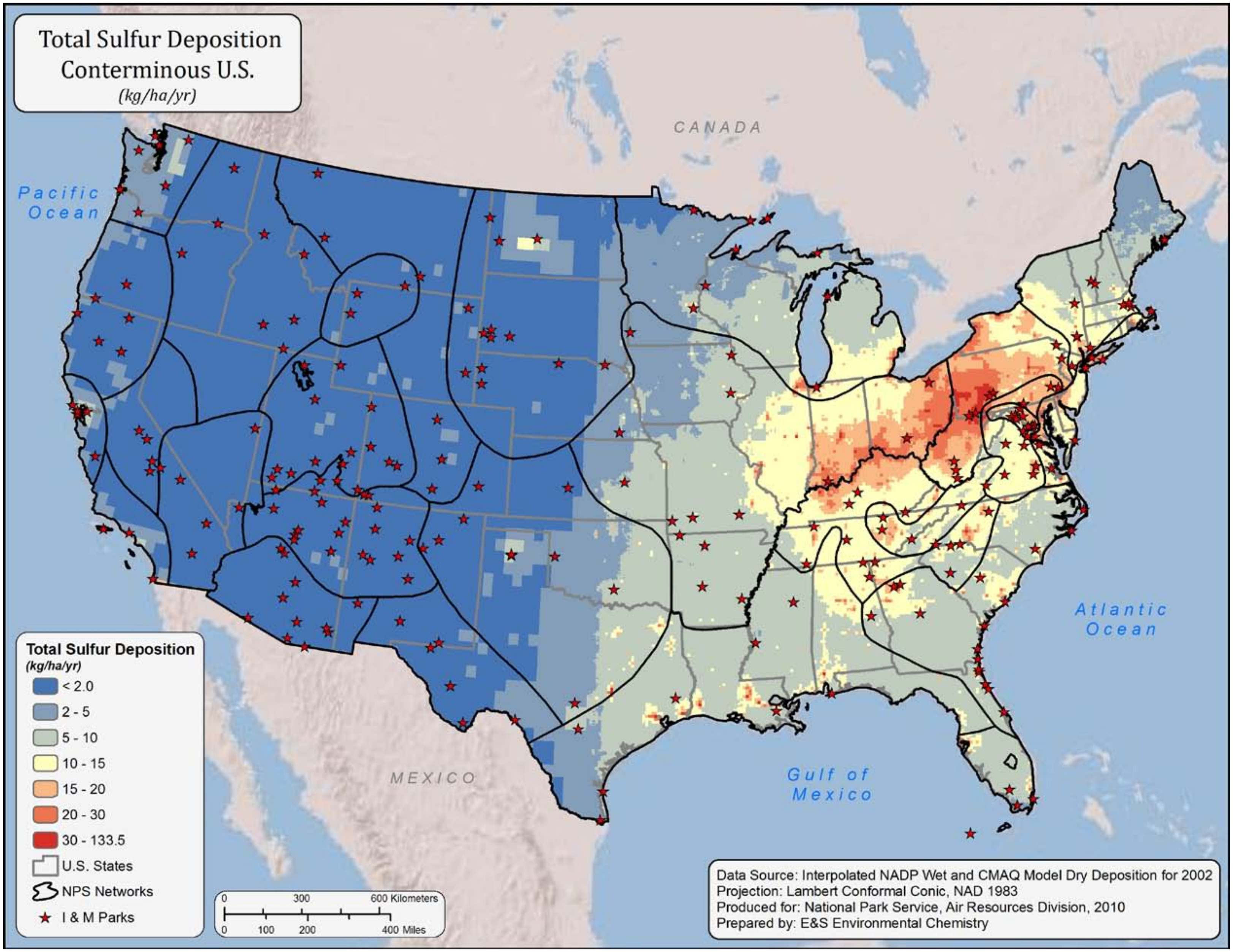


Total Sulfur Emissions by County
Conterminous U.S.
(tons per square mile per year)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Sulfur Emissions
(tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 939
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
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 A

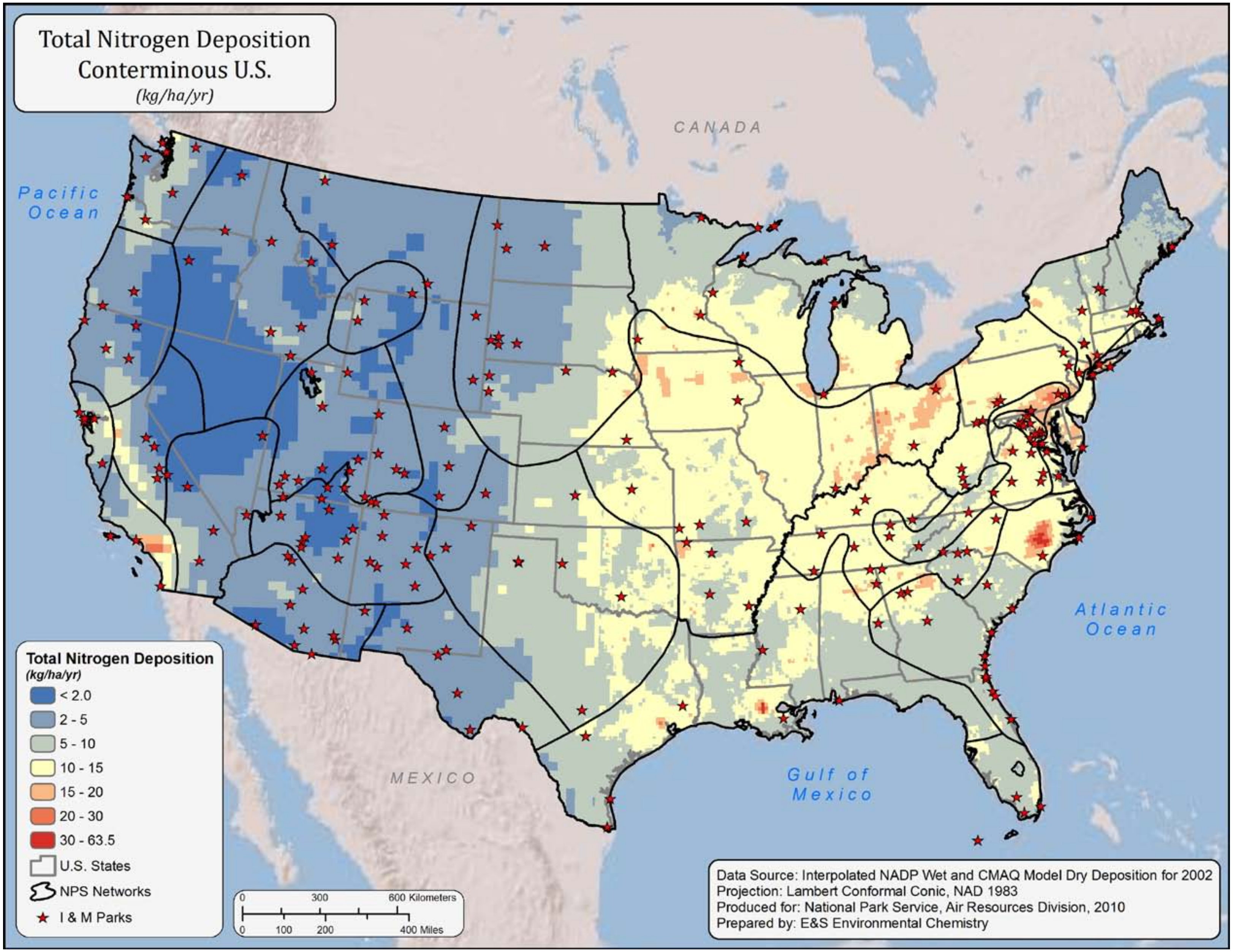

Total Nitrogen Emissions by County
Conterminous U.S.
(tons per sq. mi per year)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Nitrogen Emissions
(tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 618
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
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 B



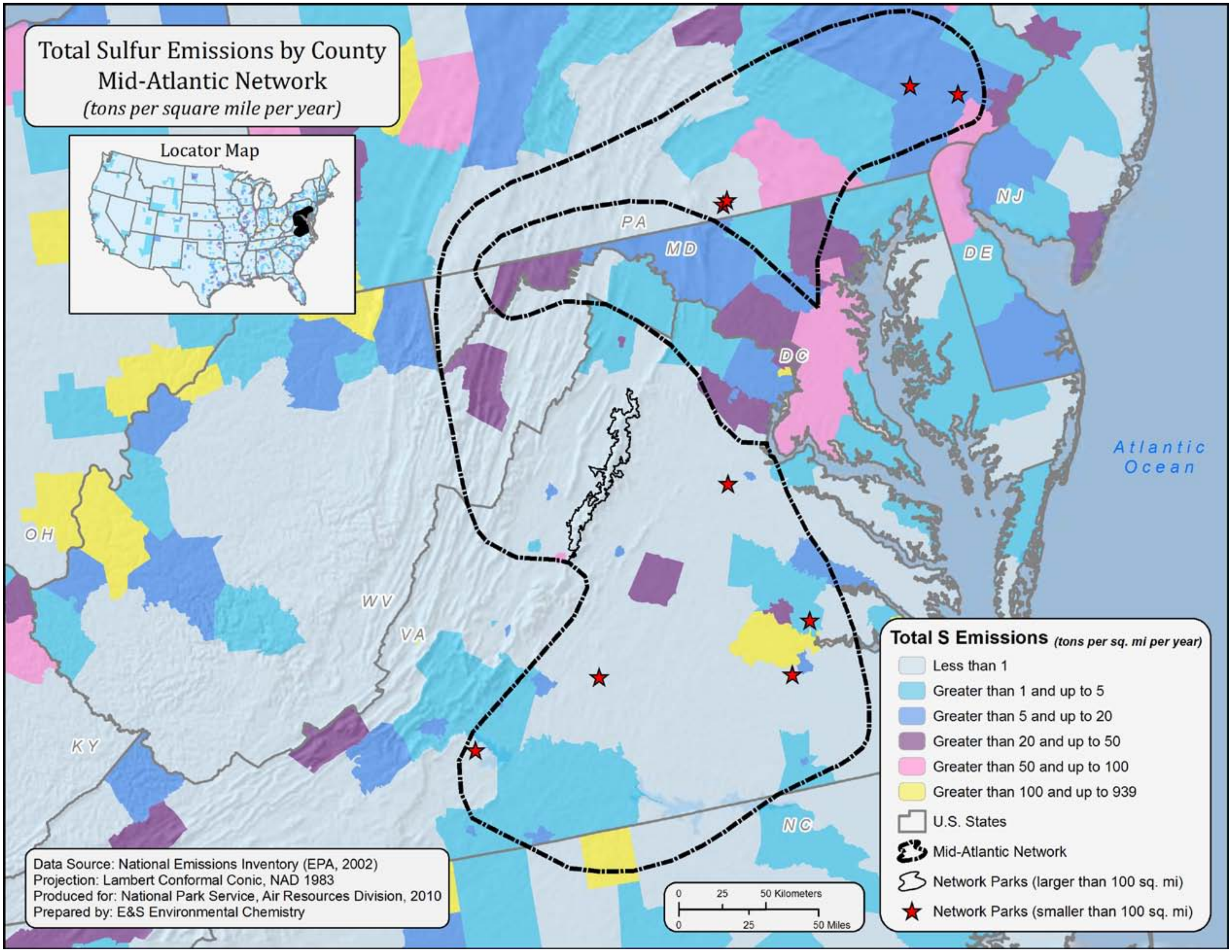
Total Sulfur Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Sulfur Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 133.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated NADP Wet and CMAQ 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 Nitrogen Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Nitrogen Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated NADP Wet and CMAQ 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 D

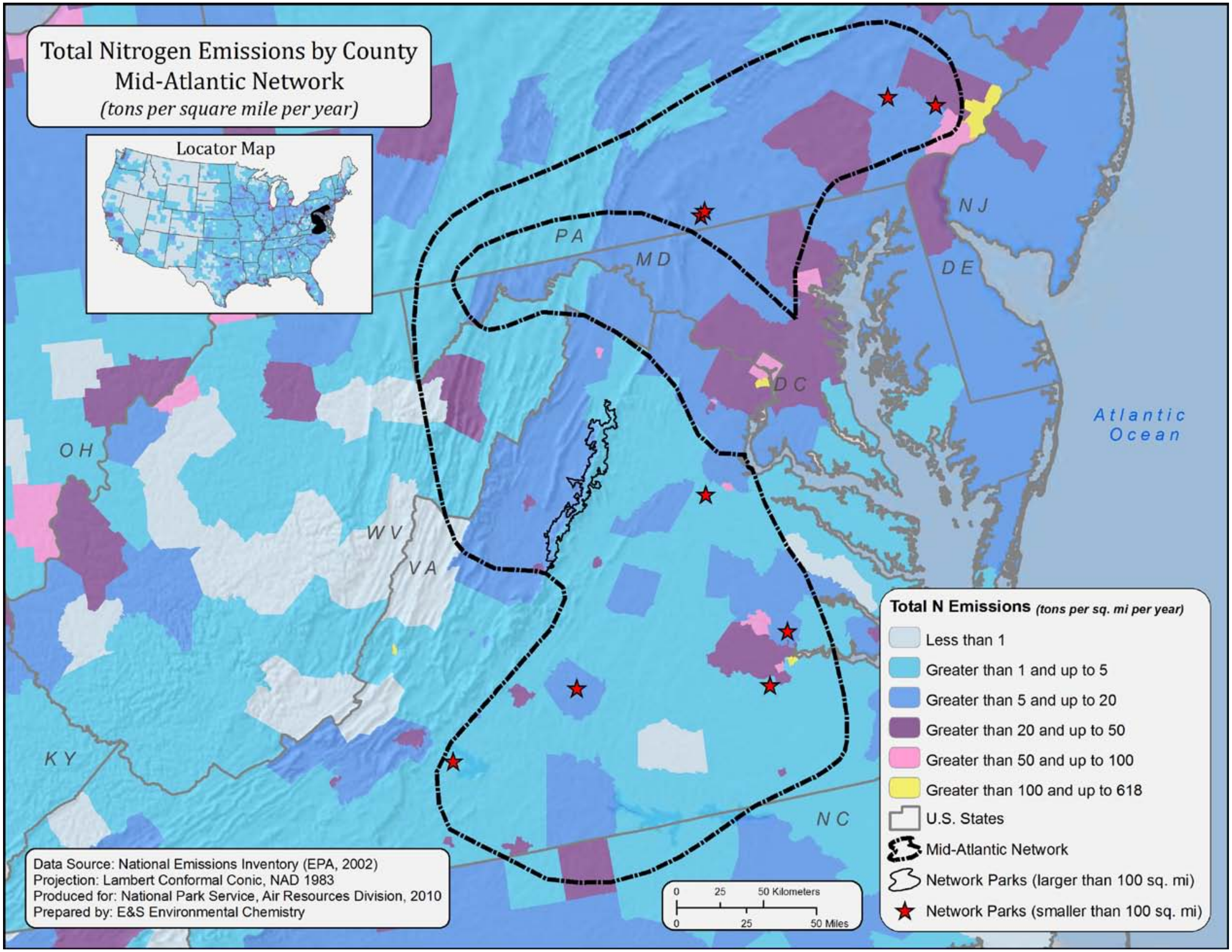
MIDN-11



Total Sulfur Emissions by County
Mid-Atlantic Network
(tons per square mile per year)
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Total S Emissions (tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 939
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
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

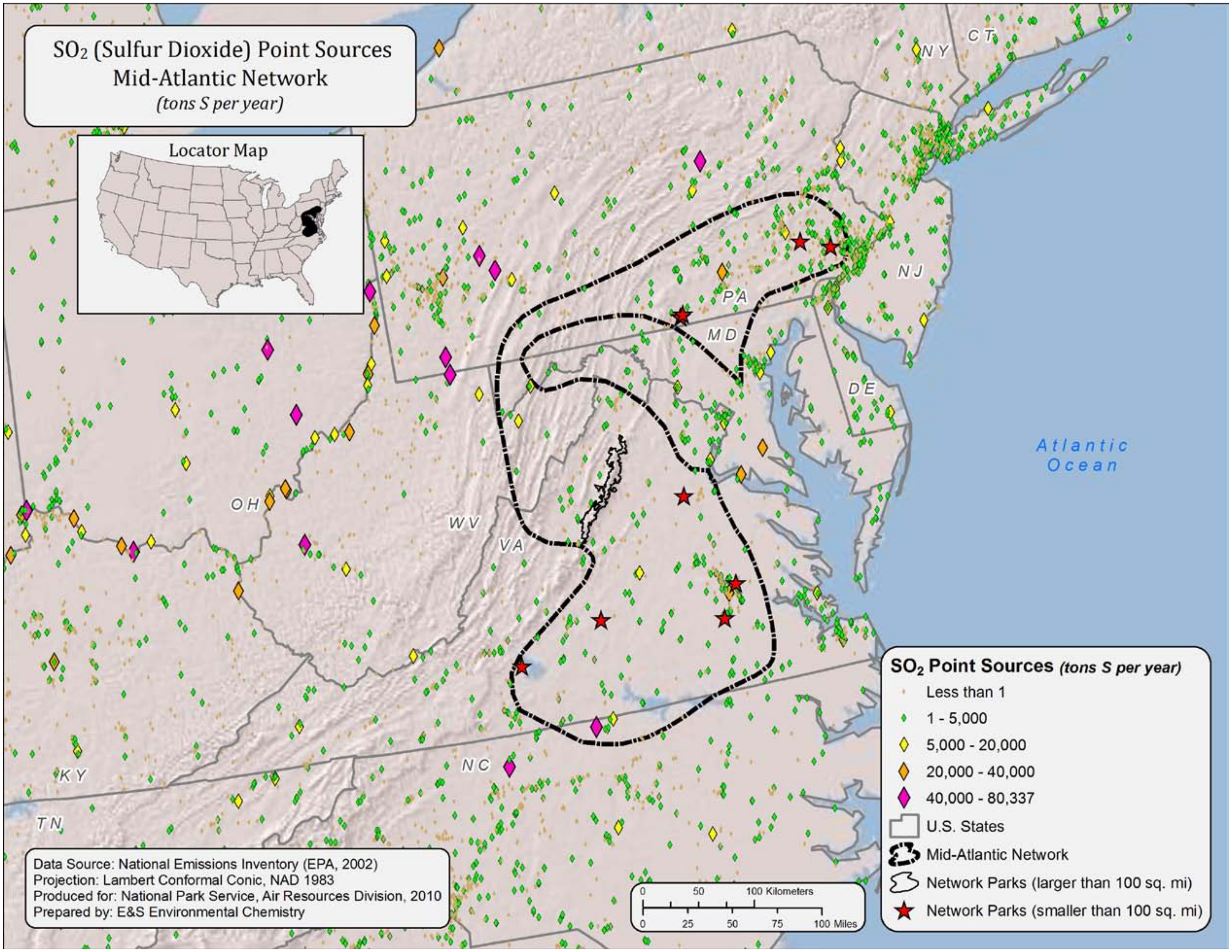
Map E

MIDN-12

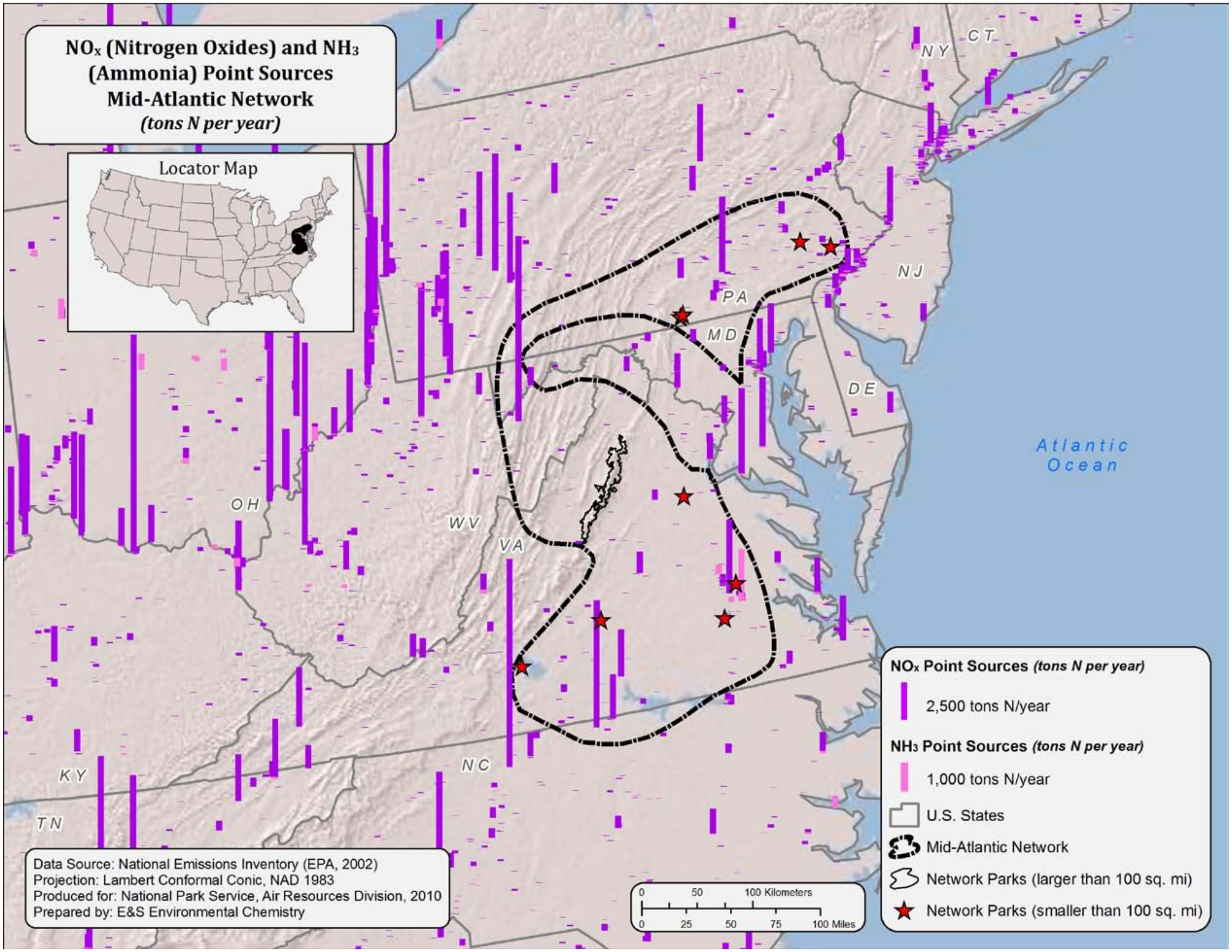


Total Nitrogen Emissions by County
Mid-Atlantic Network
(tons per square mile per year)
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Total N Emissions (tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 618
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
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

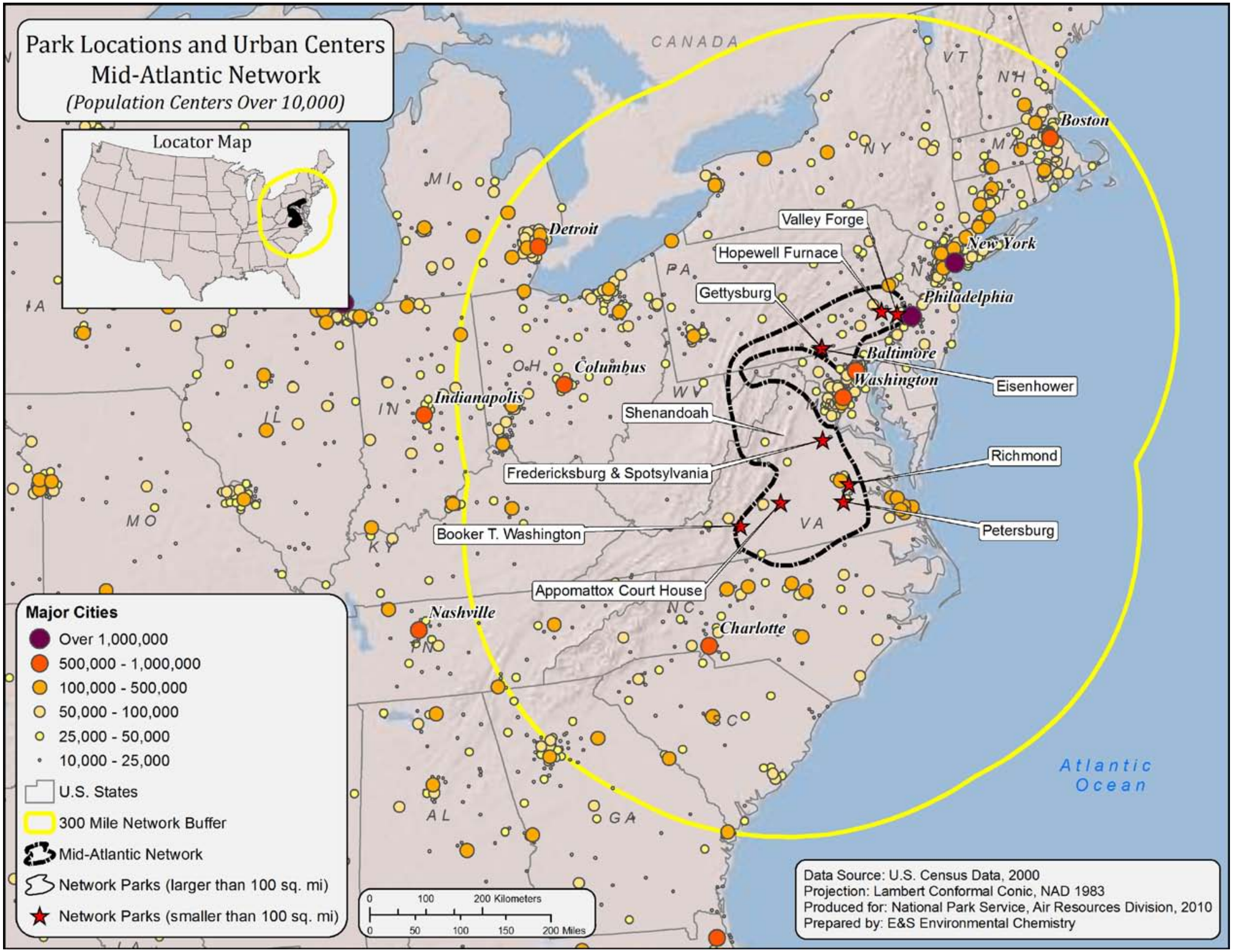
Map F


SO2 (Sulfur Dioxide) Point Sources
Mid-Atlantic Network
(tons S per year)
Locator Map
NY
CT
NJ
PA
MD
DE
OH
WV
VA
KY
TN
NC
Atlantic Ocean
SO2 Point Sources (tons S per year)
Less than 1
1 - 5,000
5,000 - 20,000
20,000 - 40,000
40,000 - 80,337
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
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
0 50 100 Kilometers
0 25 50 75 100 Miles

Map G

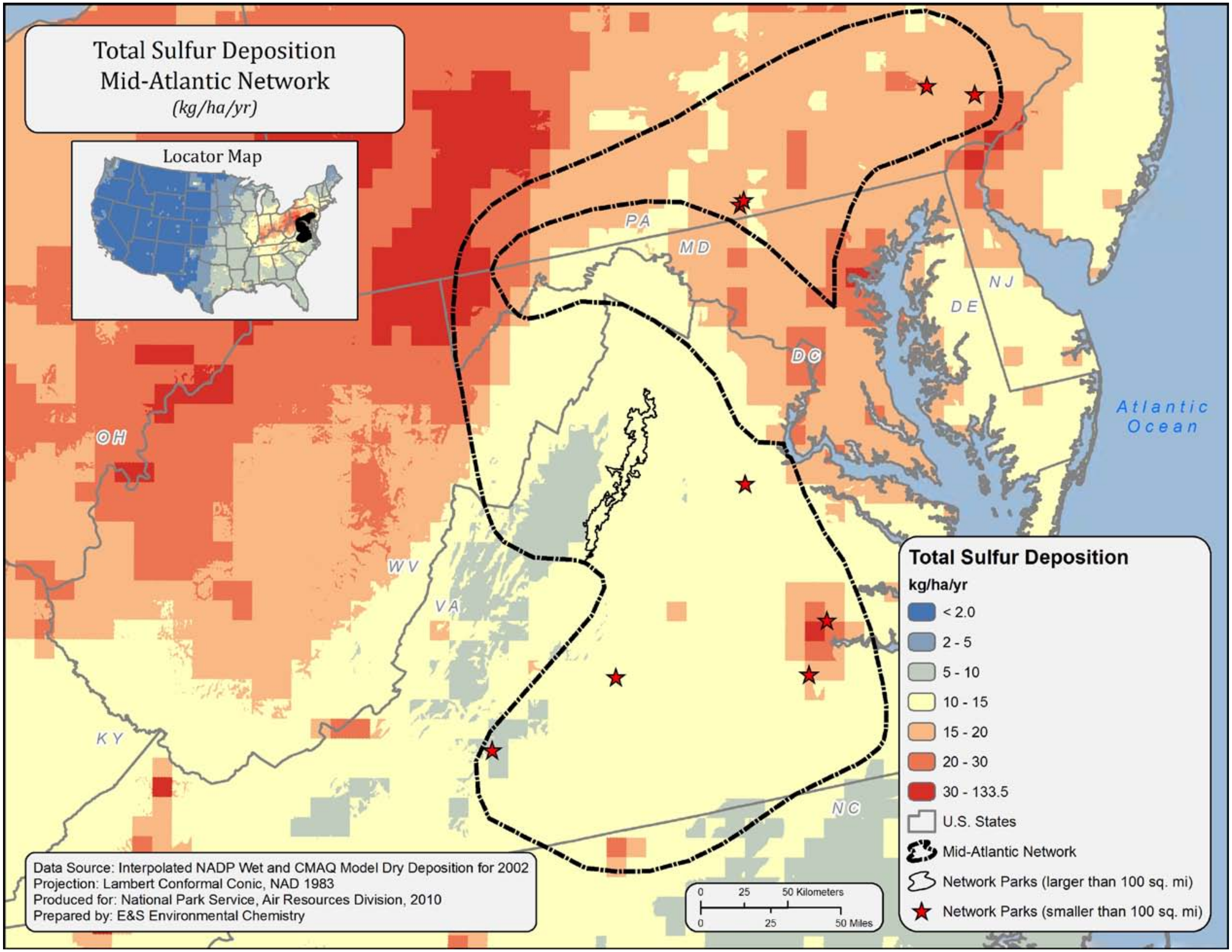

NOx (Nitrogen Oxides) and NH3 (Ammonia) Point Sources
Mid-Atlantic Network
(tons N per year)
Locator Map
NY
CT
NJ
PA
MD
DE
OH
WV
VA
KY
TN
NC
Atlantic Ocean
NOx Point Sources (tons N per year)
2,500 tons N/year
NH3 Point Sources (tons N per year)
1,000 tons N/year
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 50 100 Kilometers
0 25 50 75 100 Miles
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 H

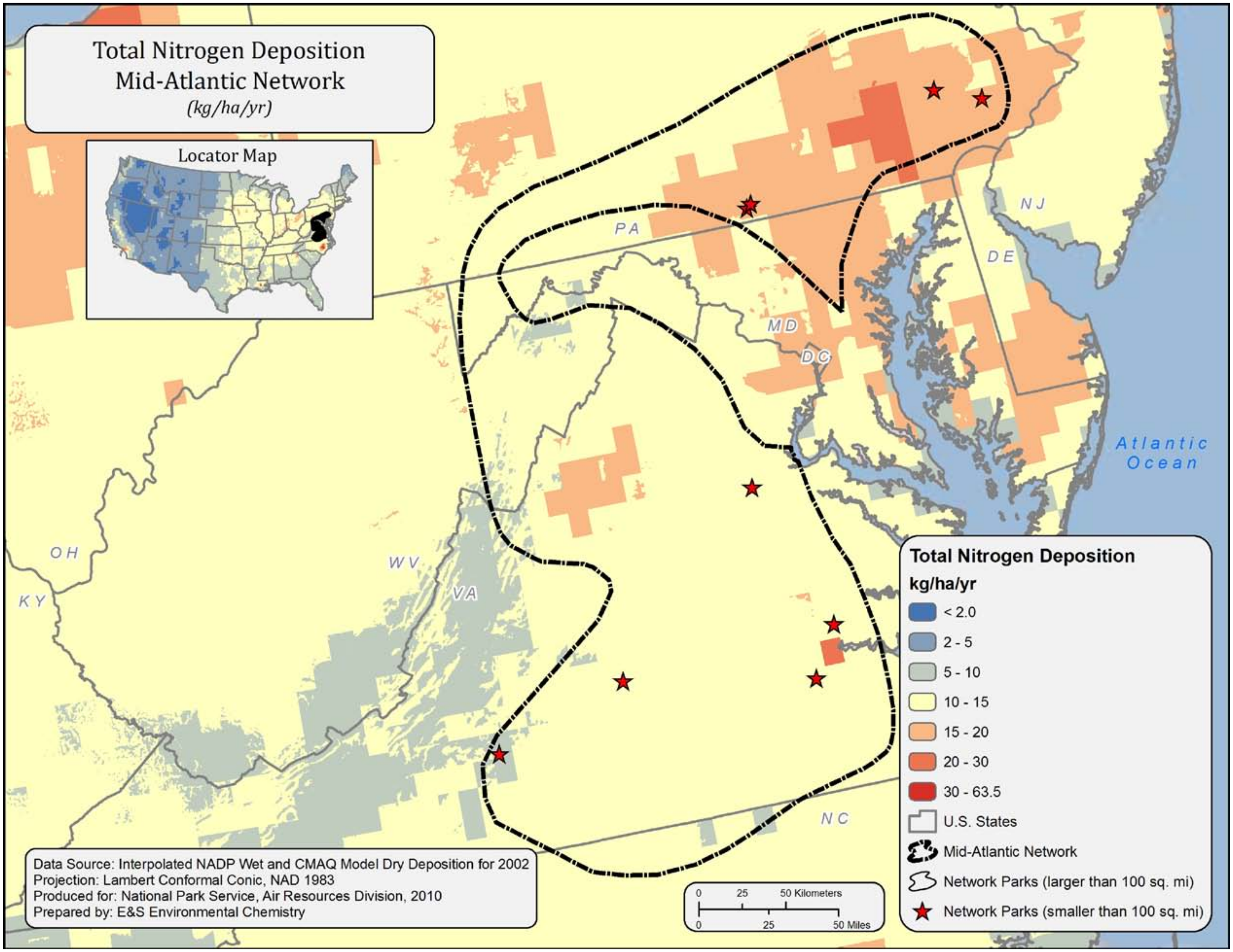


Park Locations and Urban Centers
Mid-Atlantic Network
(Population Centers Over 10,000)
Locator Map
Major Cities
Over 1,000,000
500,000 - 1,000,000
100,000 - 500,000
50,000 - 100,000
25,000 - 50,000
10,000 - 25,000
U.S. States
300 Mile Network Buffer
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Valley Forge
Hopewell Furnace
Gettysburg
Eisenhower
Shenandoah
Fredericksburg & Spotsylvania
Richmond
Petersburg
Booker T. Washington
Appomattox Court House
Boston
New York
Philadelphia
Baltimore
Washington
Detroit
Columbus
Indianapolis
Nashville
Charlotte
CANADA
Atlantic Ocean
Data Source: U.S. Census Data, 2000
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

Map I

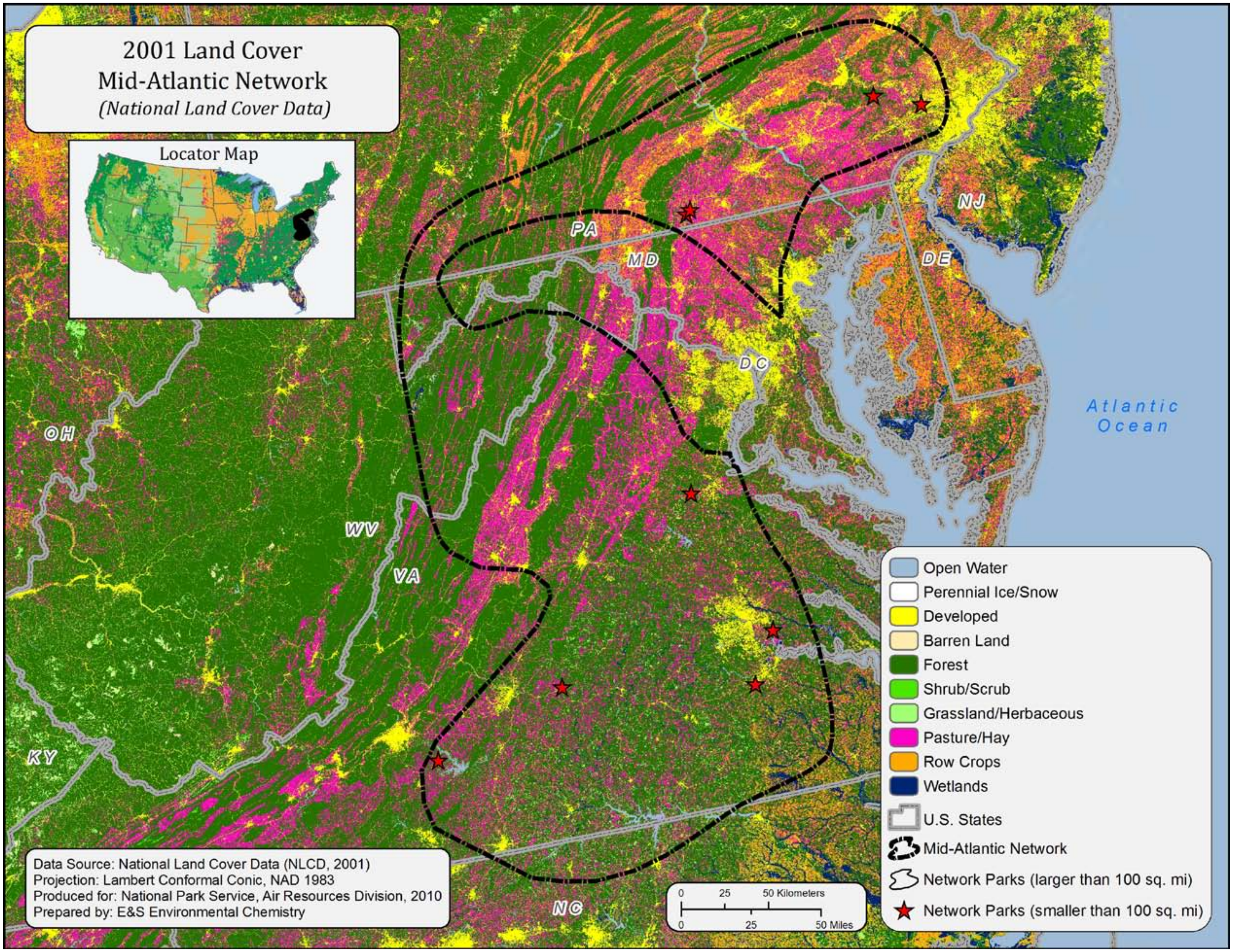

Total Sulfur Deposition
Mid-Atlantic Network
(kg/ha/yr)
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Total Sulfur Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 133.5
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: Interpolated NADP Wet and CMAQ 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
0 25 50 Kilometers
0 25 50 Miles

Map J

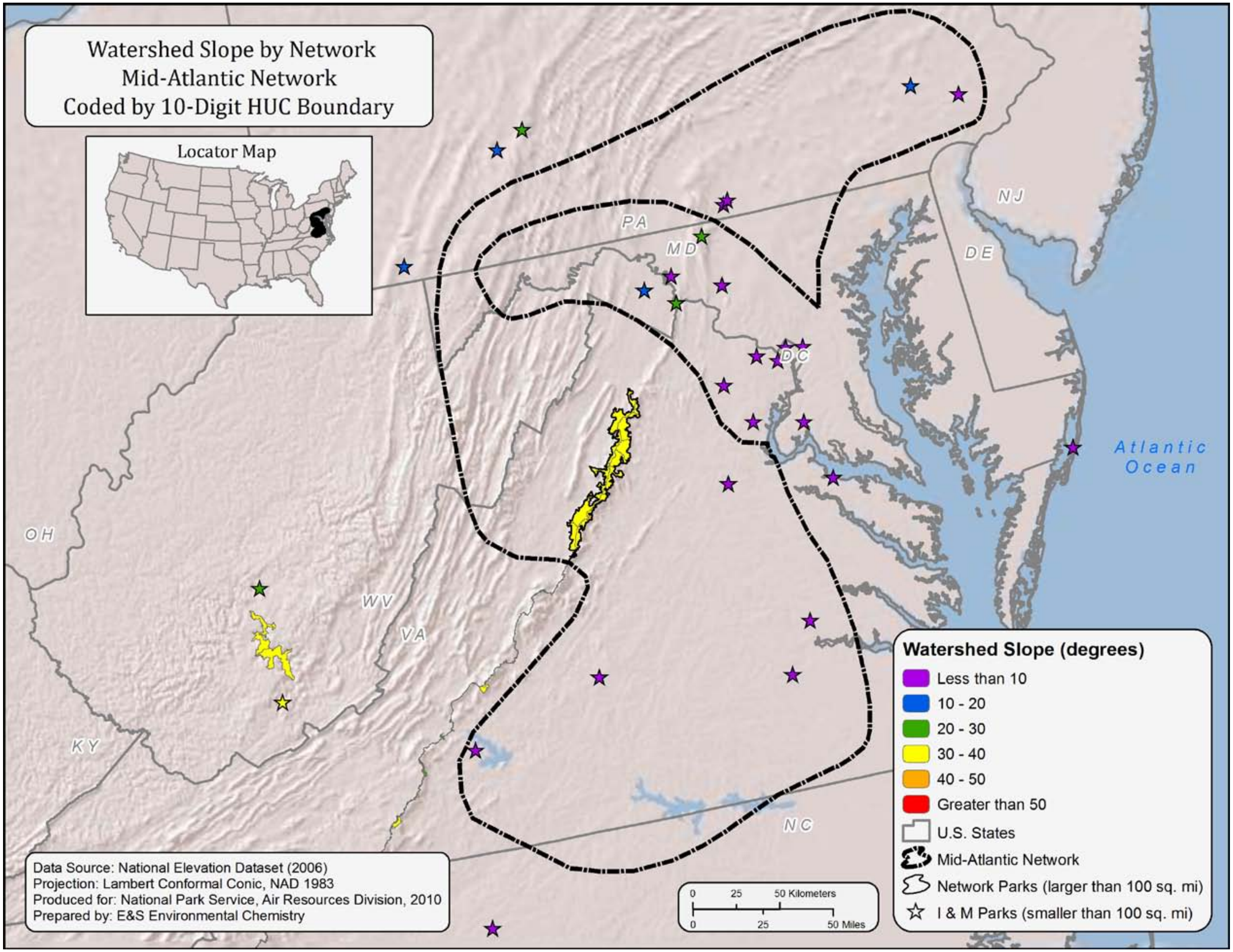


Total Nitrogen Deposition
Mid-Atlantic Network
(kg/ha/yr)
Locator Map
PA
NJ
DE
MD
DC
OH
KY
WV
VA
NC
Atlantic Ocean
Total Nitrogen Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: Interpolated NADP Wet and CMAQ 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
0 25 50 Kilometers
0 25 50 Miles

Map K


2001 Land Cover
Mid-Atlantic Network
(National Land Cover Data)
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetlands
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
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

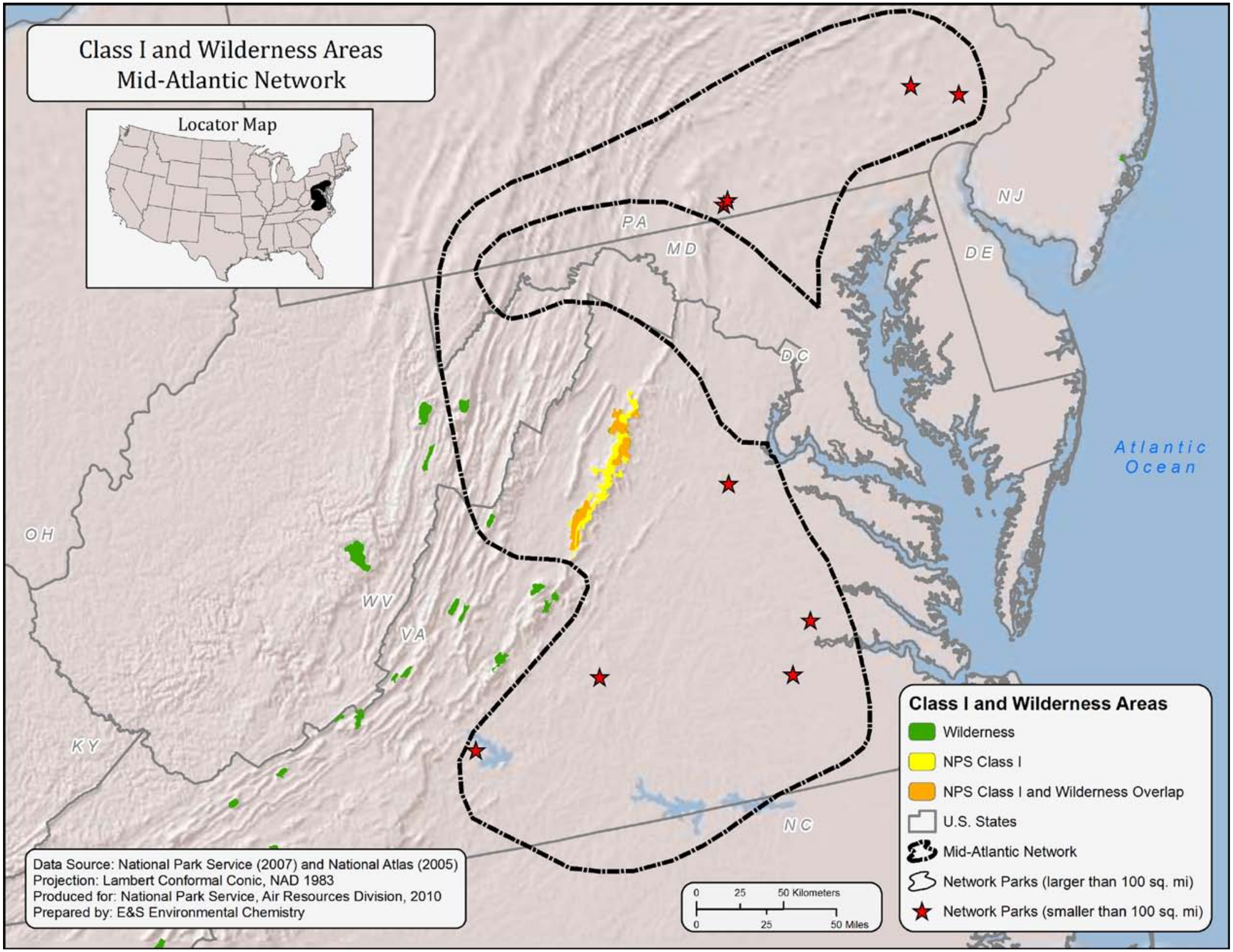
Map L



Watershed Slope by Network
Mid-Atlantic Network
Coded by 10-Digit HUC Boundary
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Watershed Slope (degrees)
Less than 10
10 - 20
20 - 30
30 - 40
40 - 50
Greater than 50
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
I & M Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
Data Source: National Elevation Dataset (2006)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

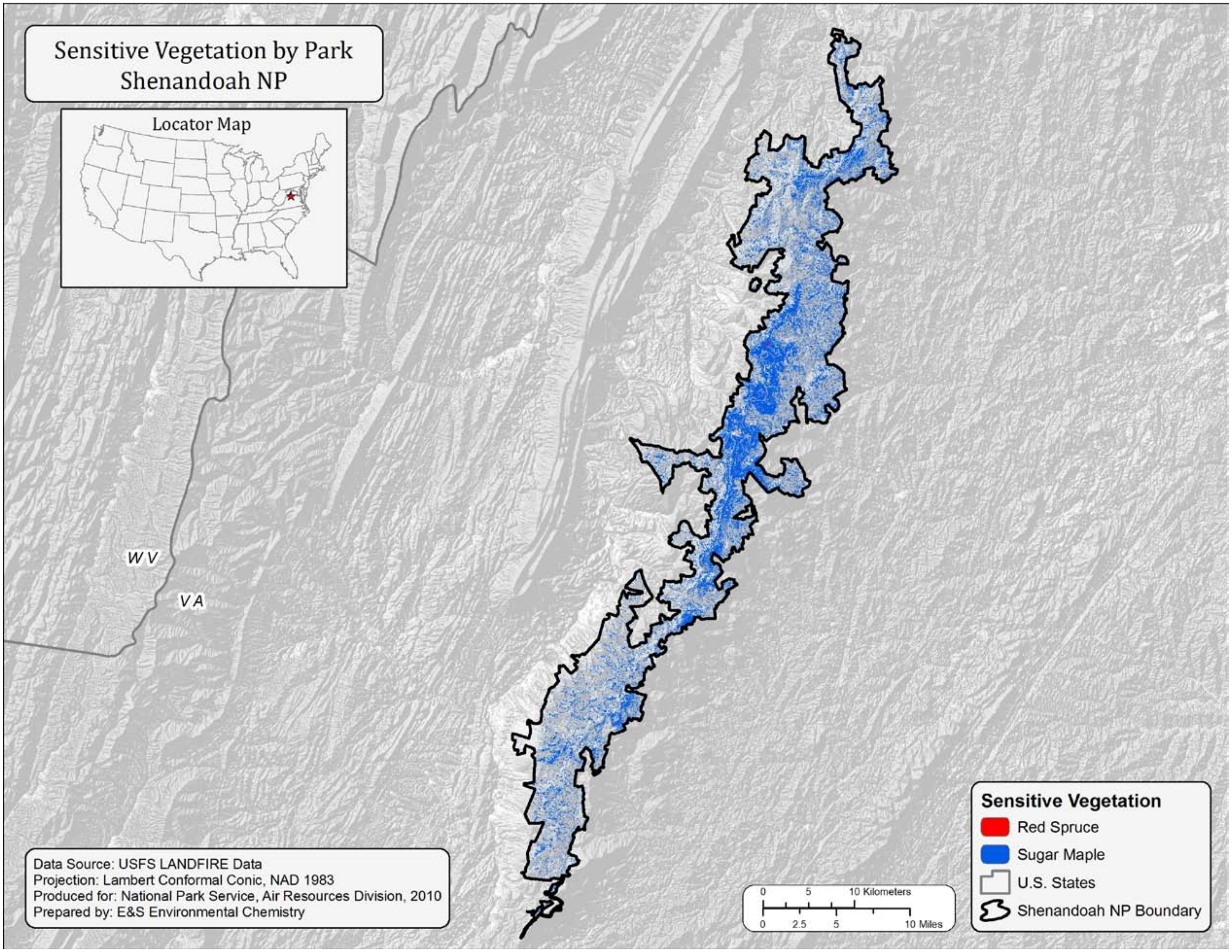
Map M

MIDN-20

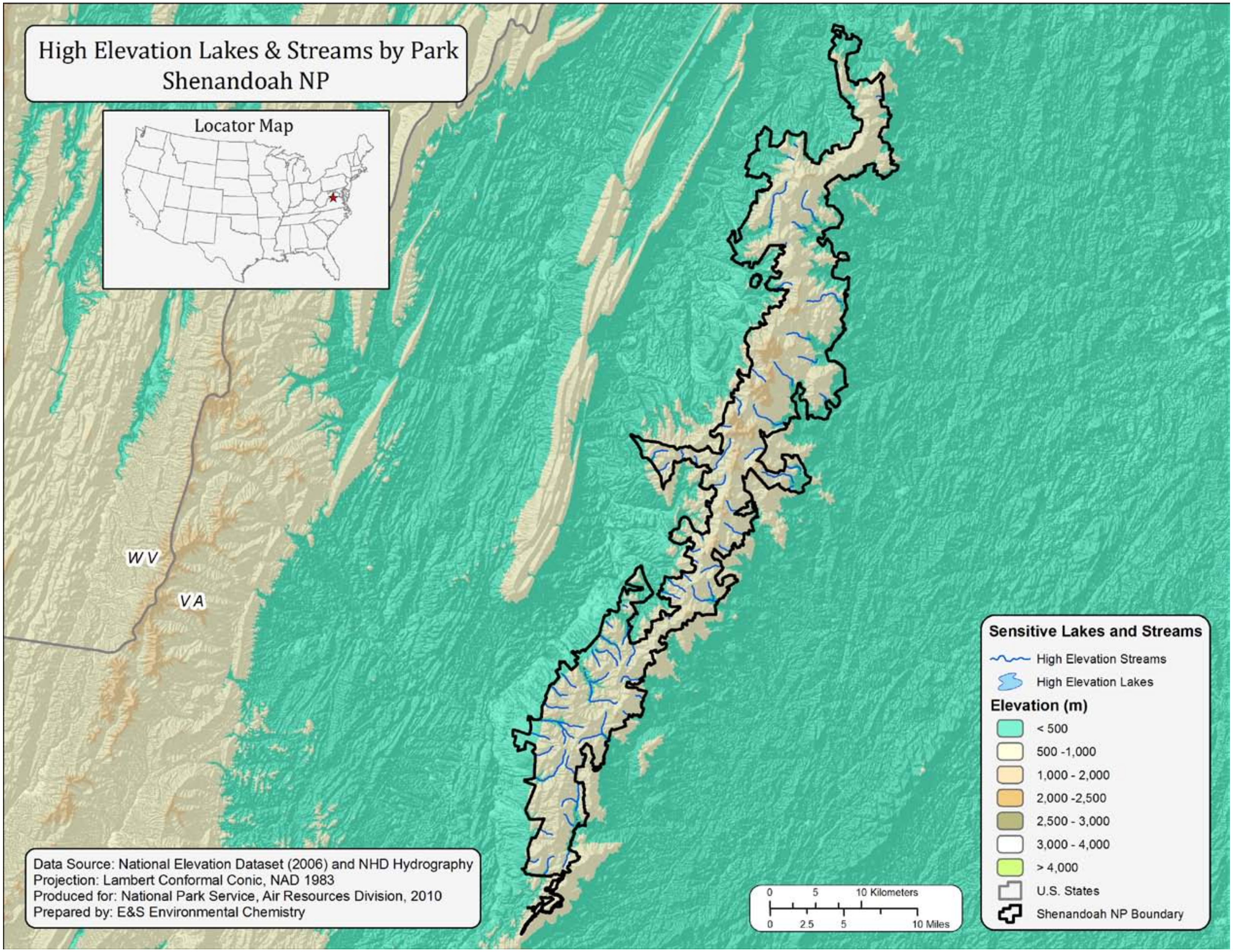


Class I and Wilderness Areas
Mid-Atlantic Network
Locator Map
PA
MD
NJ
DE
DC
OH
WV
VA
KY
NC
Atlantic Ocean
Class I and Wilderness Areas
Wilderness
NPS Class I
NPS Class I and Wilderness Overlap
U.S. States
Mid-Atlantic Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
Data Source: National Park Service (2007) and National Atlas (2005)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

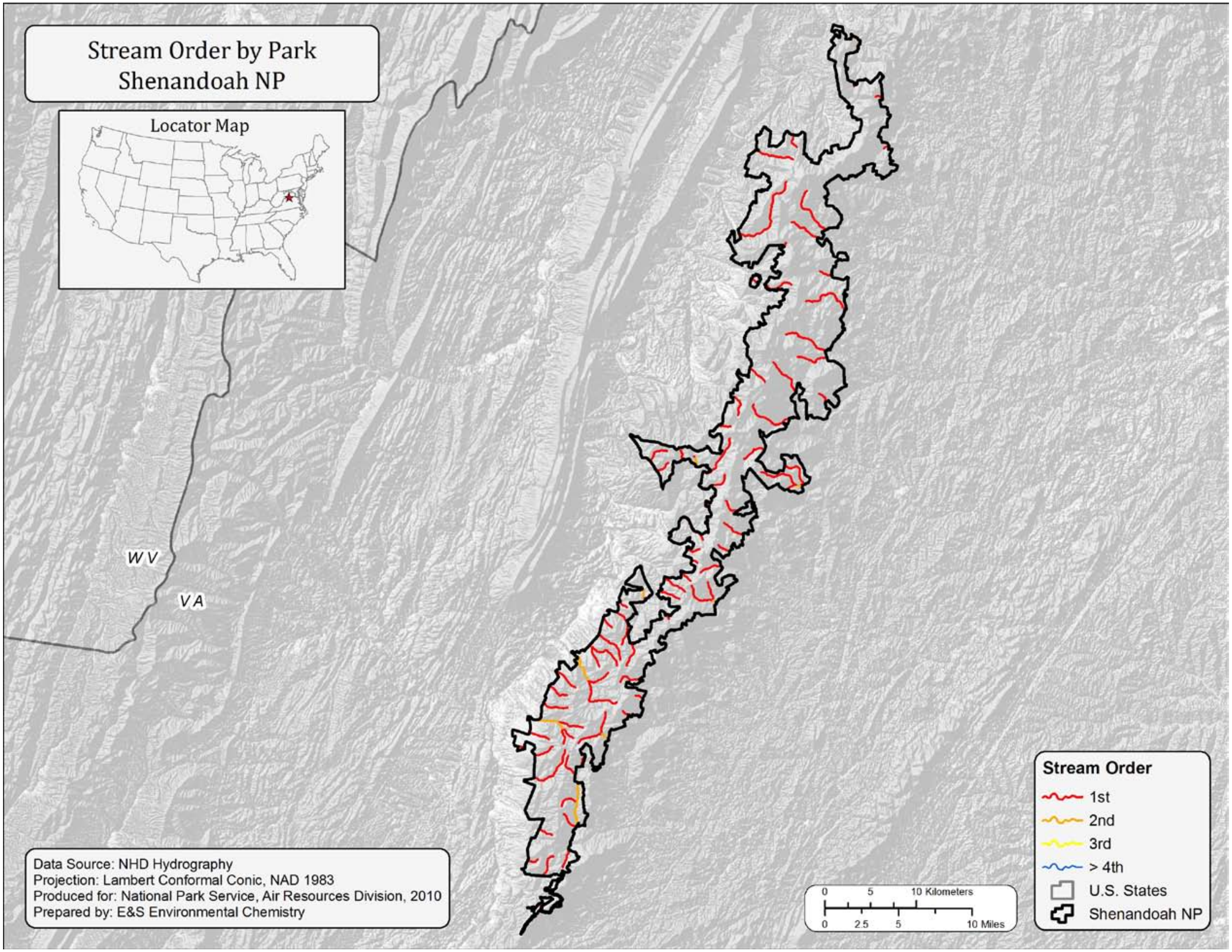
Map N


Sensitive Vegetation by Park
Shenandoah NP
Locator Map
WV
VA
Data Source: USFS LANDFIRE Data
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 5 10 Kilometers
0 2.5 5 10 Miles
Sensitive Vegetation
Red Spruce
Sugar Maple
U.S. States
Shenandoah NP Boundary

Map P-1


High Elevation Lakes & Streams by Park
Shenandoah NP
Locator Map
WV
VA
Sensitive Lakes and Streams
High Elevation Streams
High Elevation Lakes
Elevation (m)
< 500
500 -1,000
1,000 - 2,000
2,000 -2,500
2,500 - 3,000
3,000 - 4,000
> 4,000
U.S. States
Shenandoah NP Boundary
0 5 10 Kilometers
0 2.5 5 10 Miles
Data Source: National Elevation Dataset (2006) and NHD Hydrography
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

Map P-2


Stream Order by Park
Shenandoah NP
Locator Map
W V
V A
Data Source: NHD Hydrography
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 5 10 Kilometers
0 2.5 5 10 Miles
Stream Order
1st
2nd
3rd
> 4th
U.S. States
Shenandoah NP

Map P-3

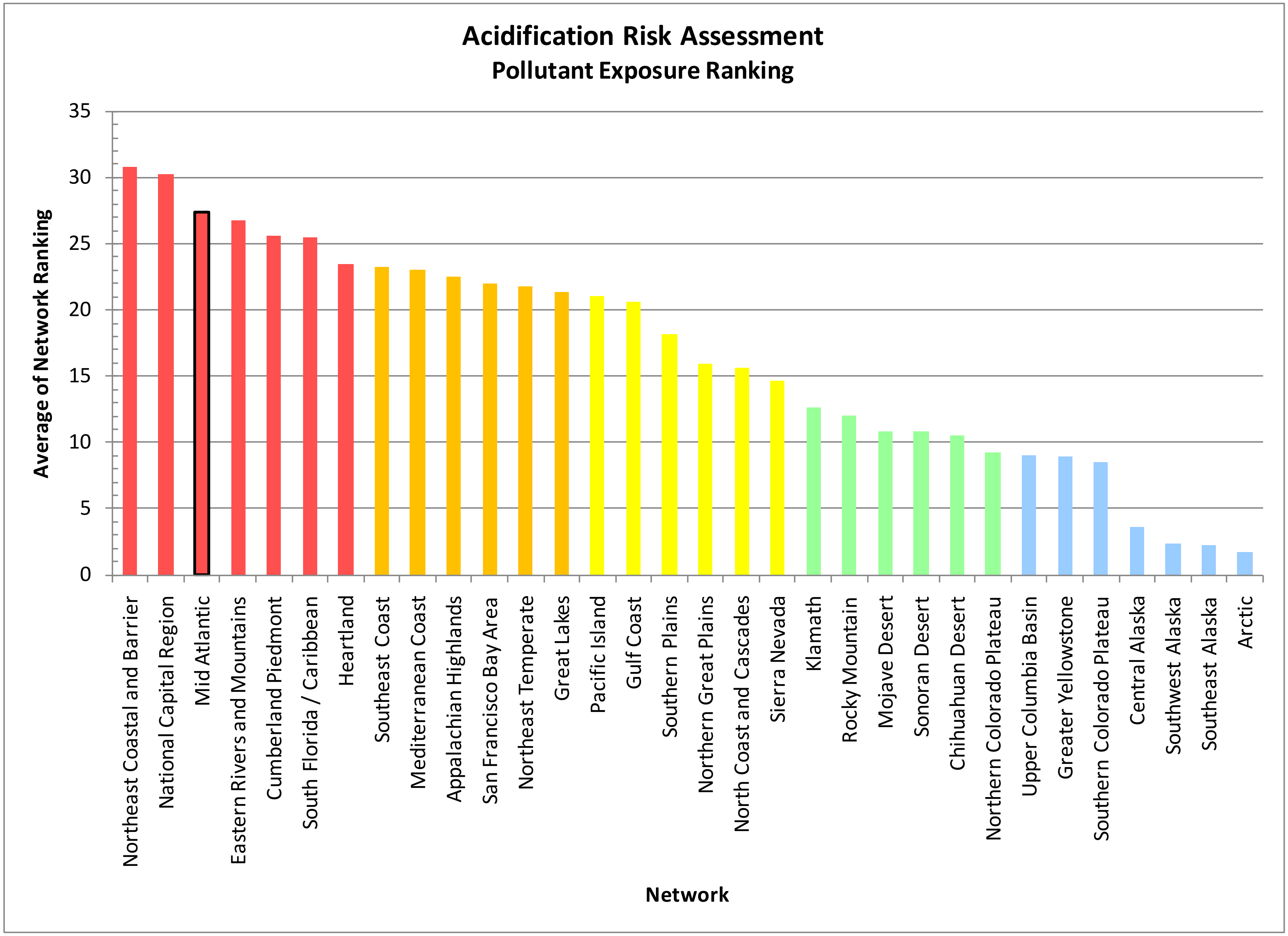

Acidification Risk Assessment
Pollutant Exposure Ranking
Average of Network Ranking
0
5
10
15
20
25
30
35
Northeast Coastal and Barrier
National Capital Region
Mid Atlantic
Eastern Rivers and Mountains
Cumberland Piedmont
South Florida / Caribbean
Heartland
Southeast Coast
Mediterranean Coast
Appalachian Highlands
San Francisco Bay Area
Northeast Temperate
Great Lakes
Pacific Island
Gulf Coast
Southern Plains
Northern Great Plains
North Coast and Cascades
Sierra Nevada
Klamath
Rocky Mountain
Mojave Desert
Sonoran Desert
Chihuahuan Desert
Northern Colorado Plateau
Upper Columbia Basin
Greater Yellowstone
Southern Colorado Plateau
Central Alaska
Southwest Alaska
Southeast Alaska
Arctic
Network

Figure A

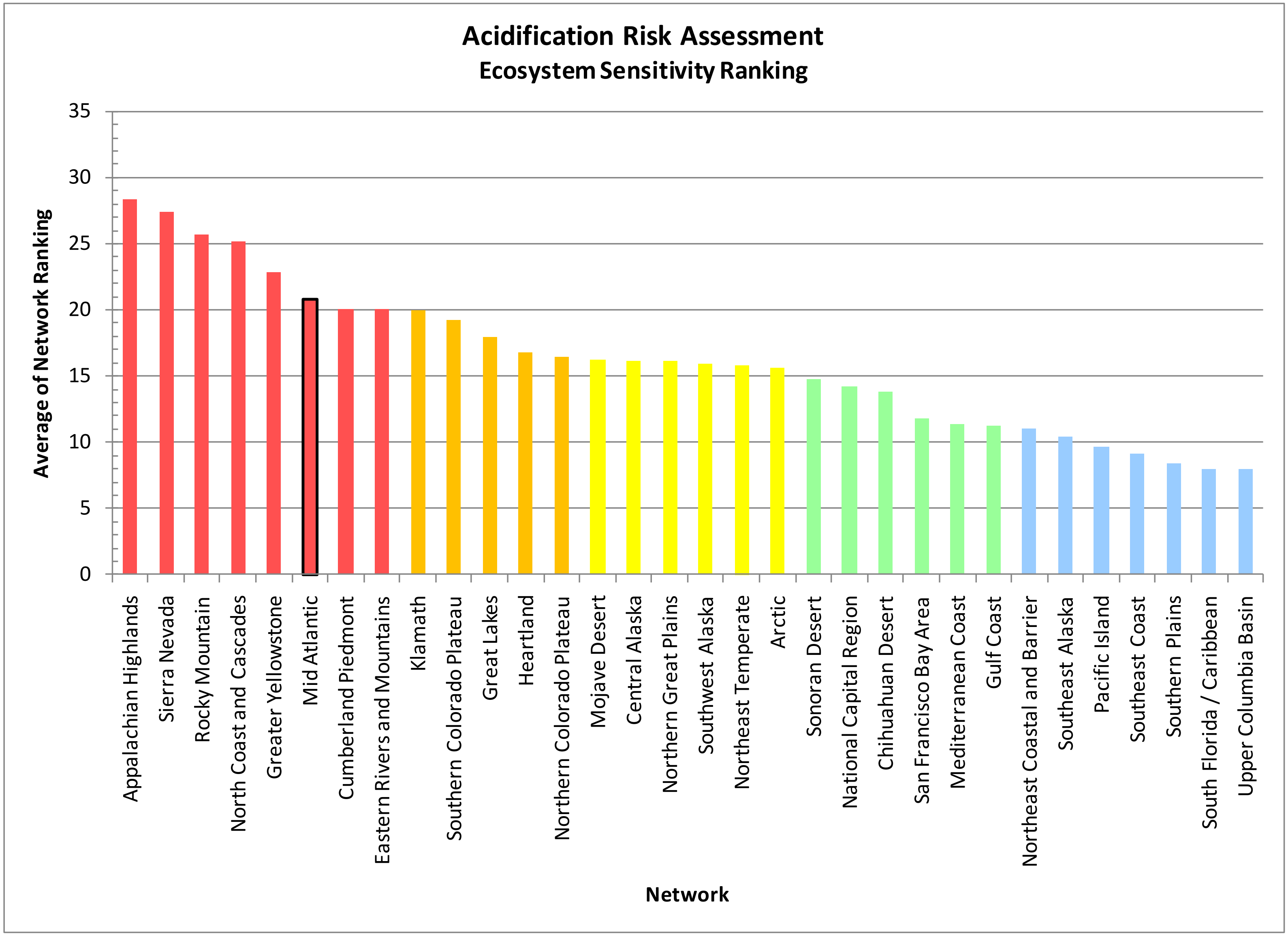

Acidification Risk Assessment
Ecosystem Sensitivity Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Appalachian Highlands
Sierra Nevada
Rocky Mountain
North Coast and Cascades
Greater Yellowstone
Mid Atlantic
Cumberland Piedmont
Eastern Rivers and Mountains
Klamath
Southern Colorado Plateau
Great Lakes
Heartland
Northern Colorado Plateau
Mojave Desert
Central Alaska
Northern Great Plains
Southwest Alaska
Northeast Temperate
Arctic
Sonoran Desert
National Capital Region
Chihuahuan Desert
San Francisco Bay Area
Mediterranean Coast
Gulf Coast
Northeast Coastal and Barrier
Southeast Alaska
Pacific Island
Southeast Coast
Southern Plains
South Florida / Caribbean
Upper Columbia Basin
Network

Figure B

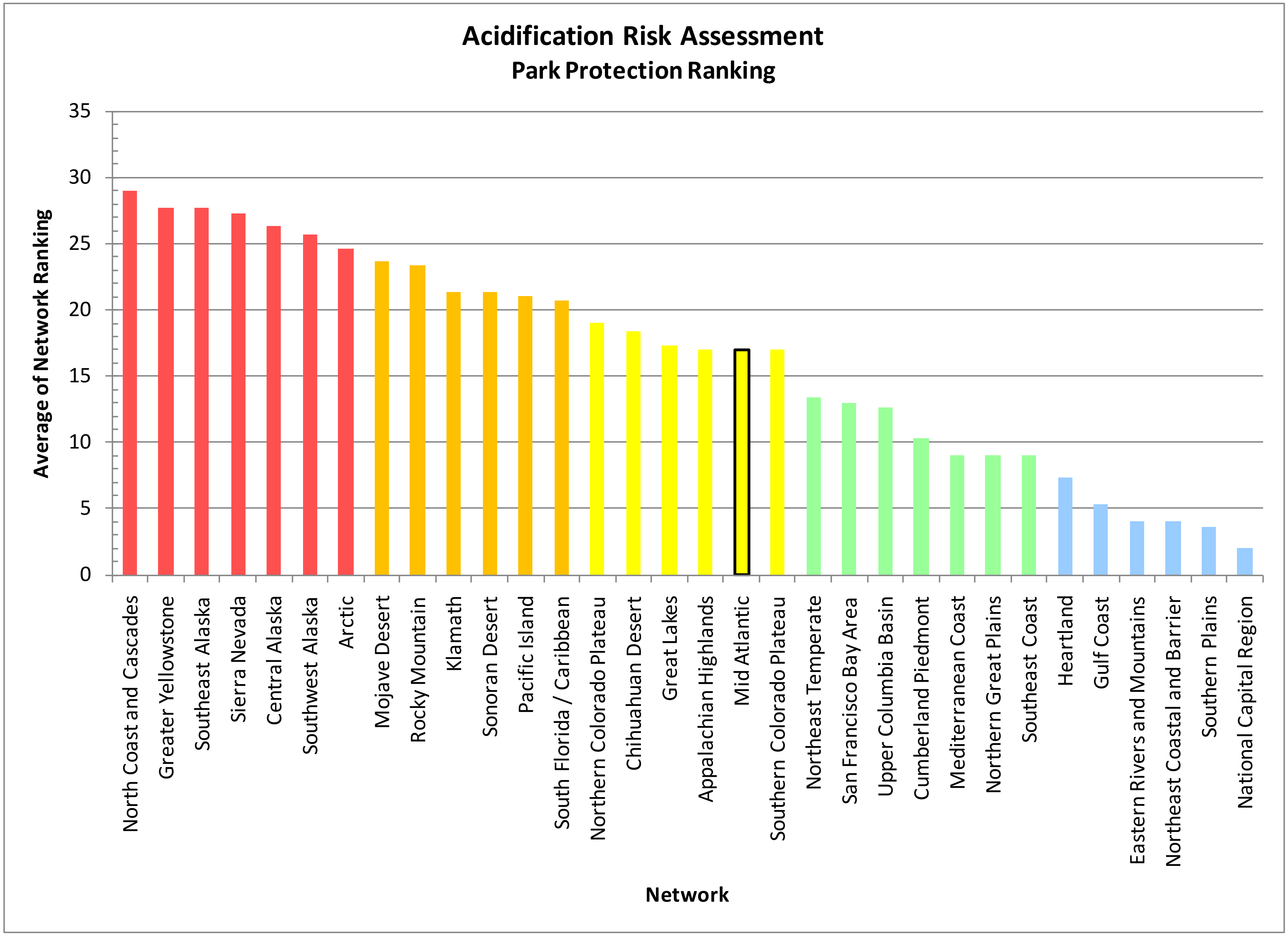

Acidification Risk Assessment
Park Protection Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
North Coast and Cascades
Greater Yellowstone
Southeast Alaska
Sierra Nevada
Central Alaska
Southwest Alaska
Arctic
Mojave Desert
Rocky Mountain
Klamath
Sonoran Desert
Pacific Island
South Florida / Caribbean
Northern Colorado Plateau
Chihuahuan Desert
Great Lakes
Appalachian Highlands
Mid Atlantic
Southern Colorado Plateau
Northeast Temperate
San Francisco Bay Area
Upper Columbia Basin
Cumberland Piedmont
Mediterranean Coast
Northern Great Plains
Southeast Coast
Heartland
Gulf Coast
Eastern Rivers and Mountains
Northeast Coastal and Barrier
Southern Plains
National Capital Region
Network

Figure C

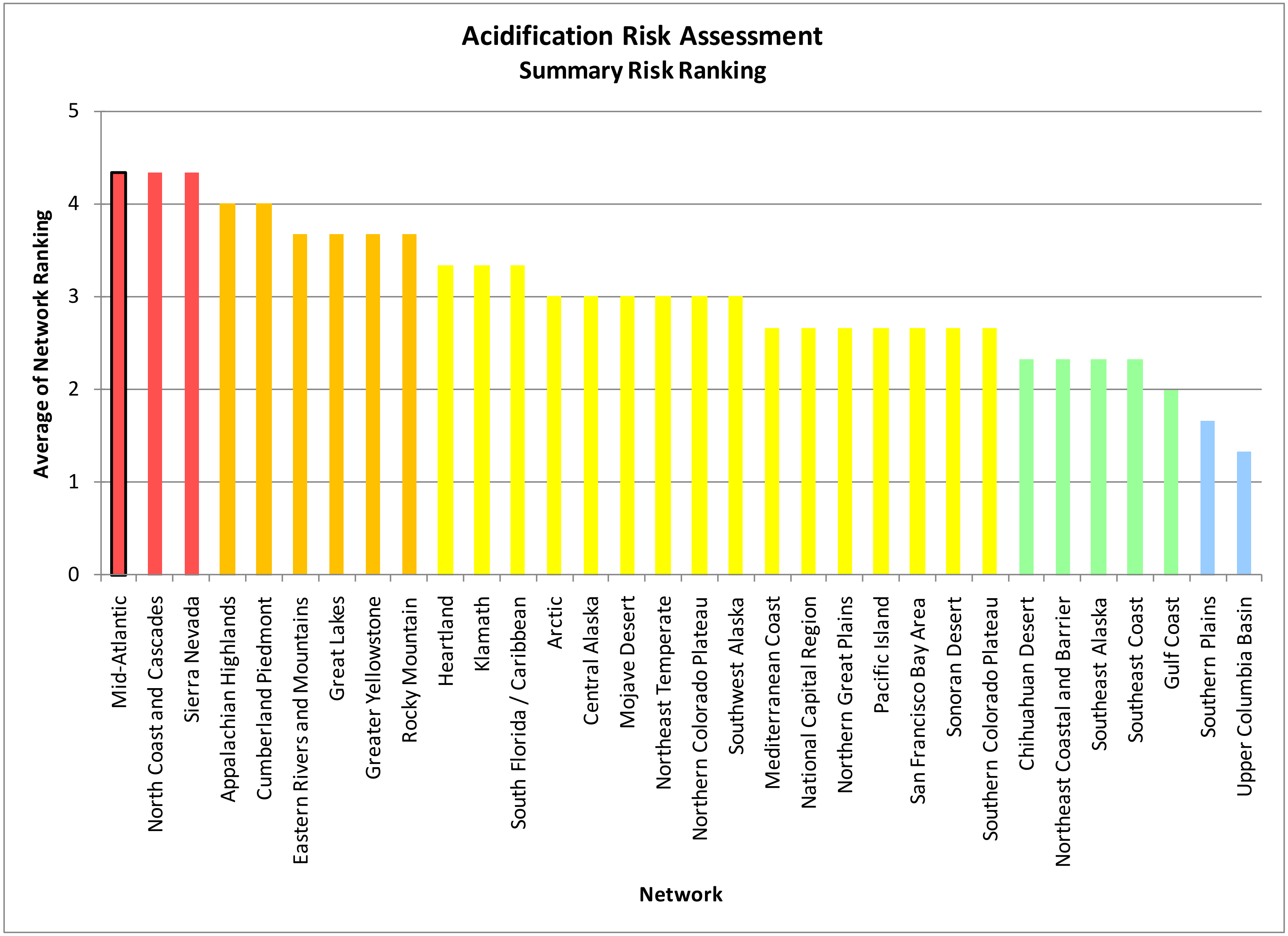

Acidification Risk Assessment
Summary Risk Ranking
Average of Network Ranking
0
1
2
3
4
5
Network
Mid-Atlantic
North Coast and Cascades
Sierra Nevada
Appalachian Highlands
Cumberland Piedmont
Eastern Rivers and Mountains
Great Lakes
Greater Yellowstone
Rocky Mountain
Heartland
Klamath
South Florida / Caribbean
Arctic
Central Alaska
Mojave Desert
Northeast Temperate
Northern Colorado Plateau
Southwest Alaska
Mediterranean Coast
National Capital Region
Northern Great Plains
Pacific Island
San Francisco Bay Area
Sonoran Desert
Southern Colorado Plateau
Chihuahuan Desert
Northeast Coastal and Barrier
Southeast Alaska
Southeast Coast
Gulf Coast
Southern Plains
Upper Columbia Basin

Figure D

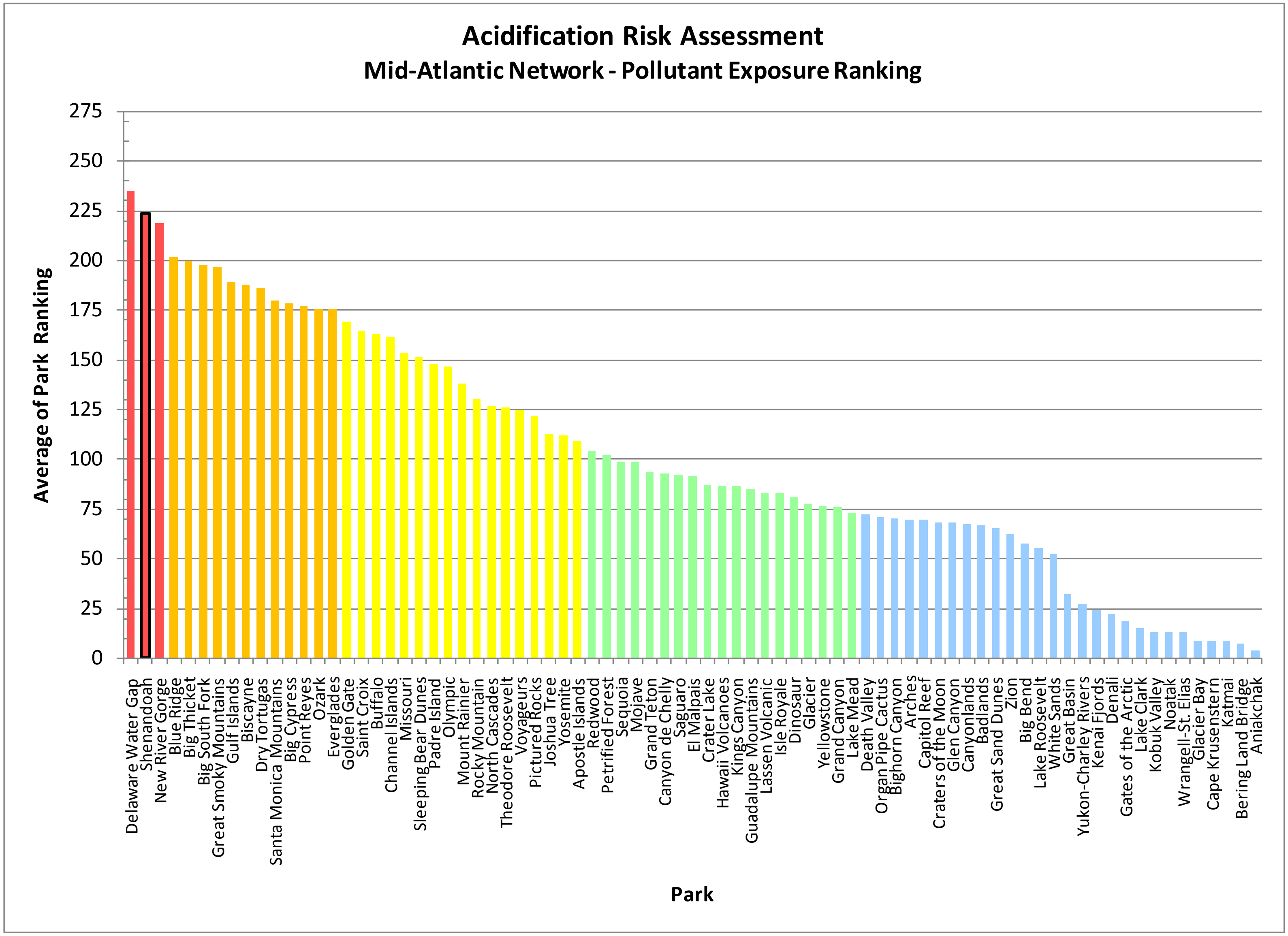

Acidification Risk Assessment
Mid-Atlantic Network - Pollutant Exposure Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Delaware Water Gap
Shenandoah
New River Gorge
Blue Ridge
Big Thicket
Big South Fork
Great Smoky Mountains
Gulf Islands
Biscayne
Dry Tortugas
Santa Monica Mountains
Big Cypress
Point Reyes
Ozark
Everglades
Golden Gate
Saint Croix
Buffalo
Channel Islands
Missouri
Sleeping Bear Dunes
Padre Island
Olympic
Mount Rainier
Rocky Mountain
North Cascades
Theodore Roosevelt
Voyageurs
Pictured Rocks
Joshua Tree
Yosemite
Apostle Islands
Redwood
Petrified Forest
Sequoia
Mojave
Grand Teton
Canyon de Chelly
Saguaro
El Malpais
Crater Lake
Hawaii Volcanoes
Kings Canyon
Guadalupe Mountains
Lassen Volcanic
Isle Royale
Dinosaur
Glacier
Yellowstone
Grand Canyon
Lake Mead
Death Valley
Organ Pipe Cactus
Bighorn Canyon
Arches
Capitol Reef
Craters of the Moon
Glen Canyon
Canyonlands
Badlands
Great Sand Dunes
Zion
Big Bend
Lake Roosevelt
White Sands
Great Basin
Yukon-Charley Rivers
Kenai Fjords
Denali
Gates of the Arctic
Lake Clark
Kobuk Valley
Noatak
Wrangell-St. Elias
Glacier Bay
Cape Krusenstern
Katmai
Bering Land Bridge
Aniakchak
Park

Figure E

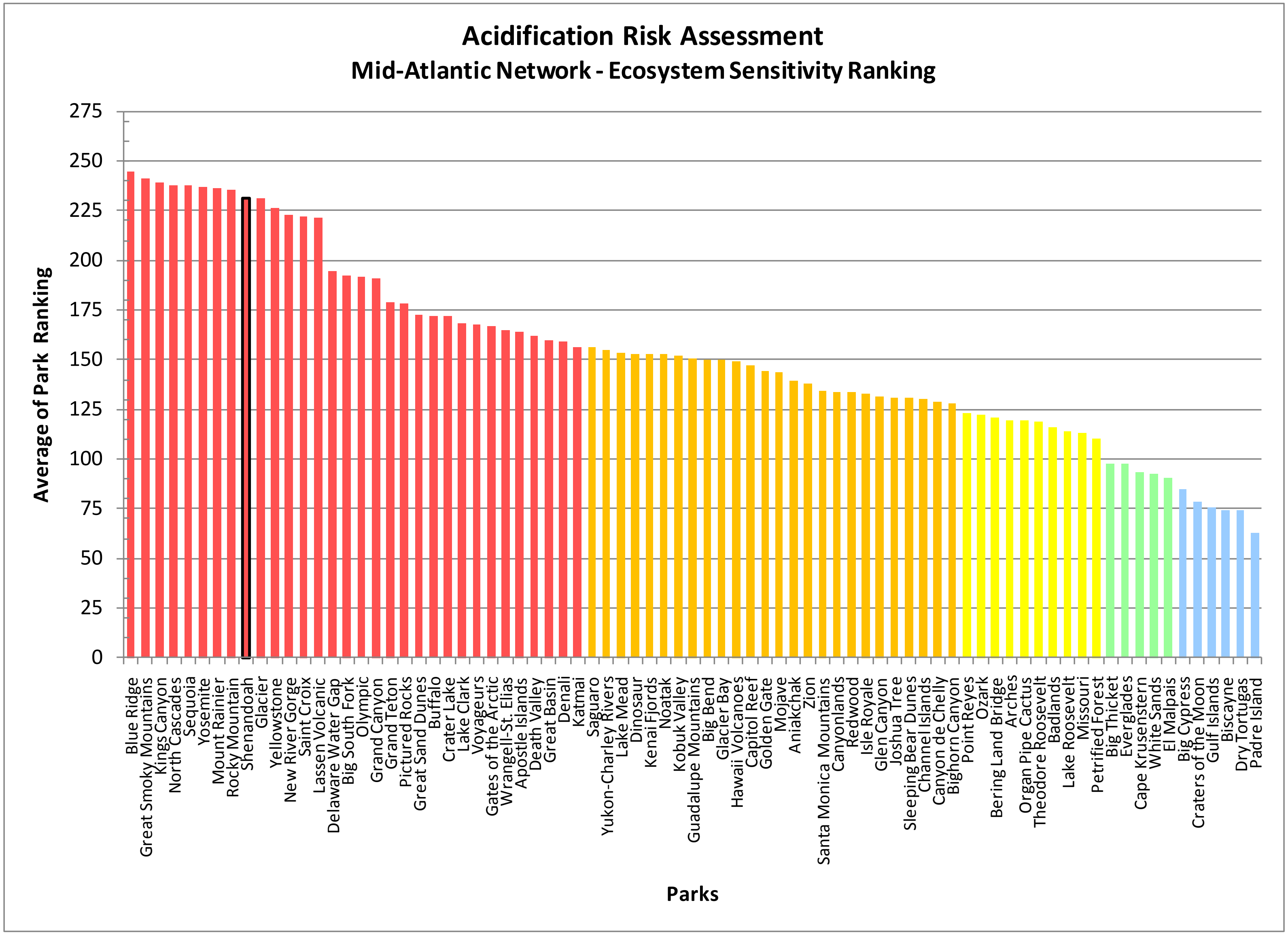

Acidification Risk Assessment
Mid-Atlantic Network - Ecosystem Sensitivity Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Blue Ridge
Great Smoky Mountains
Kings Canyon
North Cascades
Sequoia
Yosemite
Mount Rainier
Rocky Mountain
Shenandoah
Glacier
Yellowstone
New River Gorge
Saint Croix
Lassen Volcanic
Delaware Water Gap
Big South Fork
Olympic
Grand Canyon
Grand Teton
Pictured Rocks
Great Sand Dunes
Buffalo
Crater Lake
Lake Clark
Voyageurs
Gates of the Arctic
Wrangell-St. Elias
Apostle Islands
Death Valley
Great Basin
Denali
Katmai
Saguaro
Yukon-Charley Rivers
Lake Mead
Dinosaur
Kenai Fjords
Noatak
Kobuk Valley
Guadalupe Mountains
Big Bend
Glacier Bay
Hawaii Volcanoes
Capitol Reef
Golden Gate
Mojave
Aniakchak
Zion
Santa Monica Mountains
Canyonlands
Redwood
Isle Royale
Glen Canyon
Joshua Tree
Sleeping Bear Dunes
Channel Islands
Canyon de Chelly
Bighorn Canyon
Point Reyes
Ozark
Bering Land Bridge
Arches
Organ Pipe Cactus
Theodore Roosevelt
Badlands
Lake Roosevelt
Missouri
Petrified Forest
Big Thicket
Everglades
Cape Krusenstern
White Sands
El Malpais
Big Cypress
Craters of the Moon
Gulf Islands
Biscayne
Dry Tortugas
Padre Island
Parks

Figure F

MIDN-30

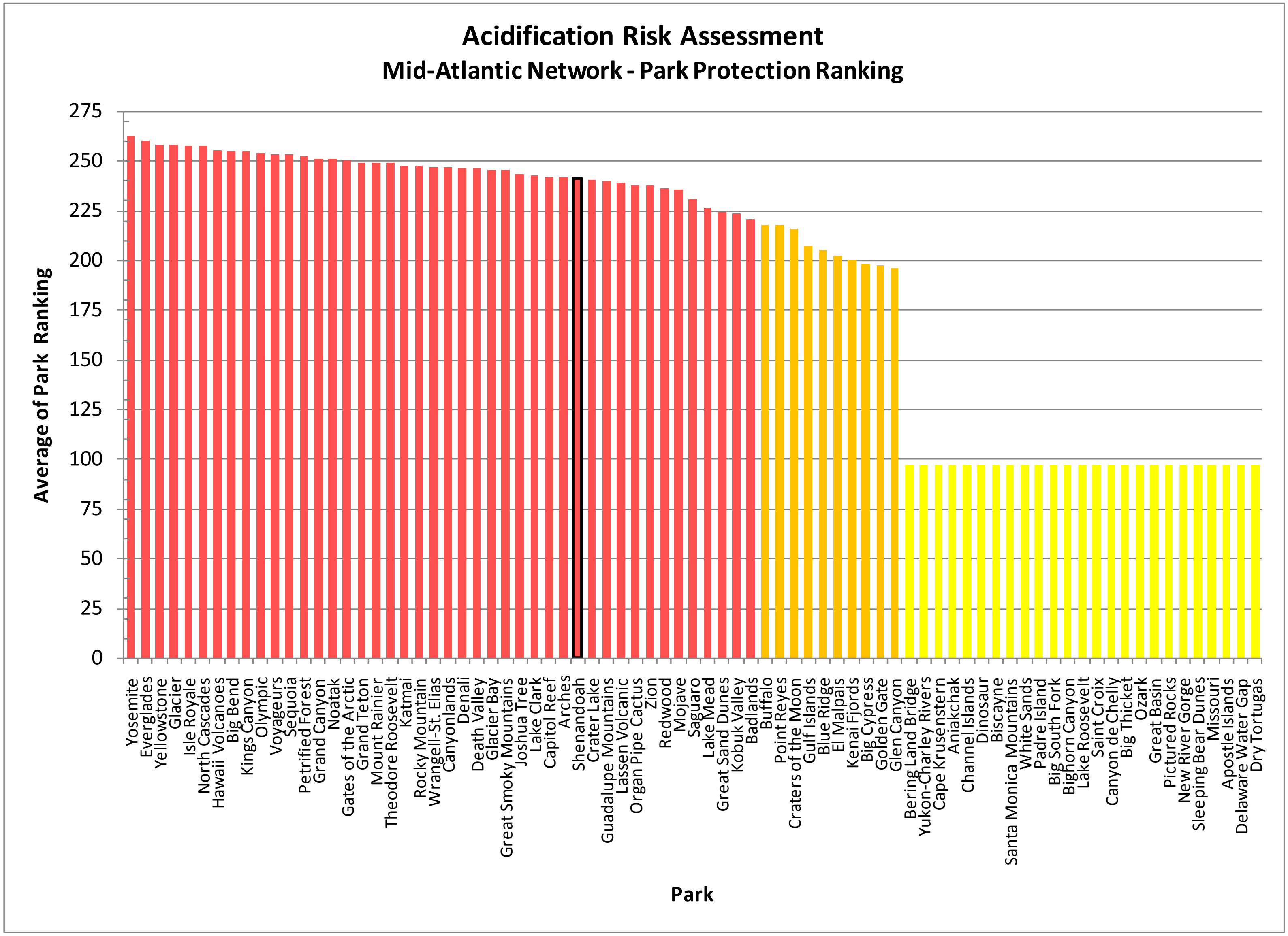


Figure G

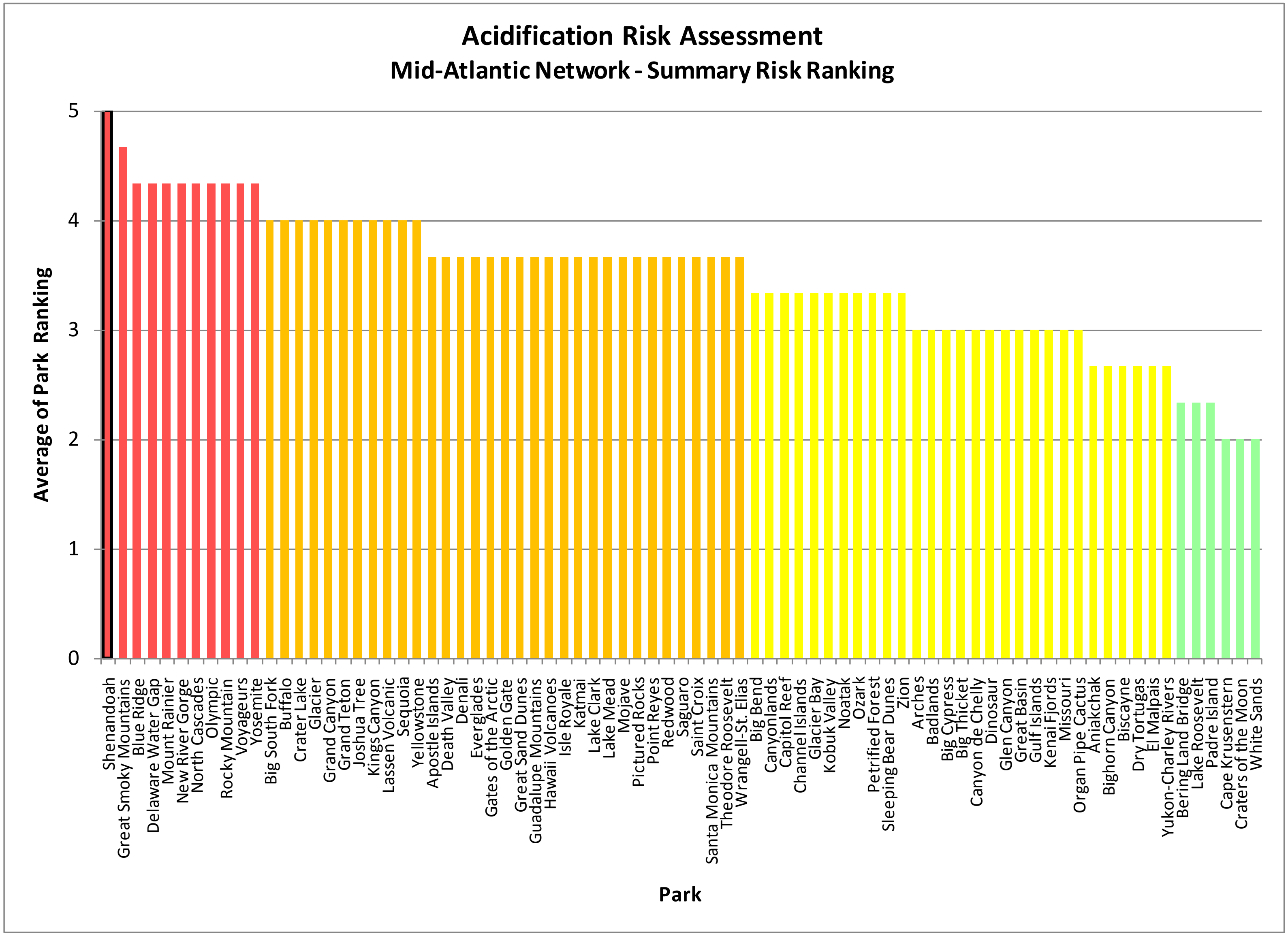

Acidification Risk Assessment
Mid-Atlantic Network - Summary Risk Ranking
Average of Park Ranking
0
1
2
3
4
5
Park
Shenandoah
Great Smoky Mountains
Blue Ridge
Delaware Water Gap
Mount Rainier
New River Gorge
North Cascades
Olympic
Rocky Mountain
Voyageurs
Yosemite
Big South Fork
Buffalo
Crater Lake
Glacier
Grand Canyon
Grand Teton
Joshua Tree
Kings Canyon
Lassen Volcanic
Sequoia
Yellowstone
Apostle Islands
Death Valley
Denali
Everglades
Gates of the Arctic
Golden Gate
Great Sand Dunes
Guadalupe Mountains
Hawaii Volcanoes
Isle Royale
Katmai
Lake Clark
Lake Mead
Mojave
Pictured Rocks
Point Reyes
Redwood
Saguaro
Saint Croix
Santa Monica Mountains
Theodore Roosevelt
Wrangell-St. Elias
Big Bend
Canyonlands
Capitol Reef
Channel Islands
Glacier Bay
Kobuk Valley
Noatak
Ozark
Petrified Forest
Sleeping Bear Dunes
Zion
Arches
Badlands
Big Cypress
Big Thicket
Canyon de Chelly
Dinosaur
Glen Canyon
Great Basin
Gulf Islands
Kenai Fjords
Missouri
Organ Pipe Cactus
Aniakchak
Bighorn Canyon
Biscayne
Dry Tortugas
El Malpais
Yukon-Charley Rivers
Bering Land Bridge
Lake Roosevelt
Padre Island
Cape Krusenstern
Craters of the Moon
White Sands

Figure H

NPS 962/107398, April 2011

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Air Resources Division
PO Box 25287
Denver, CO 80225

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