National Park Service
U.S. Department of the Interior

Natural Resource Program Center

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

Rocky Mountain Network (ROMN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/324

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

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February 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Denver, Colorado

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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/n-sensitivity.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Rocky Mountain Network (ROMN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/324. National Park Service, Denver, Colorado..

NPS 960/106688, February 2011

Rocky Mountain Network (ROMN)

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 three parks in the Rocky Mountain Network that are larger than 100 square miles: Glacier (GLAC), Great Sand Dunes (GRSA), and Rocky Mountain (ROMO). In addition, there are three smaller parks.

Total annual N emissions, by county, are shown in Map C for lands in and surrounding the Rocky Mountain Network. County-level emissions within the network ranged from less than 1 ton per square mile to 5 to 20 tons per square mile. Limited smaller areas had higher emissions than that. In general, annual county N emissions were less than 5 tons per square mile throughout most of the network. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map D. There are several relatively large (larger than about 2,000 tons per year) sources of oxidized N within and near the network, especially in the southern half of the network. Urban centers within the network and within a 300 mile buffer around the network are shown in Map E. Human population centers are sparse, except along the eastern edge of the Colorado Front Range. ROMO is located in close proximity to several population centers. GLAC and GRSA are not.

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 as low as 2 to 5 kg N/ha/yr to as high as 5 to 10 kg N/ha/yr. Throughout most of the network, estimated total N deposition was in the range of 2 to 5 kg N/ha/yr.

Land cover in and around the network is shown in Map G. The predominant cover types within this network are generally highly mixed. Much of the network is covered with shrubland and grassland/herbaceous vegetation. Forests predominate in the northwest and southwest. Row crops are also common in some areas.

Map H shows the distribution within the larger (larger than 100 square miles) parks that occur in this network 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 types within these parks are alpine, wetland, and grassland and meadow; arid and semi-arid vegetation types are also fairly common.

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. The three largest parks in this network are all Class I. There is also considerable wilderness area within the network, outside NPS jurisdiction.

Park-specific maps are shown for the two largest parks in this network (GLAC and ROMO) in Maps J-1 through J-4. Alpine lands are widely distributed throughout both parks. The sensitive vegetation types wetlands and to a lesser extent grassland and meadow are common in GLAC. Grassland and meadow and arid and semi-arid lands are both common in ROMO.

High-elevation lakes within GLAC and ROMO, which might be more prone than lakes at lower elevation to N-limitation, and therefore potentially more susceptible to eutrophication in response to atmospheric N input, are shown in Maps J-3 and J-4. Both parks have many high-elevation lakes.

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 Rocky Mountain 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 relatively low. However, the network Ecosystem Sensitivity ranking is in the second highest quintile among networks (Figure B). This is because there are many high-elevation lakes in some of the parks that occur in this network, and some vegetation types in the parks in this network are among those expected to be especially sensitive to nutrient enrichment effects from N deposition. ROMO has 102 high elevation lakes; GLAC has 9; and GRSA has 5. This network also ranks in the second highest quintile in Park Protection, having substantial 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 in the bottom of the highest quintile among all networks (Figure D). This is despite the relatively low levels of N emissions and deposition. The overall level of concern for nutrient N enrichment effects on I&M parks within this network is considered High.

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.

All parks in this network are ranked in the lowest quintile (including GRSA) to the middle quintile (including ROMO) for Pollutant Exposure. In contrast, all parks in the network except Florissant Fossil Beds (FLFO) are ranked either in the highest quintile (including GRSA and ROMO) or second highest quintile (including GLAC) for Ecosystem Sensitivity. ROMO, GLAC, and GRSA all contain high elevation lakes. Park Protection rankings are variable by park size. The three large parks (GLAC, GRSA, ROMO) are all ranked in the highest quintile for this theme, whereas the smaller parks are all ranked in the middle quintile.

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.

	Relative Ranking of Individual Parks[1]			
I&M Parks[2] in Network	**Pollutant Exposure**	**Ecosystem Sensitivity**	**Park Protection**	**Summary Risk**
Florissant Fossil Beds	Moderate	Moderate	Moderate	Very Low
Glacier	Low	High	Very High	Very High
Grant-Kohrs Ranch	Very Low	High	Moderate	Very Low
Great Sand Dunes	Very Low	Very High	Very High	Very High
Little Bighorn Battlefield	Very Low	Very High	Moderate	Low
Rocky Mountain	Moderate	Very High	Very High	Very 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.

The Summary Risk ranking also varied by park size. The three large parks are all ranked in the highest quintile, showing Very High risk of nutrient N enrichment. The three smaller parks are all ranked in the lowest or second lowest quintile, showing Very Low or Low Summary Risk.

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)

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)

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)

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, NO_x) and reduced (ammonia, NH_3) 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)

Map J-1. Park-specific map: sensitive vegetation types in GLAC. (Source of data: See Appendix A)

Map J-2. Park-specific map: sensitive vegetation types in ROMO. (Source of data: See Appendix A)

Map J-3. Park-specific map: high-elevation lakes in GLAC. (Source of data: U.S. EPA National Elevation Dataset and U.S. EPA/USGS National Hydrography Dataset Plus [http://www.horizon-systems.com/nhdplus/])

Map J-4. Park-specific map: high-elevation lakes in ROMO. (Source of data: U.S. EPA National Elevation Dataset and 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.

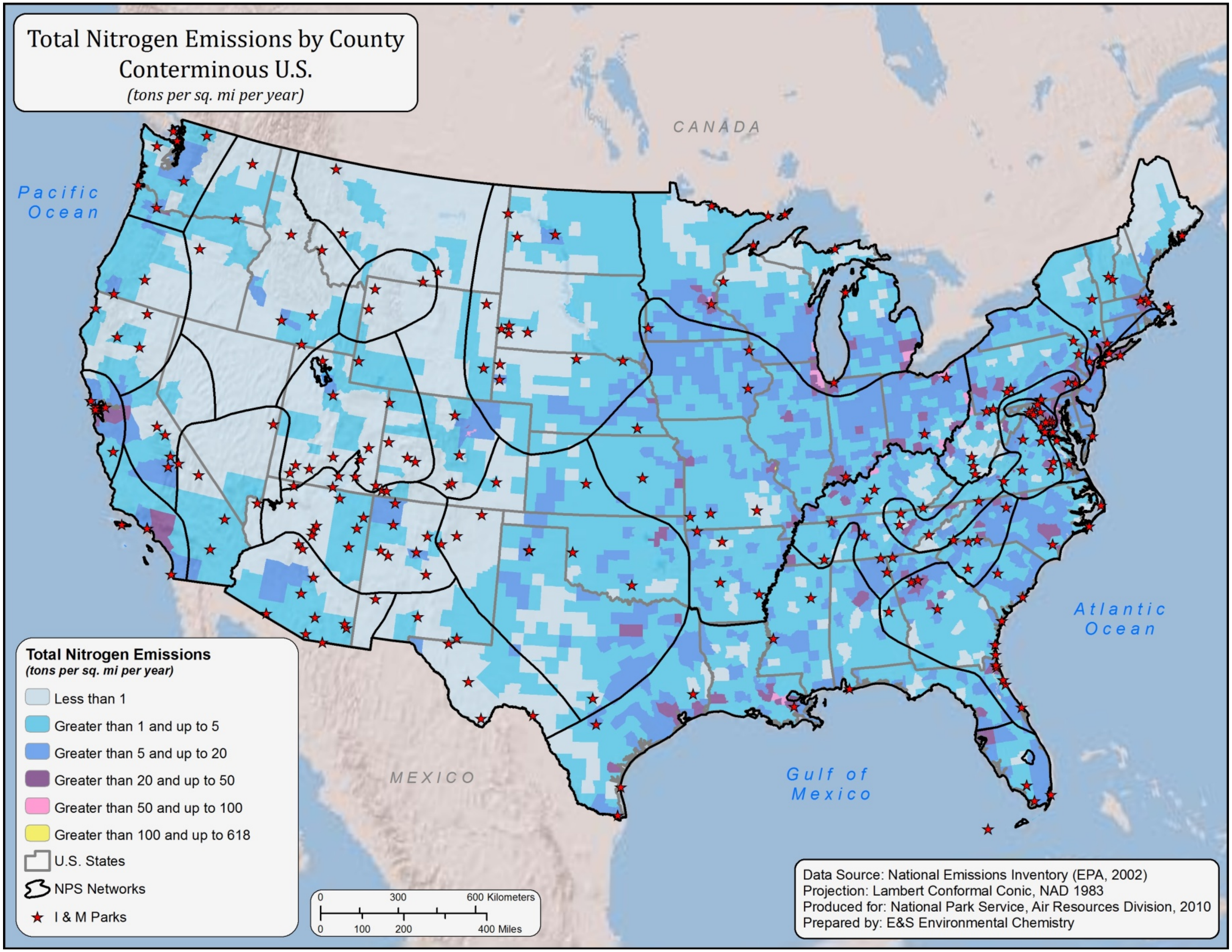
Figure D. Network Summary Risk ranking, calculated as the sum of the averages of the scores for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection.

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.

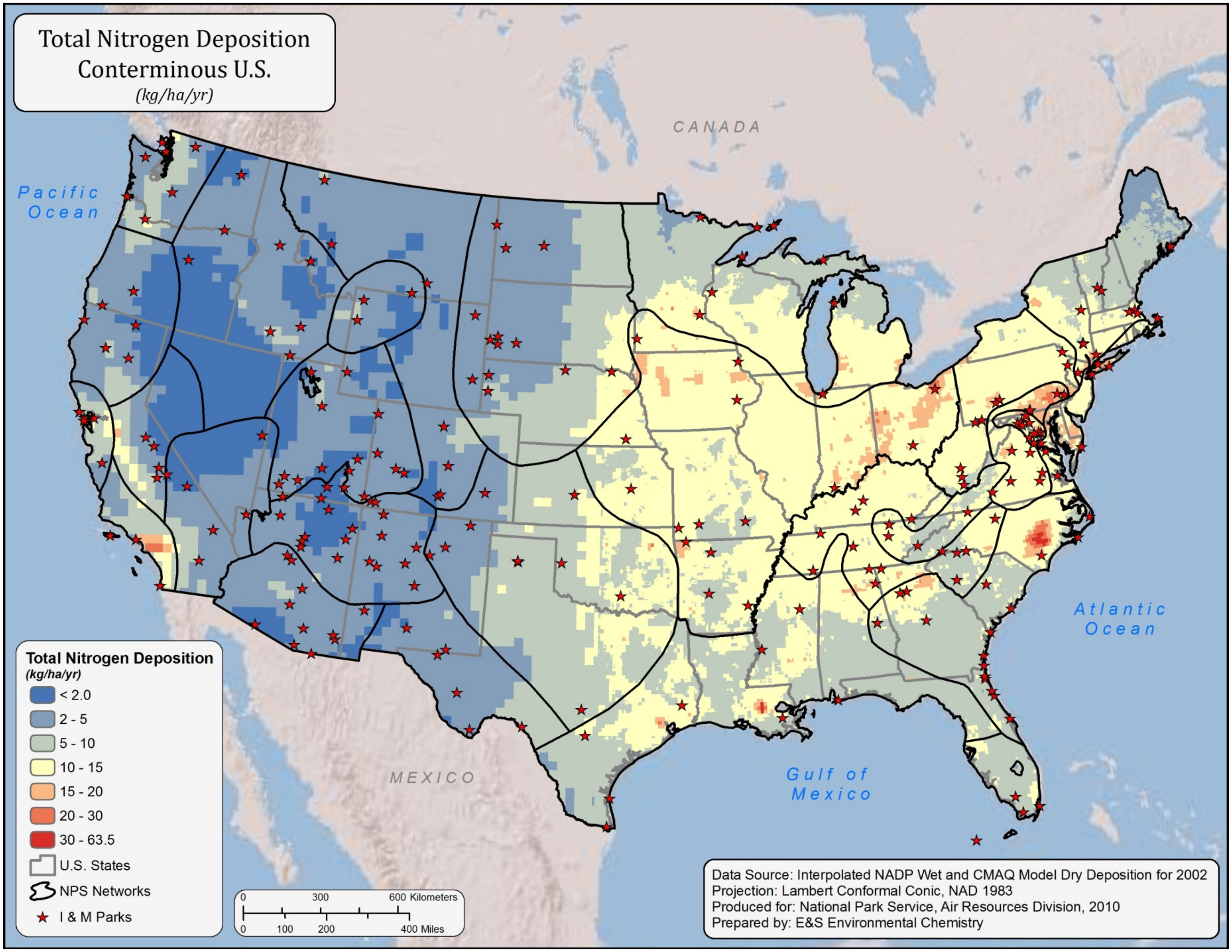
Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

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.

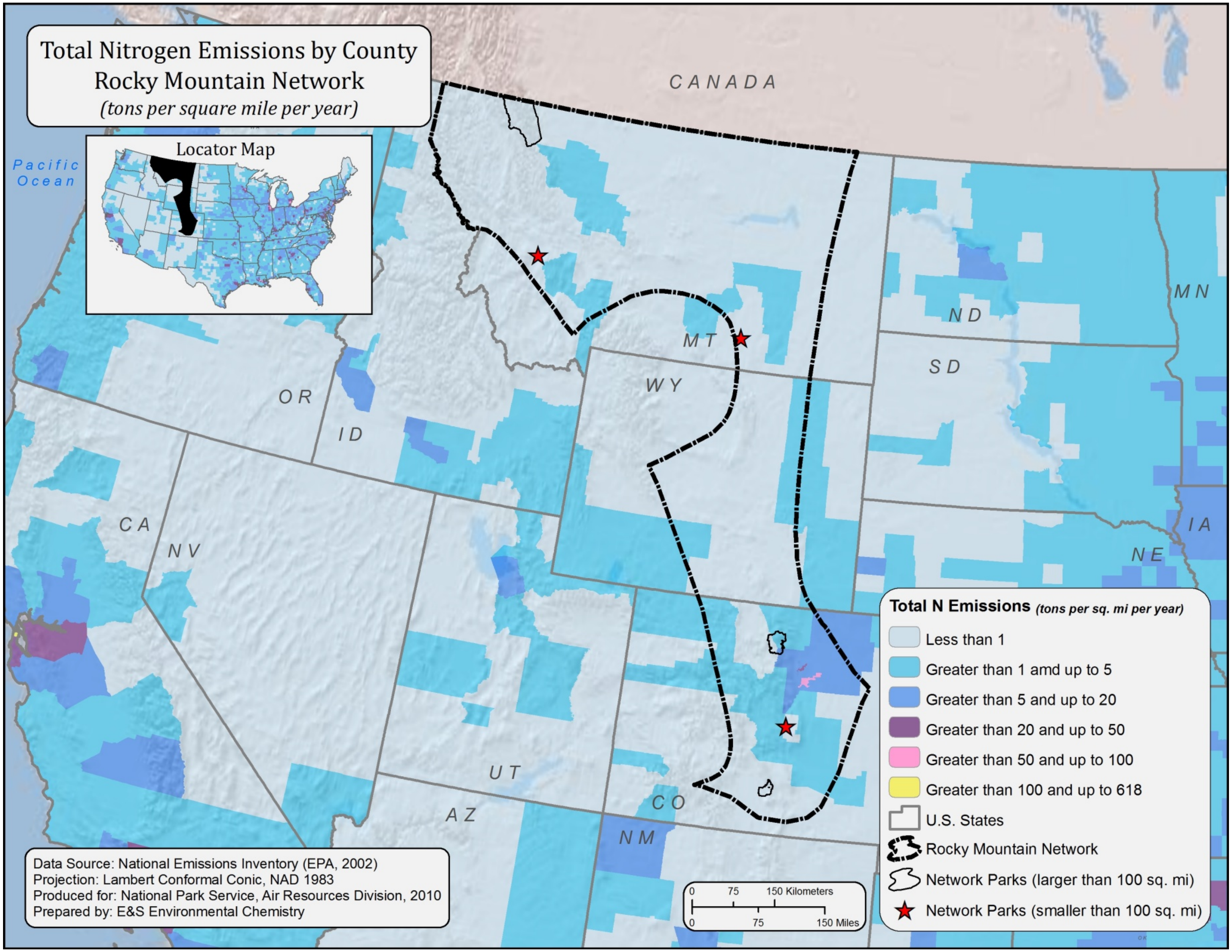

Total Nitrogen Emissions by County
Conterminous U.S.
(tons per sq. mi per year)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Nitrogen Emissions
(tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 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 A



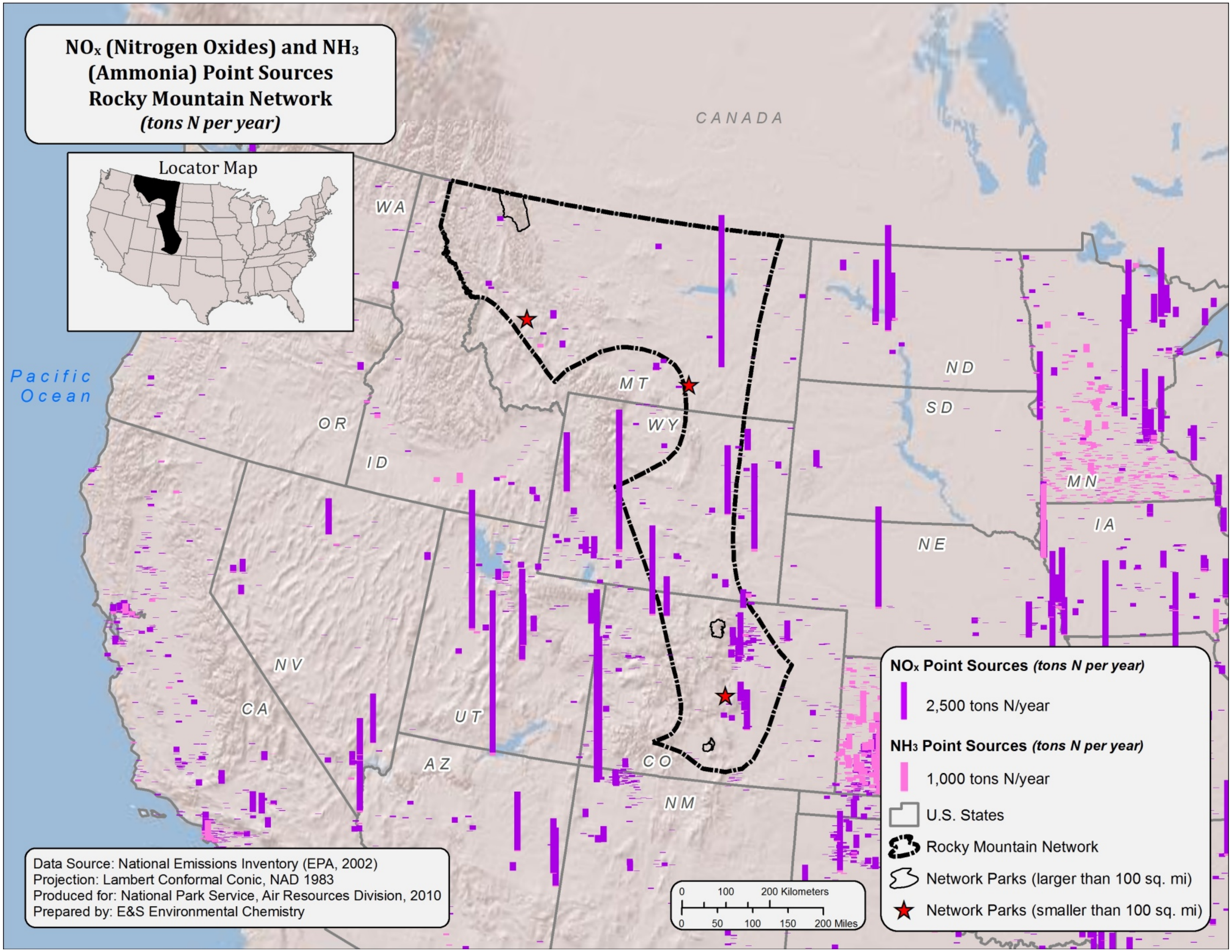
Total Nitrogen Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Nitrogen Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated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

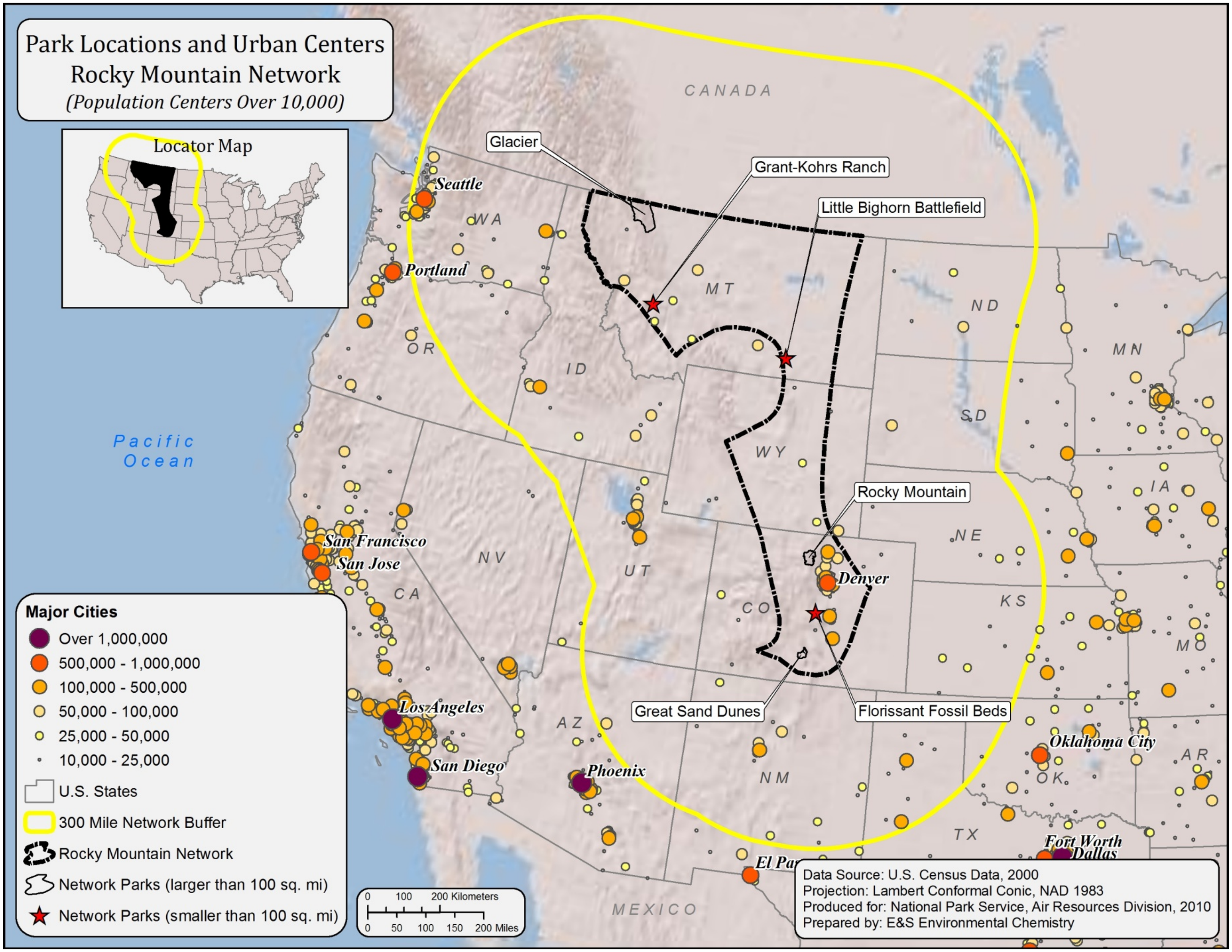


Total Nitrogen Emissions by County
Rocky Mountain Network
(tons per square mile per year)
Locator Map
Pacific Ocean
CANADA
MT
WY
OR
ID
CA
NV
UT
AZ
CO
NM
ND
SD
MN
NE
IA
Total N Emissions (tons per sq. mi per year)
Less than 1
Greater than 1 amd up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 618
U.S. States
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 75 150 Kilometers
0 75 150 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

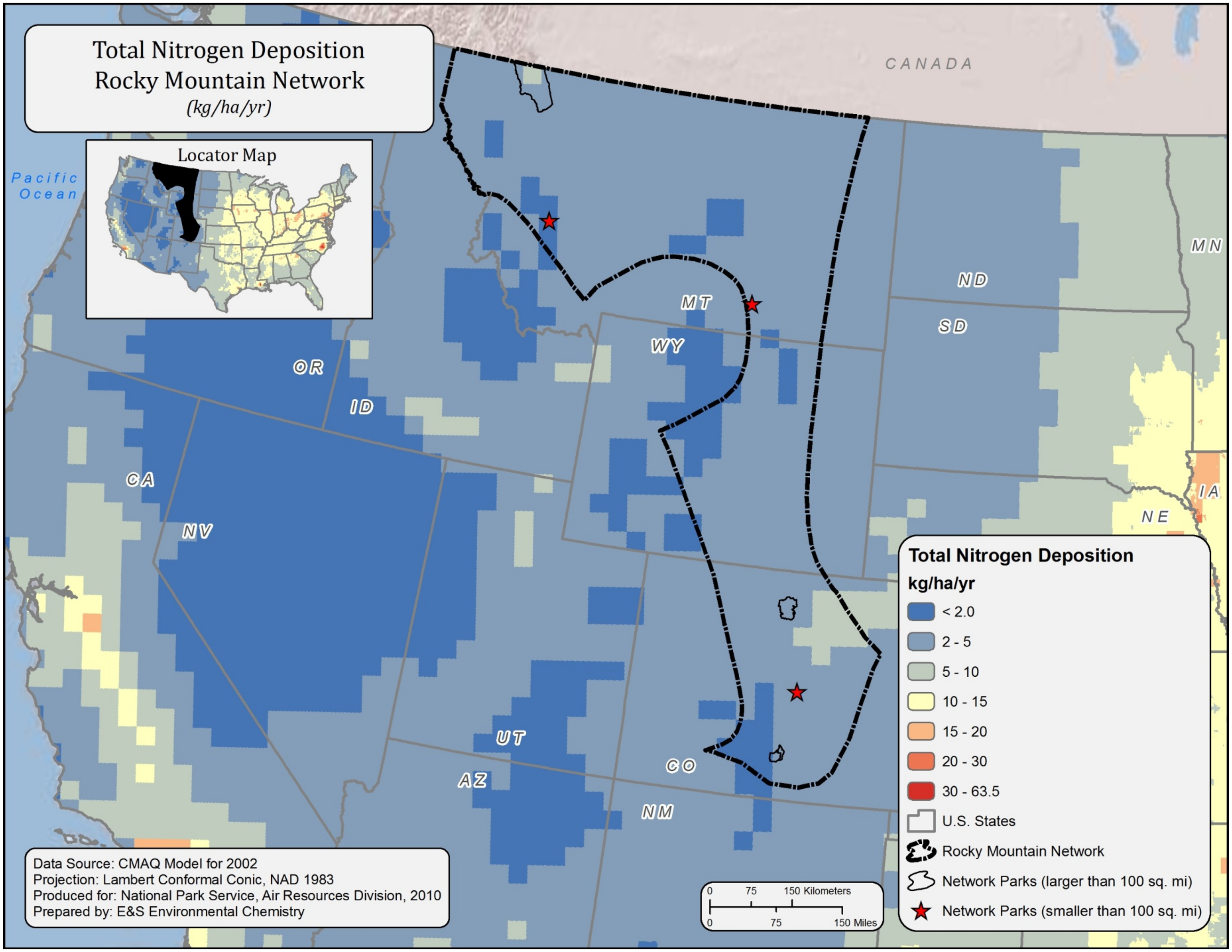
Map C


NOx (Nitrogen Oxides) and NH3 (Ammonia) Point Sources
Rocky Mountain Network
(tons N per year)
Locator Map
CANADA
Pacific Ocean
WA
OR
ID
MT
WY
ND
SD
NE
MN
IA
NV
CA
UT
AZ
CO
NM
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
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 100 200 Kilometers
0 50 100 150 200 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

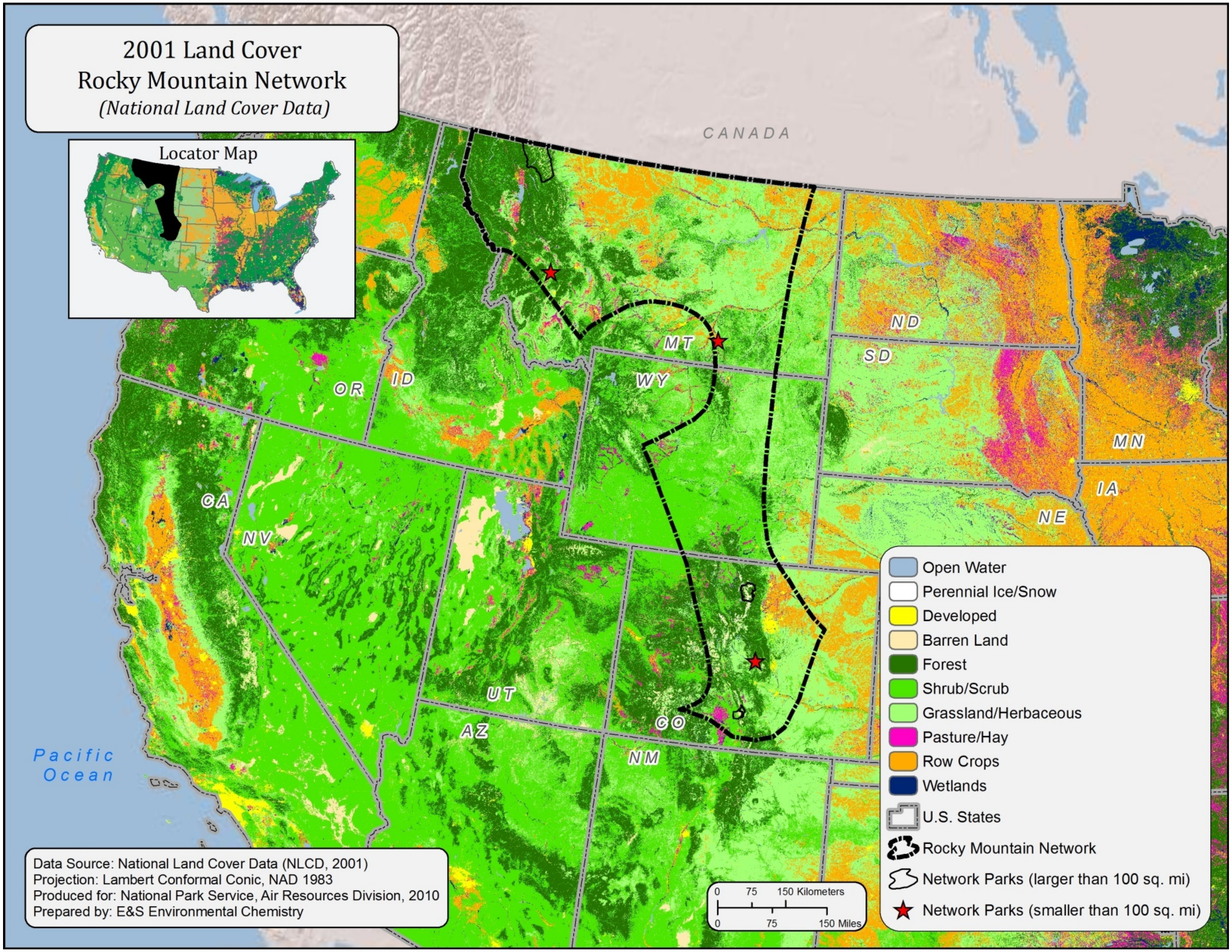
Map D


Park Locations and Urban Centers
Rocky Mountain Network
(Population Centers Over 10,000)
Locator Map
CANADA
Glacier
Grant-Kohrs Ranch
Little Bighorn Battlefield
Rocky Mountain
Great Sand Dunes
Florissant Fossil Beds
Pacific Ocean
MEXICO
WA
OR
ID
MT
ND
SD
MN
IA
NE
WY
UT
CO
NV
CA
AZ
NM
KS
MO
OK
AR
TX
Seattle
Portland
San Francisco
San Jose
Los Angeles
San Diego
Phoenix
Denver
Oklahoma City
Fort Worth
Dallas
El Paso
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
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 100 200 Kilometers
0 50 100 150 200 Miles
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

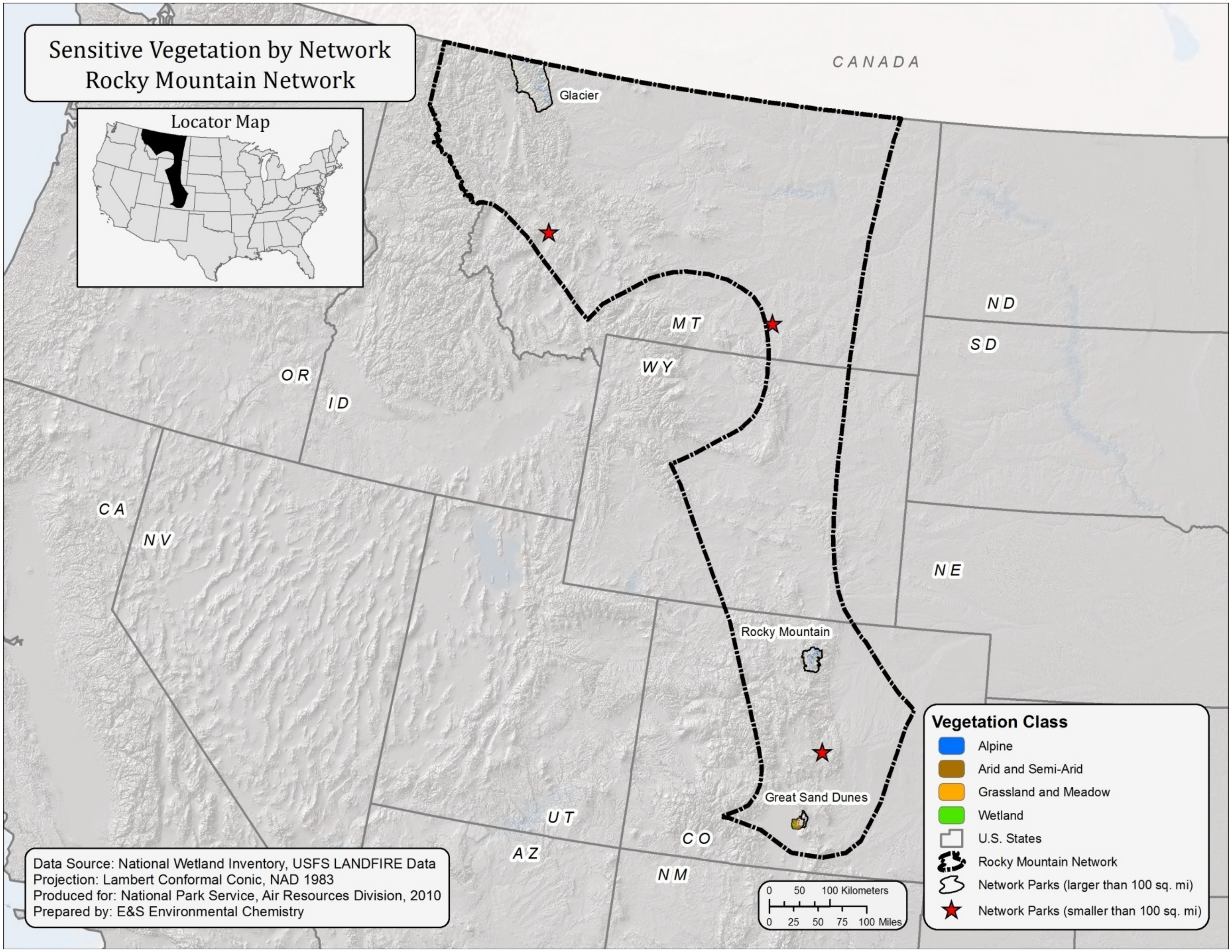
Map E


Total Nitrogen Deposition
Rocky Mountain Network
(kg/ha/yr)
Locator Map
Pacific Ocean
CANADA
OR
ID
CA
NV
UT
AZ
MT
WY
CO
NM
ND
SD
NE
MN
IA
Total Nitrogen Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 75 150 Kilometers
0 75 150 Miles
Data Source: CMAQ Model for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

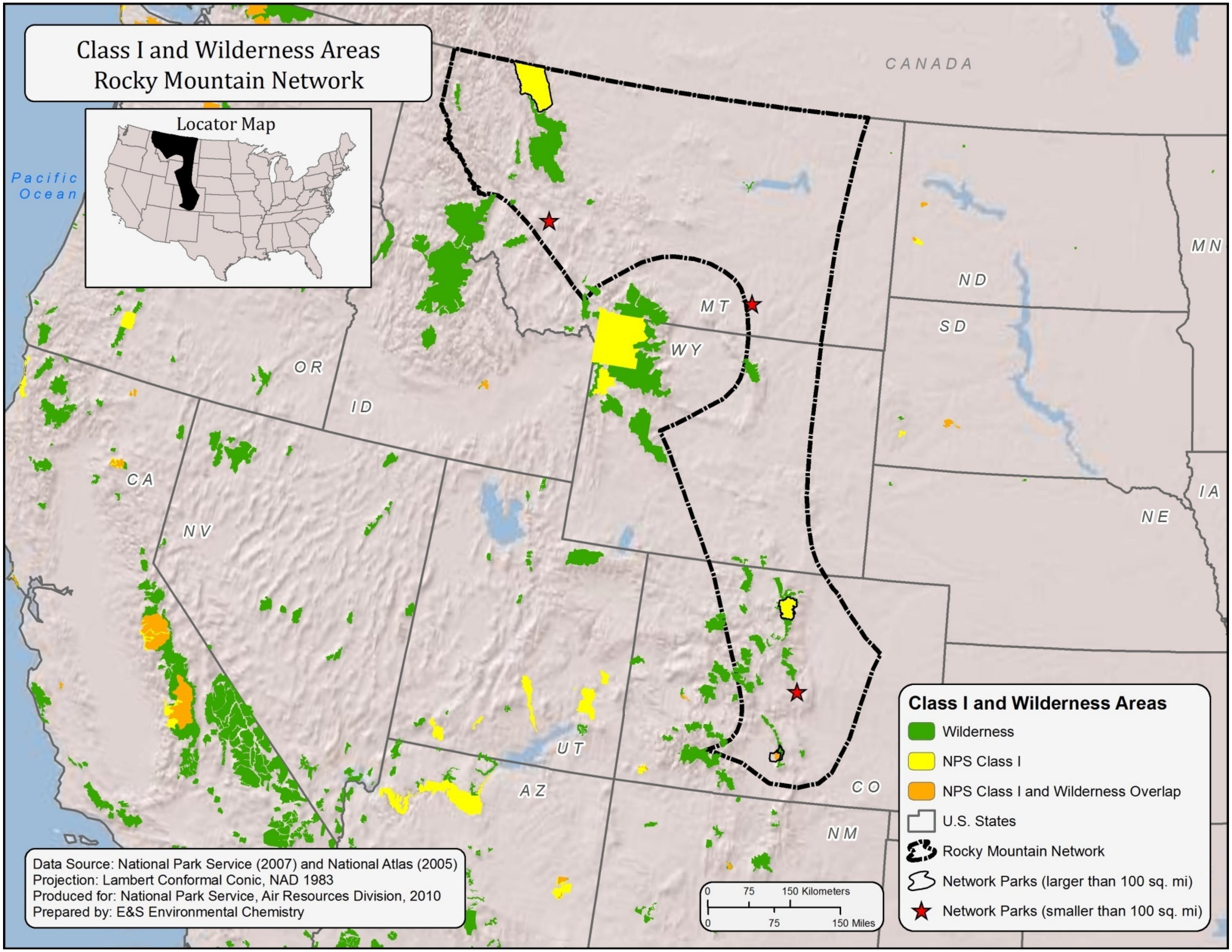
Map F


2001 Land Cover
Rocky Mountain Network
(National Land Cover Data)
Locator Map
CANADA
MT
WY
ND
SD
OR
ID
MN
IA
NE
CA
NV
UT
CO
AZ
NM
Pacific Ocean
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetlands
U.S. States
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 75 150 Kilometers
0 75 150 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

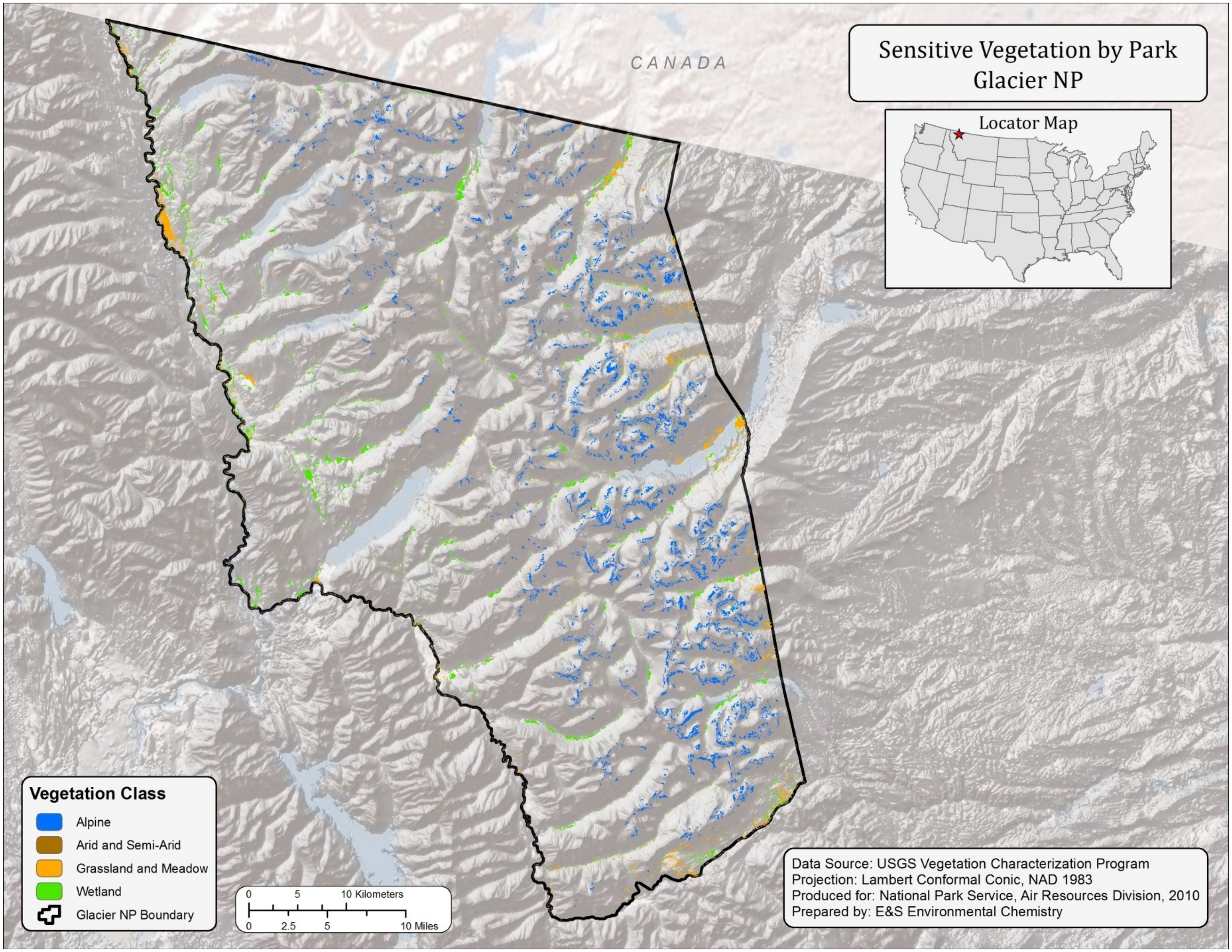
Map G


Sensitive Vegetation by Network
Rocky Mountain Network
Locator Map
CANADA
Glacier
MT
ND
SD
WY
OR
ID
CA
NV
NE
Rocky Mountain
Great Sand Dunes
UT
CO
AZ
NM
Vegetation Class
Alpine
Arid and Semi-Arid
Grassland and Meadow
Wetland
U.S. States
Rocky Mountain 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 Wetland Inventory, USFS LANDFIRE Data
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

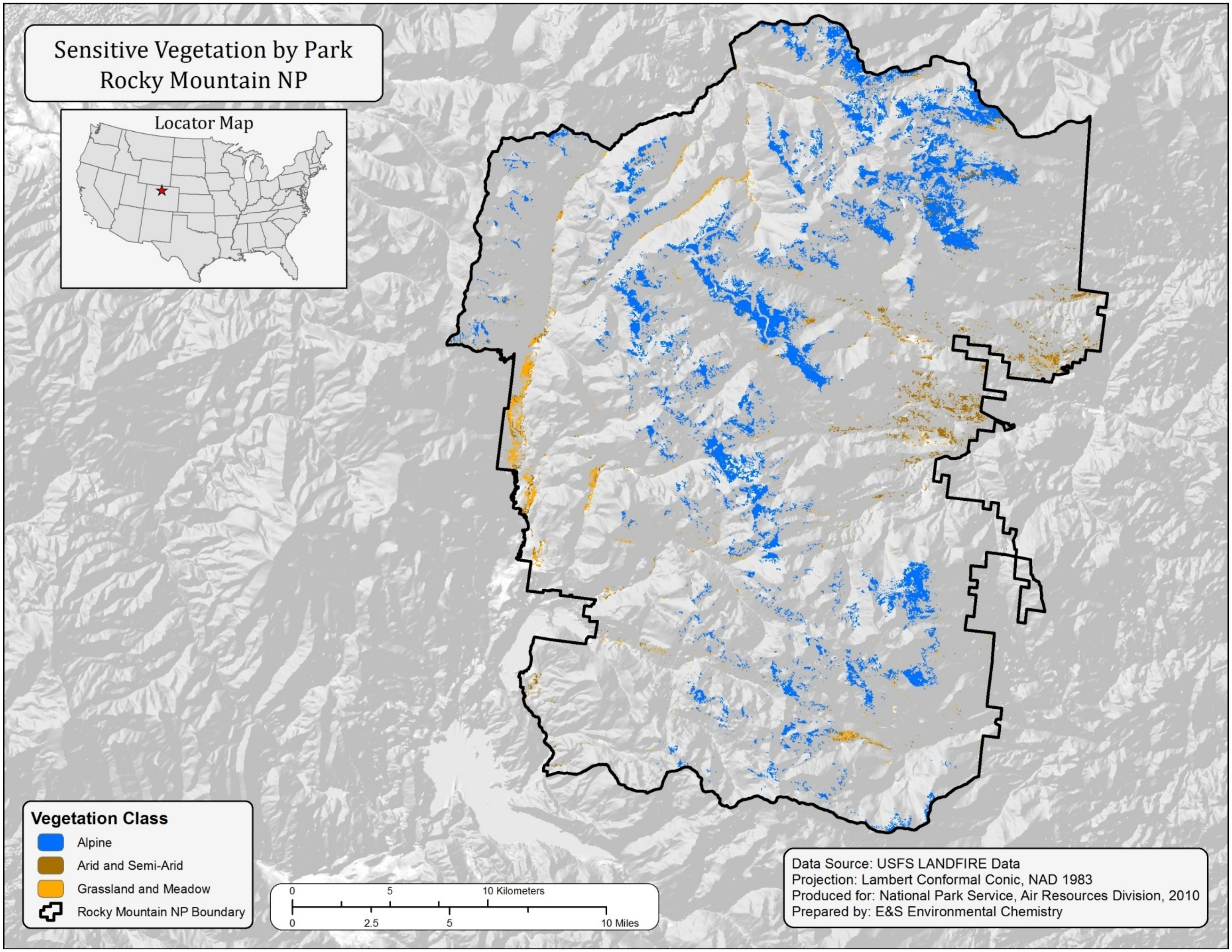
Map H


Class I and Wilderness Areas
Rocky Mountain Network
Locator Map
Pacific Ocean
CANADA
OR
ID
MT
WY
ND
SD
MN
IA
NE
CA
NV
UT
AZ
CO
NM
Class I and Wilderness Areas
Wilderness
NPS Class I
NPS Class I and Wilderness Overlap
U.S. States
Rocky Mountain Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 75 150 Kilometers
0 75 150 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

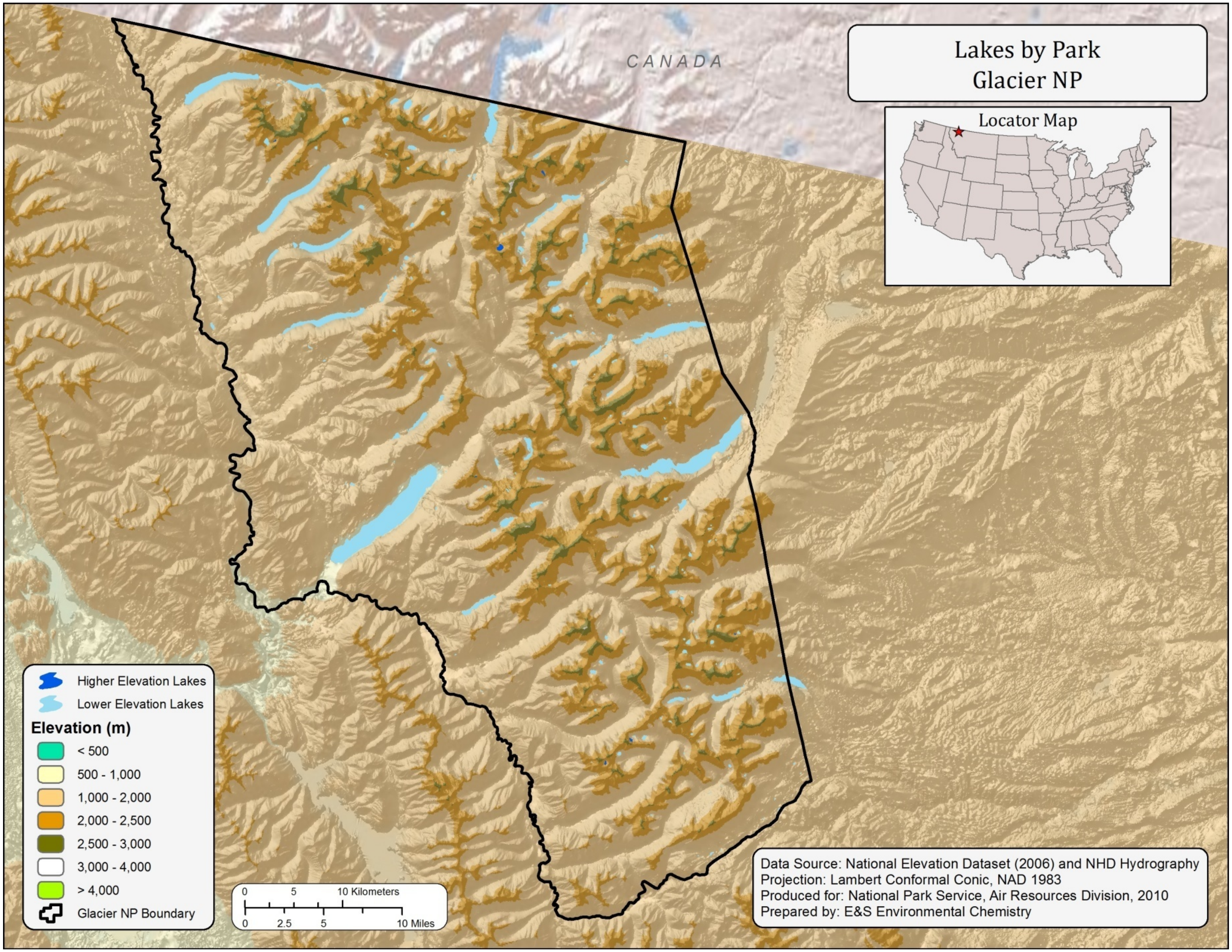
Map I


Sensitive Vegetation by Park
Glacier NP
Locator Map
CANADA
Vegetation Class
Alpine
Arid and Semi-Arid
Grassland and Meadow
Wetland
Glacier NP Boundary
0 5 10 Kilometers
0 2.5 5 10 Miles
Data Source: USGS Vegetation Characterization Program
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

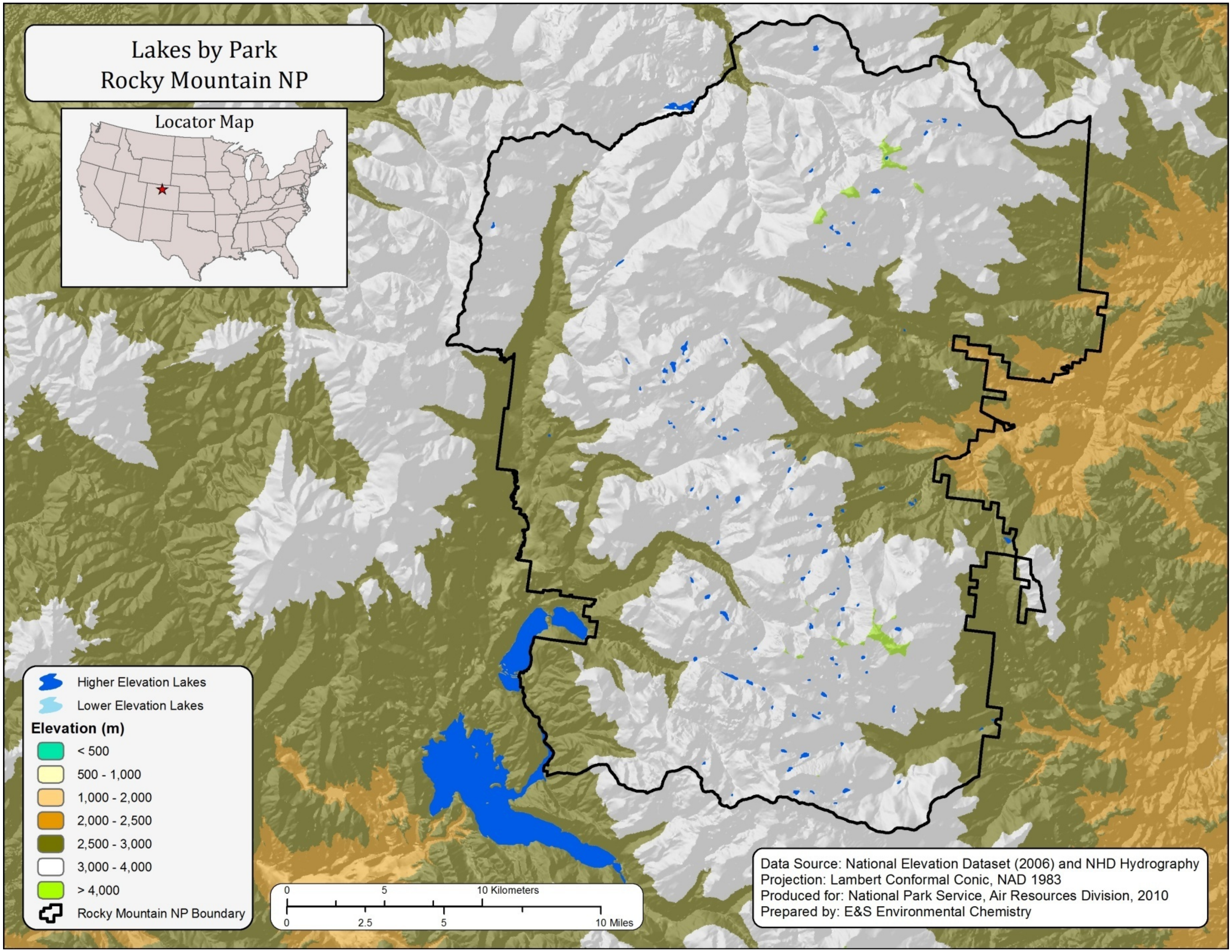
Map J-1


Sensitive Vegetation by Park
Rocky Mountain NP
Locator Map
Vegetation Class
Alpine
Arid and Semi-Arid
Grassland and Meadow
Rocky Mountain NP Boundary
0
5
10 Kilometers
0
2.5
5
10 Miles
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

Map J-2


Lakes by Park
Glacier NP
CANADA
Locator Map
Higher Elevation Lakes
Lower 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
Glacier 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 J-3



Lakes by Park
Rocky Mountain NP
Locator Map
Higher Elevation Lakes
Lower 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
Rocky Mountain 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 J-4

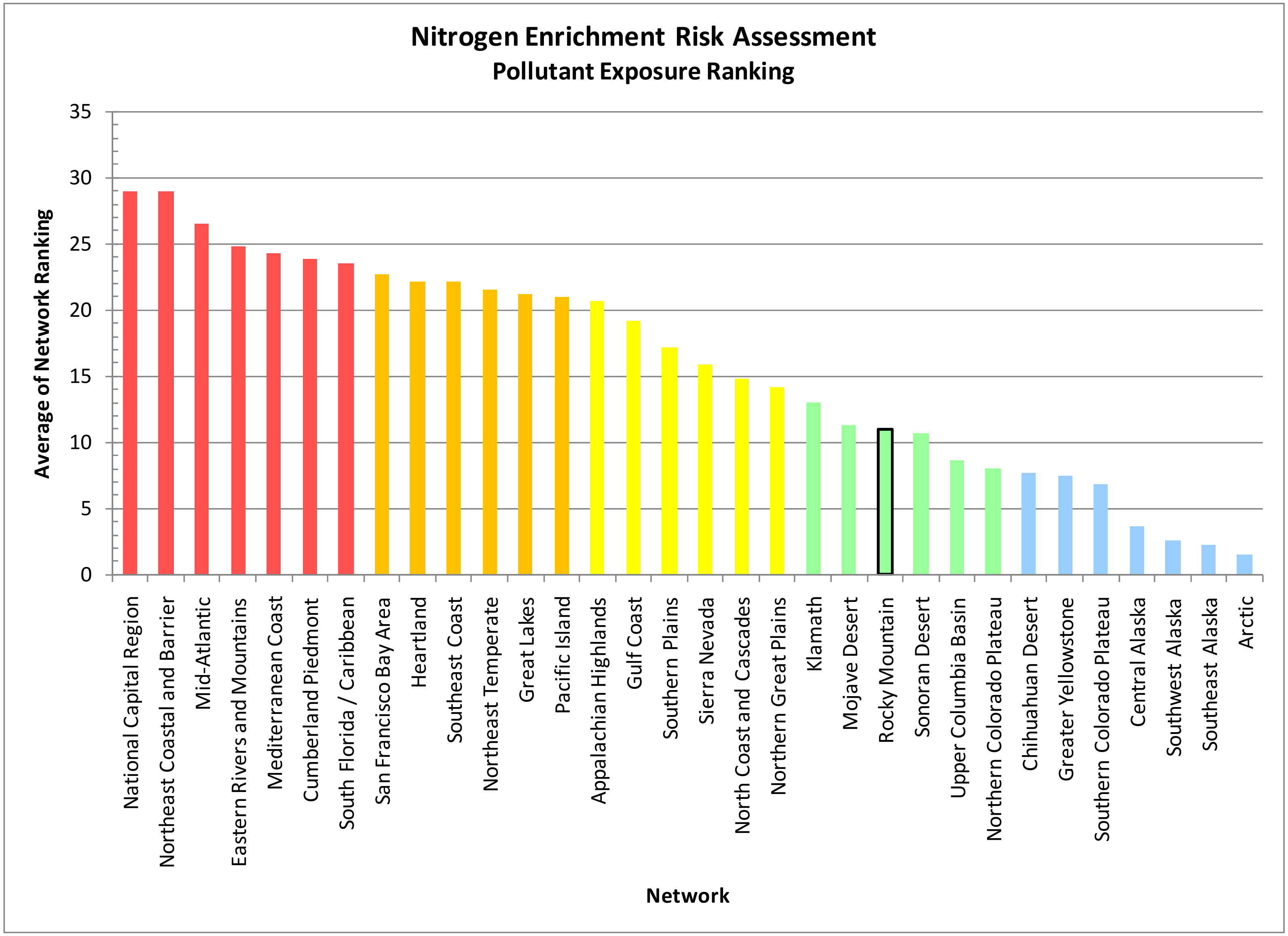

Nitrogen Enrichment Risk Assessment
Pollutant Exposure Ranking
Average of Network Ranking
Network
0
5
10
15
20
25
30
35
National Capital Region
Northeast Coastal and Barrier
Mid-Atlantic
Eastern Rivers and Mountains
Mediterranean Coast
Cumberland Piedmont
South Florida / Caribbean
San Francisco Bay Area
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
Southwest Alaska
Southeast Alaska
Arctic

Figure A

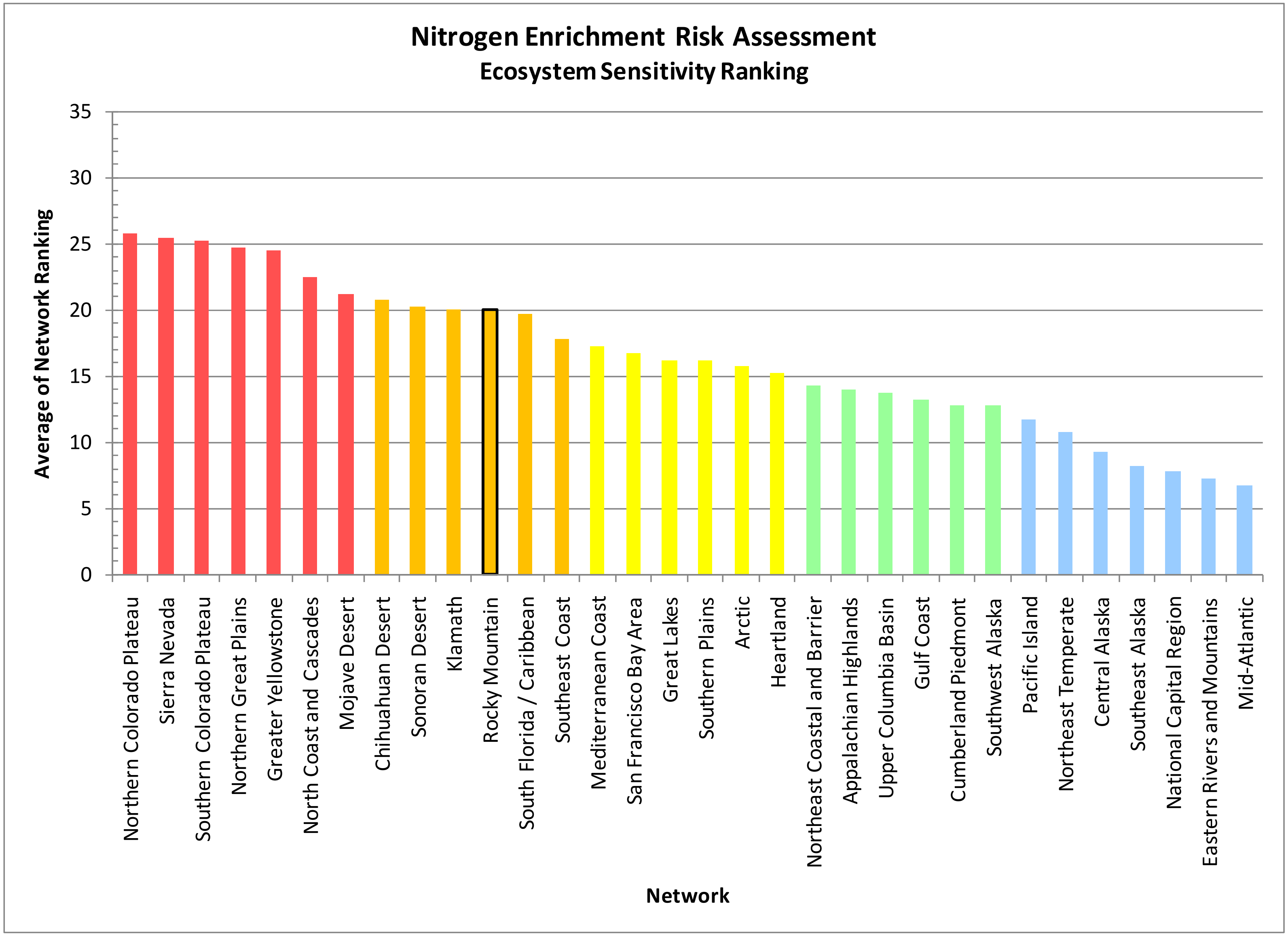

Nitrogen Enrichment Risk Assessment
Ecosystem Sensitivity Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Northern Colorado Plateau
Sierra Nevada
Southern Colorado Plateau
Northern Great Plains
Greater Yellowstone
North Coast and Cascades
Mojave Desert
Chihuahuan Desert
Sonoran Desert
Klamath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

Figure B

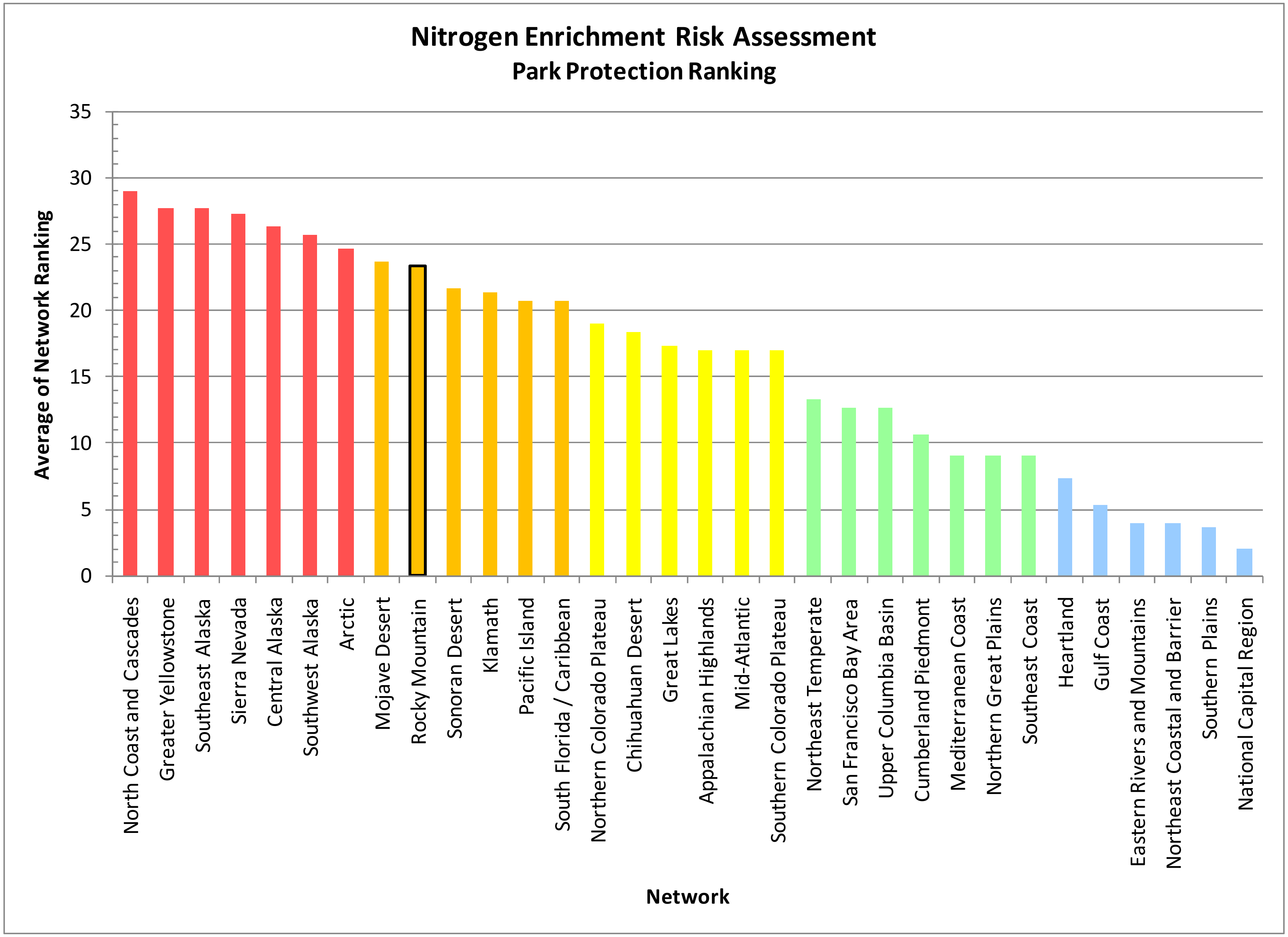

Nitrogen Enrichment Risk Assessment
Park Protection Ranking
Average of Network Ranking
0
5
10
15
20
25
30
35
North Coast and Cascades
Greater Yellowstone
Southeast Alaska
Sierra Nevada
Central Alaska
Southwest Alaska
Arctic
Mojave Desert
Rocky Mountain
Sonoran Desert
Klamath
Pacific Island
South Florida / 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

ROMN-22

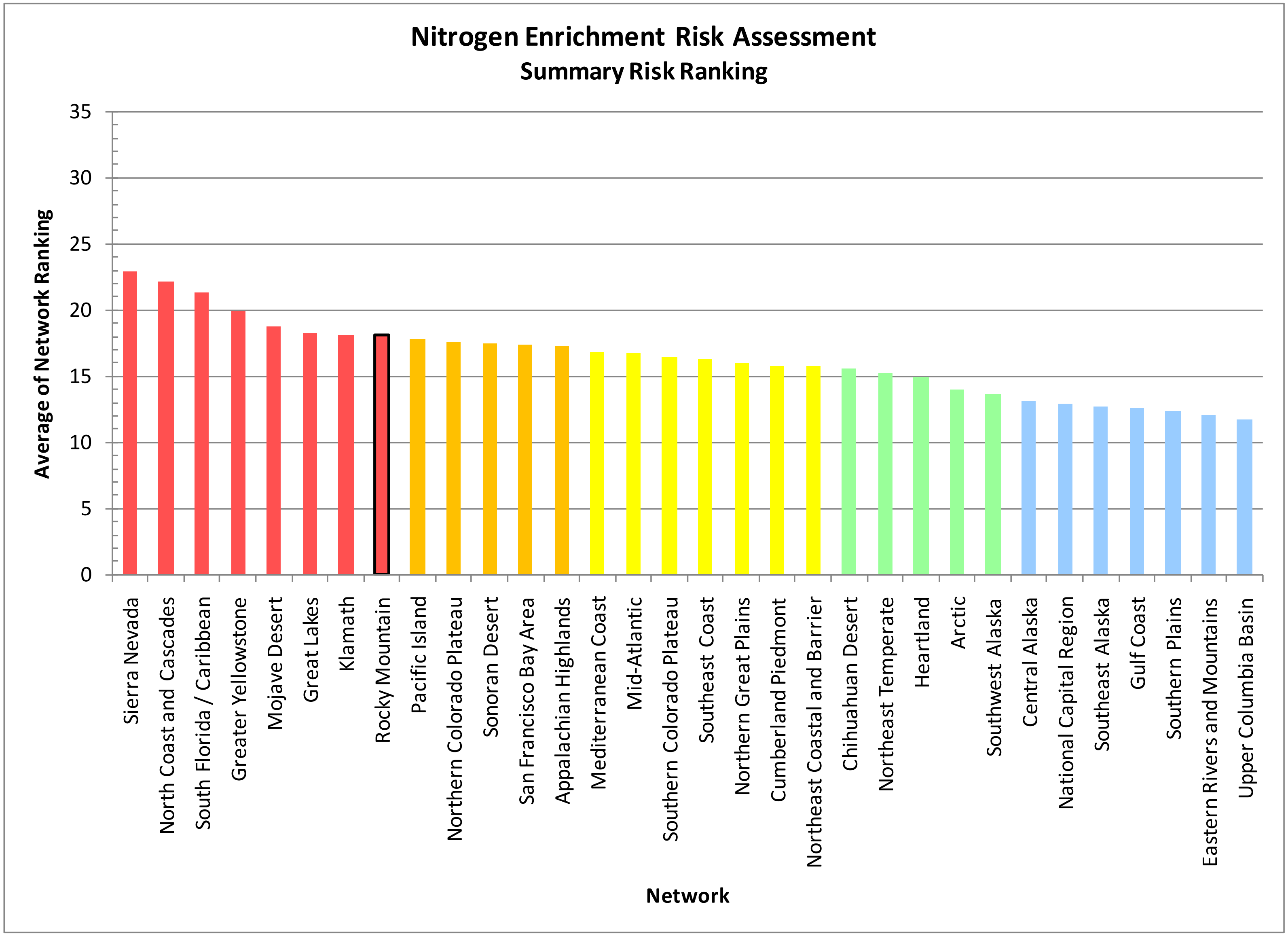


Figure D

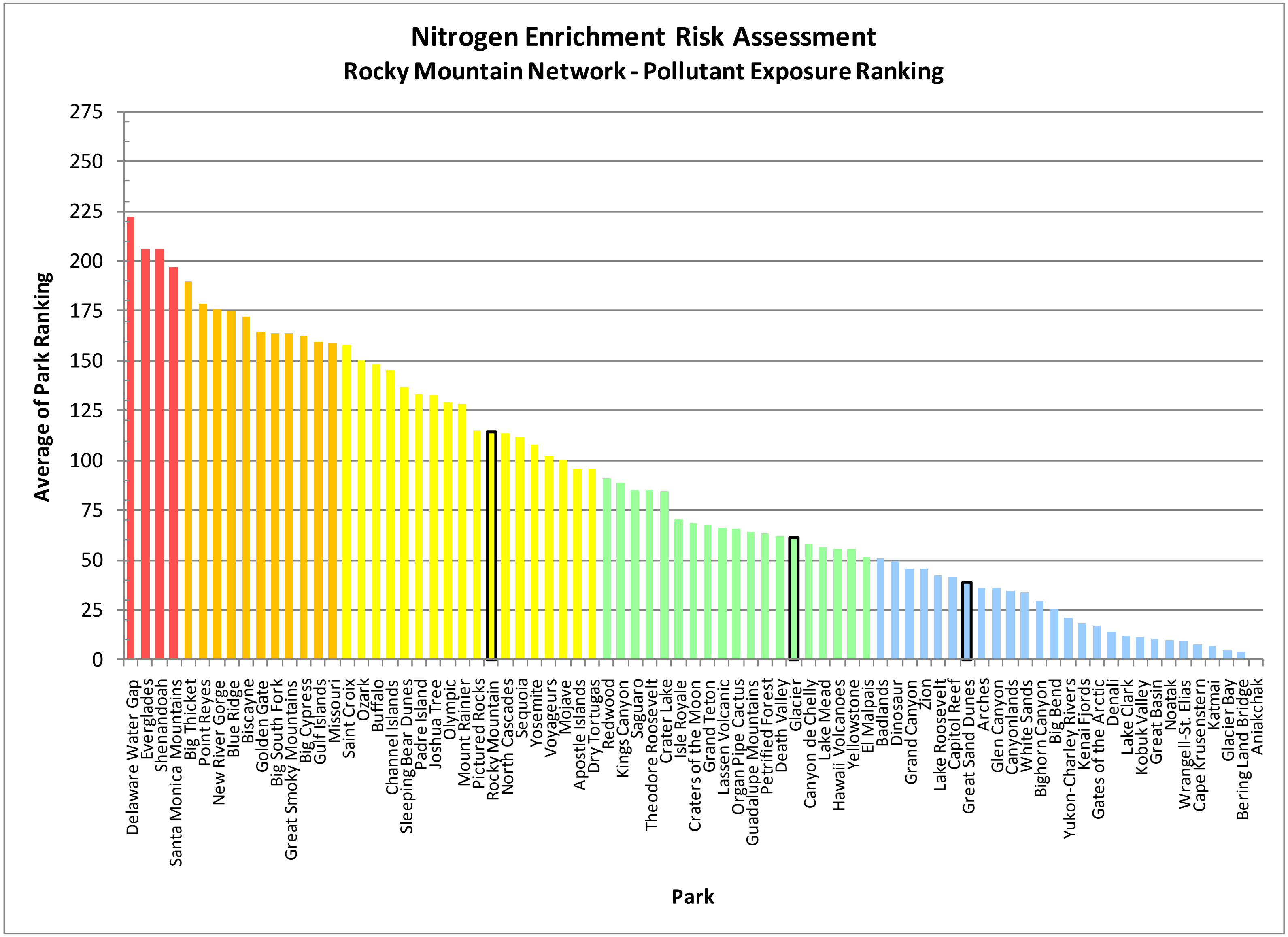

Nitrogen Enrichment Risk Assessment
Rocky Mountain Network - Pollutant Exposure Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Delaware Water Gap
Everglades
Shenandoah
Santa Monica Mountains
Big Thicket
Point Reyes
New River Gorge
Blue Ridge
Biscayne
Golden Gate
Big South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

Figure E

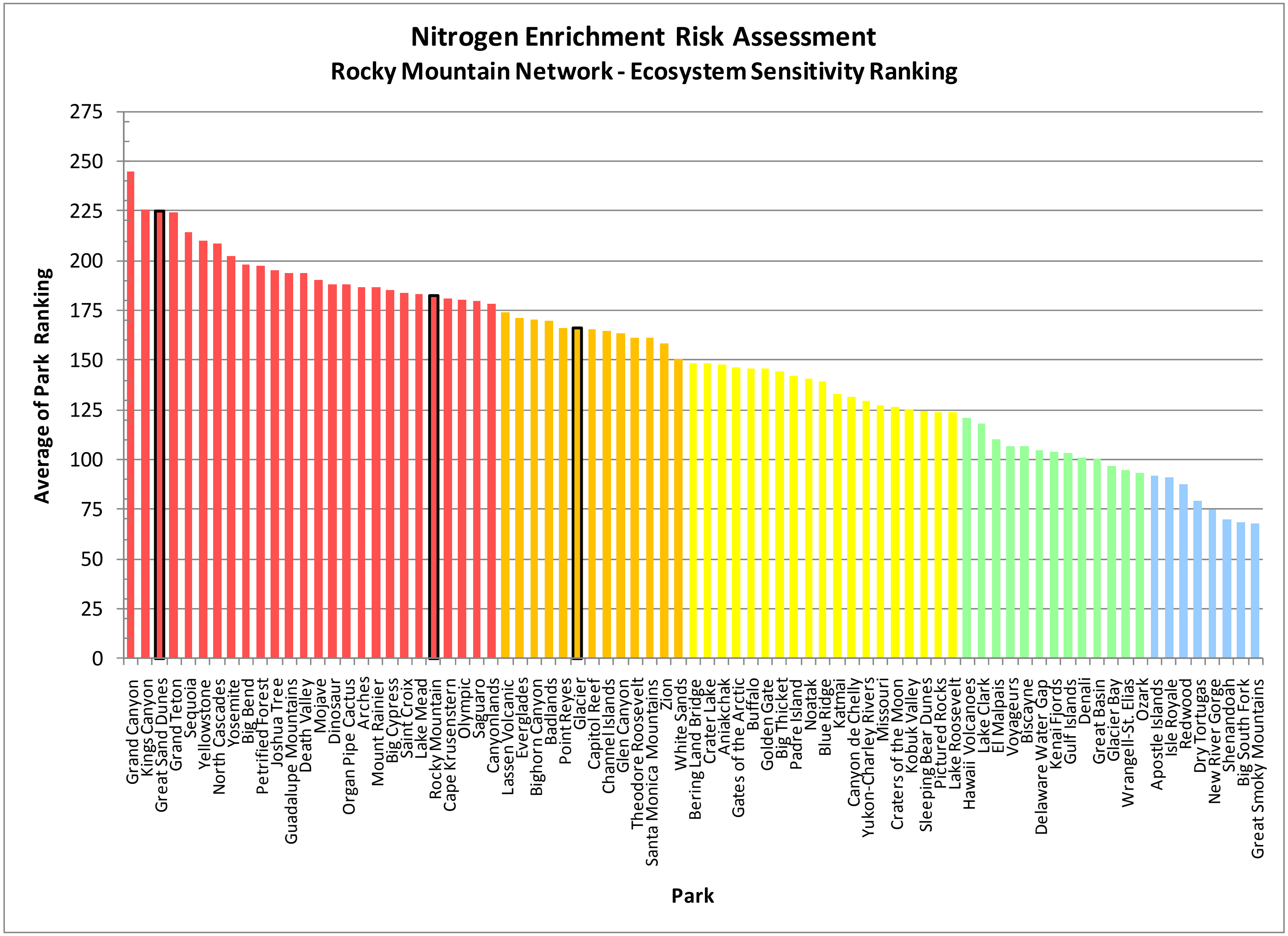

Nitrogen Enrichment Risk Assessment
Rocky Mountain Network - Ecosystem Sensitivity Ranking
Average of Park Ranking
Park
Grand Canyon
Kings Canyon
Great Sand Dunes
Grand Teton
Sequoia
Yellowstone
North Cascades
Yosemite
Big Bend
Petrified Forest
Joshua Tree
Guadalupe Mountains
Death Valley
Mojave
Dinosaur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

Figure F

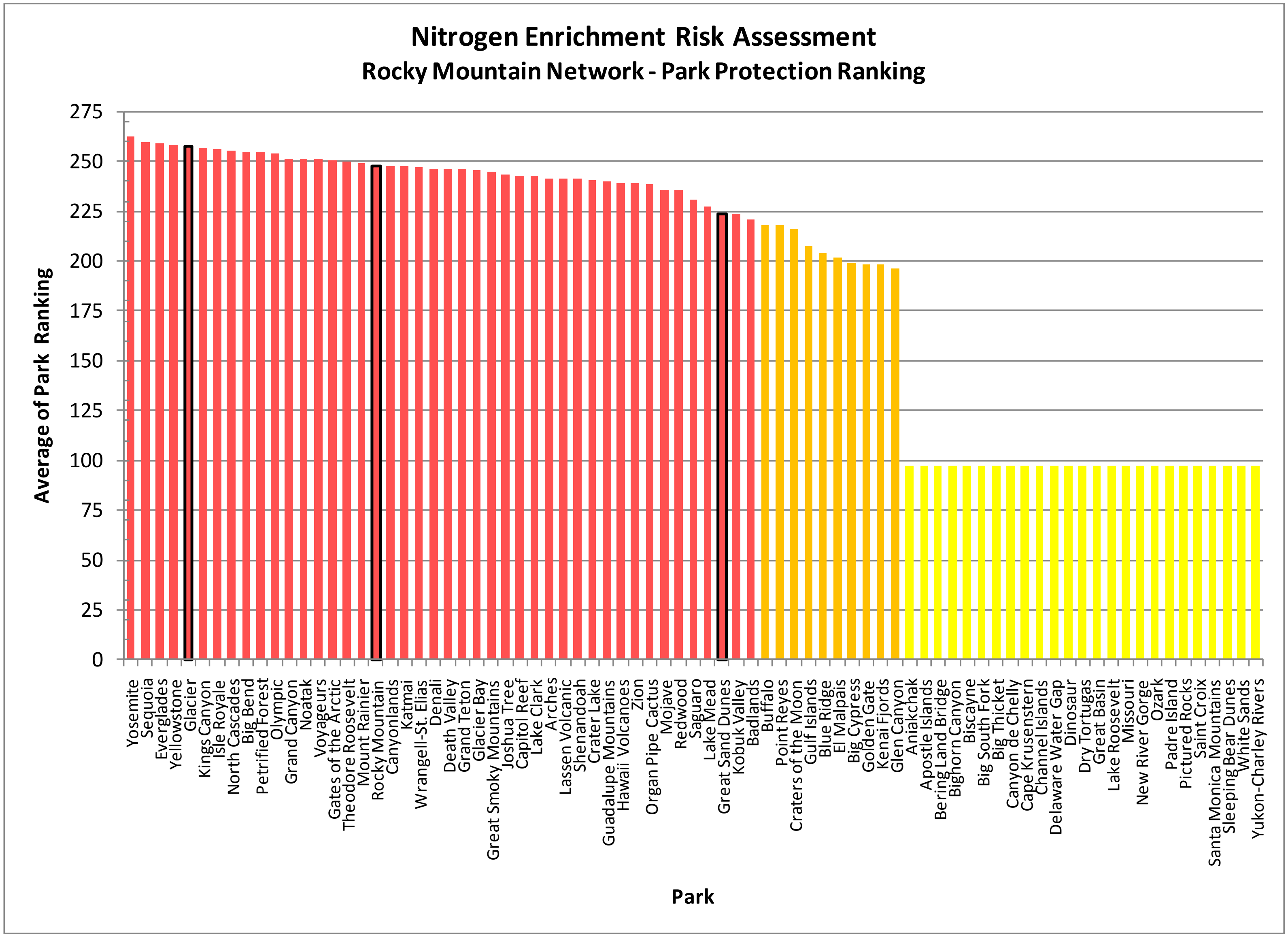

Nitrogen Enrichment Risk Assessment
Rocky Mountain Network - Park Protection Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Yosemite
Sequoia
Everglades
Yellowstone
Glacier
Kings Canyon
Isle Royale
North Cascades
Big Bend
Petrified Forest
Olympic
Grand Canyon
Noatak
Voyageurs
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
Park

Figure G

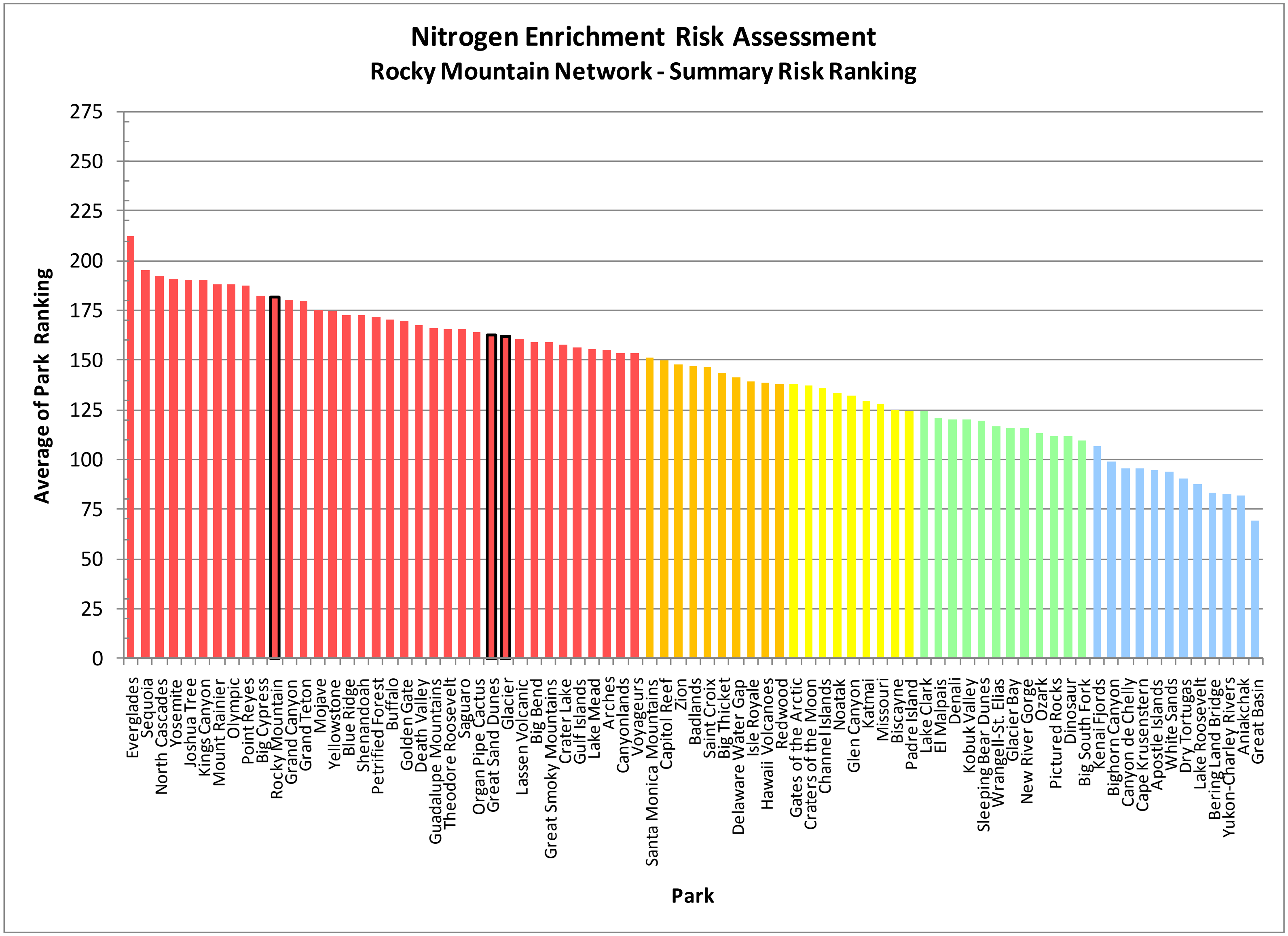

Nitrogen Enrichment Risk Assessment
Rocky Mountain Network - Summary Risk Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Everglades
Sequoia
North Cascades
Yosemite
Joshua Tree
Kings Canyon
Mount Rainier
Olympic
Point Reyes
Big Cypress
Rocky Mountain
Grand Canyon
Grand Teton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

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 960/106688, February 2011

National Park Service
U.S. Department of the Interior

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

www.nature.nps.gov/air