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

Greater Yellowstone Network (GRYN)

Natural Resource Report NPS/NPRC/ARD/NRR—2011/308

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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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/).

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NPS 960/106648, February 2011

Greater Yellowstone Network (GRYN)

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 Greater Yellowstone network: Yellowstone (YELL), Grand Teton (GRTE), and Bighorn Canyon (BICA). All are larger than 100 square miles.

Total annual N emissions, by county, are shown in Map C for lands in and surrounding the Greater Yellowstone Network. County-level emissions within the network ranged from less than 1 ton per square mile to 1 to 5 tons per square mile. In general, annual emissions within the network were less than 1 ton per square mile, although emissions were higher in the southeastern portion of the network and continuing into Idaho, in relatively close proximity to GRTE and YELL. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map D. There are few N emissions point sources of any magnitude in or near this network. The few relatively large point sources that do exist are sources of oxidized N. Urban centers within the network and within a 300 mile buffer around the network are shown in Map E. There are no human population centers of any magnitude in or near this network. However, Salt Lake City, Boise, and Denver are all within 300 miles of the network boundary.

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 below 2 kg N/ha/yr in the southeast to as high as 5 to 10 kg N/ha/yr in and around portions of GRTE and the southwestern portion of YELL.

Land cover in and around the network is shown in Map G. The predominant cover types within this network are generally a mix of forest, shrublands and grasslands, with some row crops and pasture/hay. Scattered areas of wetlands and developed lands also occur, mostly around the periphery of the network.

Map H shows the distribution within the parks that occur in this network of the five vegetation types thought to be most responsive to nutrient N enrichment effects (arctic, alpine, meadow, wetland, and arid and semi-arid). In general, the predominant sensitive vegetation types within these parks are grassland and meadow, alpine, and arid and semi-arid vegetation types. There are also substantial amounts of wetland in these parks.

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. YELL and GRTE are both Class I. Extensive wilderness areas surround these parks.

Park-specific maps are shown for the two most prominent national parks in the network: GRTE and YELL (Maps J-1 through J-4). In GRTE, alpine vegetation is abundant at the higher elevations of the Grand Teton Mountains, which run north to south along the western border of the park. Arid and semi-arid land is found at the lower elevations to the southeast. Meadow and wetland vegetation types are scattered throughout the park. A large proportion of GRTE is covered by these vegetation types thought to be most sensitive to nutrient N enrichment effects (Map J-1). A relatively high proportion of YELL is also covered with sensitive vegetation types, with a broad mix of meadow, arid and semi-arid, alpine, and wetland vegetation types (Map J-2).

High-elevation lakes within GRTE and YELL, which might be more prone than lakes at lower elevation to N-enrichment effects, and therefore potentially more susceptible to eutrophication in response to atmospheric N input, are shown in park-specific Maps J-3 and J-4. Lakes are numerous in both GRTE and YELL. High elevation lands are more common in GRTE, and many of the lakes in this park are found above 2,500 m elevation. Many of these lakes might be expected to be N-limited, and therefore might be highly sensitive to eutrophication from atmospheric N deposition.

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 Greater Yellowstone Network ranks in the lowest quintile, among networks, in N Pollutant Exposure (Figure A). Nitrogen emissions and N deposition within the network are both very low. However, the network Ecosystem Sensitivity ranking is Very High, the highest quintile among networks (Figure B). This is because there are extensive distributions of the vegetation types in this network that are among those expected to be especially sensitive to nutrient enrichment effects from N deposition, and there are also high elevation lakes. This network ranks in the top 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 highest quintile among all networks (Figure D). The overall level of concern for nutrient N enrichment effects on I&M parks within this network is considered Very 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.

Pollutant Exposure ranked Low for GRTE and YELL, but Very Low for BICA (Figure E). All three are ranked High (BICA) or Very High (GRTE, YELL) for Ecosystem Sensitivity (Figure F). GRTE and YELL both contain high elevation lakes. The three parks diverge more with respect to Park Protection, which is in the highest quintile for GRTE and YELL, but substantially lower for BICA (Figure G). The summary Park Risk metric scores both GRTE and YELL Very High, but BICA is in the lowest quintile (Figure H, Table A).

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**
Bighorn Canyon	Very Low	High	Moderate	Very Low
Grand Teton	Low	Very High	Very High	Very High
Yellowstone	Low	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.

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 GRTE. (Source of data: See Appendix A)

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

Map J-3. Park-specific map: high-elevation lakes in GRTE. (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 YELL. (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.

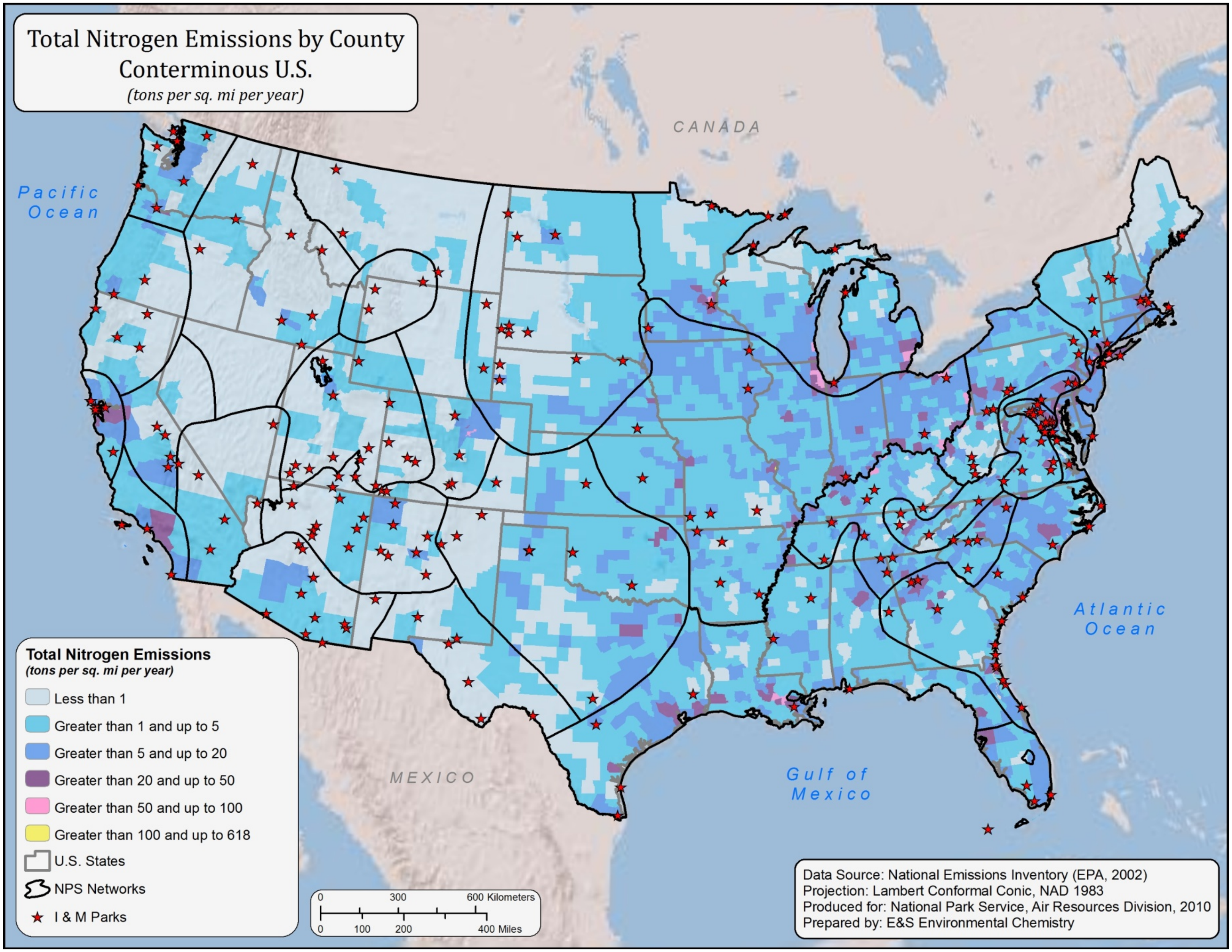
Figure D. Network Summary Risk ranking, calculated as the sum of the averages of the scores for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection.

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.

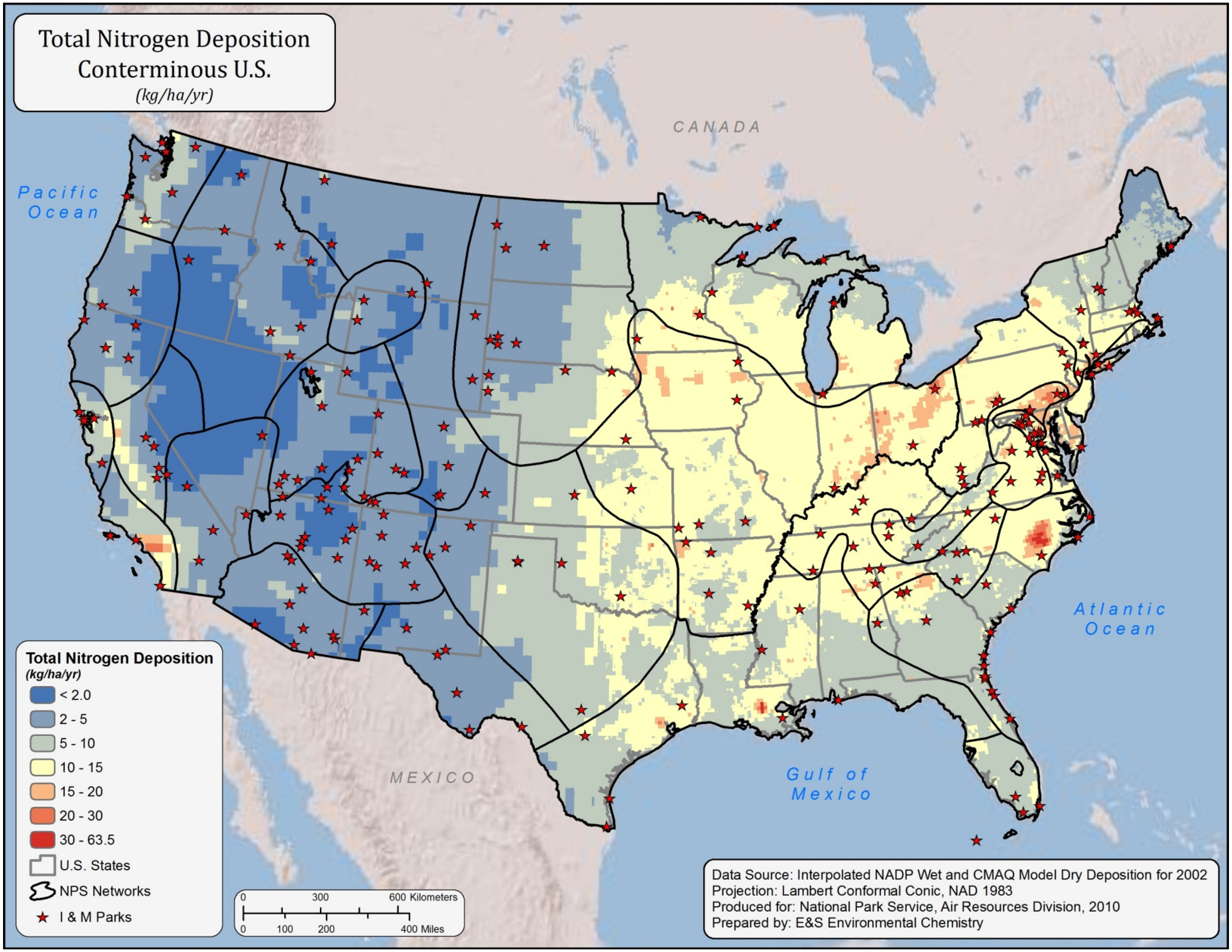
Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.

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

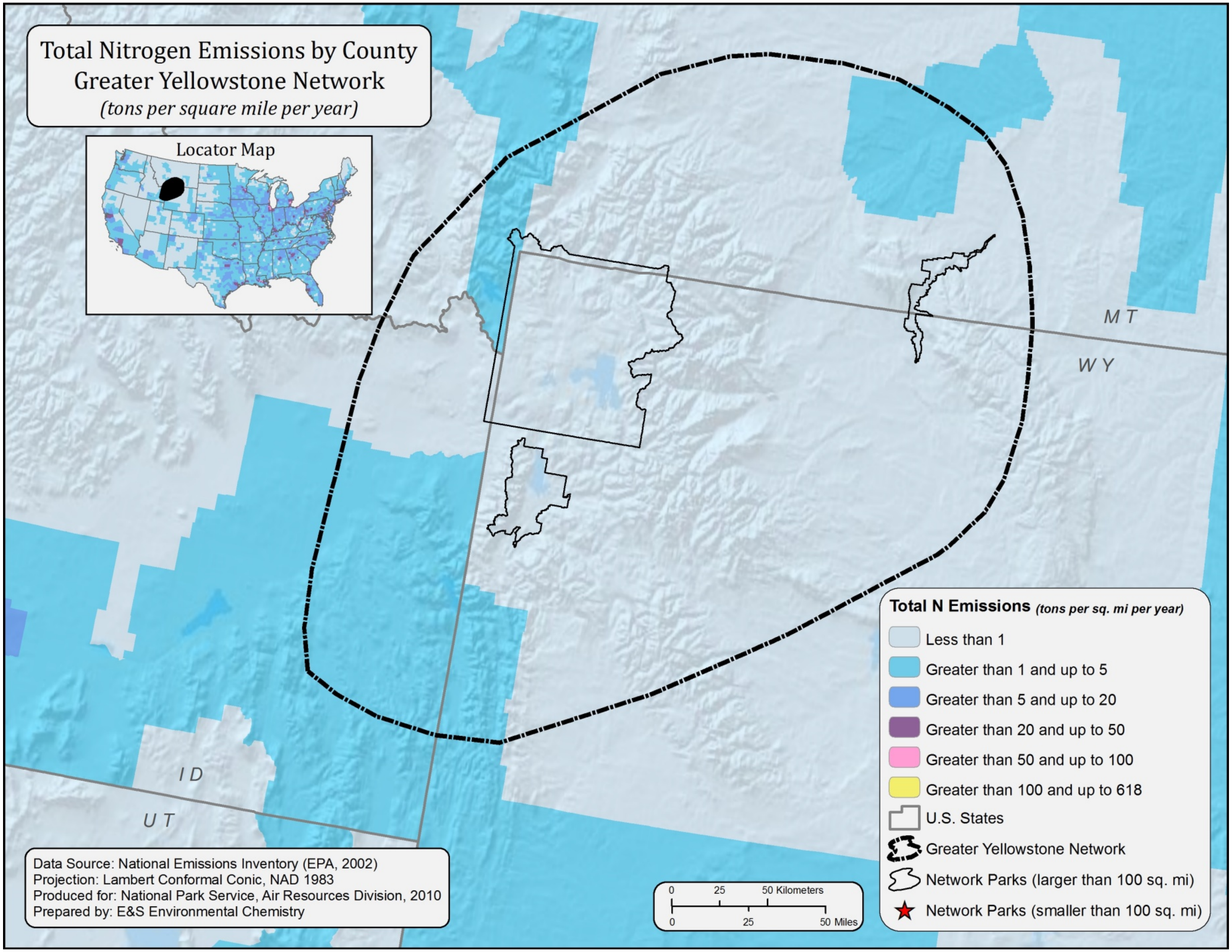
Map A

GRYN-7

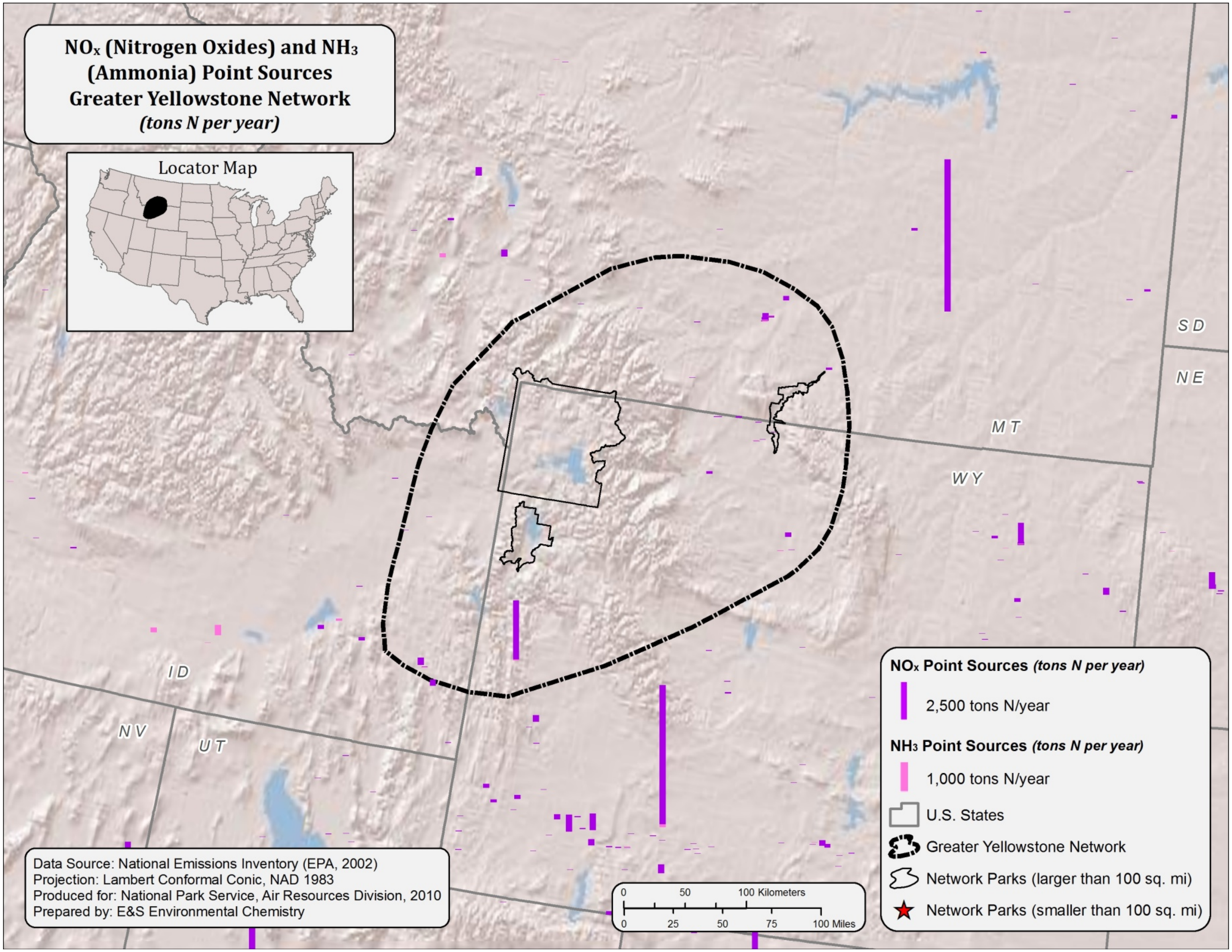


Total Nitrogen Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
Total Nitrogen Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated 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
Greater Yellowstone Network
(tons per square mile per year)
Locator Map
M T
W Y
I D
U T
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
Greater Yellowstone 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

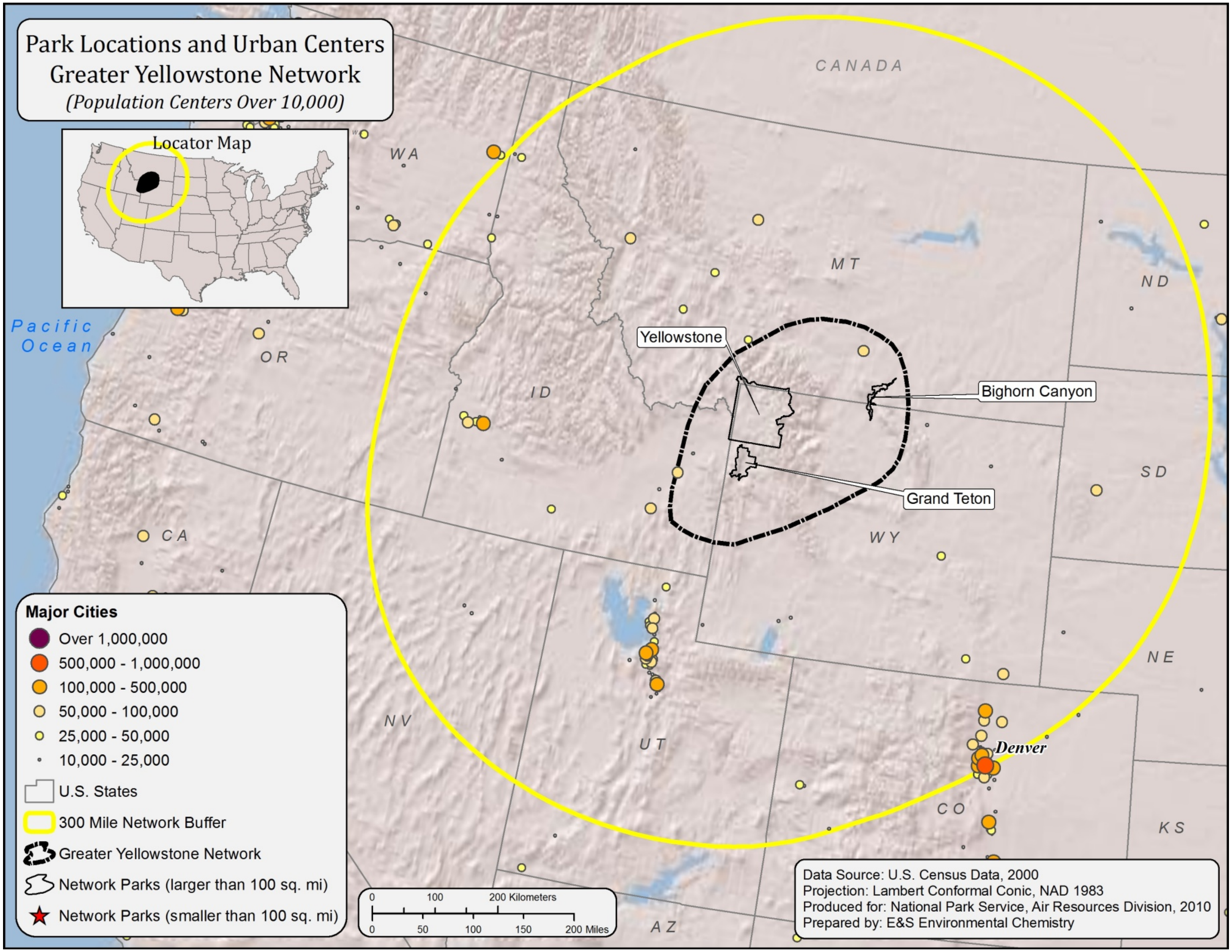
Map C



NOx (Nitrogen Oxides) and NH3 (Ammonia) Point Sources
Greater Yellowstone Network
(tons N per year)
Locator Map
S D
N E
M T
W Y
I D
N V
U T
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
Greater Yellowstone 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

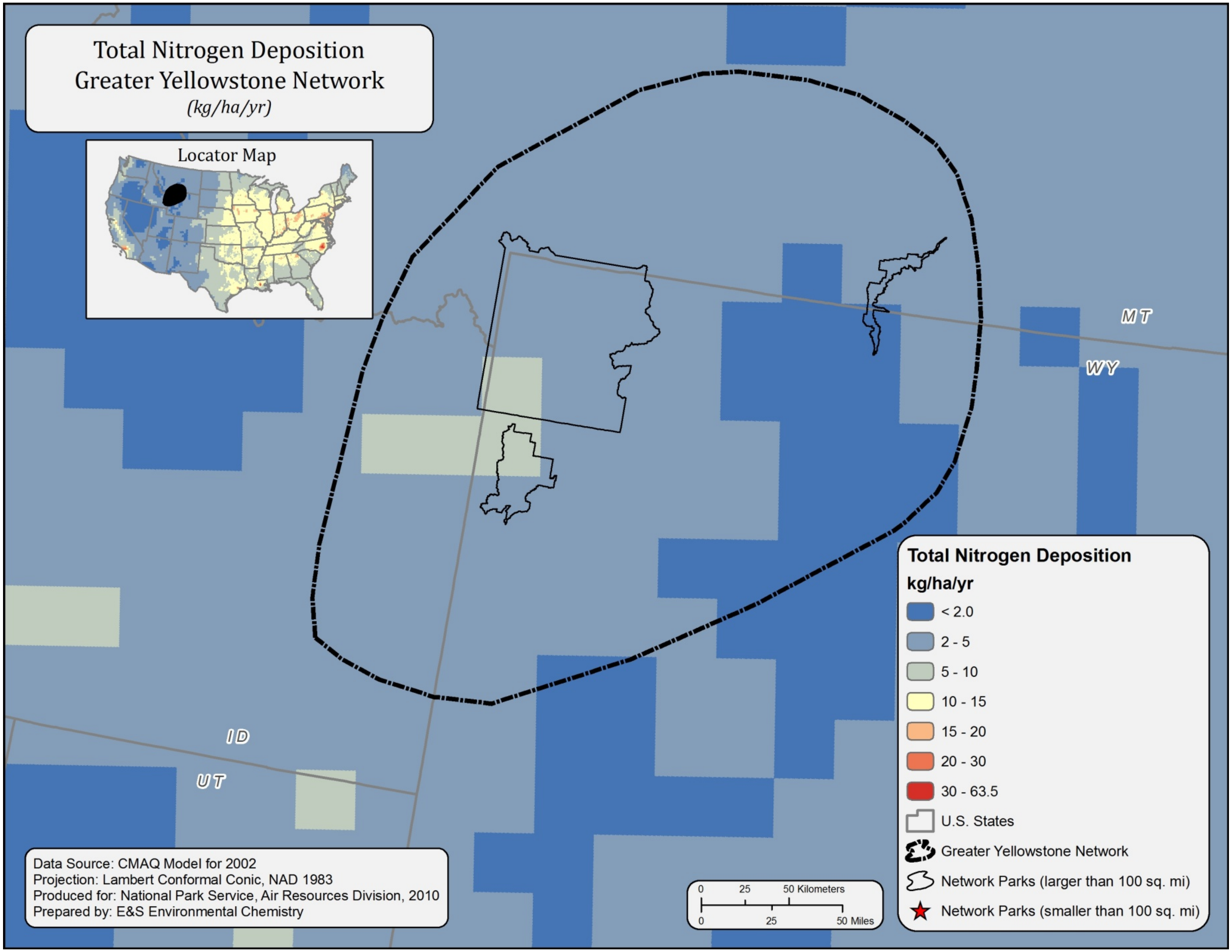
Map D

GRYN-10

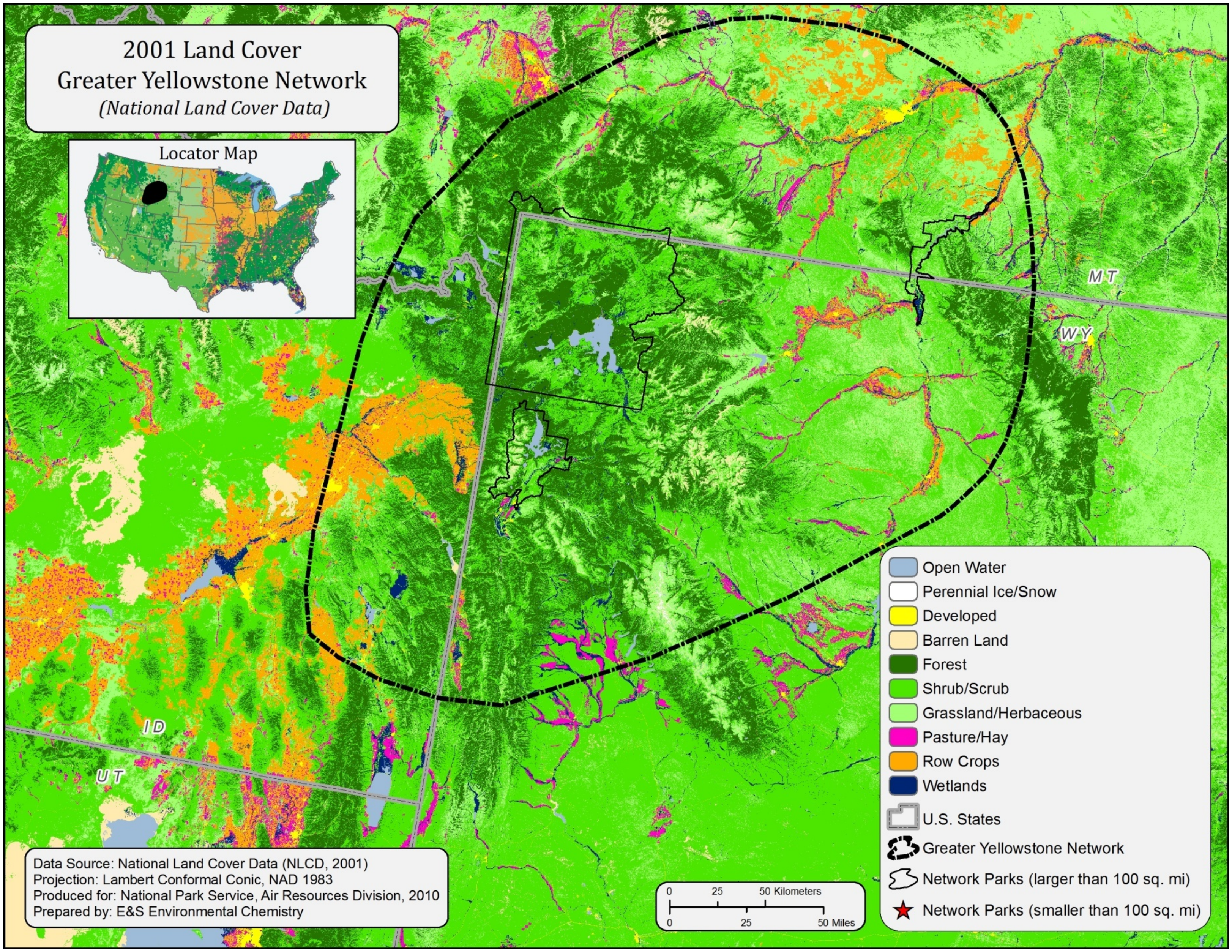


Park Locations and Urban Centers
Greater Yellowstone Network
(Population Centers Over 10,000)
Locator Map
CANADA
WA
MT
ND
Pacific Ocean
OR
ID
Yellowstone
Bighorn Canyon
SD
Grand Teton
CA
WY
Major Cities
Over 1,000,000
500,000 - 1,000,000
100,000 - 500,000
50,000 - 100,000
25,000 - 50,000
10,000 - 25,000
U.S. States
300 Mile Network Buffer
Greater Yellowstone Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
NE
NV
UT
Denver
CO
KS
AZ
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

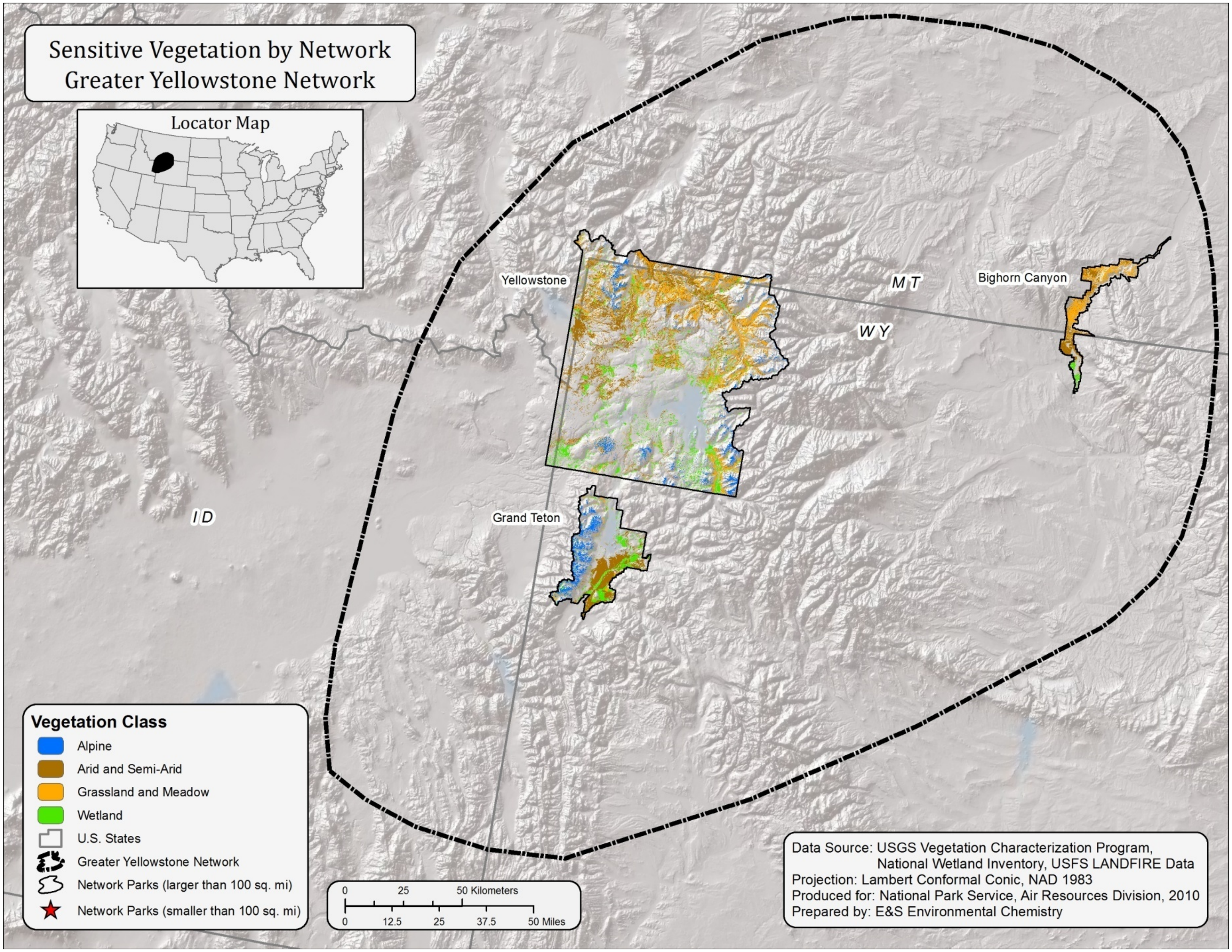

Total Nitrogen Deposition
Greater Yellowstone Network
(kg/ha/yr)
Locator Map
MT
WY
ID
UT
Total Nitrogen Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
Greater Yellowstone Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 25 50 Miles
Data Source: 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

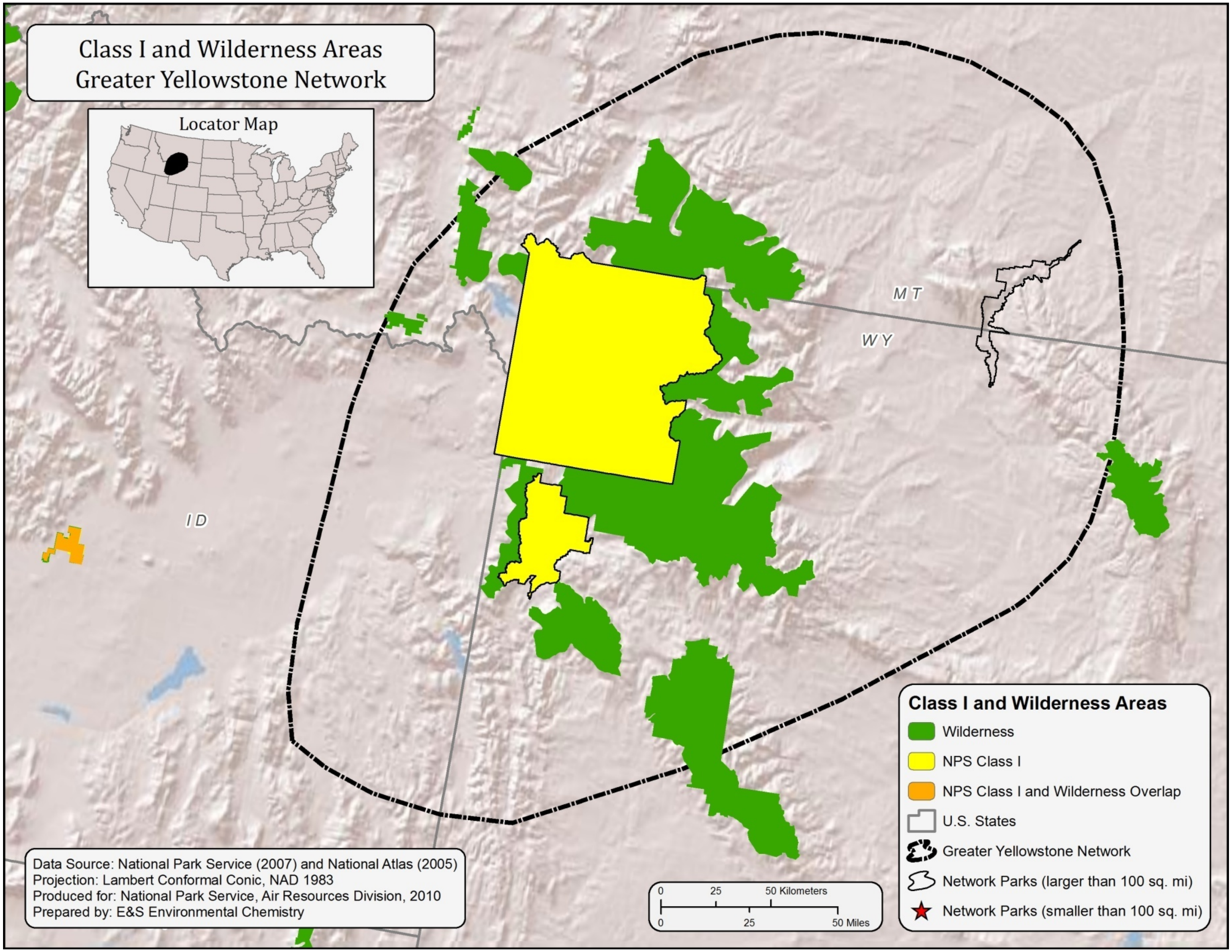


2001 Land Cover
Greater Yellowstone Network
(National Land Cover Data)
Locator Map
MT
WY
ID
UT
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetlands
U.S. States
Greater Yellowstone Network
Network Parks (larger than 100 sq. mi)
Network 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

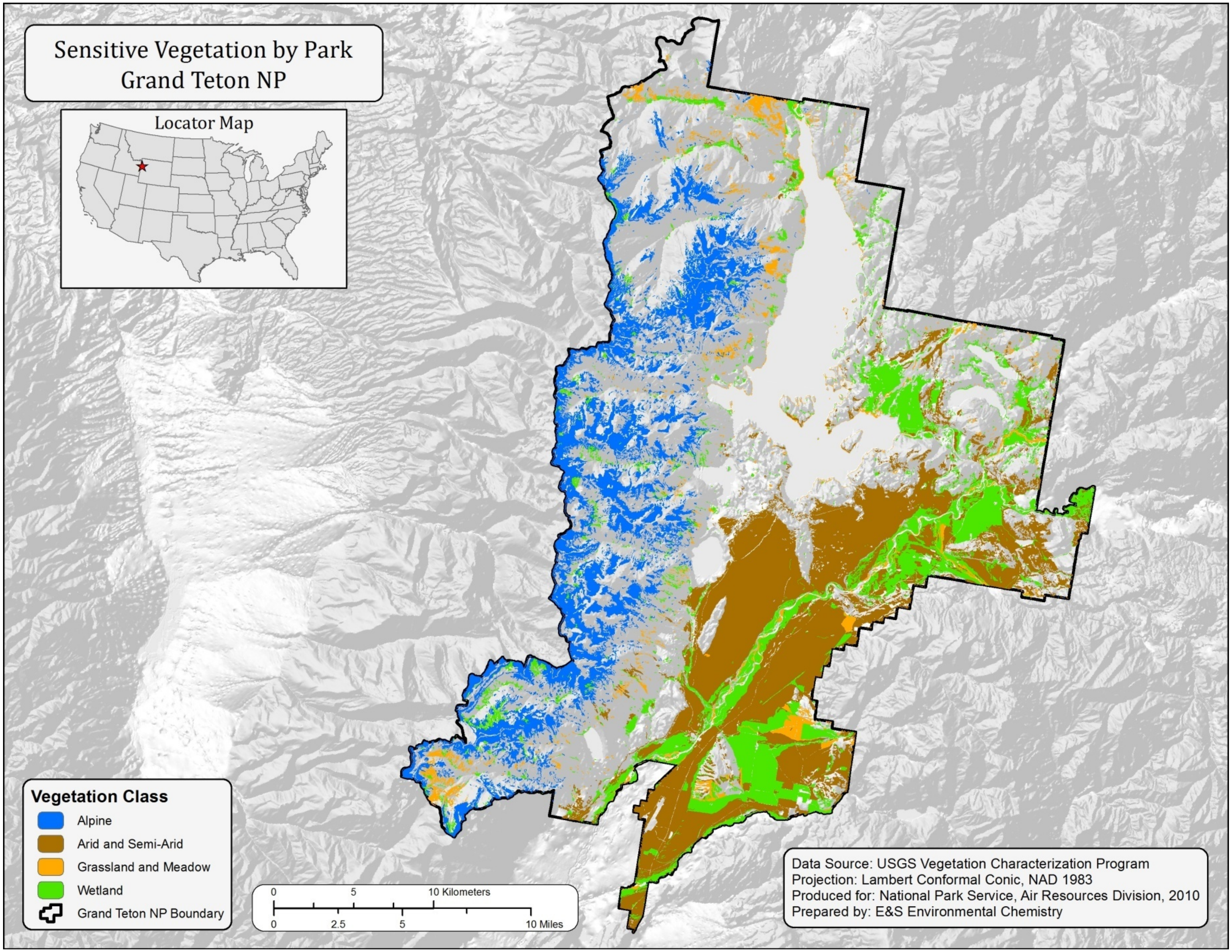
Map G


Sensitive Vegetation by Network
Greater Yellowstone Network
Locator Map
Yellowstone
Grand Teton
Bighorn Canyon
M T
W Y
I D
Vegetation Class
Alpine
Arid and Semi-Arid
Grassland and Meadow
Wetland
U.S. States
Greater Yellowstone Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 25 50 Kilometers
0 12.5 25 37.5 50 Miles
Data Source: USGS Vegetation Characterization Program,
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

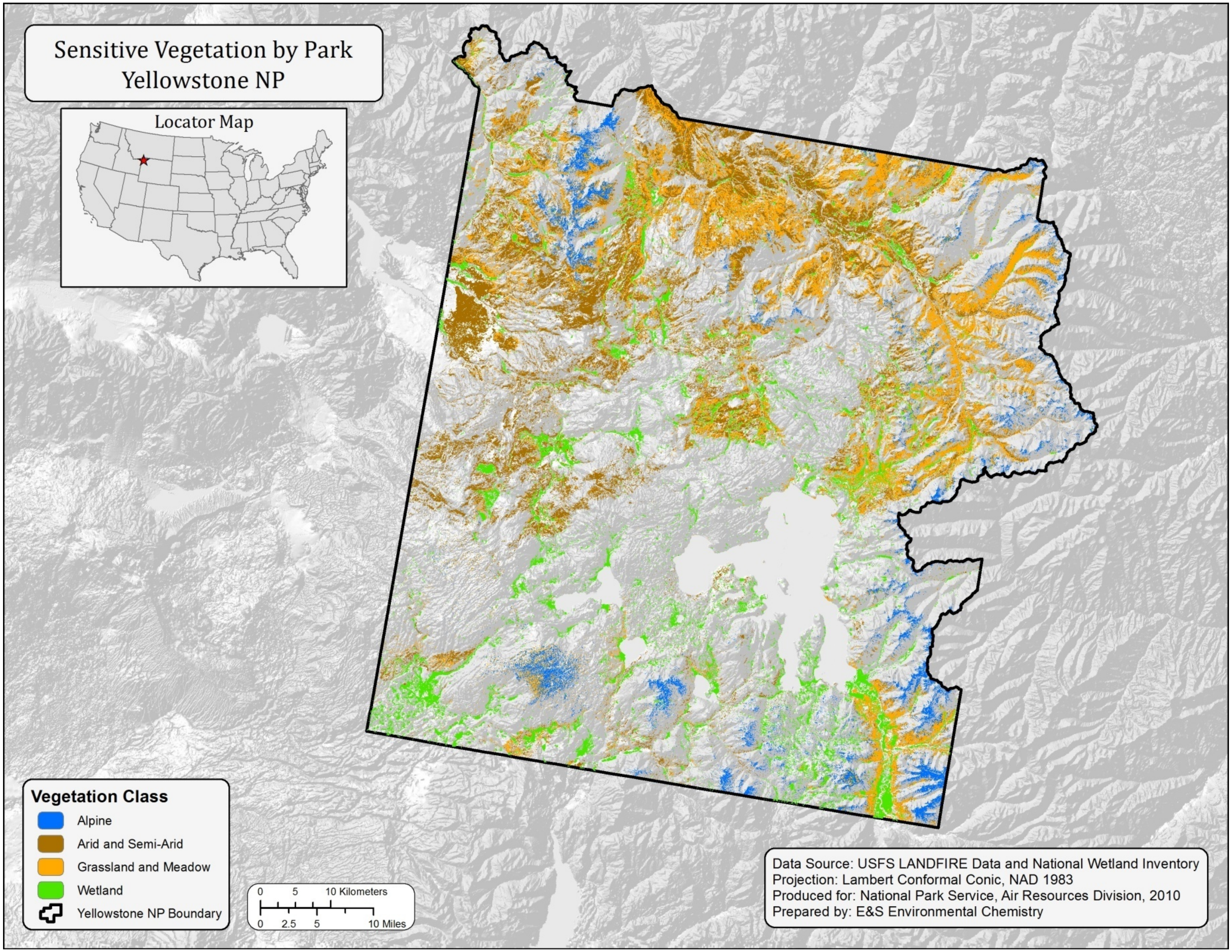

Class I and Wilderness Areas
Greater Yellowstone Network
Locator Map
M T
W Y
I D
Class I and Wilderness Areas
Wilderness
NPS Class I
NPS Class I and Wilderness Overlap
U.S. States
Greater Yellowstone Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0
25
50 Kilometers
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 I

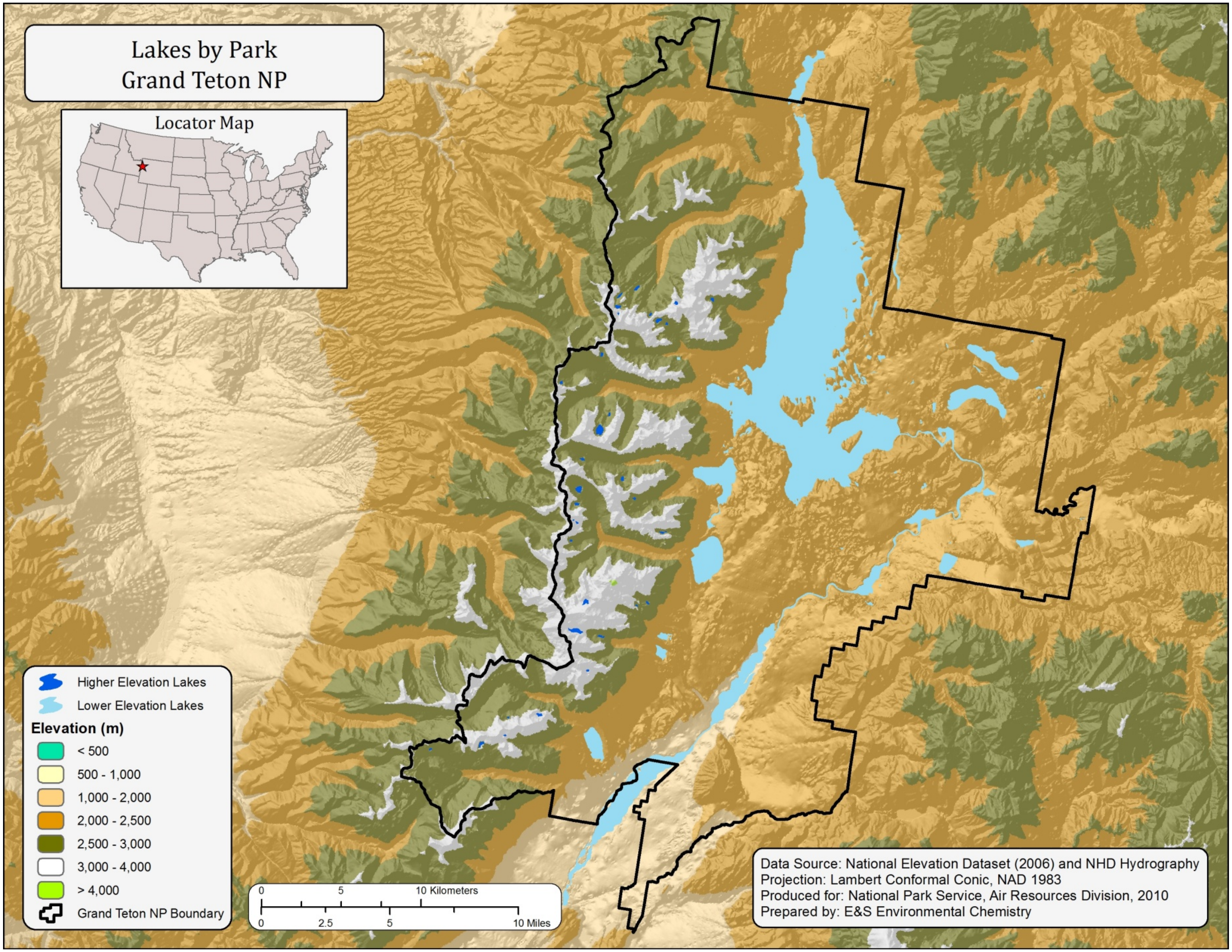


Sensitive Vegetation by Park
Grand Teton NP
Locator Map
Vegetation Class
Alpine
Arid and Semi-Arid
Grassland and Meadow
Wetland
Grand Teton NP Boundary
0
5
10 Kilometers
0
2.5
5
10 Miles
Data Source: USGS Vegetation Characterization Program
Projection: Lambert Conformal Conic, NAD 1983
Produced for: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

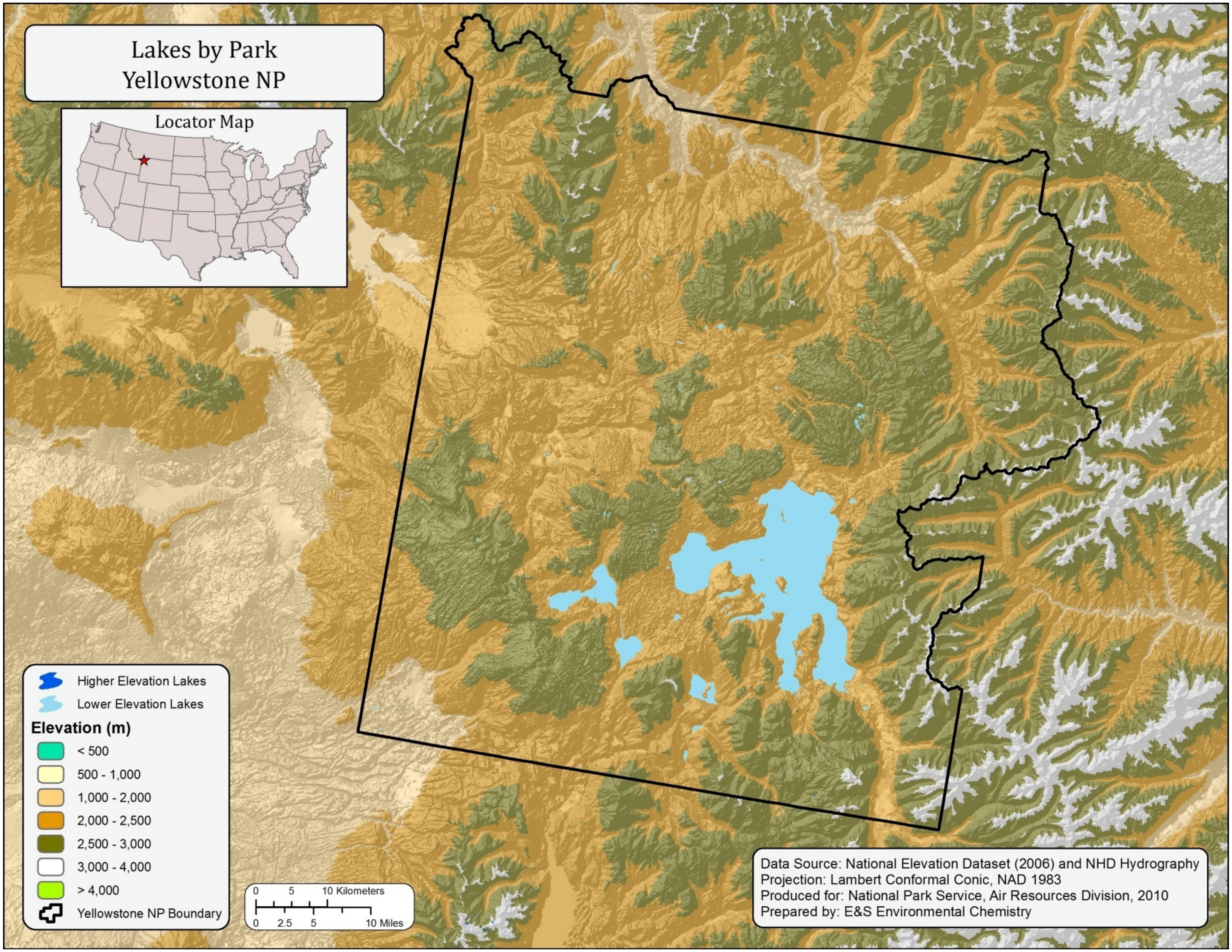
Map J-1


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

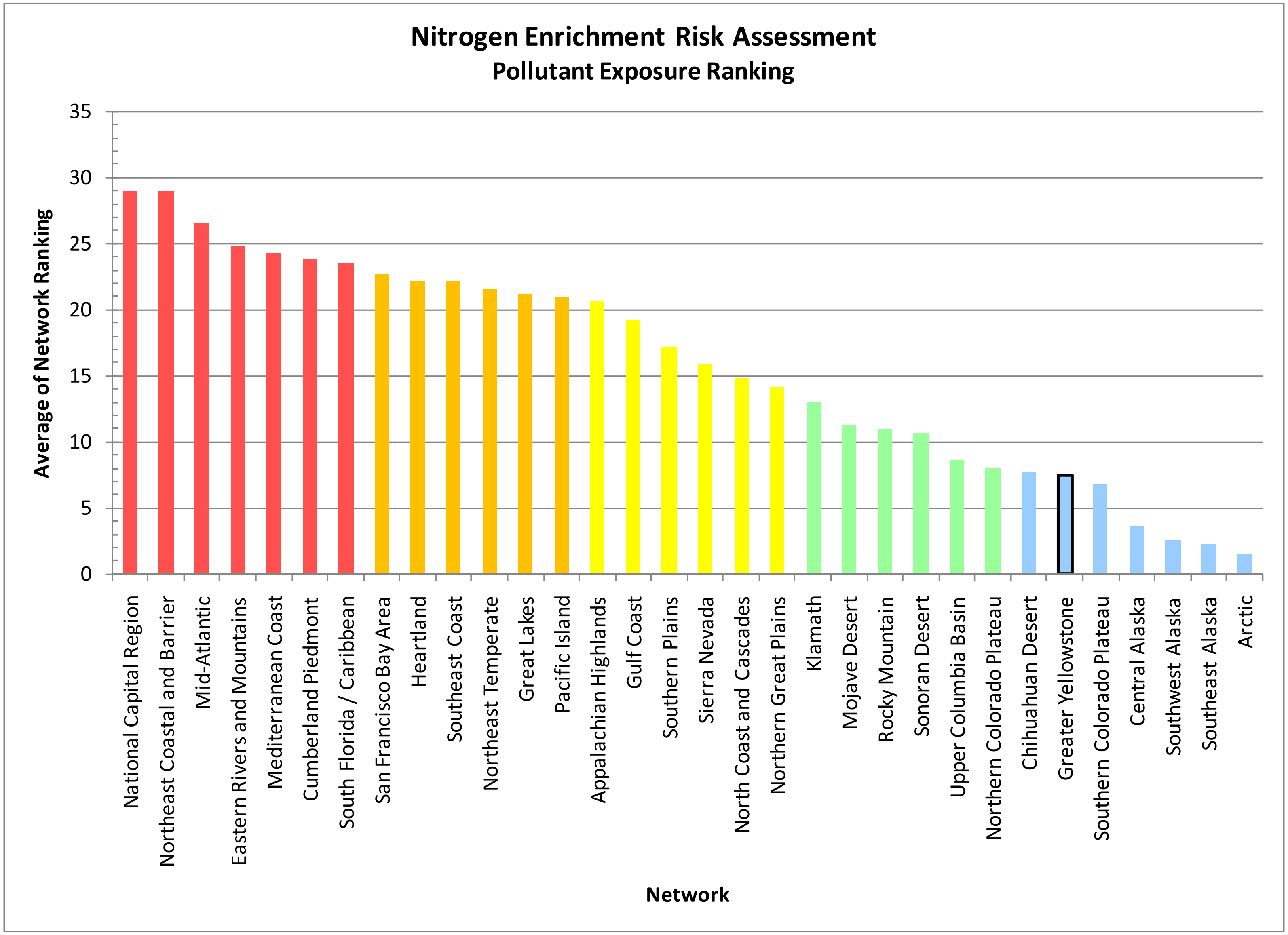
Map J-2


Lakes by Park
Grand Teton 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
Grand Teton 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
Yellowstone 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
Yellowstone 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
35
30
25
20
15
10
5
0
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
Network

Figure A

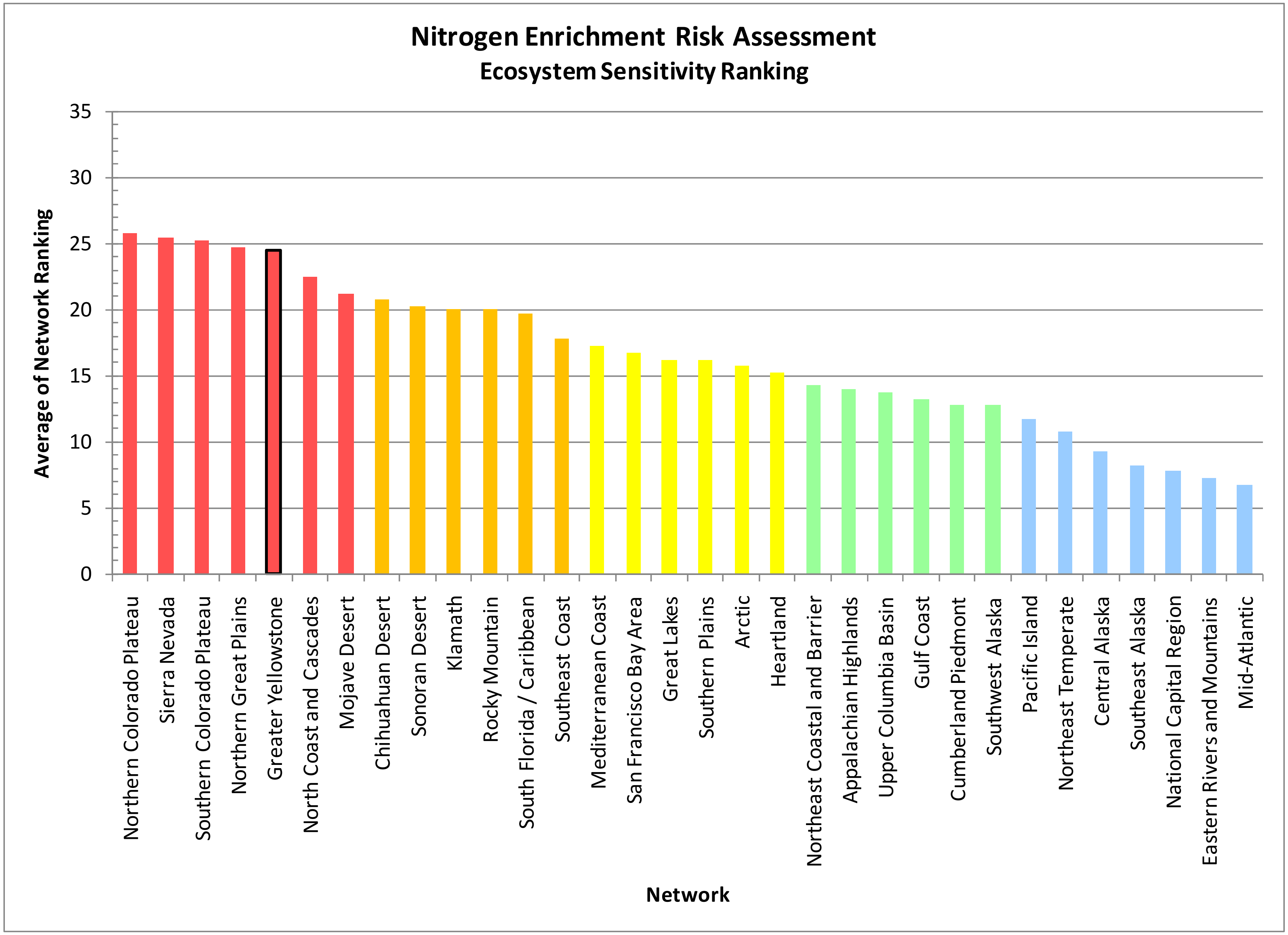

Nitrogen Enrichment Risk Assessment
Ecosystem Sensitivity Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Northern Colorado Plateau
Sierra Nevada
Southern Colorado Plateau
Northern Great Plains
Greater Yellowstone
North Coast and Cascades
Mojave Desert
Chihuahuan Desert
Sonoran Desert
Klamath
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

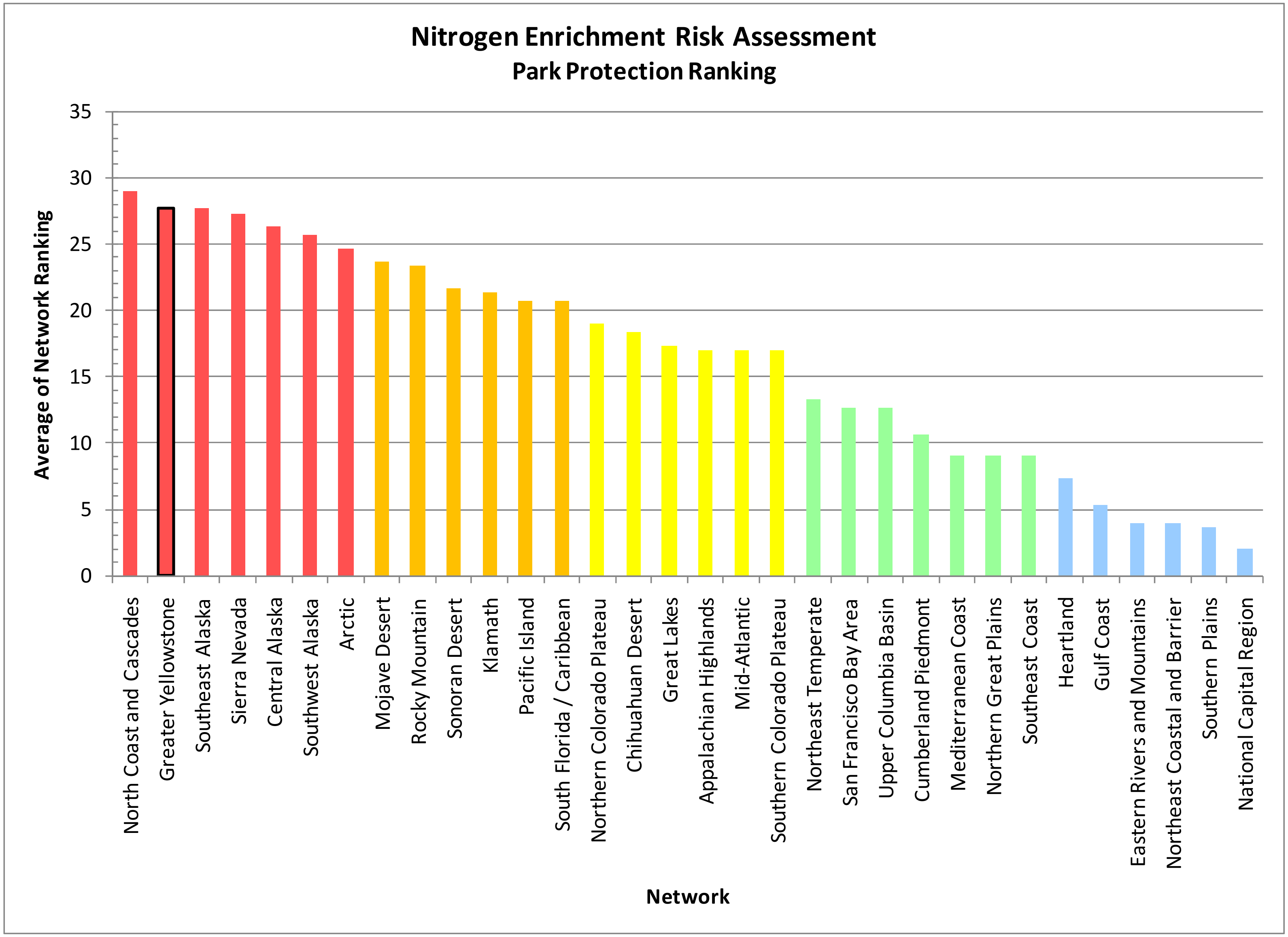

Nitrogen Enrichment Risk Assessment
Park Protection Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
North Coast and Cascades
Greater Yellowstone
Southeast Alaska
Sierra Nevada
Central Alaska
Southwest Alaska
Arctic
Mojave Desert
Rocky Mountain
Sonoran Desert
Klamath
Pacific Island
South Florida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

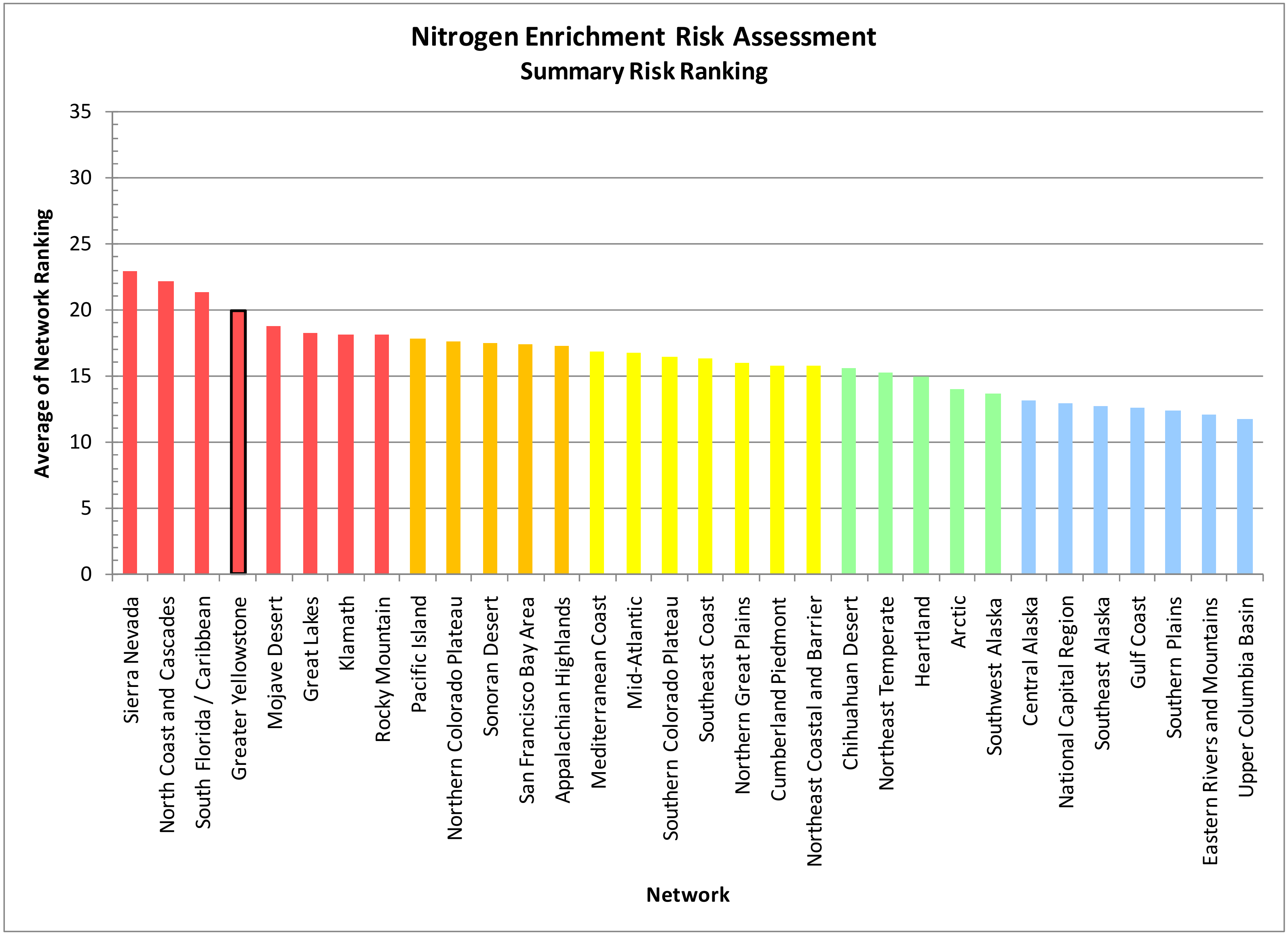

Nitrogen Enrichment Risk Assessment
Summary Risk Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Sierra Nevada
North Coast and Cascades
South Florida / Caribbean
Greater Yellowstone
Mojave Desert
Great Lakes
Klamath
Rocky Mountain
Pacific Island
Northern Colorado Plateau
Sonoran Desert
San Francisco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

Figure D

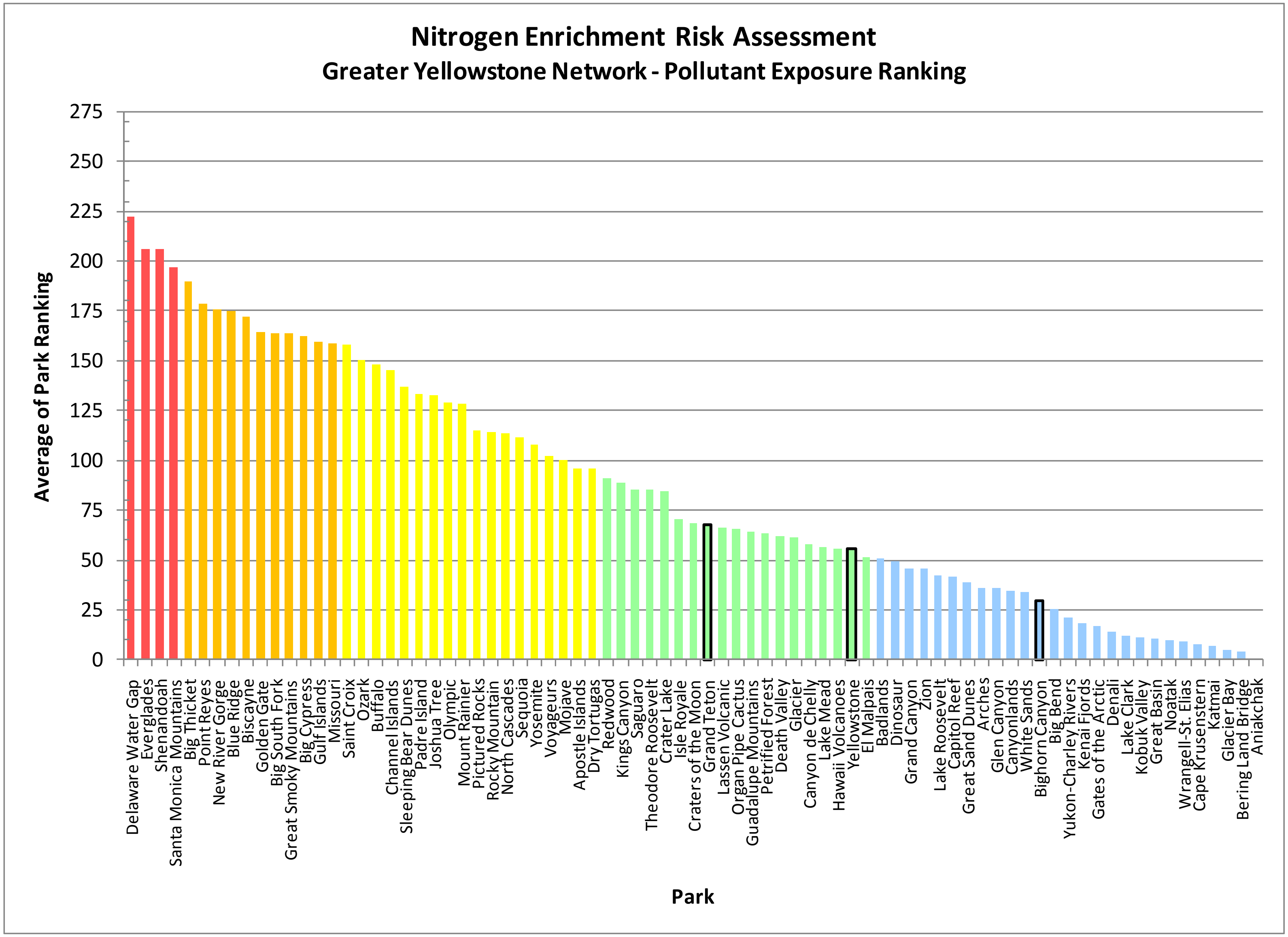

Nitrogen Enrichment Risk Assessment
Greater Yellowstone Network - Pollutant Exposure Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Delaware Water Gap
Everglades
Shenandoah
Santa Monica Mountains
Big Thicket
Point Reyes
New River Gorge
Blue Ridge
Biscayne
Golden Gate
Big South 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

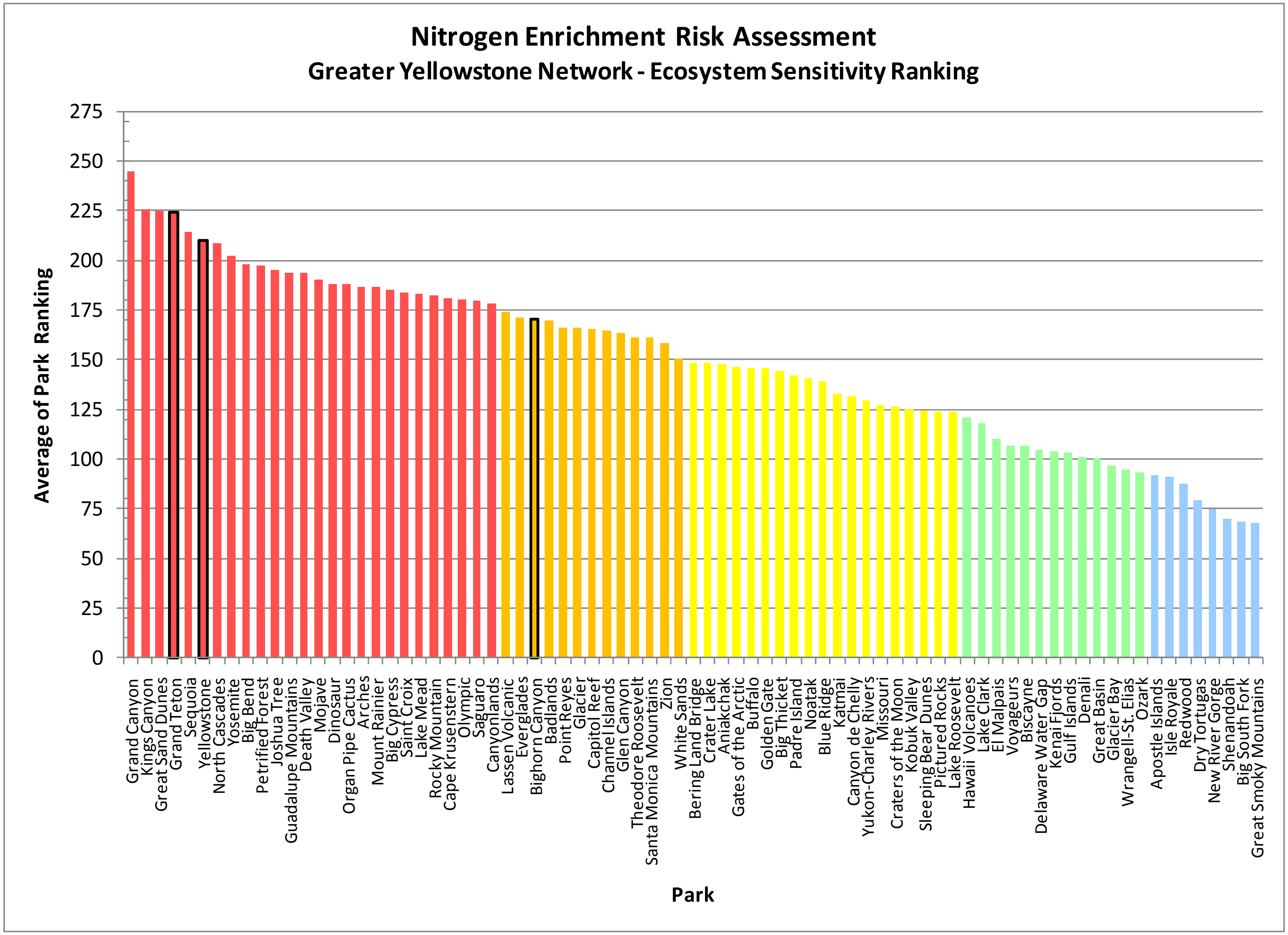
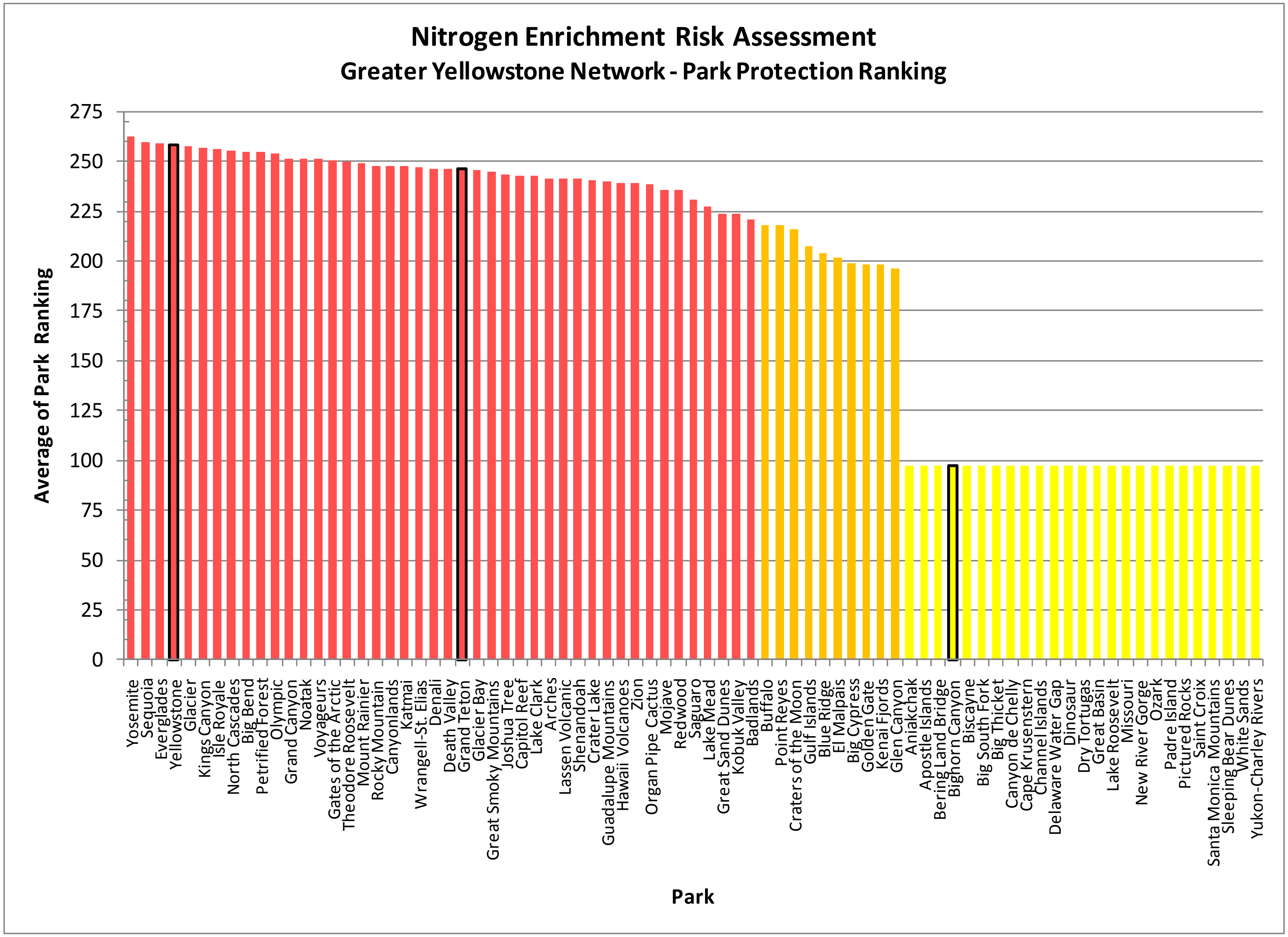

Nitrogen Enrichment Risk Assessment
Greater Yellowstone Network - Ecosystem Sensitivity Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Park
Grand Canyon
Kings Canyon
Great Sand Dunes
Grand Teton
Sequoia
Yellowstone
North Cascades
Yosemite
Big Bend
Petrified Forest
Joshua Tree
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
Greater Yellowstone 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

GRYN-26

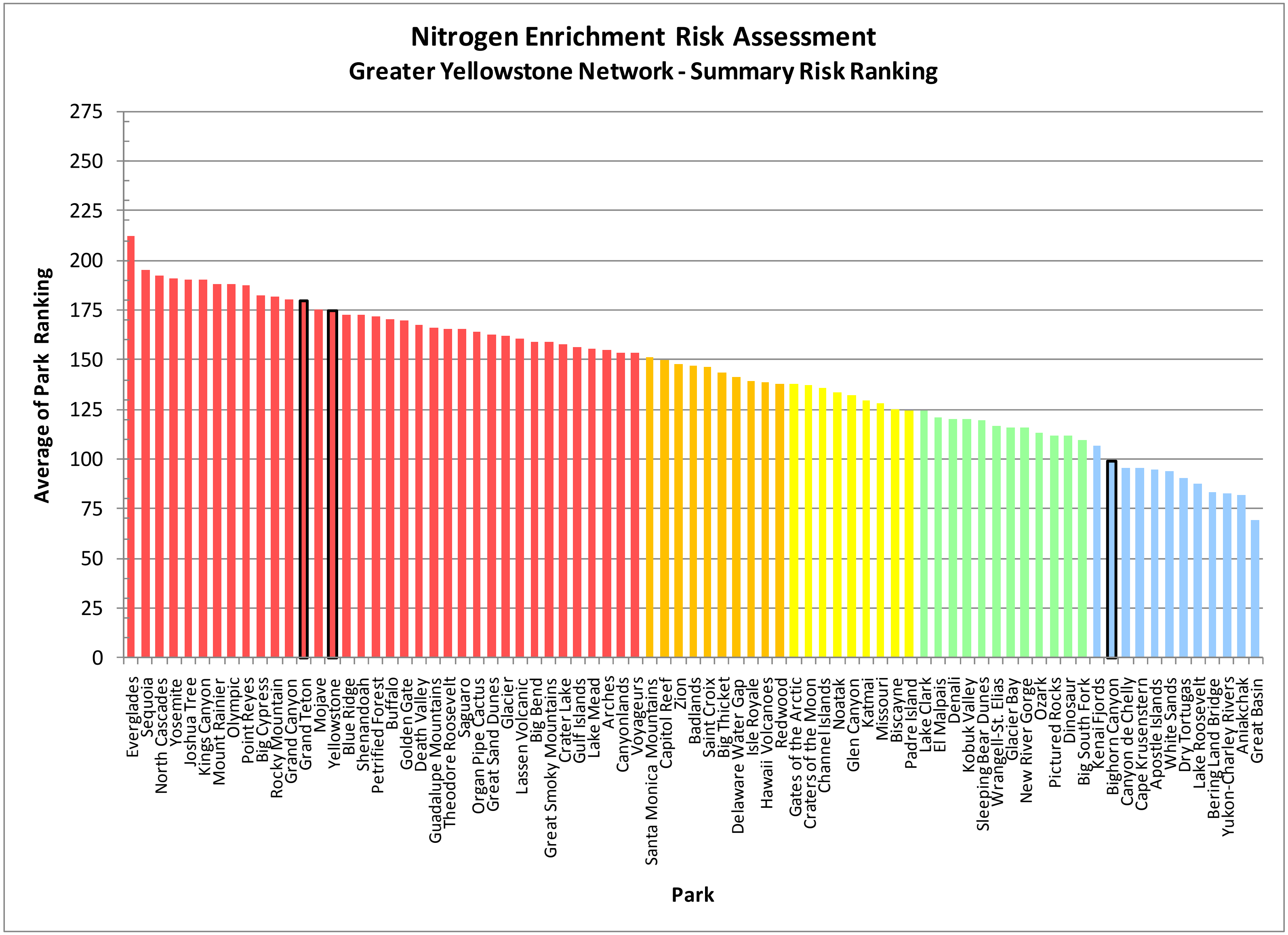


Figure H

NPS 960/106648, February 2011

National Park Service
U.S. Department of the Interior

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Denver, CO 80225

www.nature.nps.gov/air