



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

## *Sonoran Desert Network (SODN)*

Natural Resource Report NPS/NRPC/ARD/NRR—2011/327



**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

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## Sonoran Desert Network (SODN)

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

Total annual N emissions, by county, are shown in Map C for lands in and surrounding the Sonoran Desert Network. County-level emissions within the network ranged from less than 1 ton per square mile to between 5 and 20 tons per square mile. In general, annual county N emissions were less than 5 tons per square mile throughout most of the network. Point source emissions of oxidized (nitrogen oxides,  $\text{NO}_x$ ) and reduced (ammonia,  $\text{NH}_3$ ) N are shown in Map D. There are few N point sources of any magnitude (i.e., larger than about 500 tons per square mile) in this network. Of the point sources that do occur, the larger ones are sources of oxidized, rather than reduced, N. Urban centers within the network and within a 300 mile buffer around the network are shown in Map E. Most of the human population centers of any magnitude (i.e., larger than 50,000 people) are located in and around Phoenix and Tucson.

Total N deposition in and around the network is shown in Map F. Included in this analysis are both wet and dry forms of N deposition and both the oxidized and reduced N species. Total N deposition within the network ranged from less than 2 kg N/ha/yr at some of the coastal areas in the northern part of the network to as high as 5 to 10 kg N/ha/yr. Estimated deposition is less than 5 kg N/ha/yr throughout most of the network, including all of the areas that contain I&M parks.

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

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). The two largest parks in this network are both desert parks. The predominant sensitive vegetation type within these parks is arid and semi-arid vegetation.

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

Network rankings are given in Figures A through C as the average ranking of the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection metrics, respectively. Figure D shows the

overall network Summary Risk ranking. In each figure, the rank for this particular network is highlighted to show its relative position compared with the ranks of the other 31 networks.

The Sonoran Desert Network 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 relatively high, within the second highest quintile among networks (Figure B). This is mainly because the vegetation in this network is largely comprised of arid and semi-arid vegetation types, which are among those expected to be especially sensitive to nutrient enrichment effects from N deposition. This network ranks in the second highest quintile in Park Protection, having moderate 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 middle of the second 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 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.

The two I&M parks in the Sonoran Desert Network that are larger than 100 square miles (SAGU and ORPI) are both ranked in the second lowest quintile in Pollutant Exposure (Figure E). The Pollutant Exposure rankings for the smaller parks are more variable, ranging from the lowest quintile (4 parks) to the middle quintile (2 parks; Table A). Ecosystem Sensitivity for the two large parks is in the highest quintile among parks, as is Park Protection (Figures F and G). Ecosystem Sensitivity rankings are also Very High for five of the smaller parks: Casa Grande Ruins (CAGR), Coronado (CORO), Gila Cliff Dwellings (GICL) Montezuma Castle (MOCA), and Tonto (TONT; Table A). Park Protection rankings for the smaller parks vary from Moderate (six parks) to Very High (CHIR).

In combination, the Summary Park Risk ranking places both large parks in the highest quintile among parks. CHIR and CORO are both ranked in the second highest quintile. Both ORPI and SAGU have risk of nutrient N effects from atmospheric N deposition that is considered Very High (Figure H). The risk to CHIR and CORO is considered High; ranks for other parks in this network are lower (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.

I&M Parks <sup>2</sup> in Network	Relative Ranking of Individual Parks <sup>1</sup>			
	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Casa Grande Ruins	Moderate	Very High	Moderate	Moderate
Chiricahua	Very Low	High	Very High	High
Coronado	Very Low	Very High	High	High
Fort Bowie	Very Low	High	Moderate	Very Low
Gila Cliff Dwellings	Very Low	Very High	High	Moderate
Montezuma Castle	Low	Very High	Moderate	Moderate
<b><i>Organ Pipe Cactus</i></b>	Low	Very High	Very High	Very High
<b><i>Saguaro</i></b>	Low	Very High	Very High	Very High
Tonto	Moderate	Very High	Moderate	Moderate
Tumacacori	Low	High	Moderate	Low
Tuzigoot	Low	Moderate	Moderate	Very Low

<sup>1</sup> 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).  
<sup>2</sup> Park name is printed in bold italic for parks larger than 100 square miles.

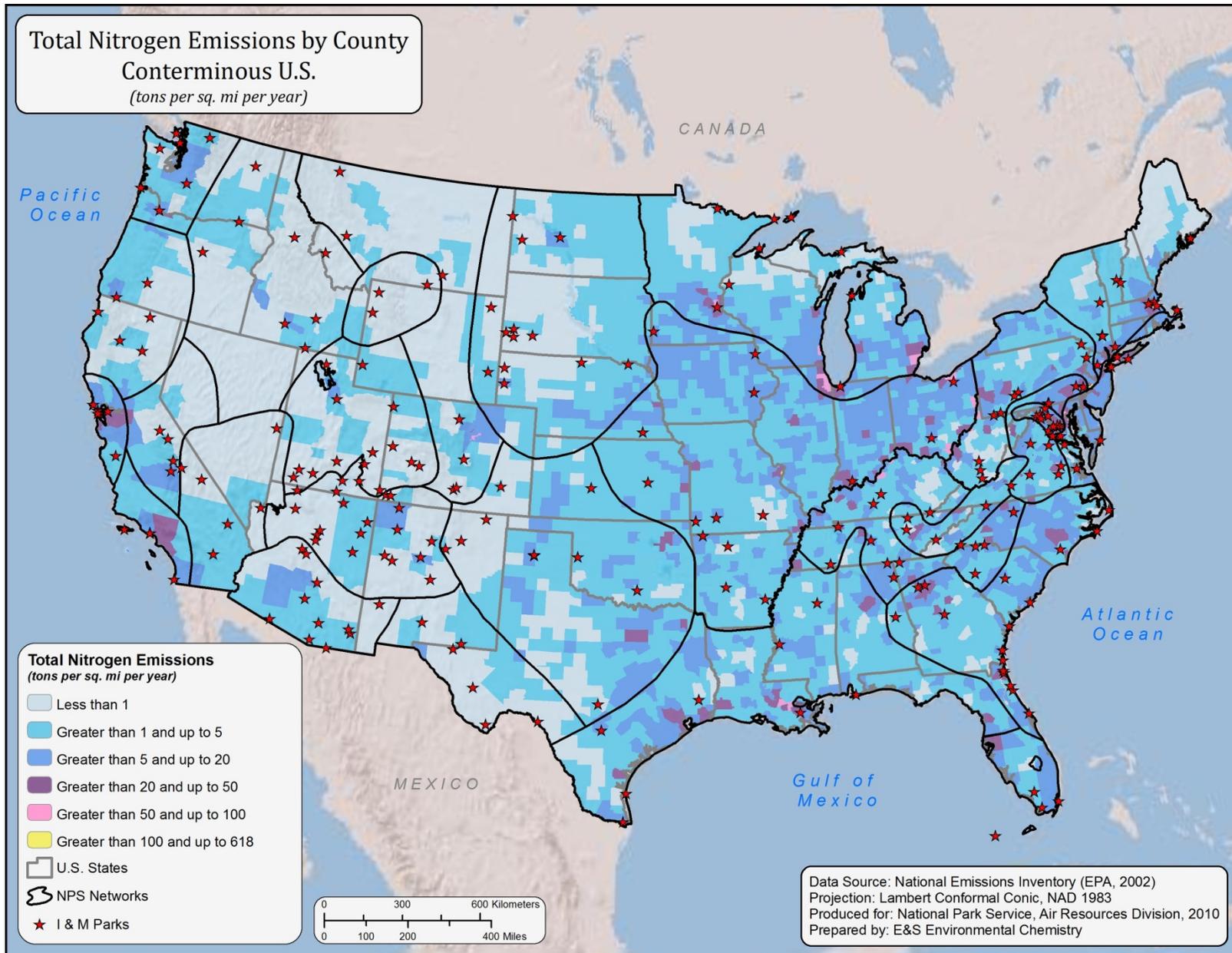
- Map A. National map of total N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NO<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) forms of N are included. The total is expressed in tons per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- 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<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) 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<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) 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<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) 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<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) 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](http://www.mrlc.gov/nlcd_multizone_map.php))
- Map H. Distribution within the larger parks that occur in this network of the five terrestrial vegetation types thought to be most sensitive to N-nutrient enrichment effects: arctic, alpine, meadow, wetland, and arid and semi-arid. (Source of data: See Appendix A)
- Map I. Lands within the network that are classified as Class I or wilderness area. (Source of data: USGS 2005 [National Atlas; <http://nationalatlas.gov>] and NPS)
- Figure A. Network rankings for Pollutant Exposure, calculated as the average of scores for all Pollutant Exposure variables.
- Figure B. Network rankings for Ecosystem Sensitivity, calculated as the average of scores for all Ecosystem Sensitivity variables.
- Figure C. Network rankings for Park Protection, calculated as the average of scores for all Park Protection variables.
- Figure D. Network Summary Risk ranking, calculated as the sum of the averages of the scores for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection.
- Figure E. Park rankings for Pollutant Exposure for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Pollutant Exposure variables.
- Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

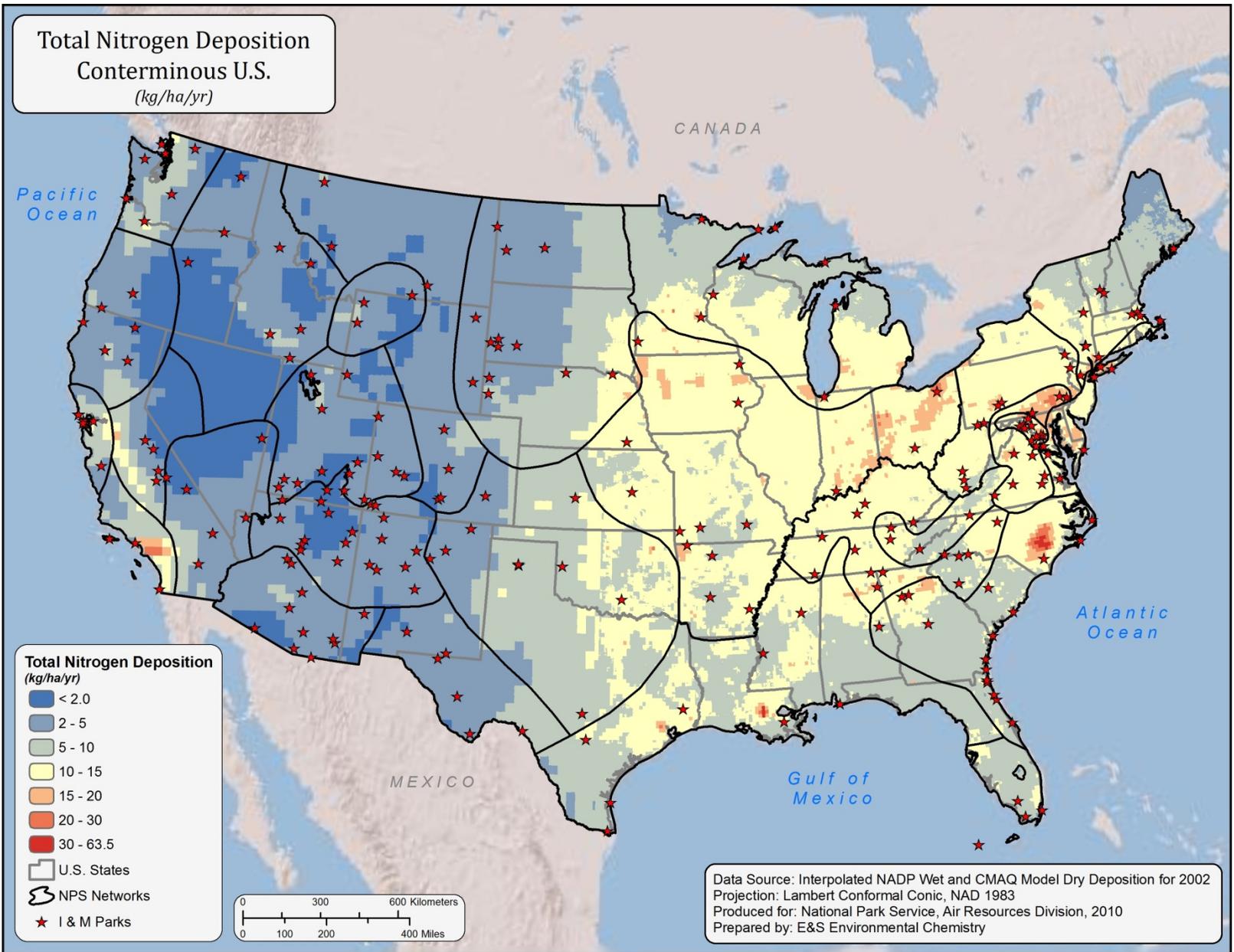
Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.

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

SODN-6

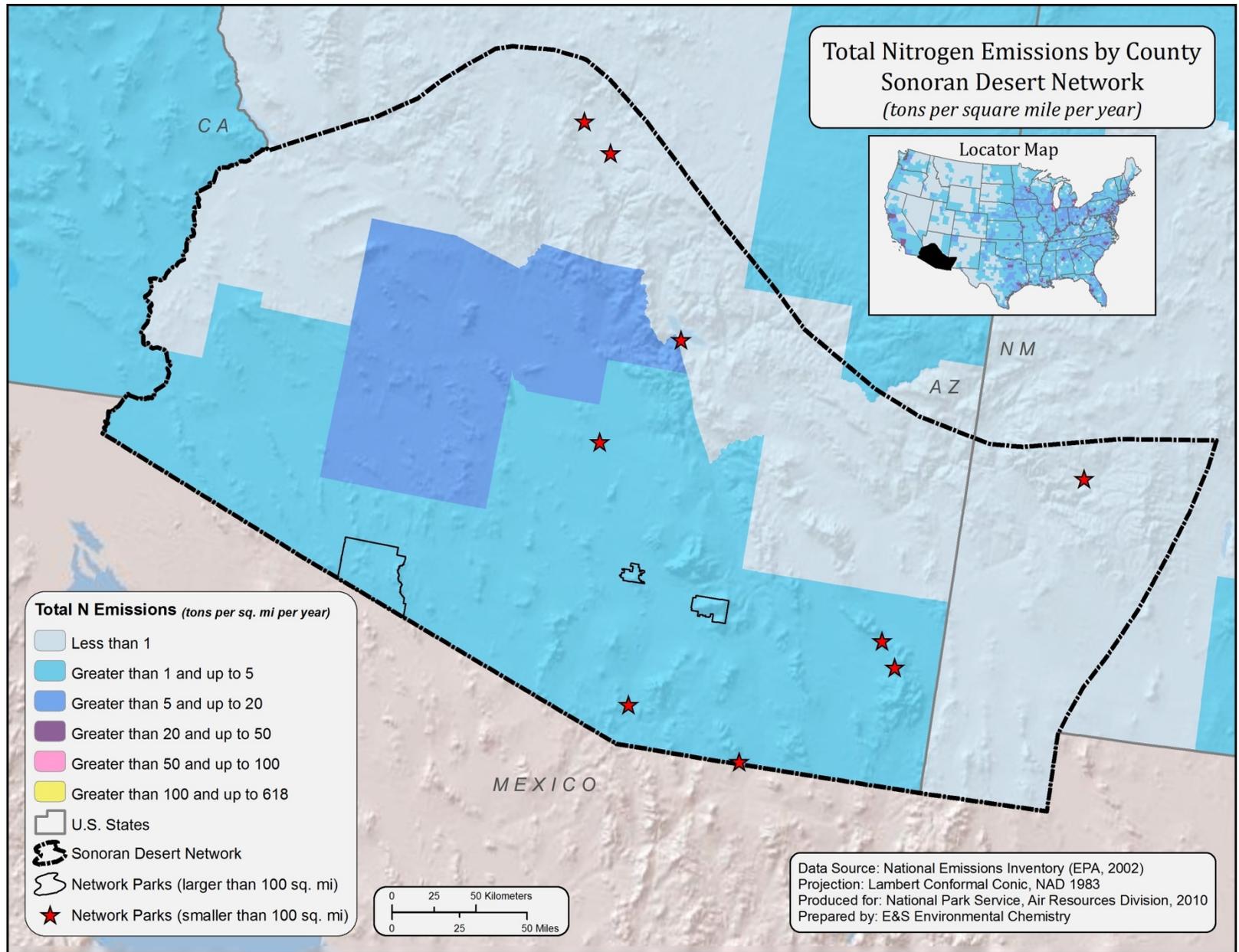


Map A

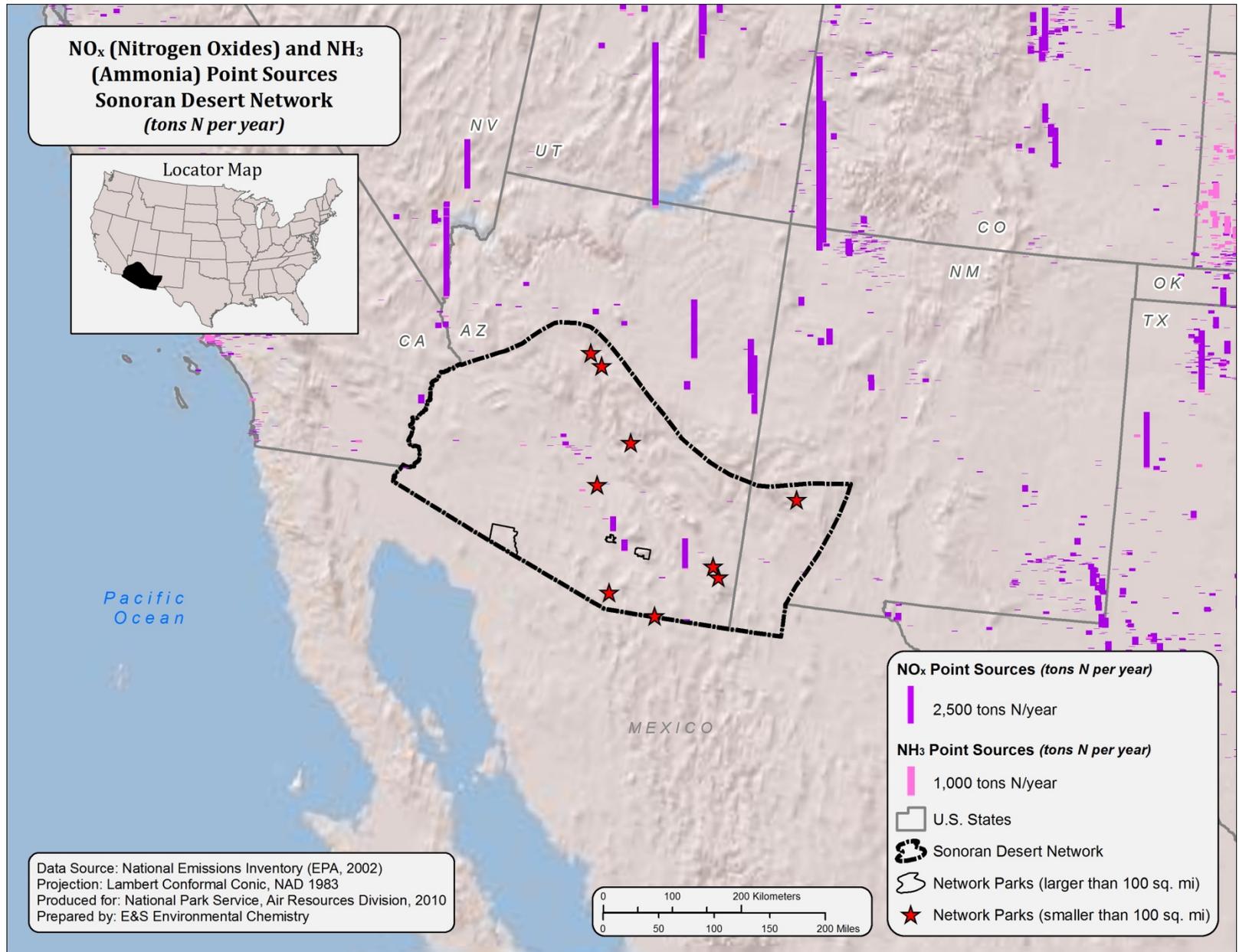


SODN-7

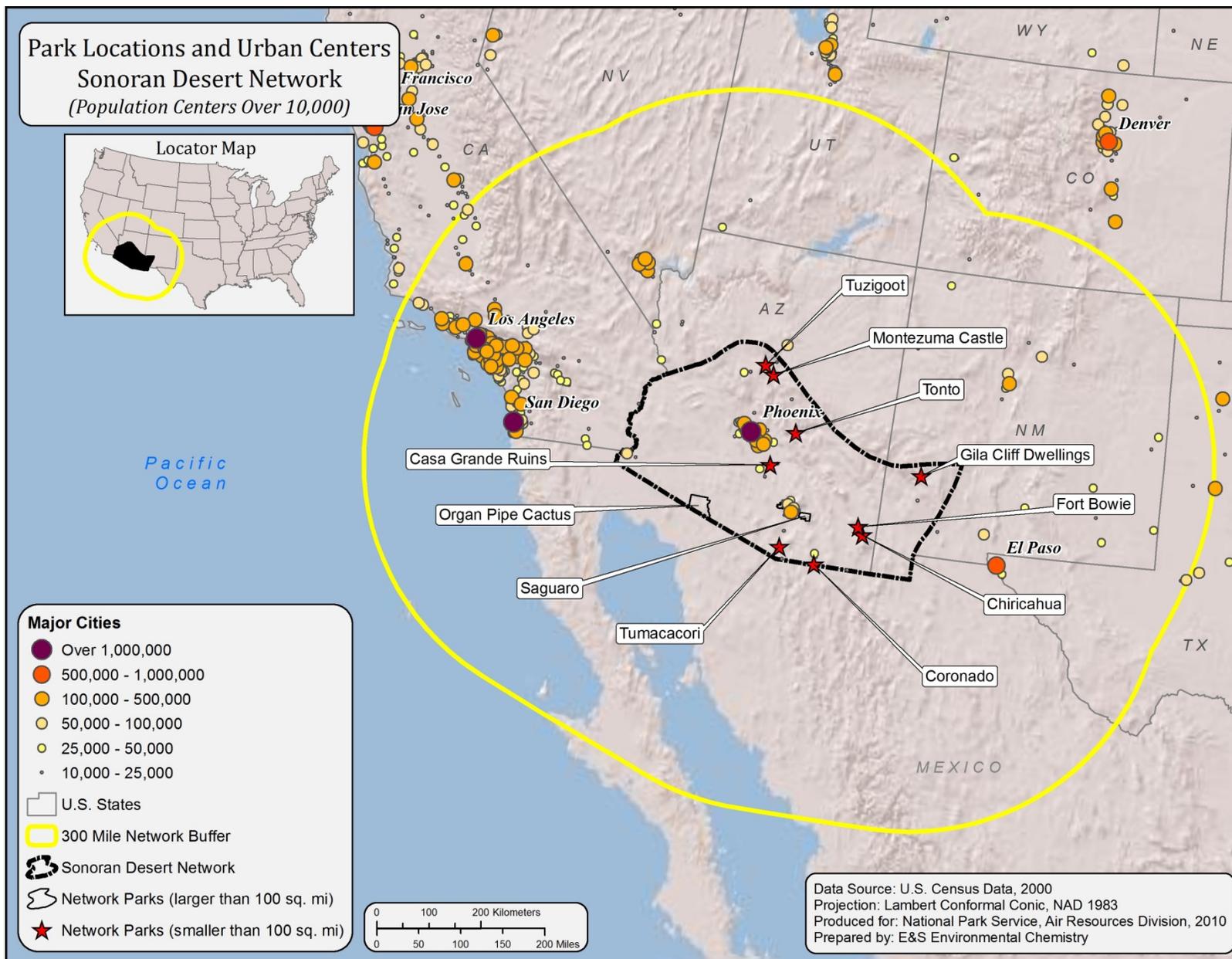
Map B



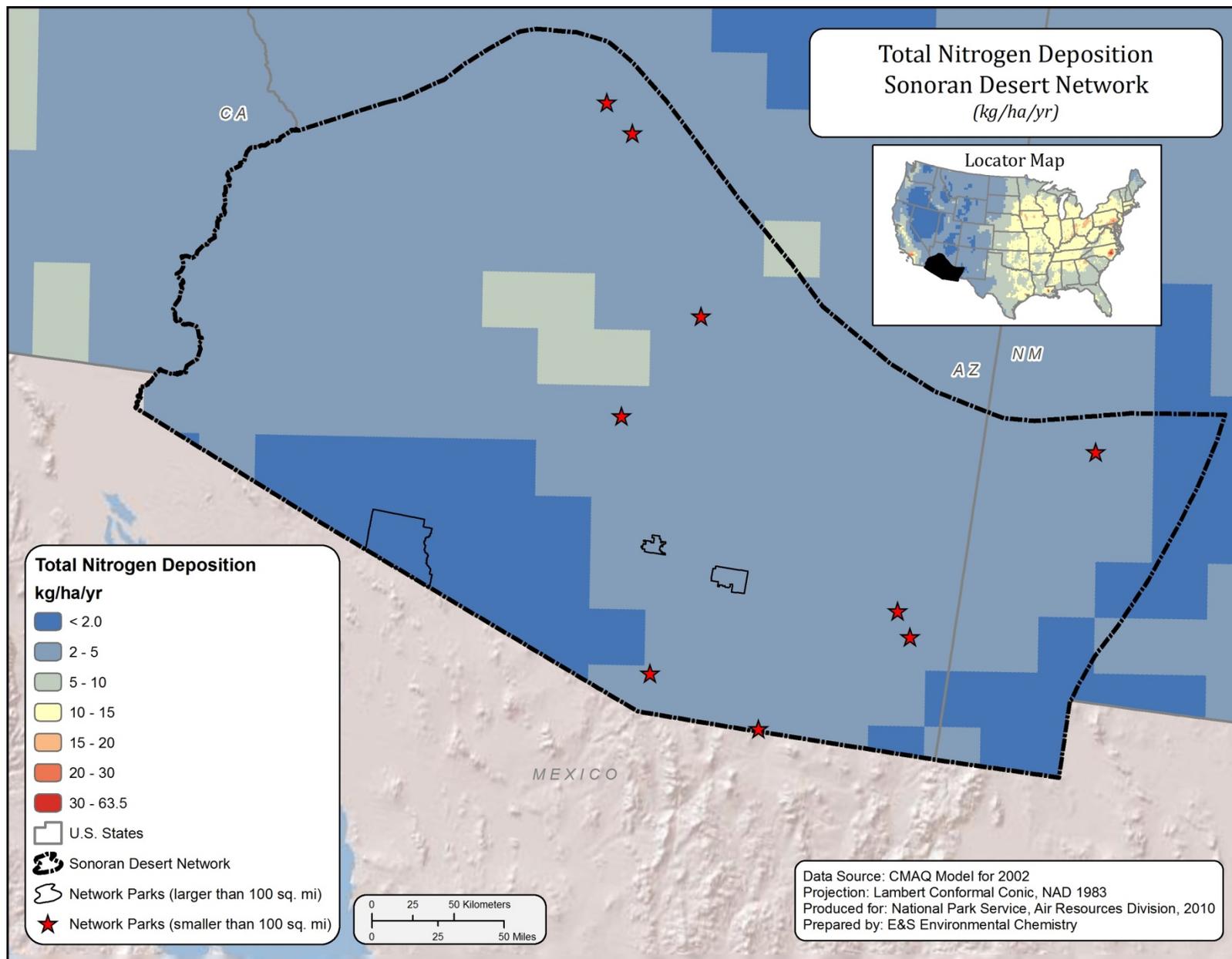
Map C



Map D

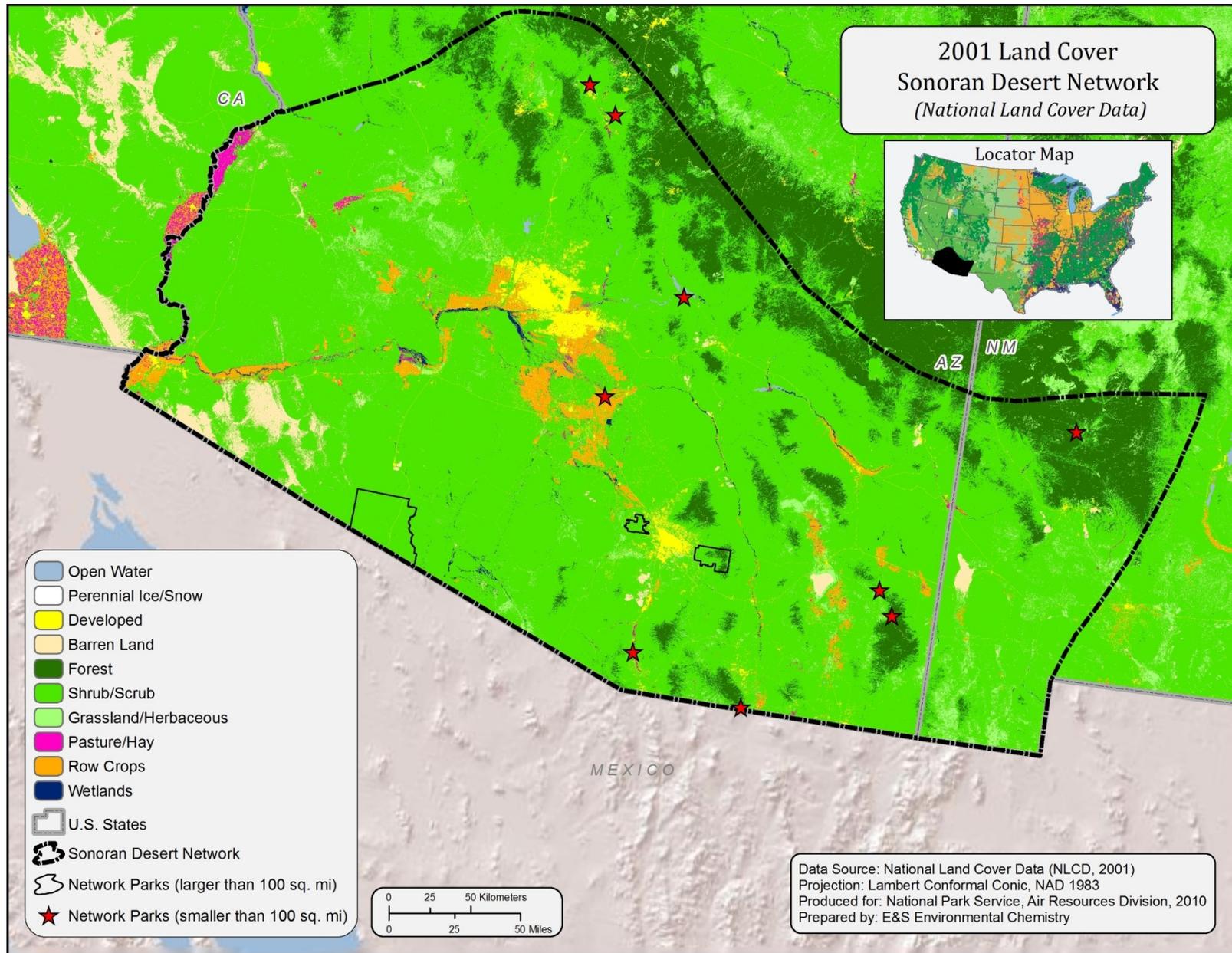


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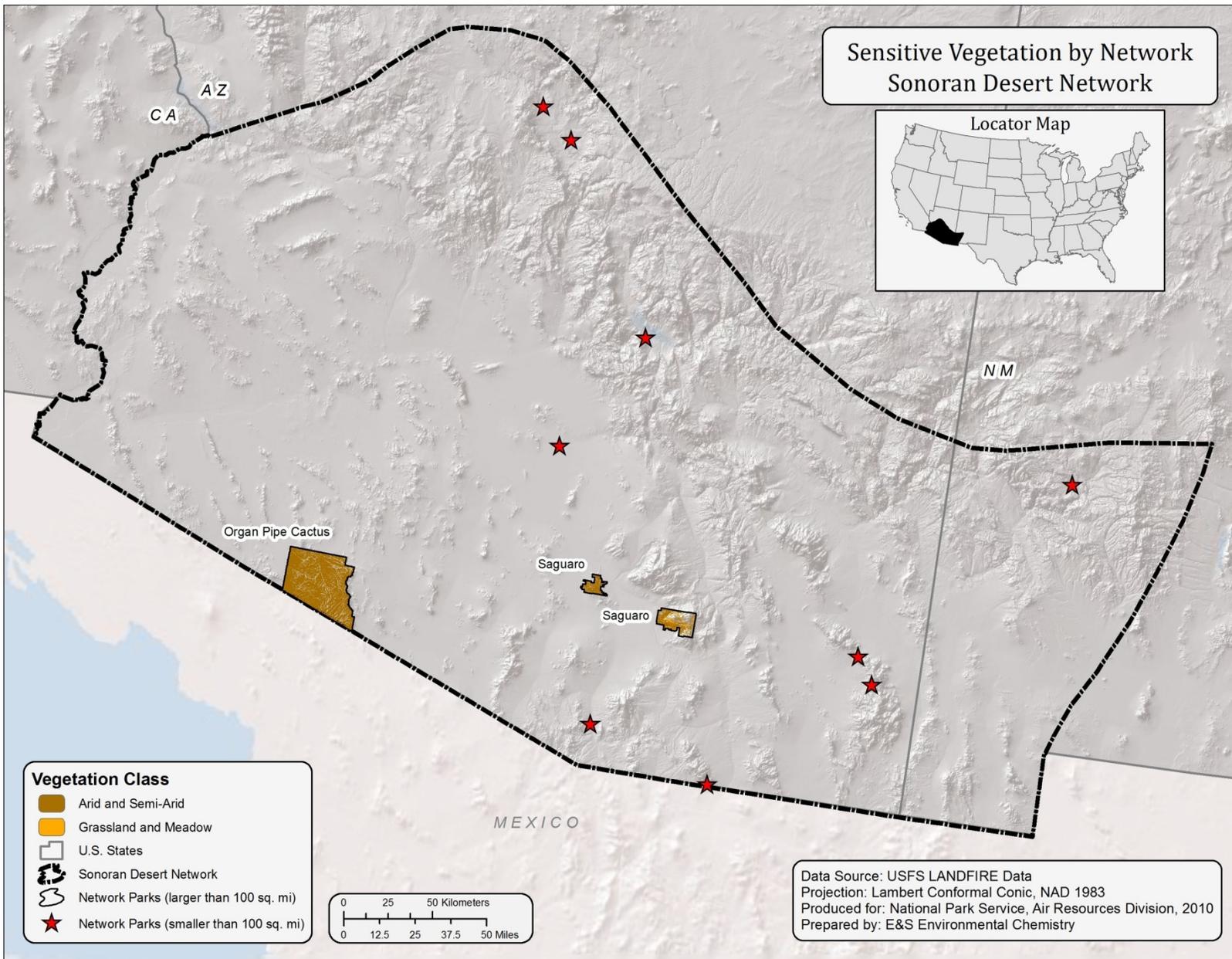


Map F

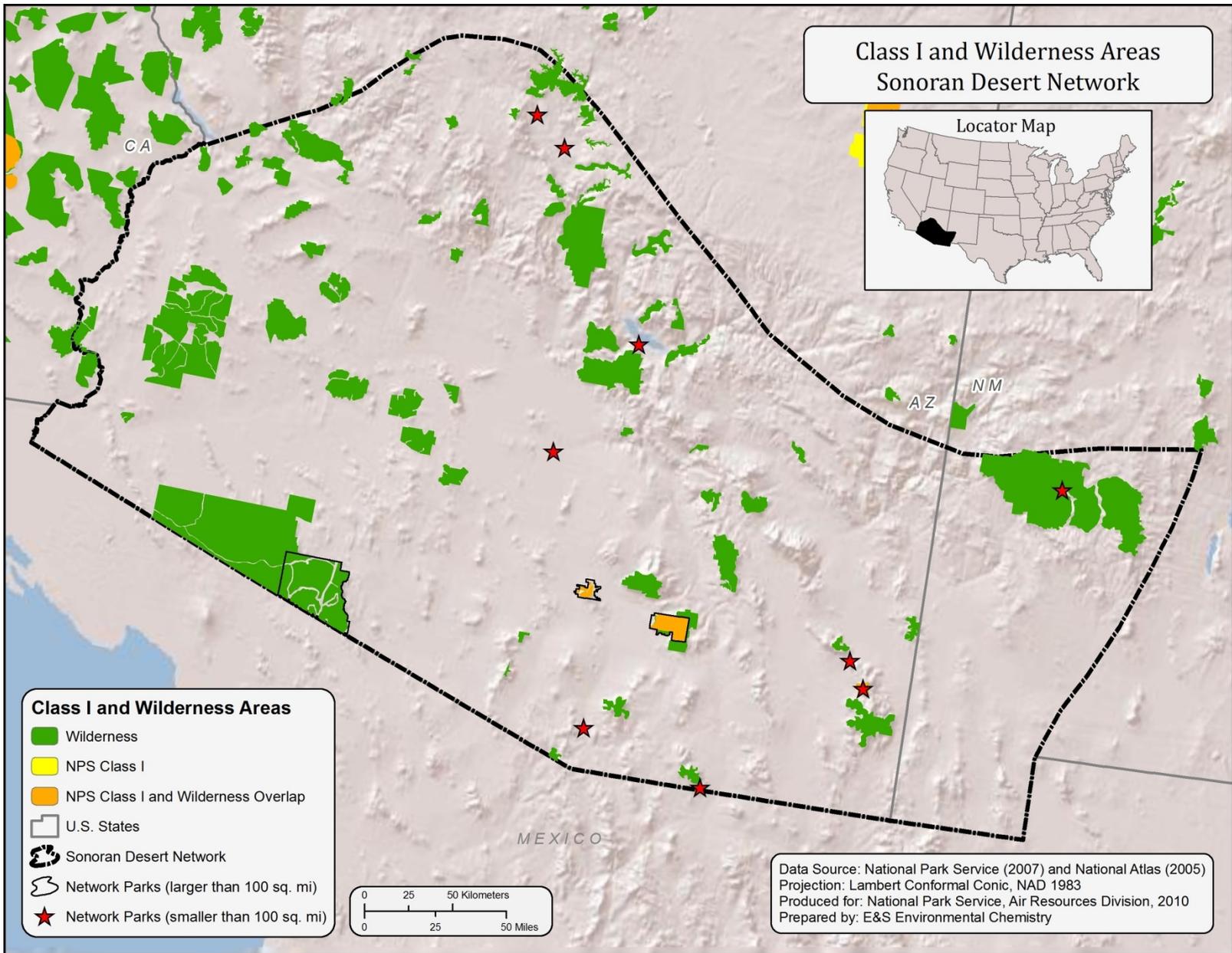
SODN-12



Map G



Map H



Map I

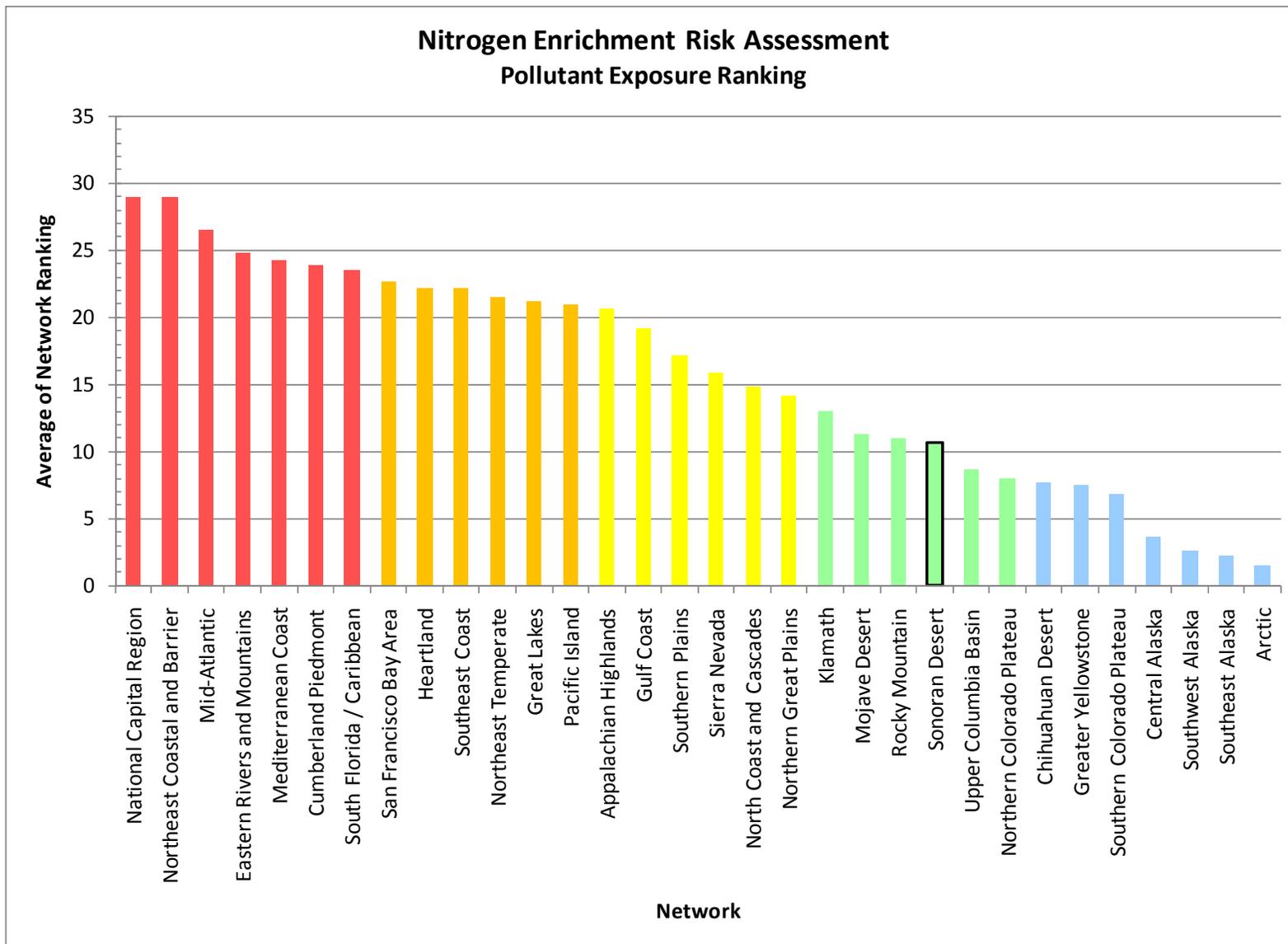


Figure A

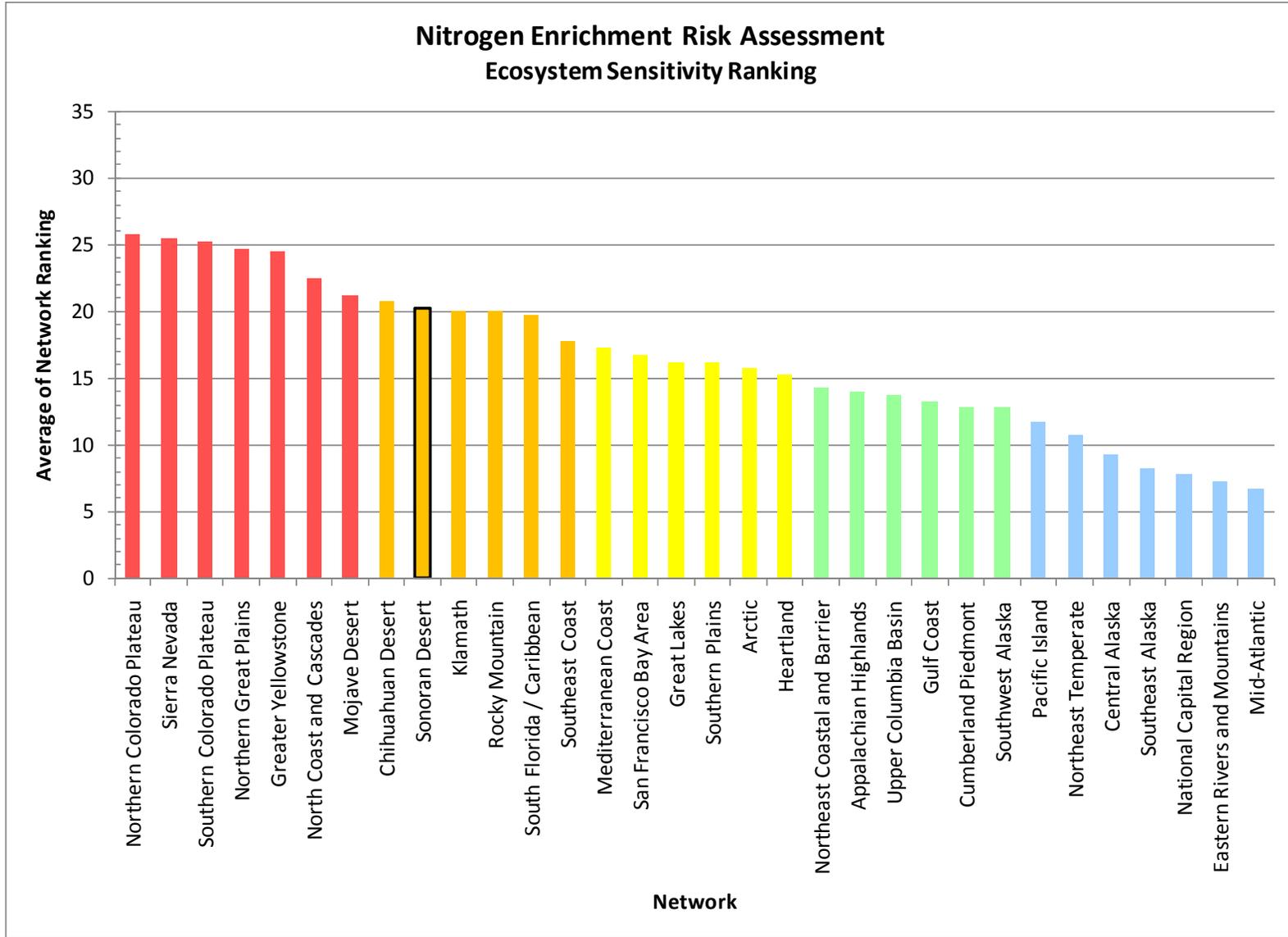


Figure B

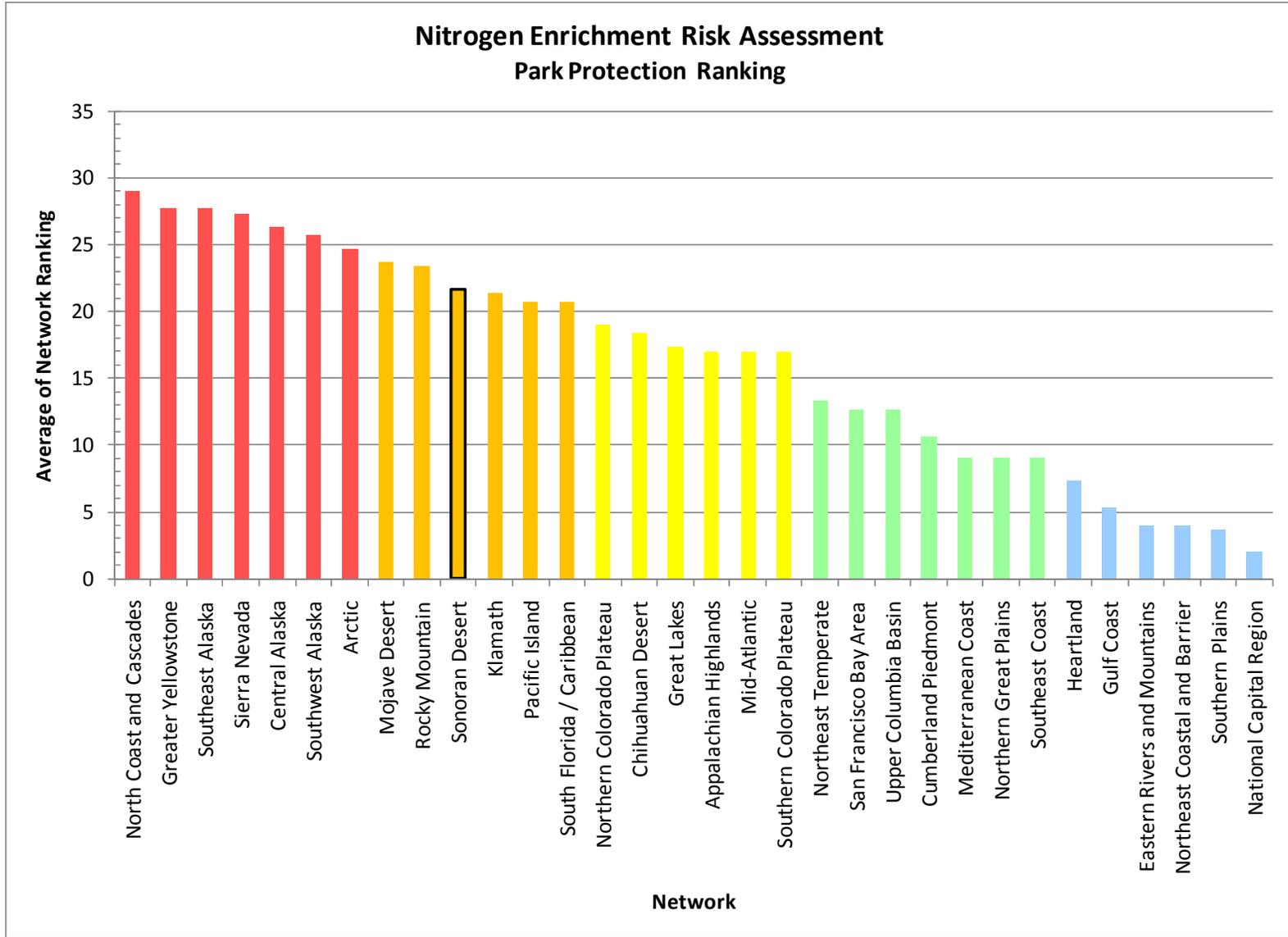


Figure C

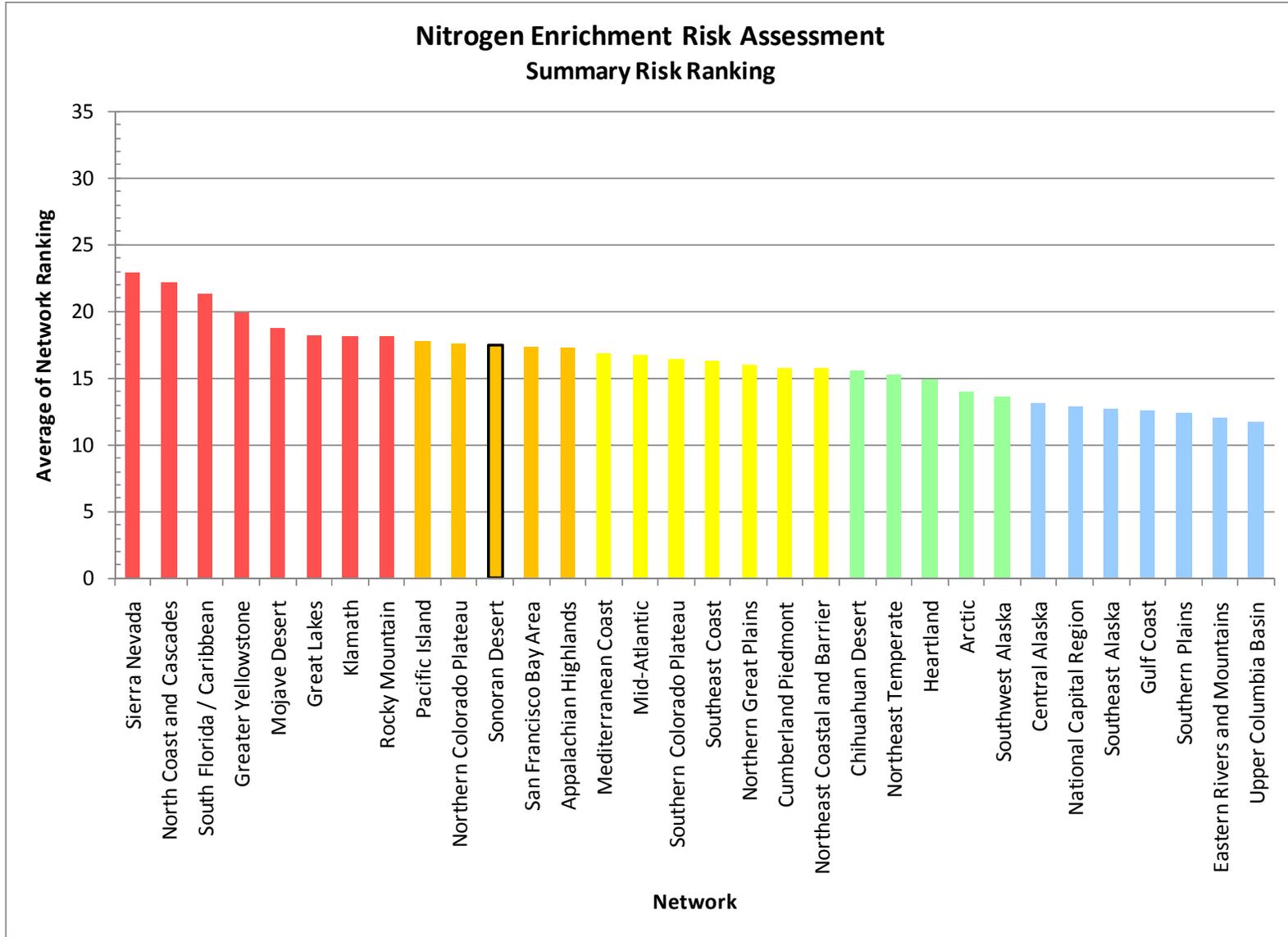


Figure D

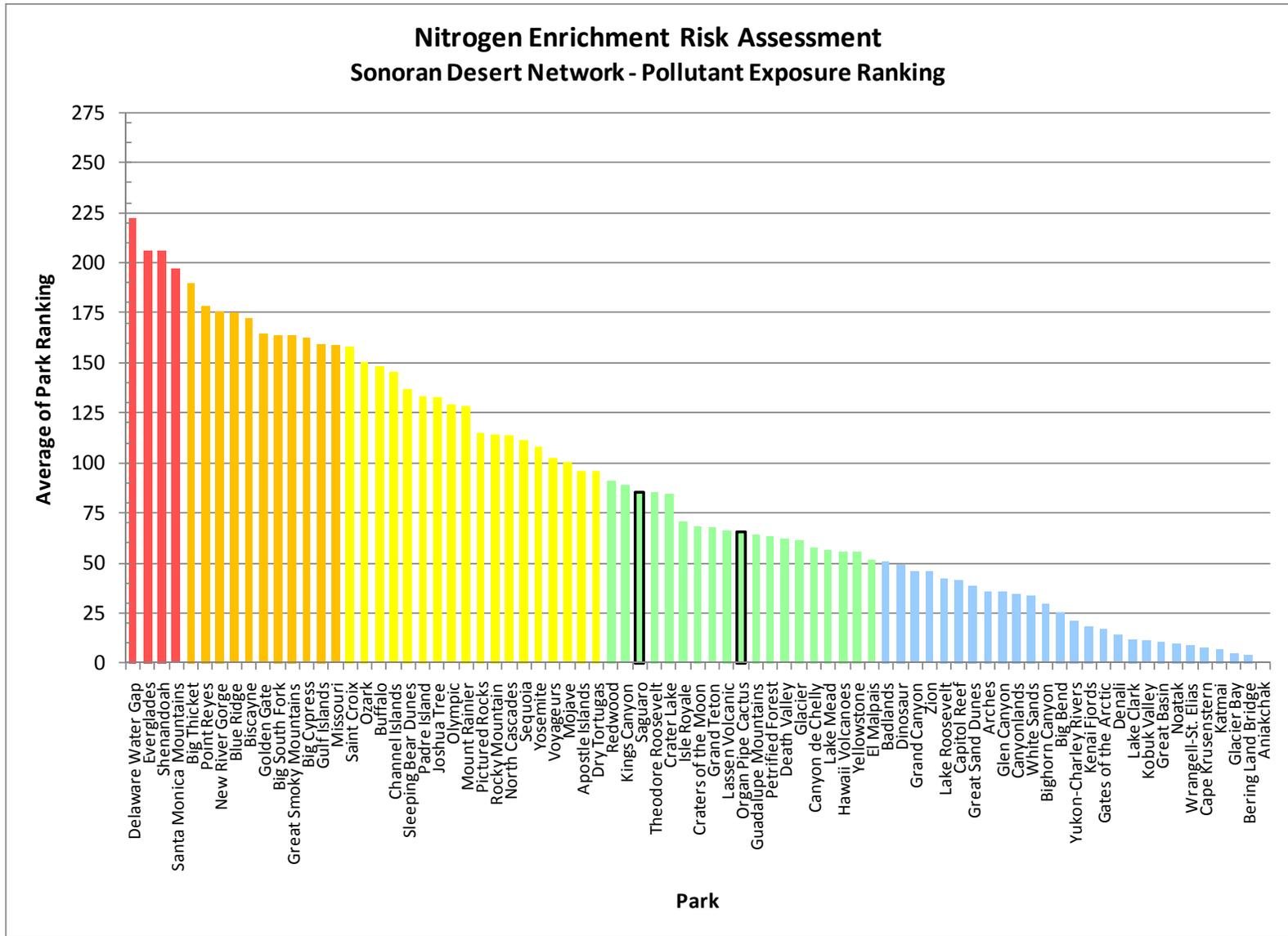


Figure E

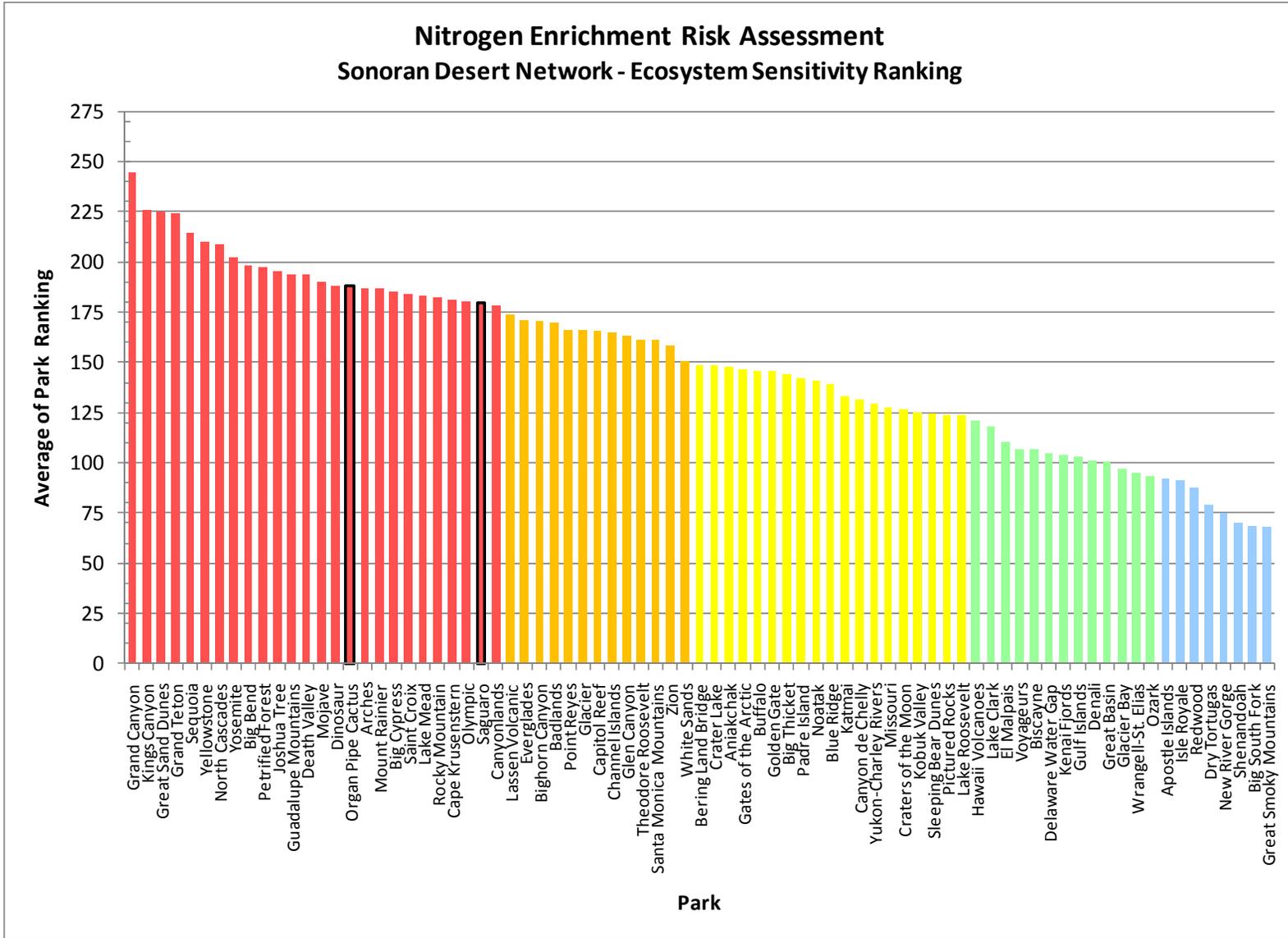


Figure F

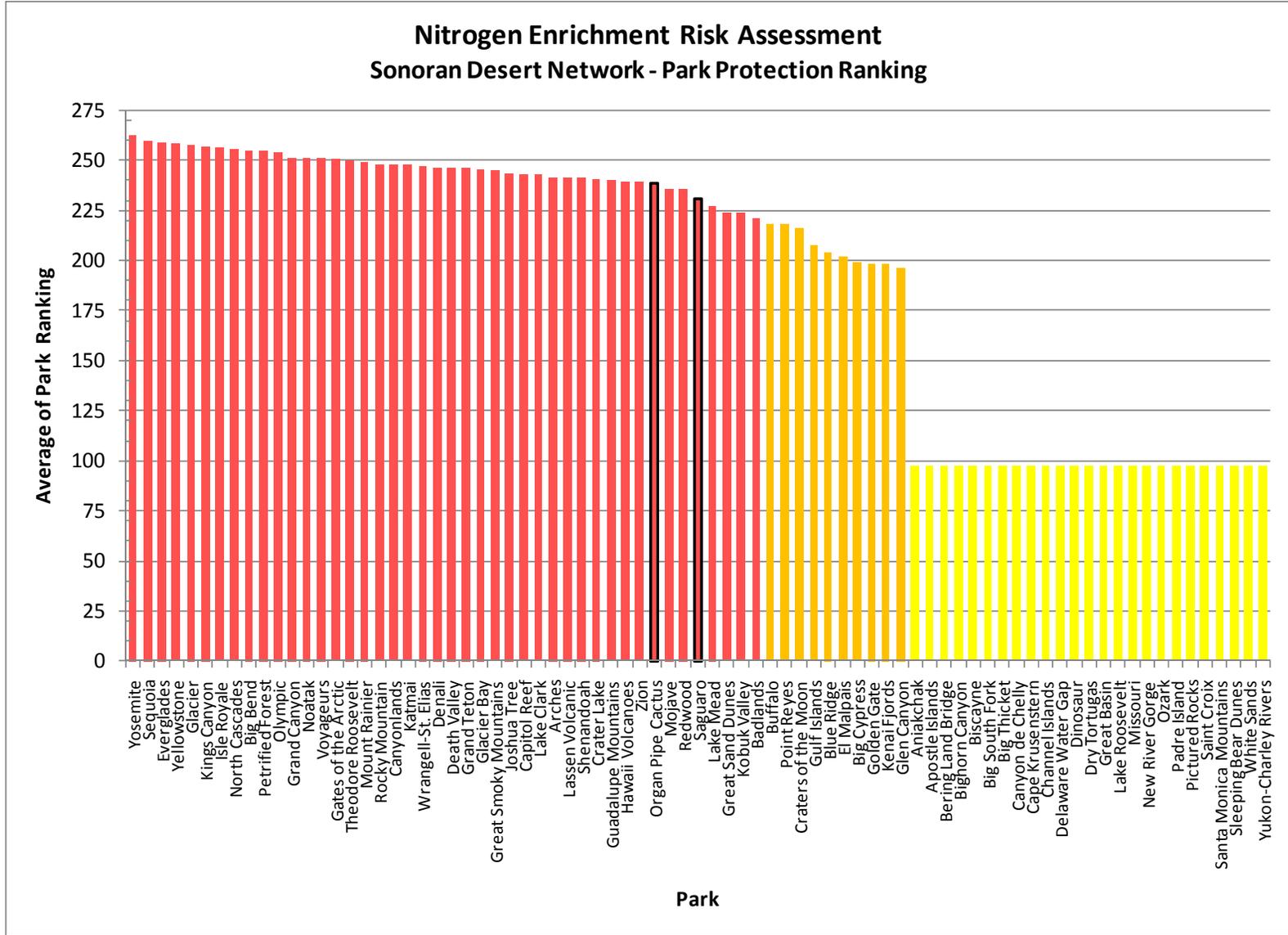


Figure G

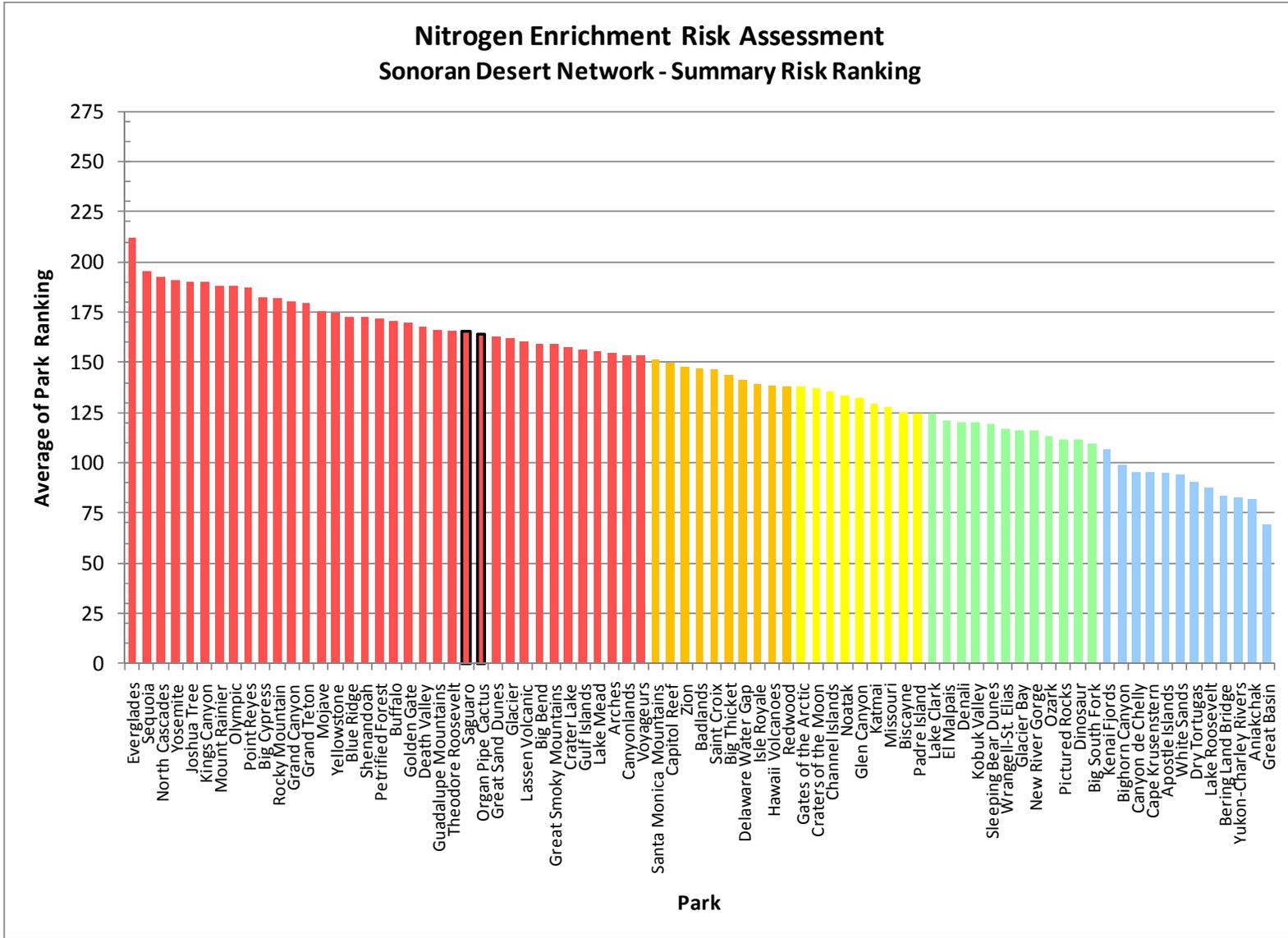


Figure H

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.

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**National Park Service**  
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