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

*Pacific Island Network (PACN)*

Natural Resource Report NPS/NRPC/ARD/NRR—2011/370

**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

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

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This report received peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Air Resources Division of the NPS (http://www.nature.nps.gov/air/Permits/ARIS/networks/acidification-eval.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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NPS 988/107406, April 2011

# Pacific Island Network (PACN)

The Pacific Island Network includes islands at diverse locations in the Pacific Ocean (Map PACN-1). It includes the Hawaiian Islands, northern Mariana Islands, Guam, and American Samoa. There are nine parks in the Pacific Island Network. Only one is larger than 100 square miles: Hawaii Volcanoes (HAVO), which is located on the island of Hawaii. Data reflecting sensitivity to, and effects from, acidic deposition are sparse for the American Affiliated Islands.

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 N, respectively, for the year 2002. Maps C and D show total S and N deposition, respectively, again for the year 2002. Deposition data are not available for the Pacific Islands Network, but deposition would be expected to be relatively high on some of the Hawaiian Islands, especially Oahu, and lower elsewhere.

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Hawaii portion of the Pacific Island Network. County-level S emissions within the network ranged from less than 1 ton per square mile on the big island of Hawaii and Kauai up to the range of 5 to 20 tons per square mile on Oahu. Other islands in the Hawaiian archipelago have S emissions in the range of 1 to 5 tons per square mile per year. County-level N emissions within the network ranged from less than 1 ton per square mile on the big island of Hawaii to between 20 and 50 tons per square mile on Oahu. Annual emissions of N on the other Hawaiian Islands were intermediate, between 1 and 5 tons per square mile. Emissions data are not available for the American Affiliated Islands. Individual point sources of S are shown on Map G. There are very few S point sources on any of the Hawaiian Islands and none of any magnitude. All emitted less than 5,000 tons S per year. Point source emissions of oxidized (nitrogen oxides, $NO_x$) and reduced (ammonia, $NH_3$) N are shown in Map H. There are relatively few N point sources in Hawaii. Most are located on Oahu and emit oxidized N.

Urban centers within the network and within a 300-mile buffer around the network are shown on Maps I-1 and I-2. Map I-1 shows the Hawaiian Islands, while Map I-2 shows the American Affiliated Islands, including Guam, American Samoa, and the Northern Mariana Islands. The only population center of any magnitude (more than 100,000 people) is Honolulu on Oahu. There are no large population centers in the American Affiliated Islands (Map I-2).

Maps J and K (total S and N deposition) are not shown for the Pacific Island Network because there are no data available. Deposition of S and N are expected to be low on the American Affiliated Islands, but not necessarily on all of the Hawaiian islands, especially Oahu.

Land cover in and around the network is shown in Maps L-1 and L-2. The predominant cover types within this network are mixed and include substantial forest, row crop, shrubland, and grassland/herbaceous cover types. Pasture/hay is common on Guam.

Park slope is shown in Map M. An elevation dataset was not available for the American Affiliated Islands and therefore a slope map is not shown for this part of the network. Park slopes on the Hawaiian Islands tend to be low, generally less than 10º. One park, Haleakala (HALE) on Maui, has average slope in the range of 10° to 20º (Map M).

Park lands in Hawaii 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. There are some wilderness and Class I areas in the Hawaiian Islands, mostly limited to HAVO in the southern portion of the island of Hawaii. There are none on the American Affiliated Islands.

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 Pacific Island Network ranked at the top of the middle quintile among networks in Pollutant Exposure (Figure A). Sulfur and N emissions and S and N deposition within the network were moderate. However, the network Ecosystem Sensitivity ranking was very low, within the lowest quintile among networks (Figure B). This network ranked in the second highest quintile in Park Protection, having moderately high amounts of protected lands (Figure C).

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yielded an overall Network Risk ranking that is below the middle of the distribution among networks (Figure D). The overall level of concern for acidification effects on I&M parks within this network is considered Moderate.

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 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 one I&M park (HAVO) in the Pacific Island Network that is larger than 100 square miles ranked in the second lowest quintile in Pollutant Exposure (Figure E). This may be because HAVO is located on the southern side of the Island of Hawaii, some distance from the areas of concentrated pollution emissions sources on the islands of Oahu and Maui. Most of the smaller parks in the network also ranked Low, in the second lowest quintile, in Pollutant Exposure, except for Kalaupapa (KALA), which ranks Very High and HALE, which ranked Moderate. HAVO was in the second highest quintile in Ecosystem Sensitivity (Figure F) and in the highest quintile in Park Protection (Figure G). The smaller parks in the network varied in ranking for Ecosystem Sensitivity. One park (HALE) was ranked Very High; four parks were ranked Moderate, two are ranked Low, and one is ranked Very Low for this theme (Table A). Like HAVO, HALE was ranked in the highest quintile in Park Protection, whereas other parks in the network were ranked in the middle quintile.

The overall risk from acidic deposition to parks in this network varied. HALE was ranked Very High for park Summary Risk, and HAVO and KALA were ranked High (Figure H, Table A). The other parks in the network were ranked Moderate (three parks) or Low (three parks).

**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.

| I&M Parks[2] in Network | Relative Ranking of Individual Parks[1] | | | |
|---|---|---|---|---|
| | Pollutant Exposure | Ecosystem Sensitivity | Park Protection | Summary Risk |
| American Memorial Park | ND[3] | Moderate | Moderate | Moderate |
| Haleakala | Moderate | Very High | Very High | Very High |
| ***Hawaii Volcanoes*** | Low | High | Very High | High |
| Kalaupapa | Very High | Moderate | Moderate | High |
| Kaloko-Honokohau | Low | Very Low | Moderate | Low |
| National Park of American Samoa | ND | Moderate | Moderate | Moderate |
| Pu'uhonua o Honaunau | Low | Low | Moderate | Low |
| Puukohola Heiau | Low | Low | Moderate | Low |
| War in the Pacific | ND | Moderate | Moderate | Moderate |

[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.

[3] ND indicates no data.

Map PACN-1. Location of the islands that comprise the Pacific Island Network.

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. Regional S deposition data are not available for the Pacific Island Network. Total S deposition throughout most areas is expected to be low, below about 1 to 2 kilograms of S per hectare per year. Total S deposition for the continental United States is presented for context here for the year 2002, expressed in units of kilograms of S deposited from the atmosphere to the earth surface per hectare per year. Wet and dry forms of deposition 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 D. Deposition data are not available for the Pacific Island Network. Total N deposition throughout most areas is expected to be low, below about 2 kilograms of N per hectare per year. Total N deposition for the continental United States is presented for context here 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-1. Urban centers having more than 10,000 people within the Hawaiian portion of the network and within a 300-mile buffer around the perimeter of the network. (Source of data: U.S. Census 2000)

Map I-2. Urban centers having more than 10,000 people within the American Affiliated Islands portion of the network and within a 300-mile buffer around the perimeter of the network. (Source of data: U.S. Census 2000)

Map L-1. Land cover types in and around the Hawaiian portion of 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 L-2. Land cover types in and around the American Affiliated Islands portion of the network, based on the National Land Cover dataset. (Source of data: National Land Cover Dataset, http://www.mrlc.gov/nlcd_multizone_map.php; Liu, Z. and L. Fischer. 2006a. Commonwealth of the Northern Mariana Islands vegetation mapping using very high spatial resolution imagery, USDA Forest Service - Pacific Southwest Region, Forest Health Protection; Liu, Z., and Fischer, L. 2006b. Guam Vegetation Mapping Using Very High Spatial Resolution Imagery – Methodology. USDA Forest Service, Pacific Southwest Region, Forest Health Protection; Liu, Z. and L. Fischer (2007). American Samoa vegetation mapping using very high spatial resolution imagery, USDA Forest Service, Pacific Southwest Region, Forest Health Protection)

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)

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.

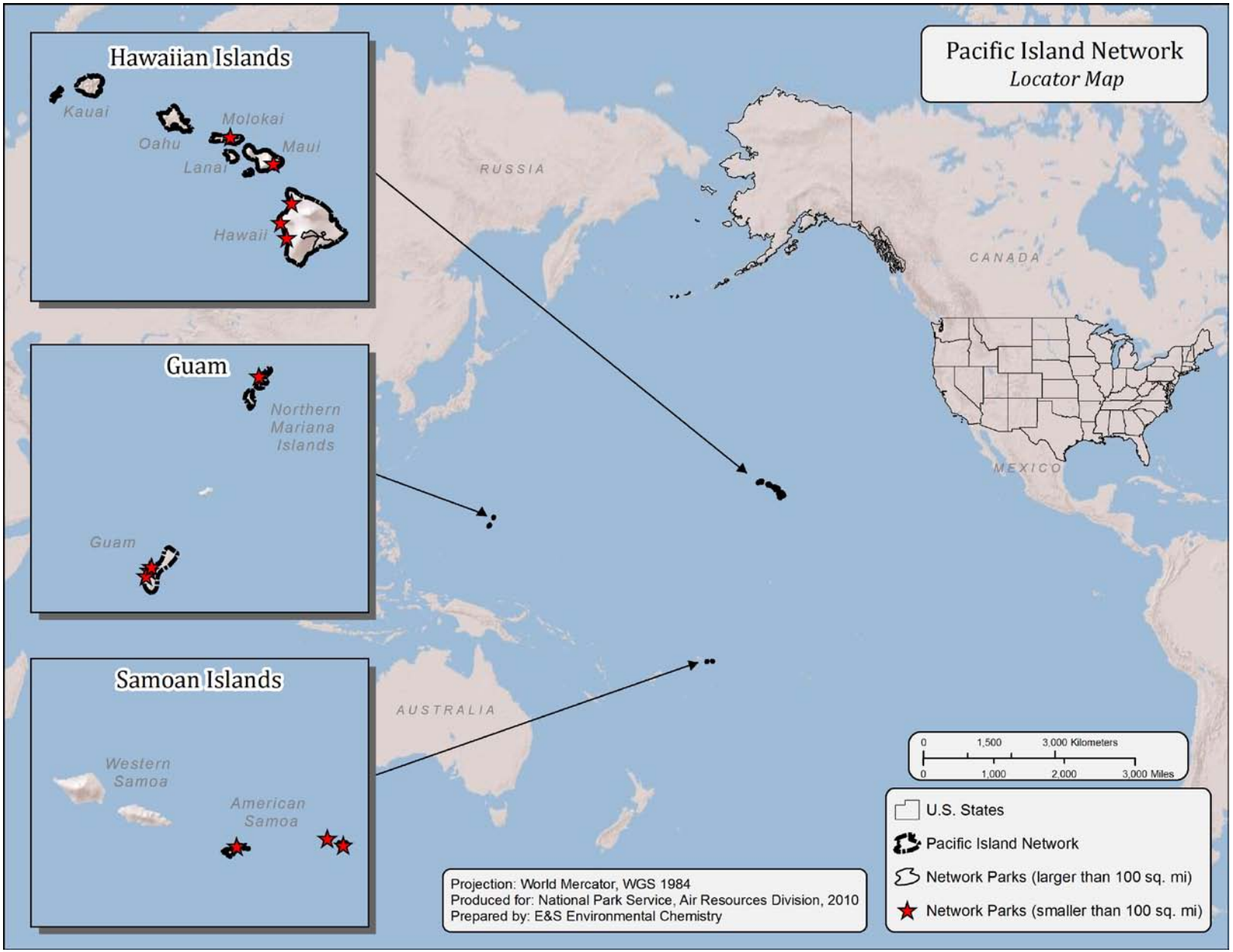
Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.

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.

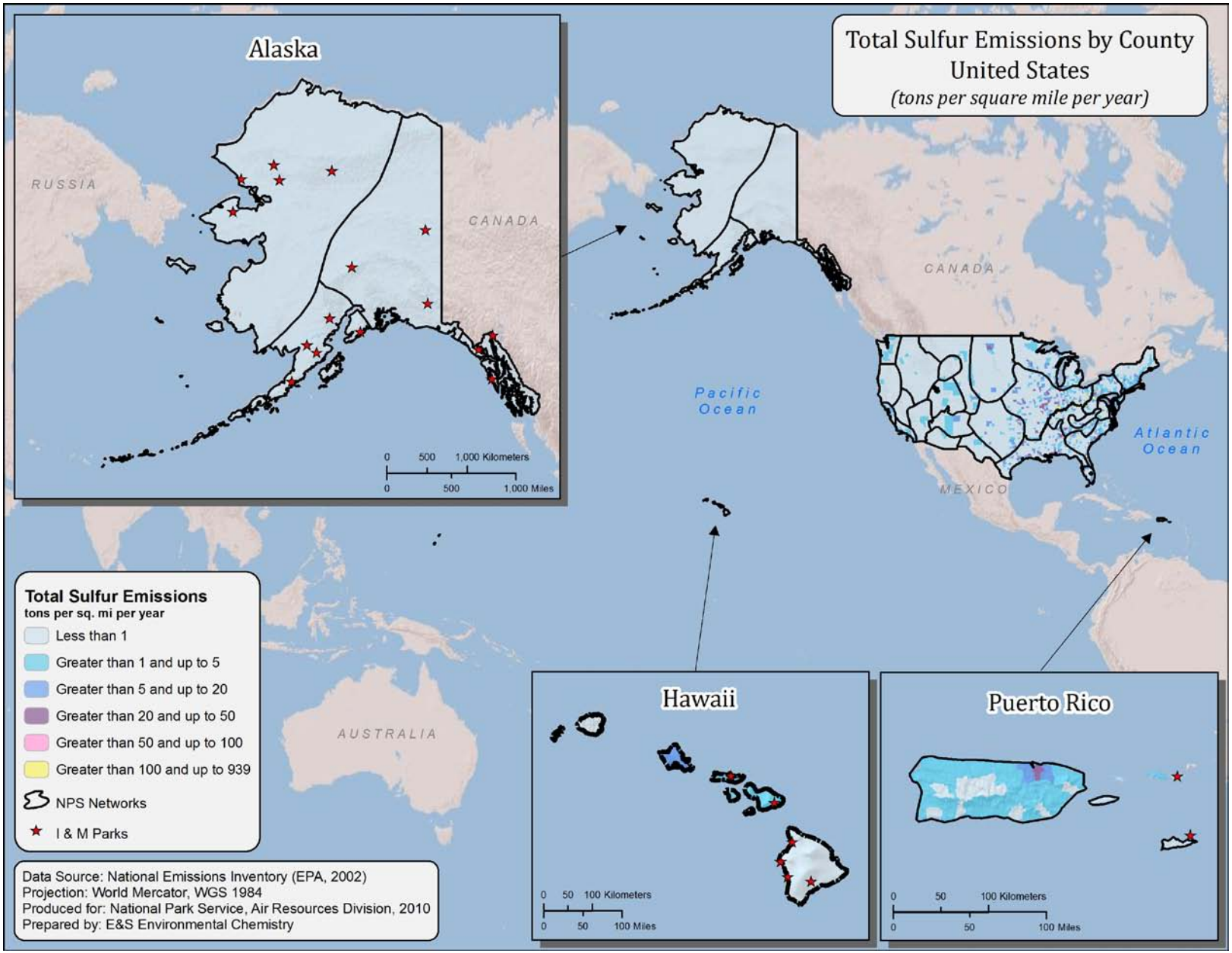
Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

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.

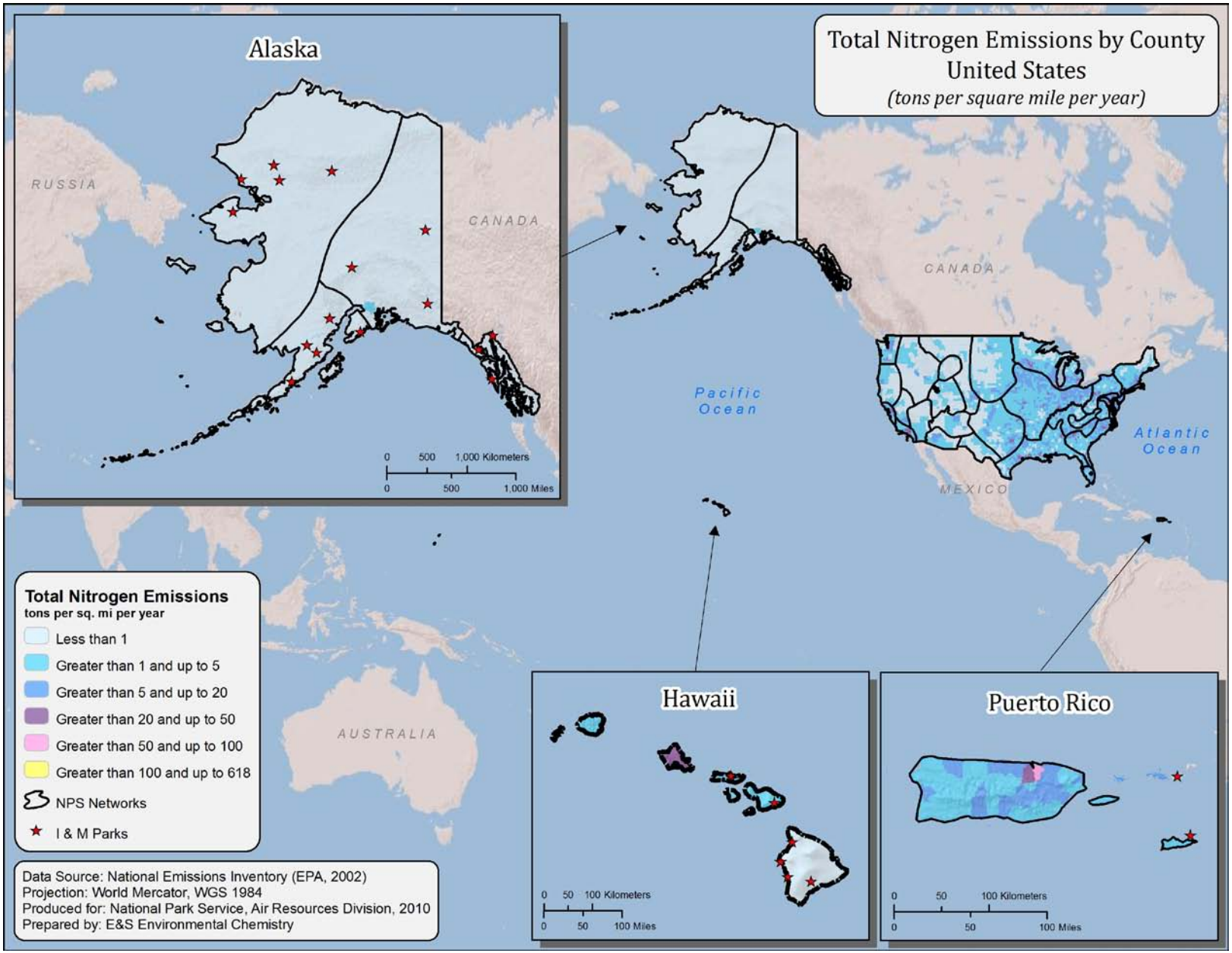
Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.


Pacific Island Network
Locator Map
Hawaiian Islands
Kauai
Oahu
Molokai
Maui
Lanai
Hawaii
Guam
Northern Mariana Islands
Guam
Samoan Islands
Western Samoa
American Samoa
RUSSIA
CANADA
MEXICO
AUSTRALIA
0 1,500 3,000 Kilometers
0 1,000 2,000 3,000 Miles
U.S. States
Pacific Island Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Projection: World Mercator, WGS 1984
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

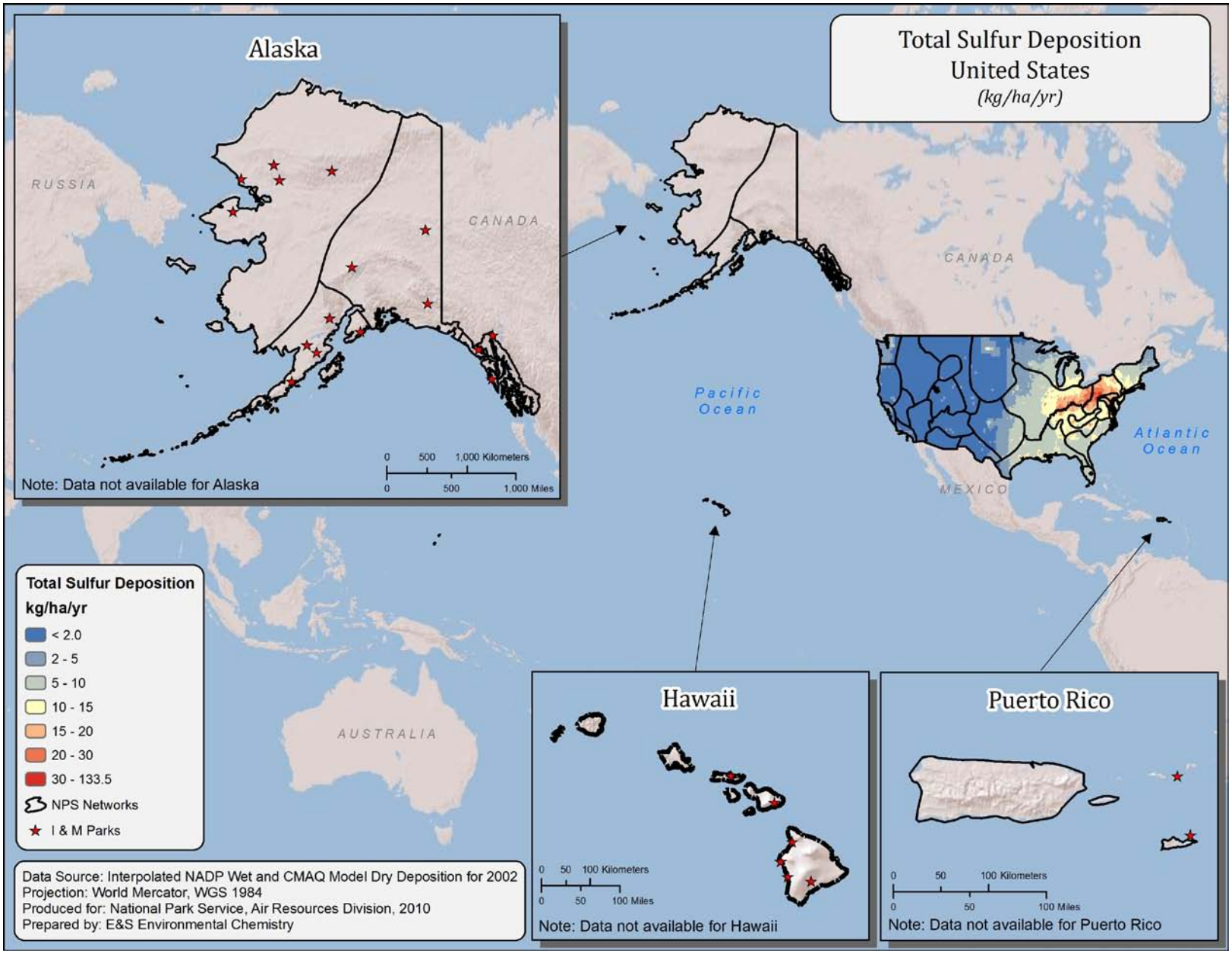
Map PACN-1


Alaska
Total Sulfur Emissions by County
United States
(tons per square mile per year)
RUSSIA
CANADA
CANADA
Pacific
Ocean
Atlantic
Ocean
MEXICO
AUSTRALIA
0 500 1,000 Kilometers
0 500 1,000 Miles
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
NPS Networks
I & M Parks
Data Source: National Emissions Inventory (EPA, 2002)
Projection: World Mercator, WGS 1984
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
Hawaii
0 50 100 Kilometers
0 50 100 Miles
Puerto Rico
0 50 100 Kilometers
0 50 100 Miles

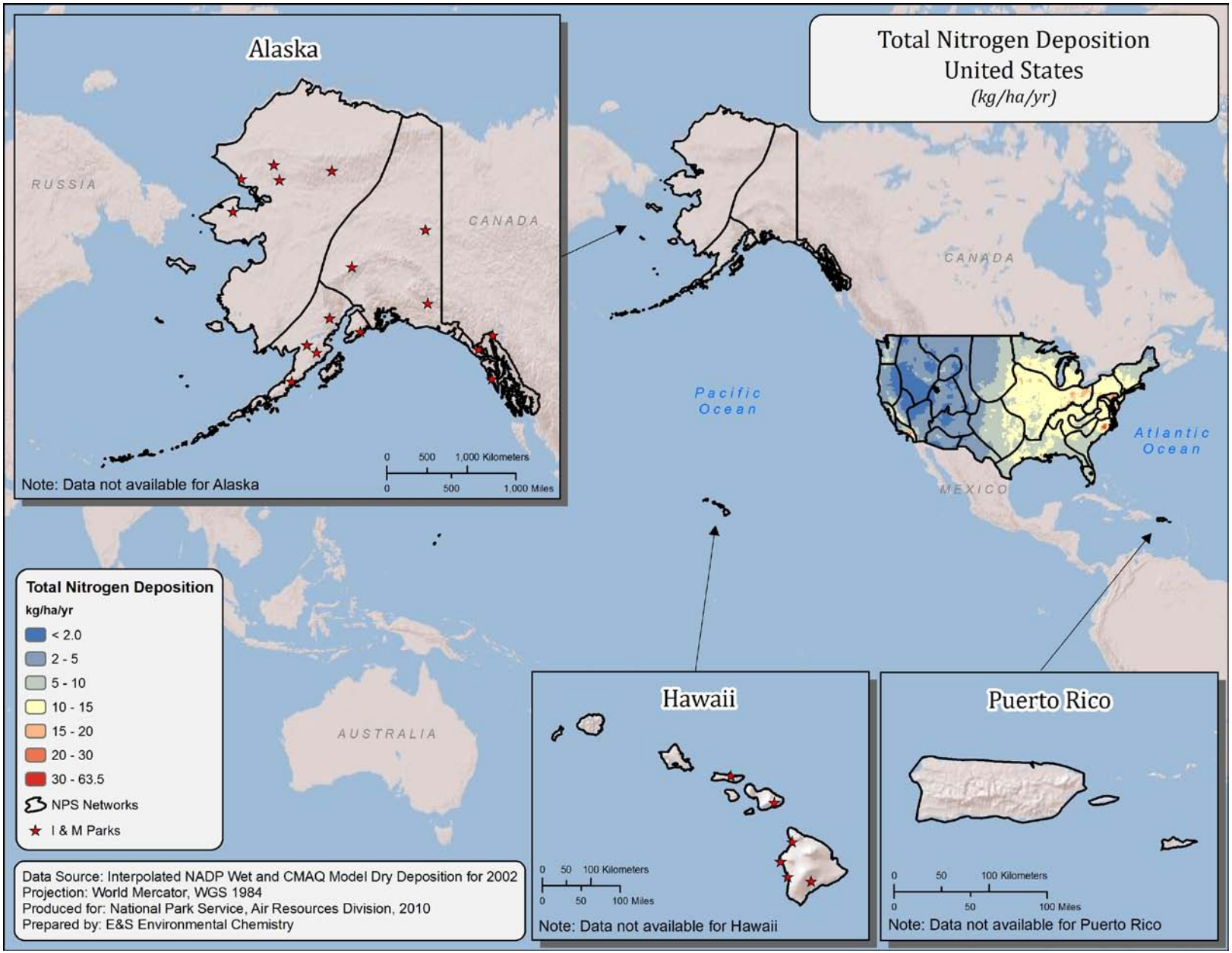
Map A


Alaska
Total Nitrogen Emissions by County
United States
(tons per square mile per year)
RUSSIA
CANADA
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
AUSTRALIA
0 500 1,000 Kilometers
0 500 1,000 Miles
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
NPS Networks
I & M Parks
Data Source: National Emissions Inventory (EPA, 2002)
Projection: World Mercator, WGS 1984
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
Hawaii
0 50 100 Kilometers
0 50 100 Miles
Puerto Rico
0 50 100 Kilometers
0 50 100 Miles

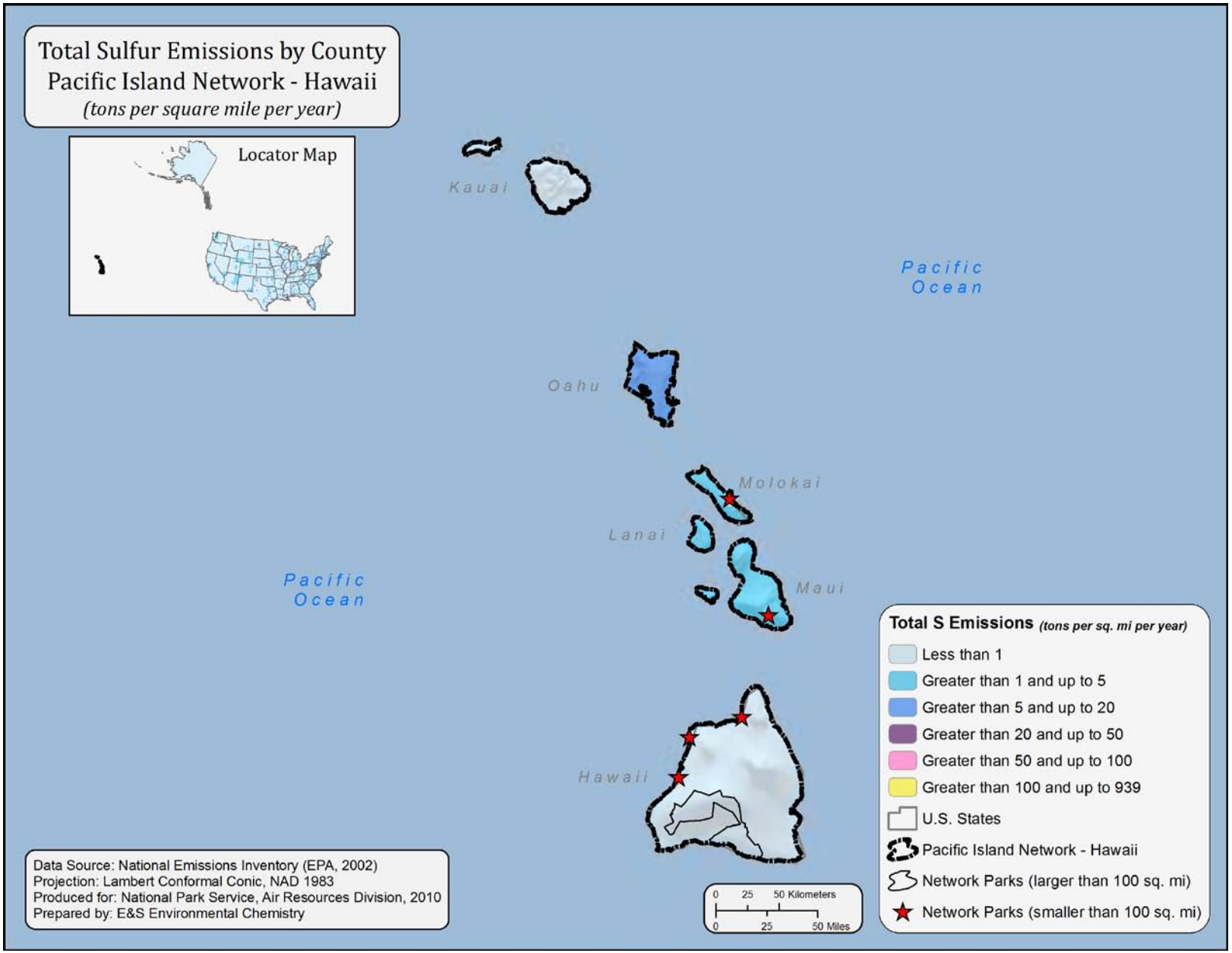
Map B


Alaska
Note: Data not available for Alaska
0 500 1,000 Kilometers
0 500 1,000 Miles
Total Sulfur Deposition
United States
(kg/ha/yr)
RUSSIA
CANADA
CANADA
MEXICO
Pacific Ocean
Atlantic Ocean
AUSTRALIA
Total Sulfur Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 133.5
NPS Networks
I & M Parks
Hawaii
0 50 100 Kilometers
0 50 100 Miles
Note: Data not available for Hawaii
Puerto Rico
0 50 100 Kilometers
0 50 100 Miles
Note: Data not available for Puerto Rico
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: World Mercator, WGS 1984
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

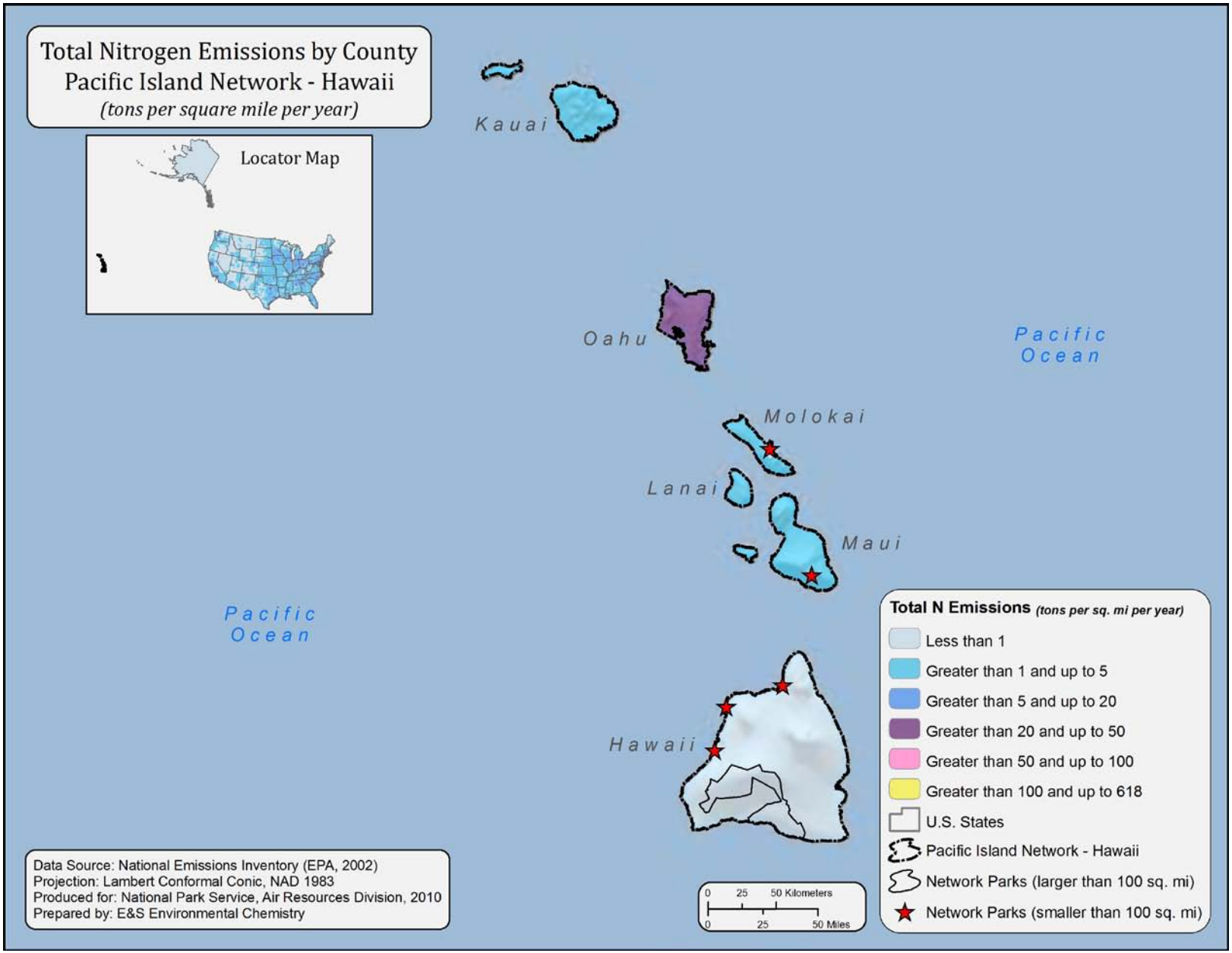
Map C


Alaska
Note: Data not available for Alaska
0 500 1,000 Kilometers
0 500 1,000 Miles
RUSSIA
CANADA
Total Nitrogen Deposition
United States
(kg/ha/yr)
Pacific Ocean
Atlantic Ocean
MEXICO
AUSTRALIA
Total Nitrogen Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
NPS Networks
I & M Parks
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: World Mercator, WGS 1984
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
Hawaii
0 50 100 Kilometers
0 50 100 Miles
Note: Data not available for Hawaii
Puerto Rico
0 50 100 Kilometers
0 50 100 Miles
Note: Data not available for Puerto Rico

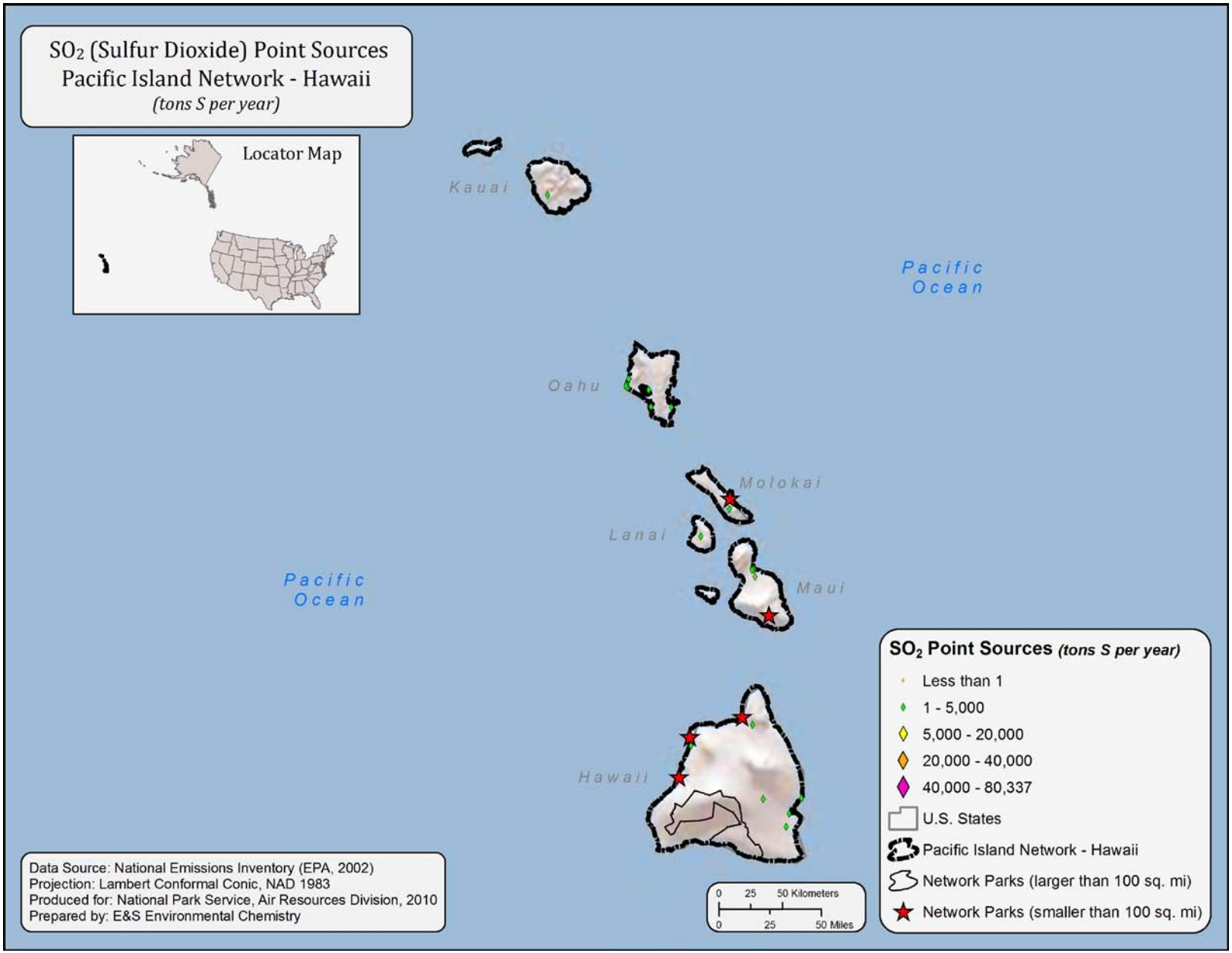
Map D


Total Sulfur Emissions by County
Pacific Island Network - Hawaii
(tons per square mile per year)
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific 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
Pacific Island Network - Hawaii
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

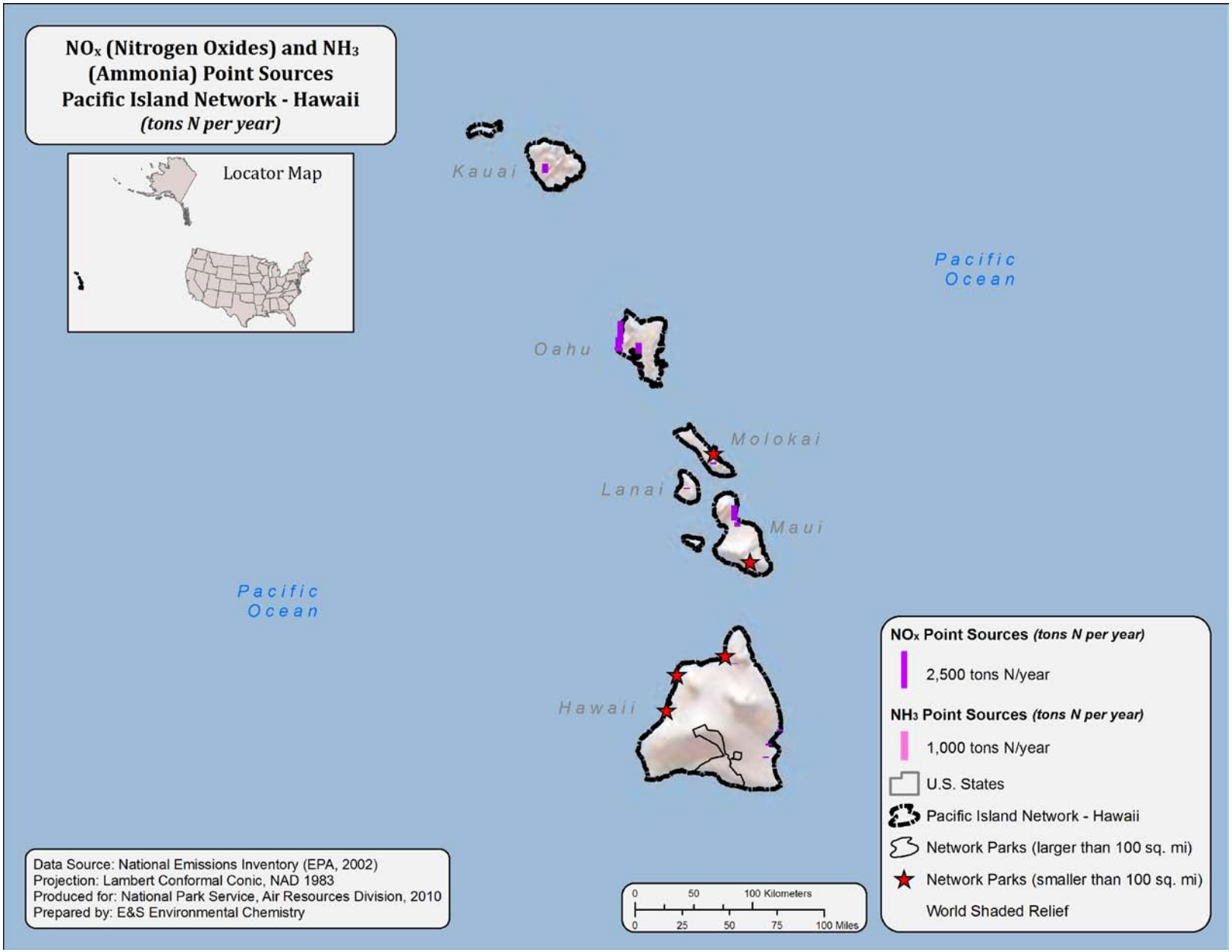
Map E


Total Nitrogen Emissions by County
Pacific Island Network - Hawaii
(tons per square mile per year)
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific 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
Pacific Island Network - Hawaii
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 25 50 Kilometers
0 25 50 Miles

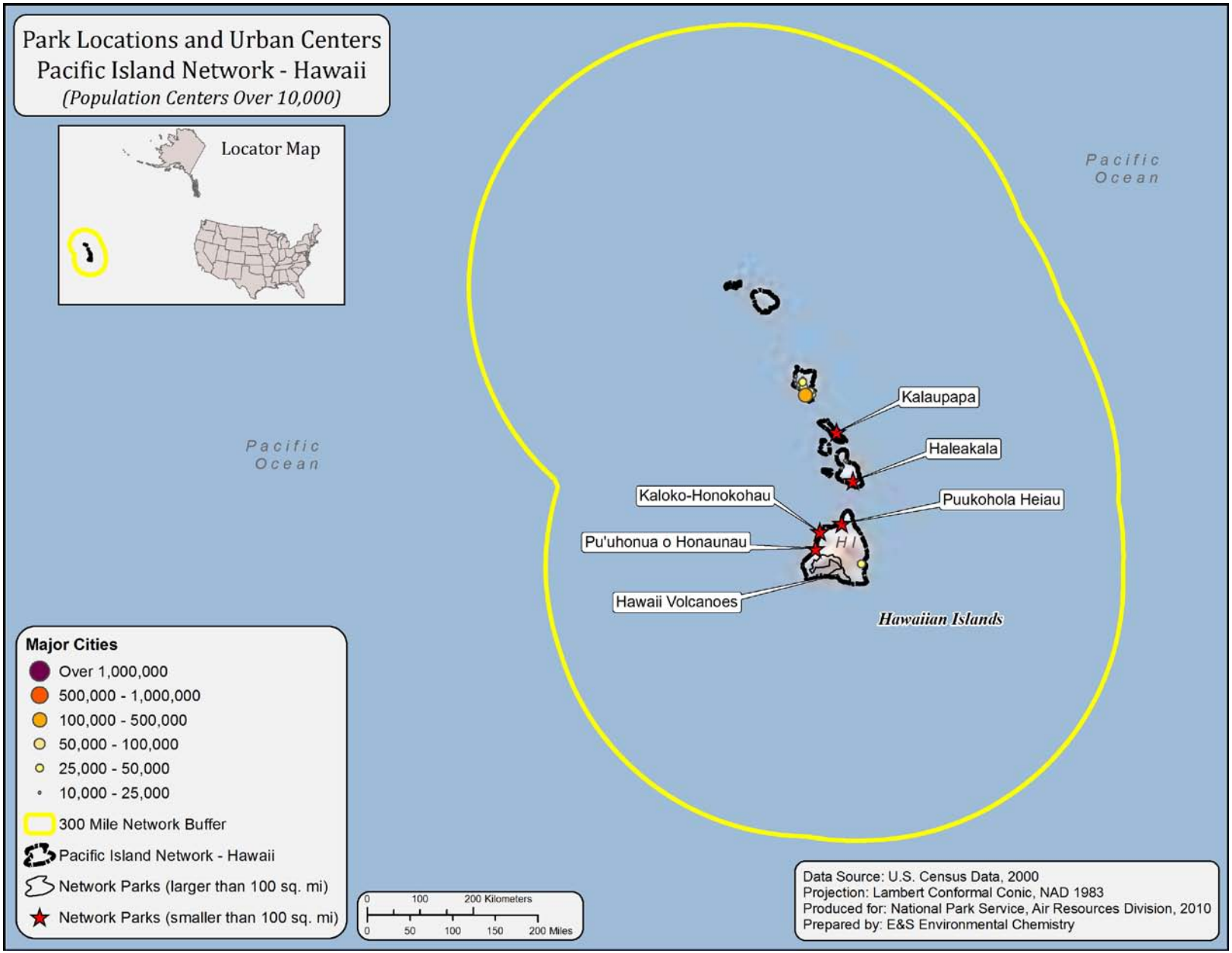
Map F


$SO_2$ (Sulfur Dioxide) Point Sources
Pacific Island Network - Hawaii
(tons S per year)
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific Ocean
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 25 50 Kilometers
0 25 50 Miles
$SO_2$ 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
Pacific Island Network - Hawaii
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

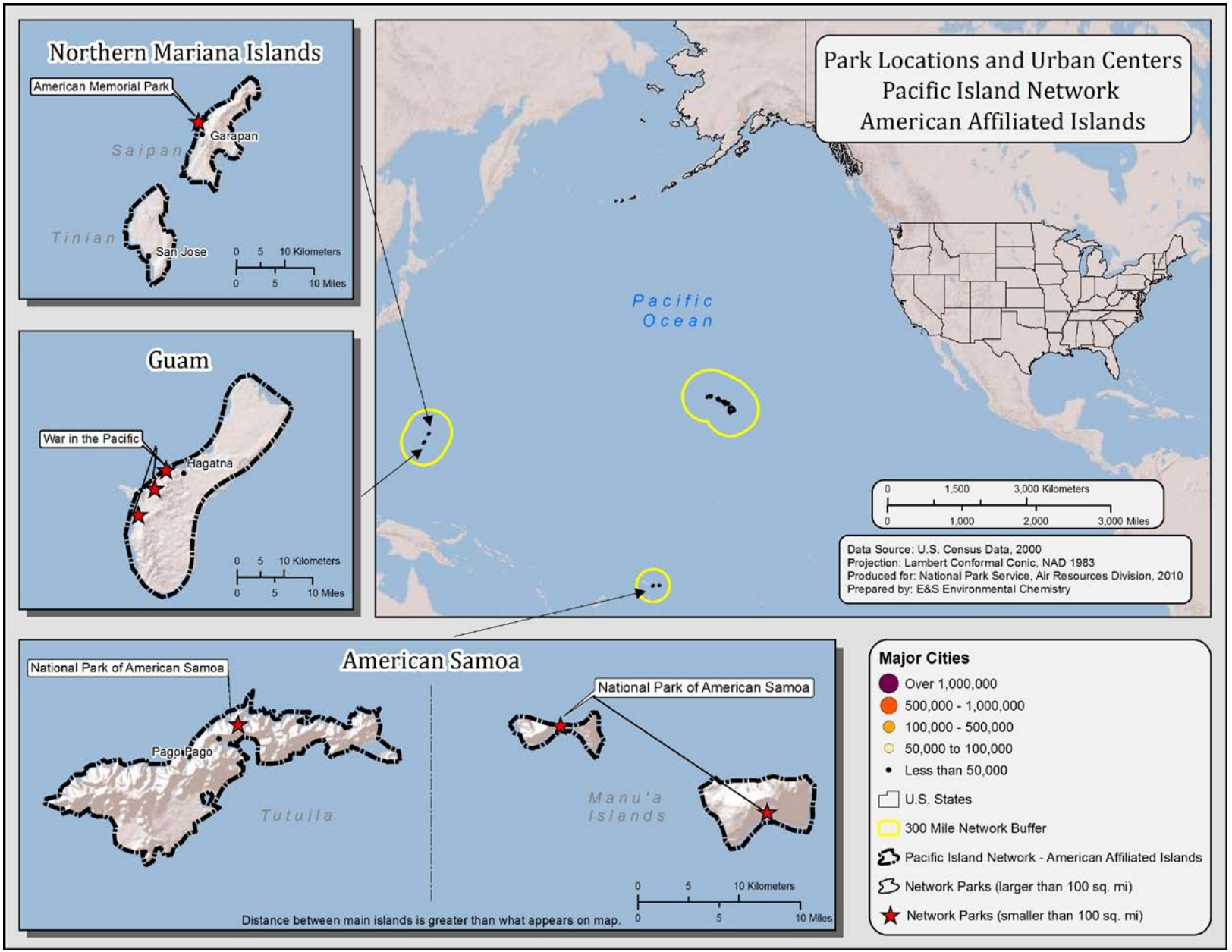
Map G


NOx (Nitrogen Oxides) and NH3 (Ammonia) Point Sources
Pacific Island Network - Hawaii
(tons N per year)
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific 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
Pacific Island Network - Hawaii
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
World Shaded Relief
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

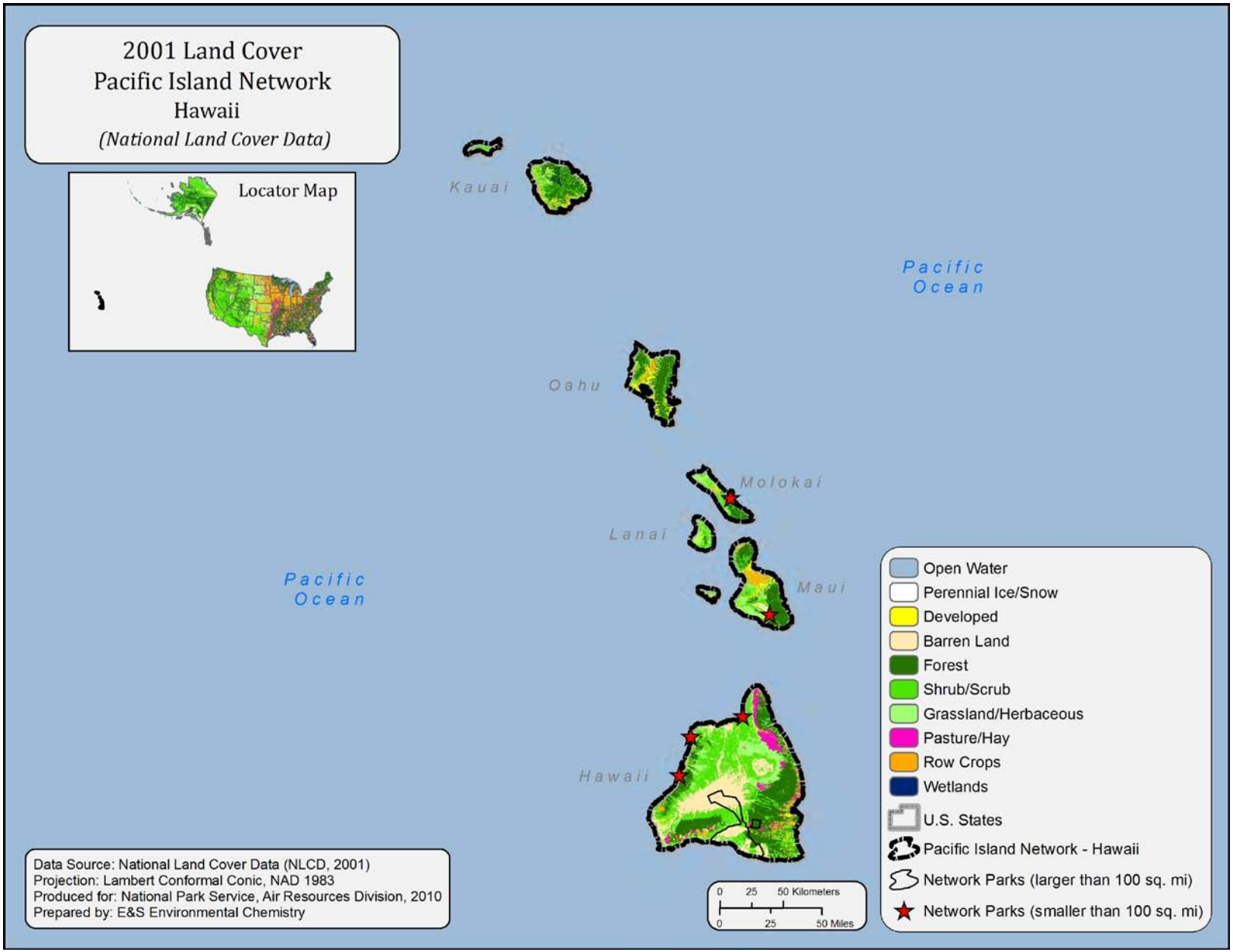
Map H


Park Locations and Urban Centers
Pacific Island Network - Hawaii
(Population Centers Over 10,000)
Locator Map
Pacific Ocean
Pacific Ocean
Kalaupapa
Haleakala
Kaloko-Honokohau
Puukohola Heiau
Pu'uhonua o Honaunau
Hawaii Volcanoes
HI
Hawaiian Islands
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
300 Mile Network Buffer
Pacific Island Network - Hawaii
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

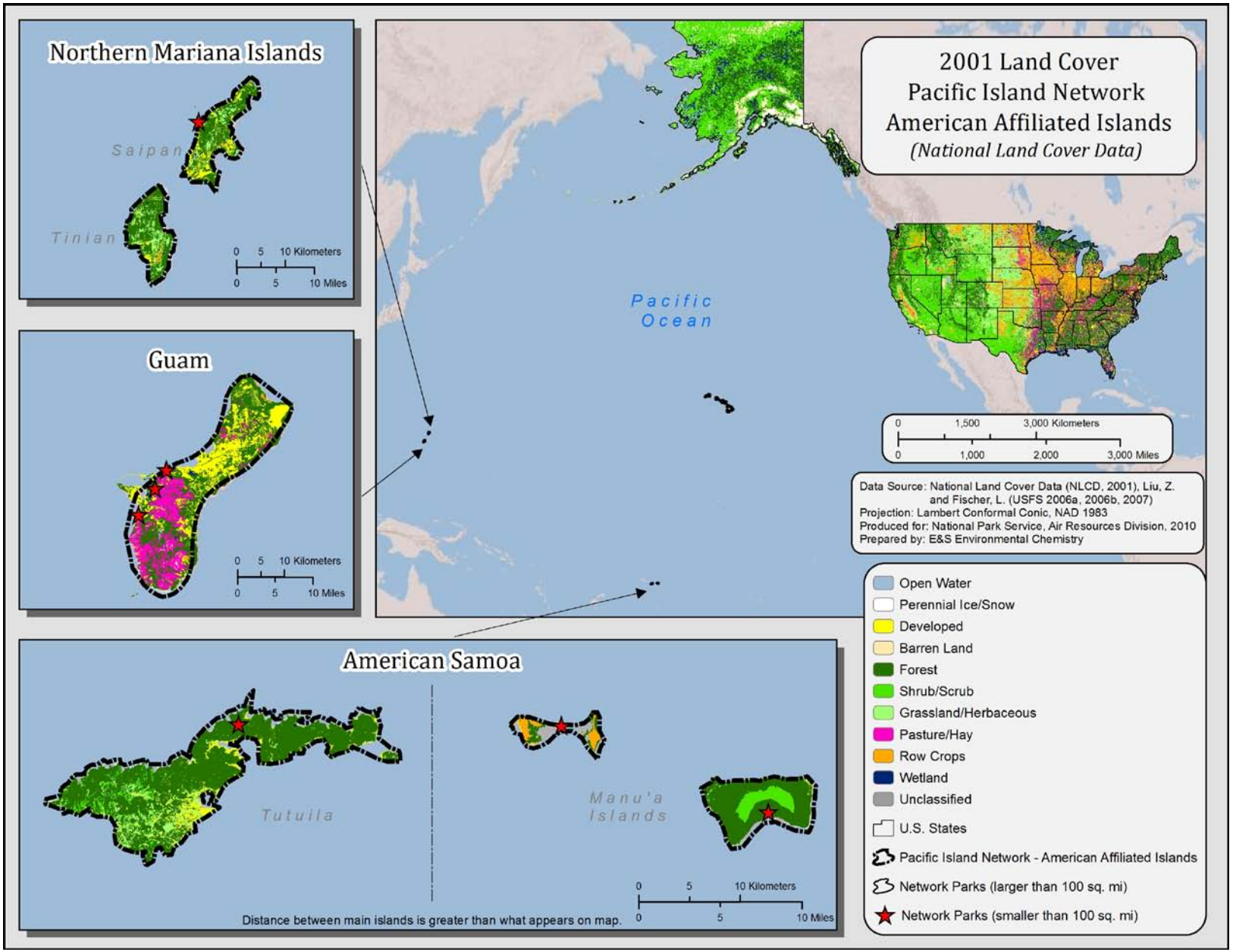
Map I-1


Northern Mariana Islands
American Memorial Park
Garapan
Saipan
Tinian
San Jose
0 5 10 Kilometers
0 5 10 Miles
Guam
War in the Pacific
Hagatna
0 5 10 Kilometers
0 5 10 Miles
Park Locations and Urban Centers
Pacific Island Network
American Affiliated Islands
Pacific Ocean
0 1,500 3,000 Kilometers
0 1,000 2,000 3,000 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
American Samoa
National Park of American Samoa
Pago Pago
Tutuila
National Park of American Samoa
Manu'a Islands
0 5 10 Kilometers
0 5 10 Miles
Distance between main islands is greater than what appears on map.
Major Cities
Over 1,000,000
500,000 - 1,000,000
100,000 - 500,000
50,000 to 100,000
Less than 50,000
U.S. States
300 Mile Network Buffer
Pacific Island Network - American Affiliated Islands
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

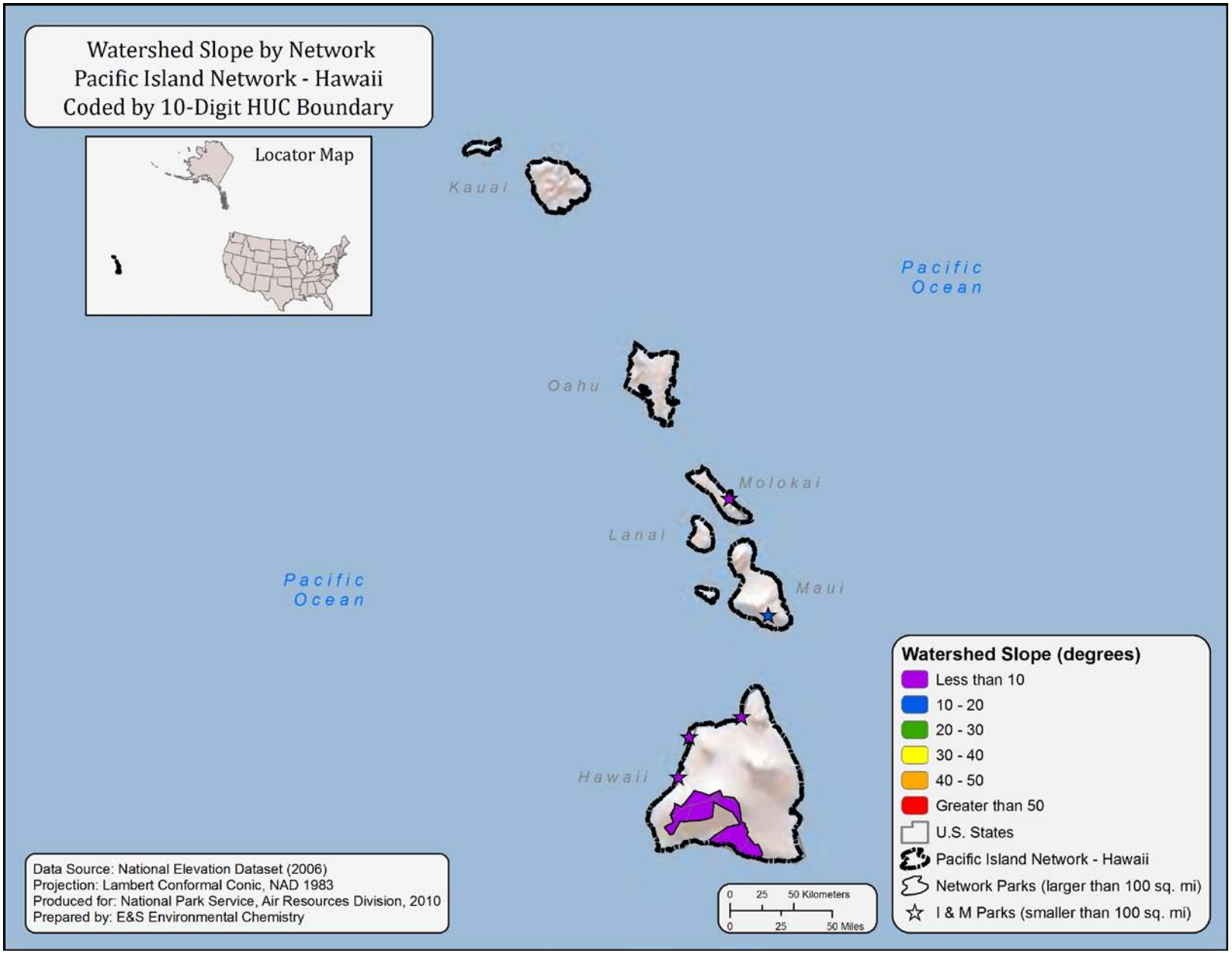
Map I-2


2001 Land Cover
Pacific Island Network
Hawaii
(National Land Cover Data)
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific Ocean
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
0 25 50 Kilometers
0 25 50 Miles
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetlands
U.S. States
Pacific Island Network - Hawaii
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

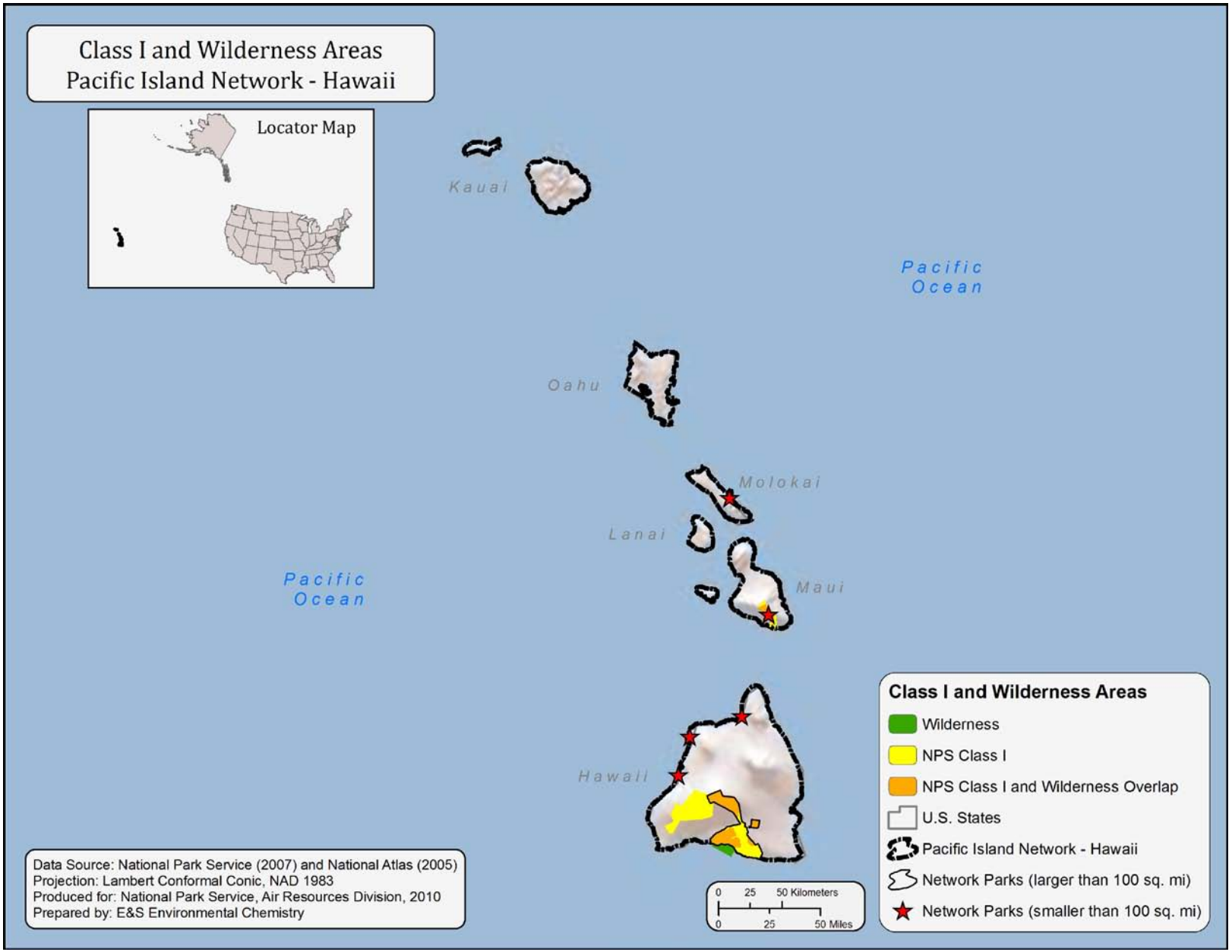
Map L-1


Northern Mariana Islands
Saipan
Tinian
0 5 10 Kilometers
0 5 10 Miles
Guam
0 5 10 Kilometers
0 5 10 Miles
American Samoa
Tutuila
Manu'a Islands
0 5 10 Kilometers
0 5 10 Miles
Distance between main islands is greater than what appears on map.
Pacific Ocean
2001 Land Cover
Pacific Island Network
American Affiliated Islands
(National Land Cover Data)
0 1,500 3,000 Kilometers
0 1,000 2,000 3,000 Miles
Data Source: National Land Cover Data (NLCD, 2001), Liu, Z. and Fischer, L. (USFS 2006a, 2006b, 2007)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetland
Unclassified
U.S. States
Pacific Island Network - American Affiliated Islands
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

Map L-2


Watershed Slope by Network
Pacific Island Network - Hawaii
Coded by 10-Digit HUC Boundary
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific Ocean
Watershed Slope (degrees)
Less than 10
10 - 20
20 - 30
30 - 40
40 - 50
Greater than 50
U.S. States
Pacific Island Network - Hawaii
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


Class I and Wilderness Areas
Pacific Island Network - Hawaii
Locator Map
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Pacific Ocean
Pacific Ocean
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
0 25 50 Kilometers
0 25 50 Miles
Class I and Wilderness Areas
Wilderness
NPS Class I
NPS Class I and Wilderness Overlap
U.S. States
Pacific Island Network - Hawaii
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

Map N

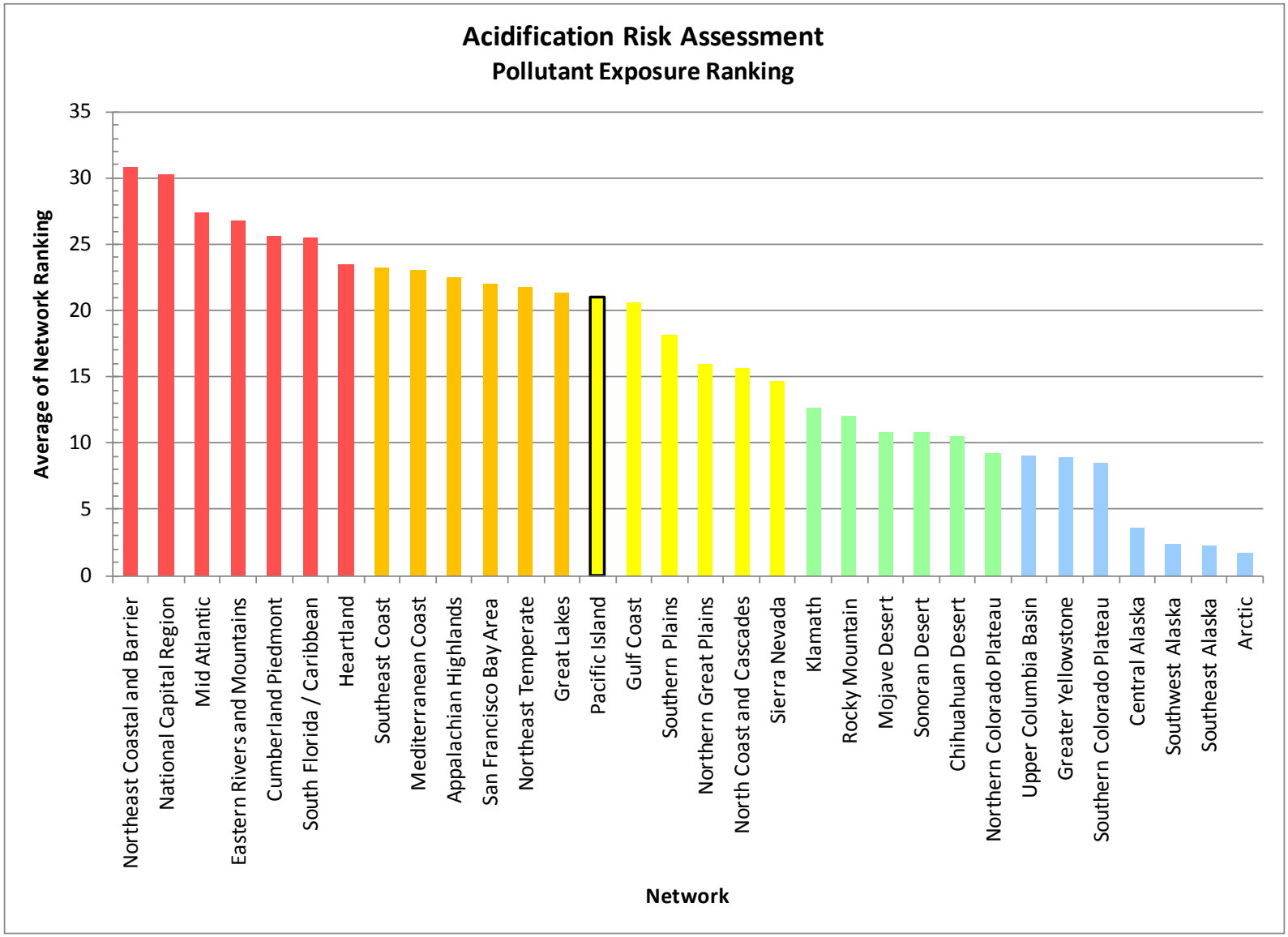

Acidification Risk Assessment
Pollutant Exposure Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Northeast Coastal and Barrier
National Capital Region
Mid Atlantic
Eastern Rivers and Mountains
Cumberland Piedmont
South Florida / Caribbean
Heartland
Southeast Coast
Mediterranean Coast
Appalachian 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

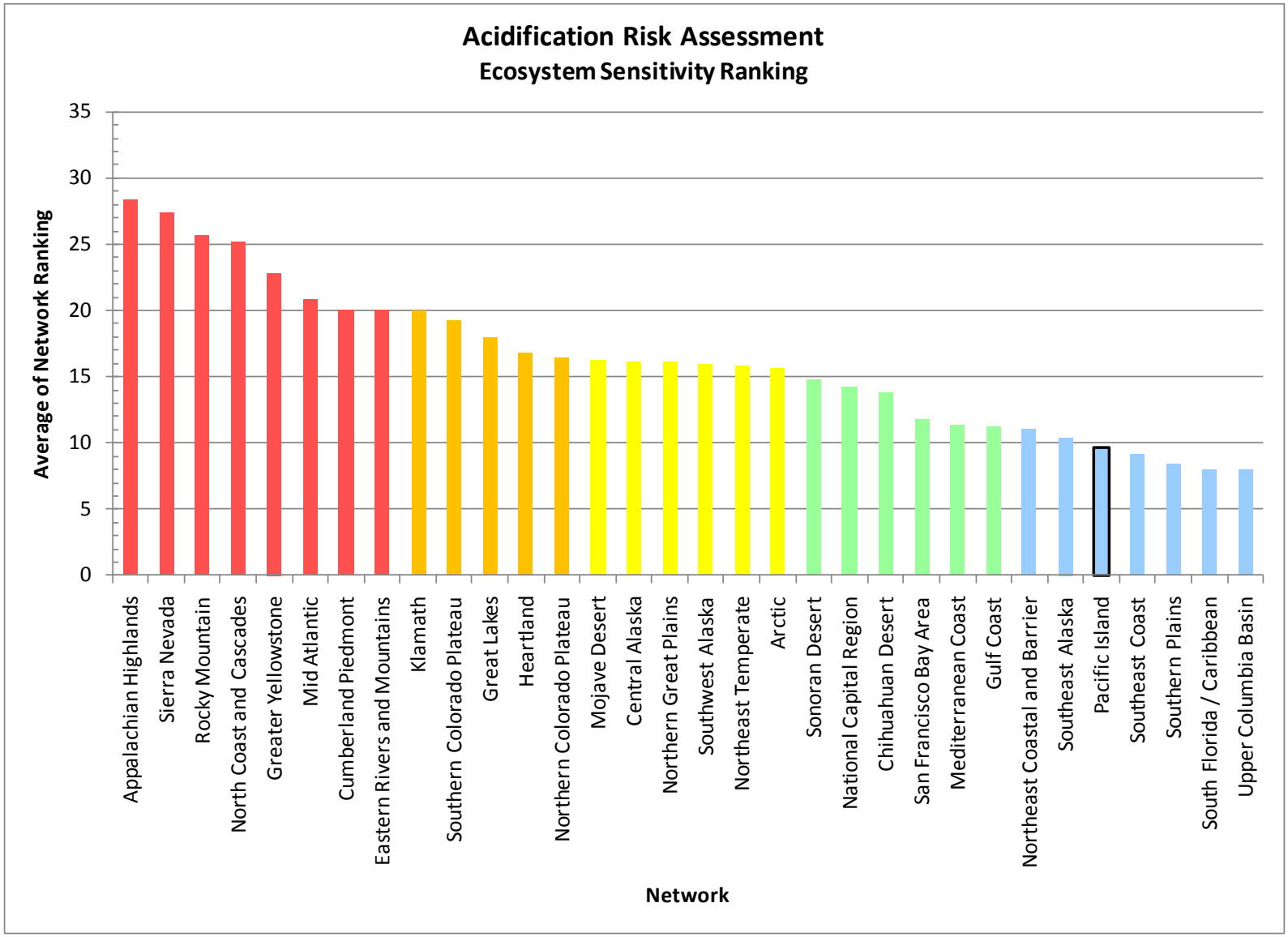

Acidification Risk Assessment
Ecosystem Sensitivity Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Appalachian Highlands
Sierra Nevada
Rocky Mountain
North Coast and Cascades
Greater Yellowstone
Mid Atlantic
Cumberland Piedmont
Eastern Rivers and Mountains
Klamath
Southern Colorado Plateau
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

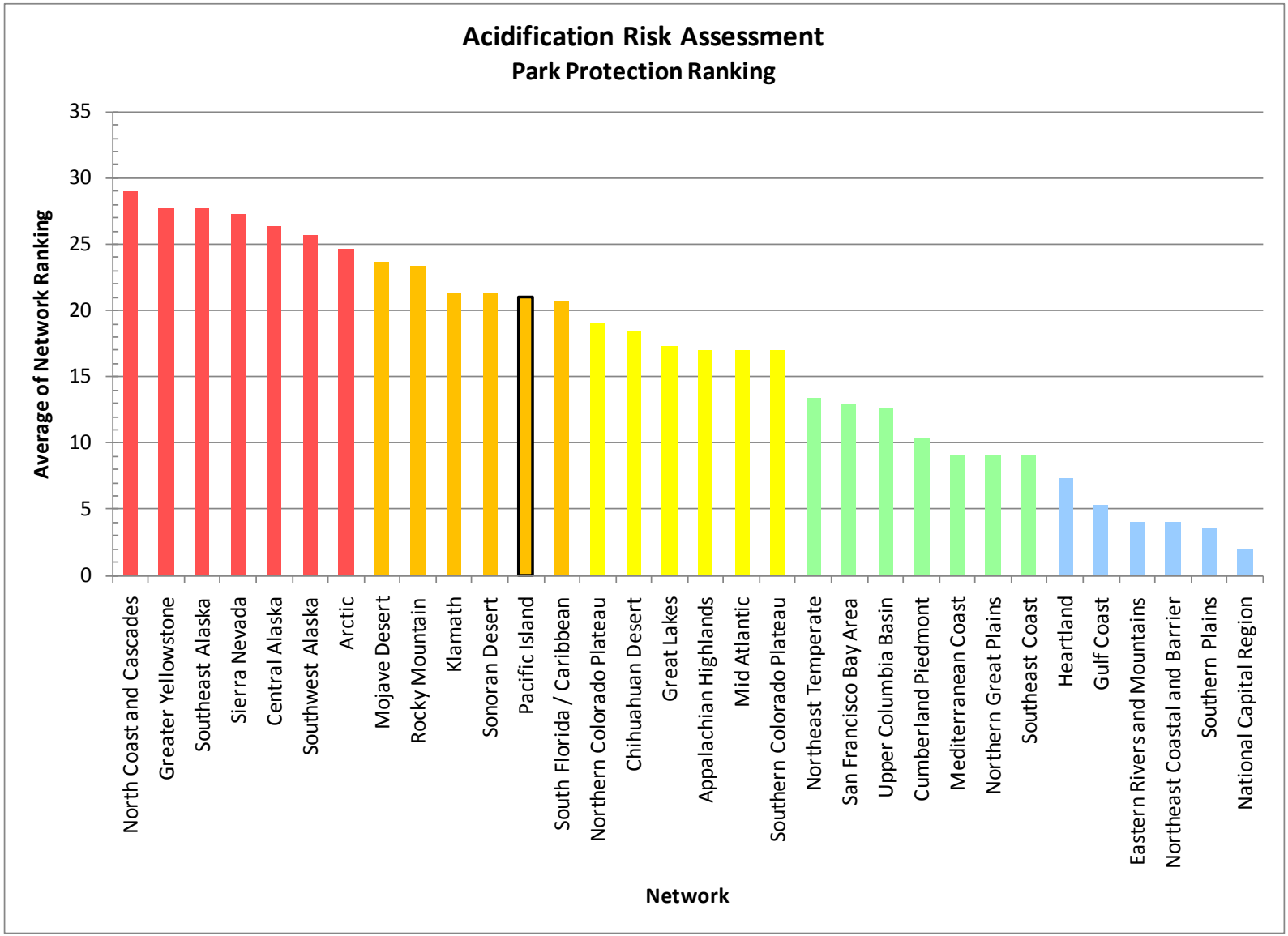

Acidification Risk Assessment
Park Protection Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
North Coast and Cascades
Greater Yellowstone
Southeast Alaska
Sierra Nevada
Central Alaska
Southwest Alaska
Arctic
Mojave Desert
Rocky Mountain
Klamath
Sonoran Desert
Pacific Island
South Florida /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

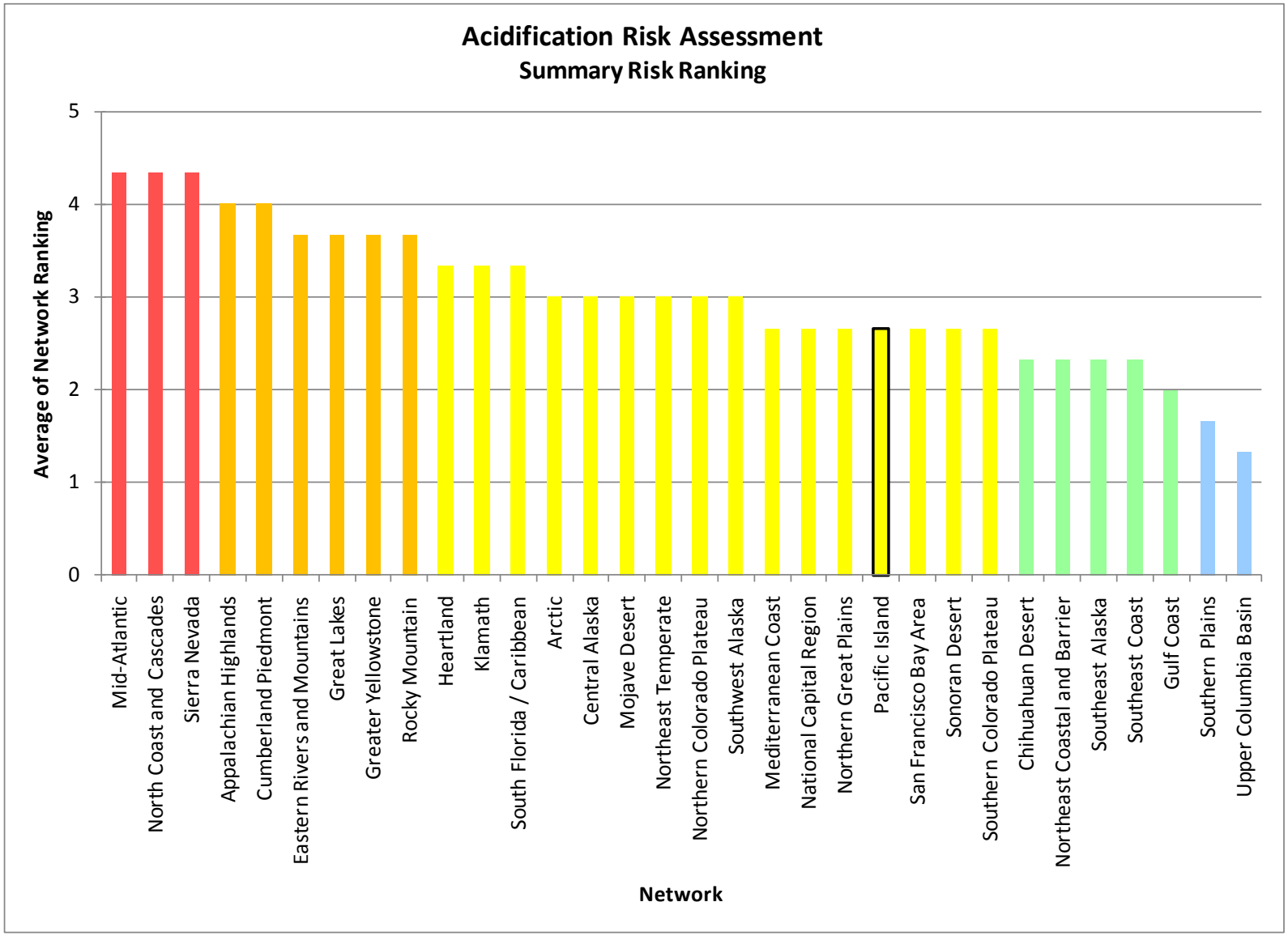

Acidification Risk Assessment
Summary Risk Ranking
Average of Network Ranking
0
1
2
3
4
5
Mid-Atlantic
North Coast and Cascades
Sierra Nevada
Appalachian Highlands
Cumberland Piedmont
Eastern Rivers and Mountains
Great Lakes
Greater Yellowstone
Rocky Mountain
Heartland
Klamath
South Florida / Caribbean
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
Network

Figure D

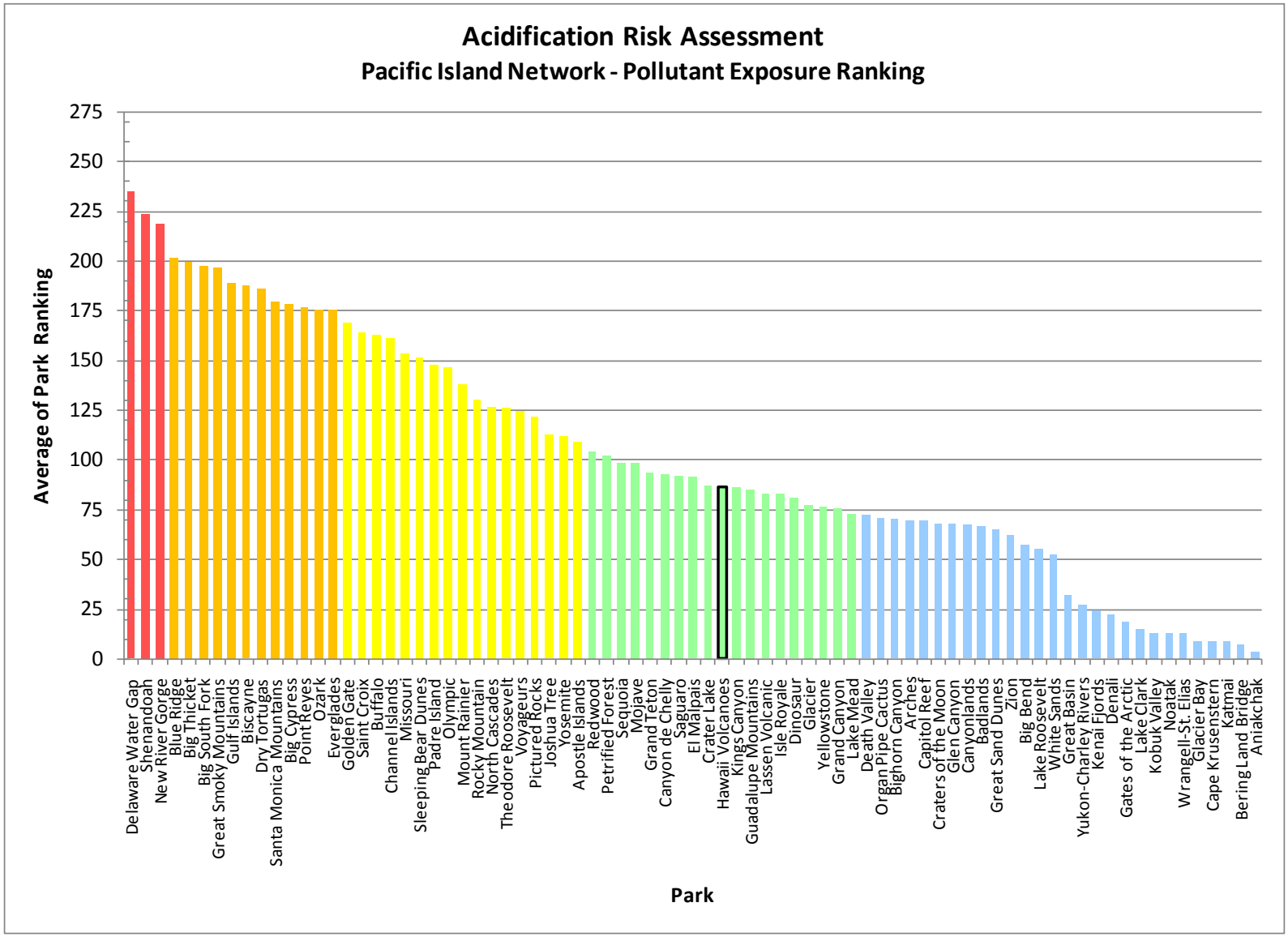

Acidification Risk Assessment
Pacific Island Network - Pollutant Exposure Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Delaware Water Gap
Shenandoah
New River Gorge
Blue Ridge
Big Thicket
Big South Fork
Great Smoky Mountains
Gulf Islands
Biscayne
Dry Tortugas
Santa Monica 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

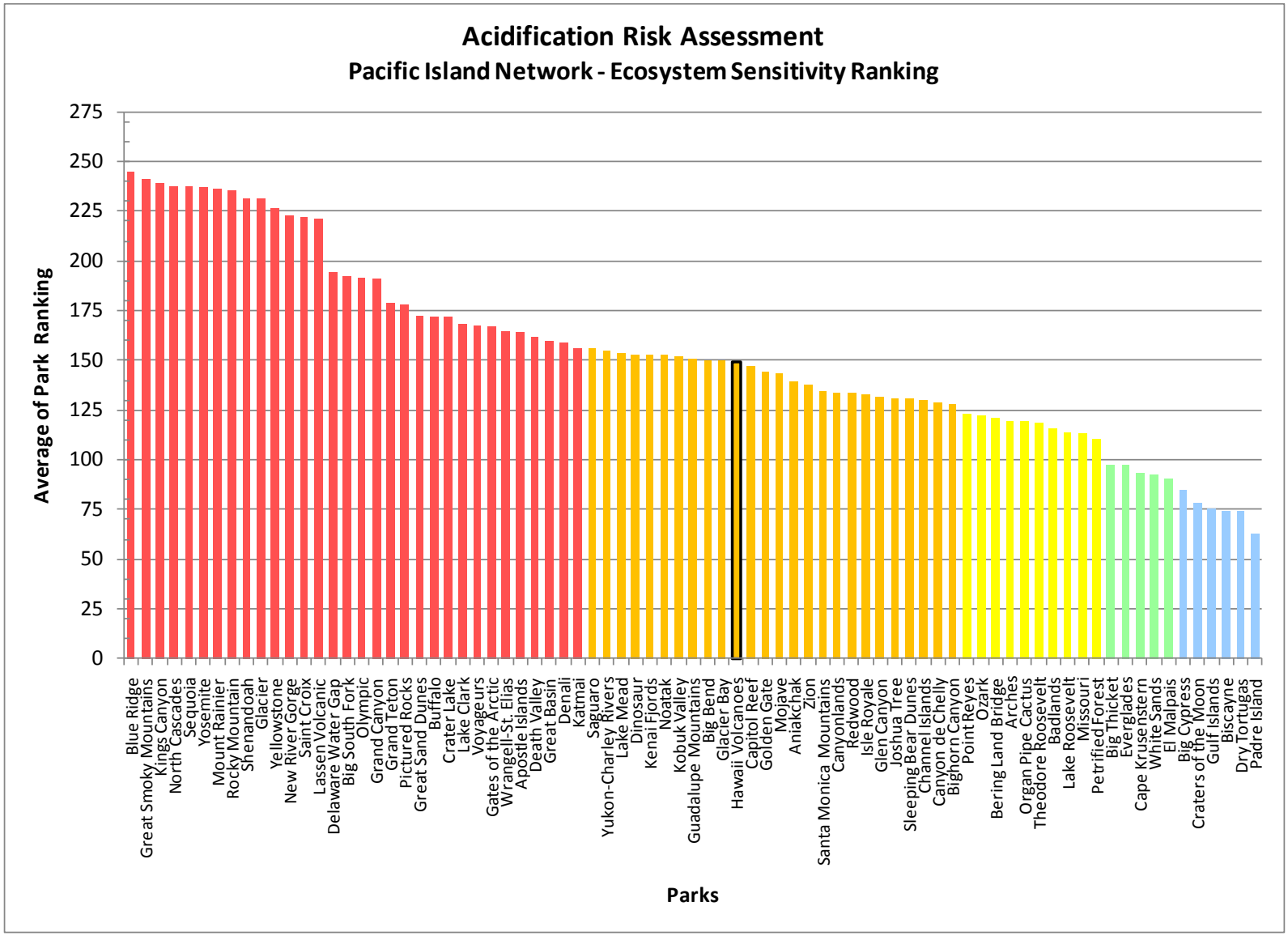

Acidification Risk Assessment
Pacific Island Network - Ecosystem Sensitivity Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Blue Ridge
Great Smoky Mountains
Kings Canyon
North Cascades
Sequoia
Yosemite
Mount Rainier
Rocky Mountain
Shenandoah
Glacier
Yellowstone
New River Gorge
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

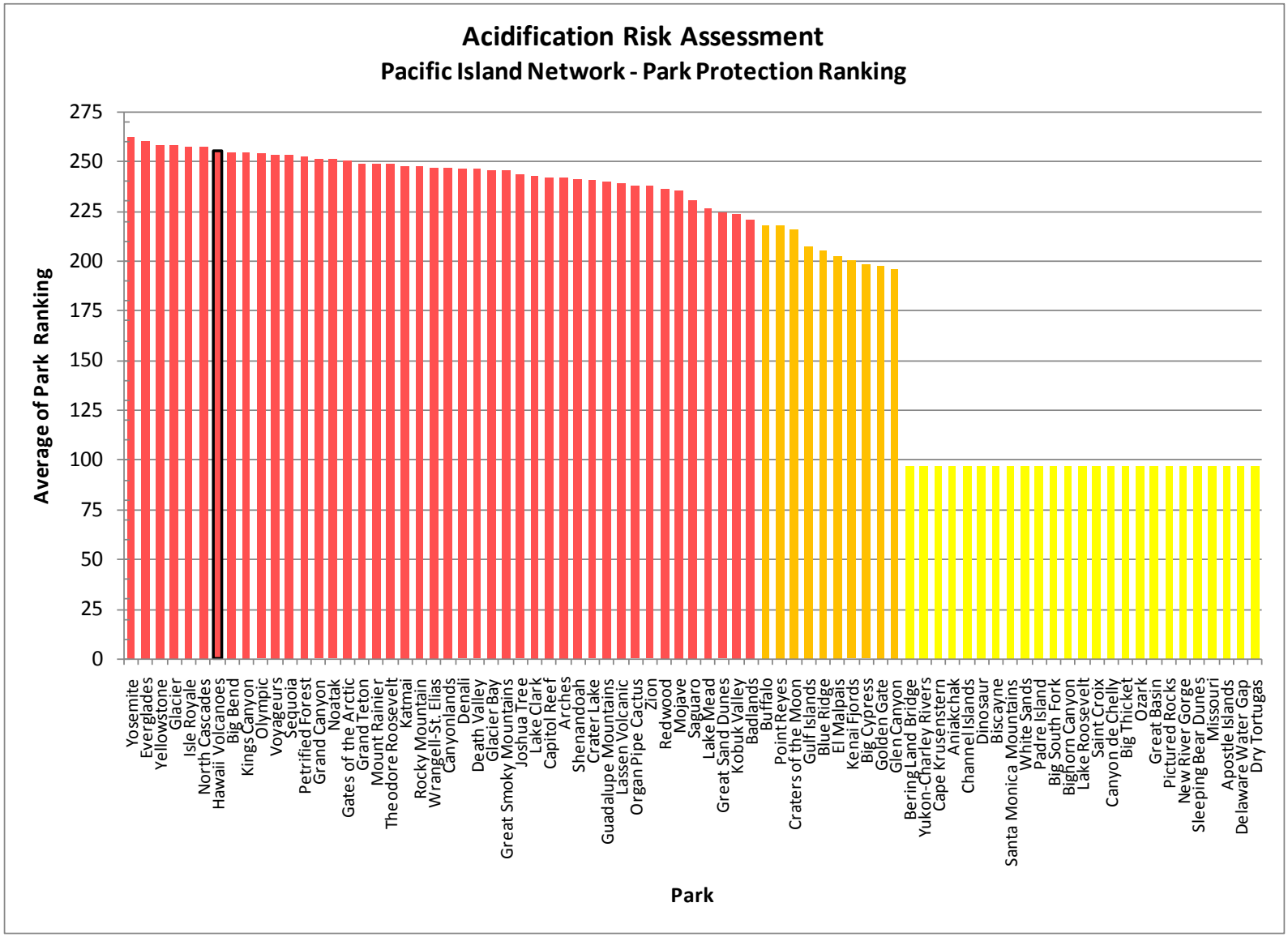

Acidification Risk Assessment
Pacific Island Network - Park Protection Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Park
Yosemite
Everglades
Yellowstone
Glacier
Isle Royale
North Cascades
Hawaii Volcanoes
Big Bend
Kings Canyon
Olympic
Voyageurs
Sequoia
Petrified Forest
Grand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

Figure G

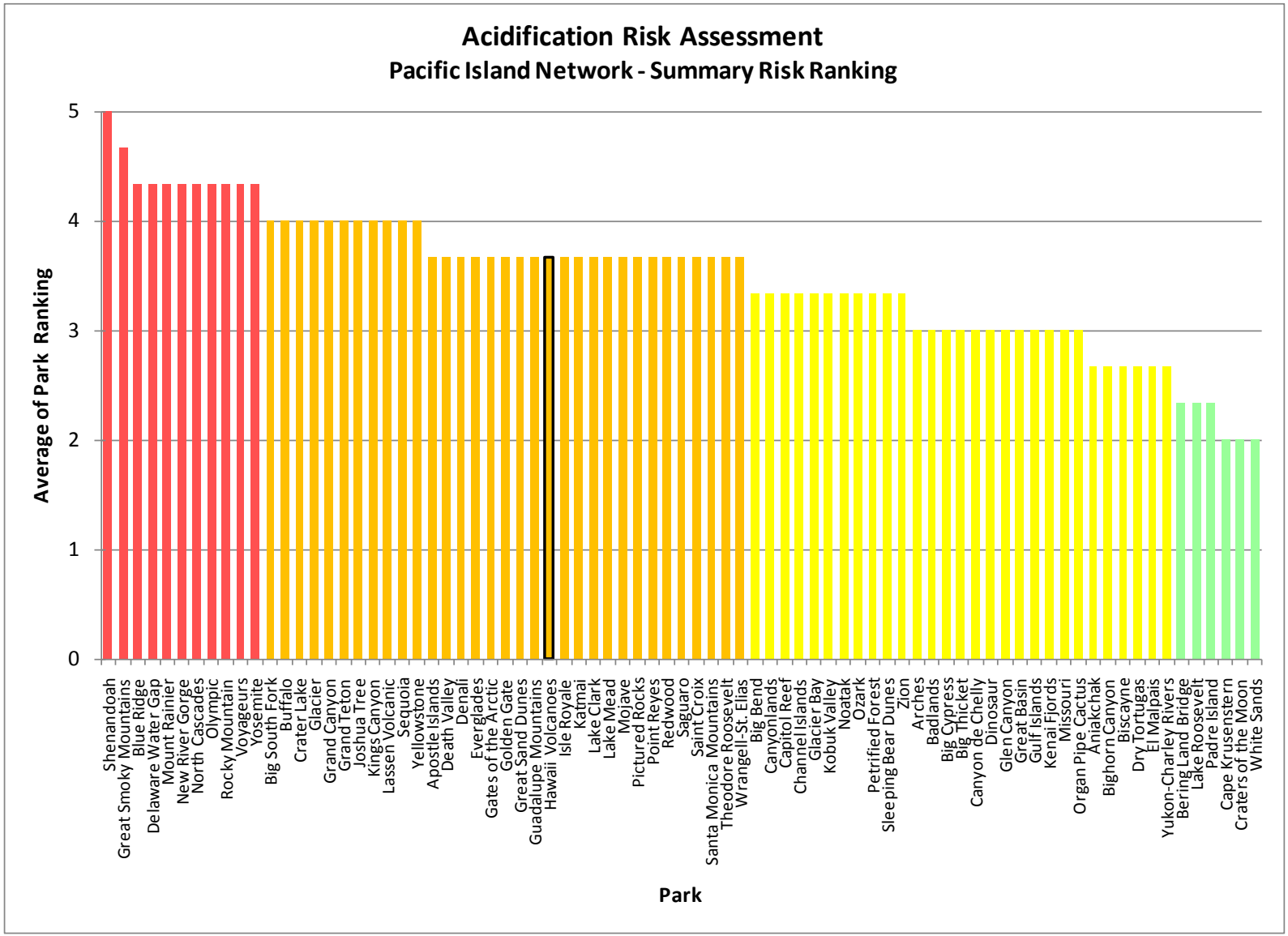

Acidification Risk Assessment
Pacific Island Network - Summary Risk Ranking
Average of Park Ranking
0
1
2
3
4
5
Park
Shenandoah
Great Smoky Mountains
Blue Ridge
Delaware Water Gap
Mount Rainier
New River Gorge
North Cascades
Olympic
Rocky Mountain
Voyageurs
Yosemite
Big South Fork
Buffalo
Crater Lake
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

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 988/107406, April 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