



Air Quality Related Values (AQRVs) for Southeast Coast Network (SECN) Parks

Effects from Ozone; Visibility Reducing Particles; and Atmospheric Deposition of Acids, Nutrients and Toxics

Natural Resource Report NPS/SECN/NRR—2016/1199



ON THE COVER

Photograph of air quality related values within various National Park units. Wildflowers, clear views, aquatic species, and lichens may all be threatened by air pollution.

Photographs courtesy of the National Park Service

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Summary

This report describes the Air Quality Related Values (AQRVs) of the Southeast Coast Network (SECN). AQRVs are those resources sensitive to air quality and include streams, lakes, soils, vegetation, fish and wildlife, and visibility. The SECN parks that are included in the NPS Inventory and Monitoring (I&M) Program, and discussed in this report, are Canaveral National Seashore (CANA), Cape Hatteras National Seashore (CAHA), Cape Lookout National Seashore (CALO), Castillo de San Marcos National Monument (CASA), Chattahoochee River National Recreational Area (CHAT), Congaree National Park (COSW), Cumberland Island National Seashore (CUIS), Fort Caroline National Memorial (FOCA), Fort Frederica National Monument (FOFR), Fort Matanzas National Monument (FOMA), Fort Pulaski National Monument (FOPU), Fort Sumter National Monument (FOSU), Horseshoe Bend National Military Park (HOBE), Kennesaw Mountain National Battlefield Park (KEMO), Moores Creek National Battlefield (MOCR), Ocmulgee National Monument (OCMU), and Timucuan Ecological and Historical Preserve (TIMU).

Sullivan et al. (2011a, 2011b) and Kohut (2007) conducted risk assessments for acidification, eutrophication, and ozone (O_3) for the SECN I&M parks; their results are described in this report. This report also describes air pollutant emissions and air quality in the SECN, and their effects on AQRVs. The primary pollutants likely to affect AQRVs include nitrogen (N) and sulfur (S) compounds (nitrate [NO_3^-], ammonium [NH_4^+], and sulfate [SO_4^{2-}]), ground-level O_3 , haze-causing particles, and airborne toxics. Background for this section can be found in “Air quality related values (AQRVs) in national parks: Effects from ozone; visibility reducing particles; and atmospheric deposition of acids, nutrients and toxics” (Sullivan 2016).

The SECN extends along the Atlantic coast from the North Carolina-Virginia border south to Cape Canaveral, Florida and inland as far as Atlanta, Georgia and the Alabama Coastal Plain. Park units in the SECN are impacted by air pollution from nearby and regional emissions sources including power plants, industry, urban areas, vehicles, and agriculture. Air quality is poor at times, with significant impacts on visibility and natural resources. Fires in the region also contribute to air pollution. Several of the park units are located in or near large population centers. Two of the units, CHAT and KEMO, are in counties near Atlanta, Georgia, that are designated nonattainment for the National Ambient Air Quality Standards (NAAQS) for O_3 .

For earlier risk assessments described in this report, S and N emissions from 2002 were summarized (Sullivan et al. 2011a, Sullivan et al. 2011b). Annual county-level S emissions in 2002 within the SECN region varied substantially. A large portion of the network had sulfur dioxide (SO_2) emissions less than 1 ton per square mile per year ($ton/mi^2/yr$). However, there were areas scattered throughout the network with higher emissions, including a few counties that emitted more than 100 $tons/mi^2/yr$. There were many emissions point source of SO_2 in the vicinity of SECN park lands. Most emitted less than 5,000 tons/yr, although there were a few that emitted larger amounts, ranging from 5,000 to over 40,000 tons/yr. There were also many relatively large ($> 2,000$ tons/yr) point sources of oxidized N around the network. Provisions of the Clean Air Act (CAA) required emissions reductions at many large sources of S and N (e.g., power plants), and current emissions are lower

than those reported in 2002. During 2011, SO₂ emissions in the vicinity of most SECN parks were less than 25 tons/mi²/yr based on the U.S. Environmental Protection Agency's (EPA's) National Emissions Inventory (NEI). Sulfur and N deposition levels in the SECN were high, but have decreased in recent years as a result of emissions reductions. Despite recent decreases in atmospheric N deposition, empirical estimates of the critical load (CL) of N deposition for protection of sensitive ecosystem elements are exceeded at nearly all receptors and national parks in the network.

Sulfur and N pollutants can cause acidification of streams, lakes, and soils. Nitrogen can also cause nutrient enrichment of aquatic ecosystems and can cause undesirable nutrient enrichment of natural terrestrial ecosystems, leading to changes in plant species occurrence and diversity. There are important links to carbon (C) cycling and climate change.

Ozone pollution can harm human health, reduce plant growth, and cause visible injury to plant foliage. Three parks (CHAT, KEMO, and OCMU) consistently ranked High for each of the O₃ risk indices considered. Effects of O₃ exposure in this network are expected to be considerable, but have not been well documented.

Atmospheric O₃ concentrations at 568 monitoring sites nationwide showed generally stable levels throughout the 1990s, but declined between 2002 and 2007, due largely to oxidized N emissions reductions (U.S. EPA 2008). Even though there have been widespread improvements in atmospheric O₃ levels, however, there were still 51 sites classified as nonattainment areas in 2007 because of failure to meet the O₃ NAAQS (U.S. EPA 2008). The highest O₃ concentrations in the United States in 2007 were located in Georgia and five other states (U.S. EPA 2008). There were 18 sites in the U.S. EPA (2008) study that showed O₃ levels that 1) were above the new O₃ standard (fourth highest daily maximum 8-hour concentration equal to 0.075 ppm) in 2007, and 2) showed an increase of more than 0.005 ppm. Two of these sites were located in or near Jacksonville, FL and Columbus, GA, within the SECN region.

Particulate pollution can cause haze, reducing visibility. Visibility monitoring near some of the SECN parks indicates that haze levels are very high at times.

Airborne toxics, including mercury (Hg), can harm humans, fish, and wildlife. The SECN region is located in an area that is generally expected to have relatively high Hg methylation potential. This could contribute to Hg bioaccumulation to high levels in fish and fish-eating wildlife. Other airborne toxics include pesticides and industrial contaminants and by-products. Agricultural pesticides like chlorpyrifos, malathion, and atrazine can volatilize and be deposited into ecosystems through atmospheric processes, potentially harming birds, fish, and other wildlife in the SECN.

Background

There are 17 parks in the Southeast Coast Network (SECN): Canaveral National Seashore (CANA), Cape Hatteras National Seashore (CAHA), Cape Lookout National Seashore (CALO), Castillo de San Marcos National Monument (CASA), Chattahoochee River National Recreational Area (CHAT), Congaree National Park (COSW), Cumberland Island National Seashore (CUIS), Fort Caroline National Memorial (FOCA), Fort Frederica National Monument (FOFR), Fort Matanzas National Monument (FOMA), Fort Pulaski National Monument (FOPU), Fort Sumter National Monument (FOSU), Horseshoe Bend National Military Park (HOBE), Kennesaw Mountain National Battlefield Park (KEMO), Moores Creek National Battlefield (MOCR), Ocmulgee National Monument (OCMU), and Timucuan Ecological and Historical Preserve (TIMU). The majority are located in close proximity to the Atlantic coastline. The largest population centers in the network are the metropolitan areas of Atlanta and Jacksonville. There are also a number of population centers in the range of 100,000 to 500,000 people, mainly in the north. Map 1 shows the network boundary along with locations of each park and population centers with more than 10,000 people around the network. The predominant land cover types within this network are generally highly mixed, with forest, shrubland, wetland, row crops, pasture/hay, and developed lands all being common.

Atmospheric Emissions and Deposition

Previous Air Quality Related Value (AQRV) assessments (Sullivan et al. 2011a; Sullivan et al. 2011b) evaluated risks to park resources from N and S deposition, using data from the 2002 National Emissions Inventory (NEI). Annual county-level sulfur (S) emissions in 2002 in the SECN region varied substantially across the network. A large portion of the network region had sulfur dioxide (SO₂) emissions less than 1 ton per square mile per year (ton/mi²/yr). However, there were areas scattered throughout the network region with higher emissions, including a few counties that emitted more than 100 tons/mi²/yr. There were many point source emissions of SO₂ in the SECN region. Most emitted less than 5,000 tons/yr, although there were a few, usually large coal-burning power plants, that emitted larger amounts, ranging from 5,000 to over 40,000 tons/yr.

County-level annual nitrogen (N) emissions in 2002 within the SECN region ranged from less than 1 ton/mi²/yr to greater than 20 tons per square mile. In general, annual county N emissions were between 1 and 20 tons/mi²/yr throughout most of the network region, with some counties having both lower and higher emissions levels. There were many relatively large (i.e., larger than about 2,000 tons per year) point sources of oxidized N (NO_x) scattered throughout the network region. Point source emissions of reduced N (NH₃) tended to be smaller, less than 1,000 tons per year.

Over most of the southeastern United States from Arkansas to Florida, SO₂ emissions generally increased during the 1990s (Malm et al. 2002). The increases were most pronounced in Arkansas (87%), Louisiana (48%), and North Carolina (37%). In contrast, Tennessee (-35%) and Georgia (-42%) showed statistically significant decreases in SO₂ emissions. These SO₂ emissions influenced regional visibility.

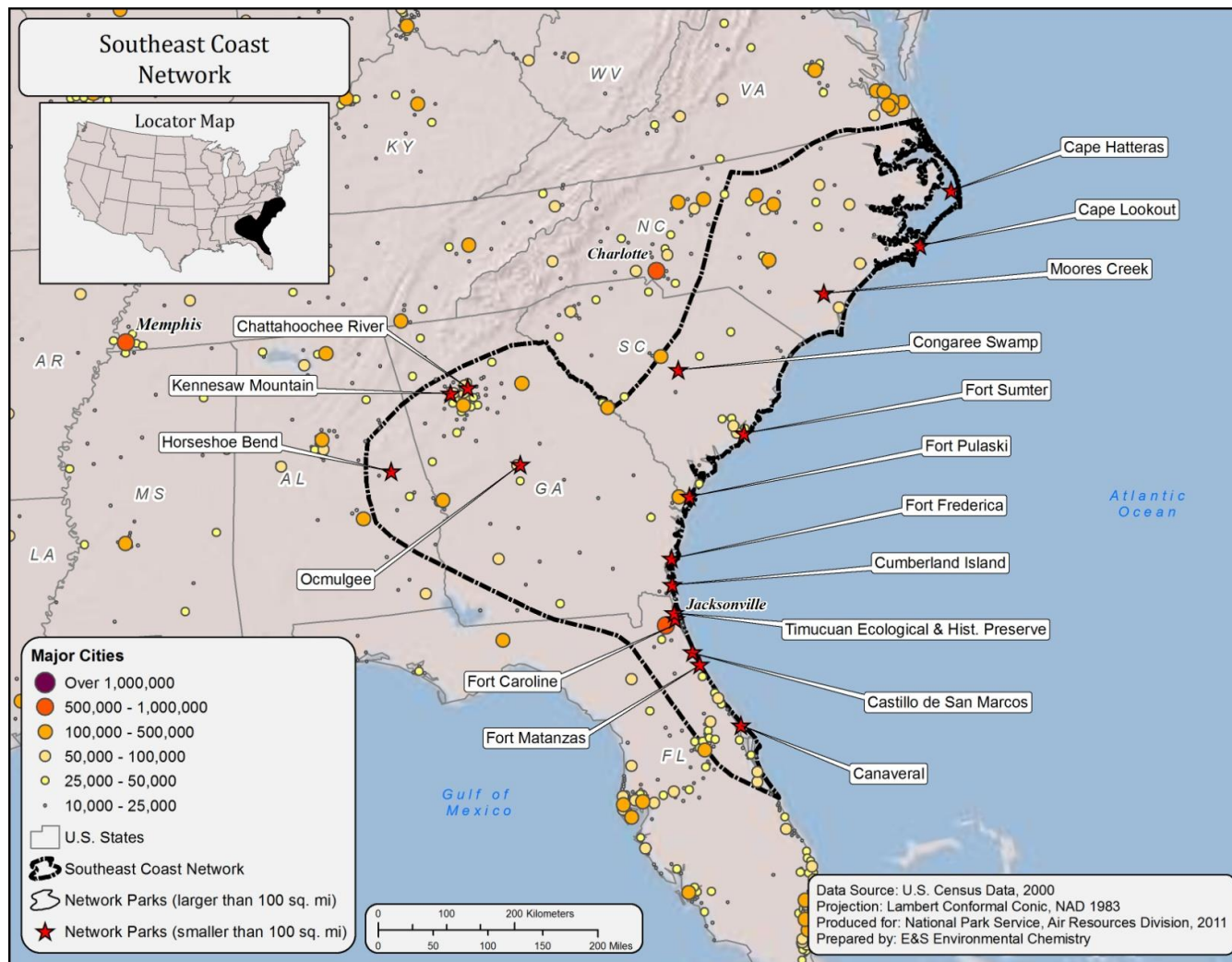
County-level N and S emissions near the SECN, based on data from the EPA's NEI during a recent time period (2011), are depicted in Maps 2 through 4 for SO₂, oxidized N (NO_x), and reduced N (NH₃), respectively. Emissions of SO₂ in the vicinity of most SECN parks was less than 25 tons/mi²/yr, although in a few counties SO₂ emissions were higher than 50 tons/mi²/year (Map 2). Patterns in NO_x emissions were generally higher (Map 3). Emissions of NH₃ near SECN parks were highest in the northern portion of the network region (Map 4).

Atmospheric deposition of both S and N in the SECN are relatively high. Total S deposition for most of the network was between 5 and 10 kg S/ha/yr in 2002. There were large areas, however, where S deposition was between 10 and 15 kg S/ha/yr. Total N deposition within the network ranged from as low as 5 to 10 kg N/ha/yr to over 30 kg N/ha/yr in some park areas. Estimated N deposition throughout most of the network was between 5 and 15 kg N/ha/yr (Sullivan et al. 2011b).

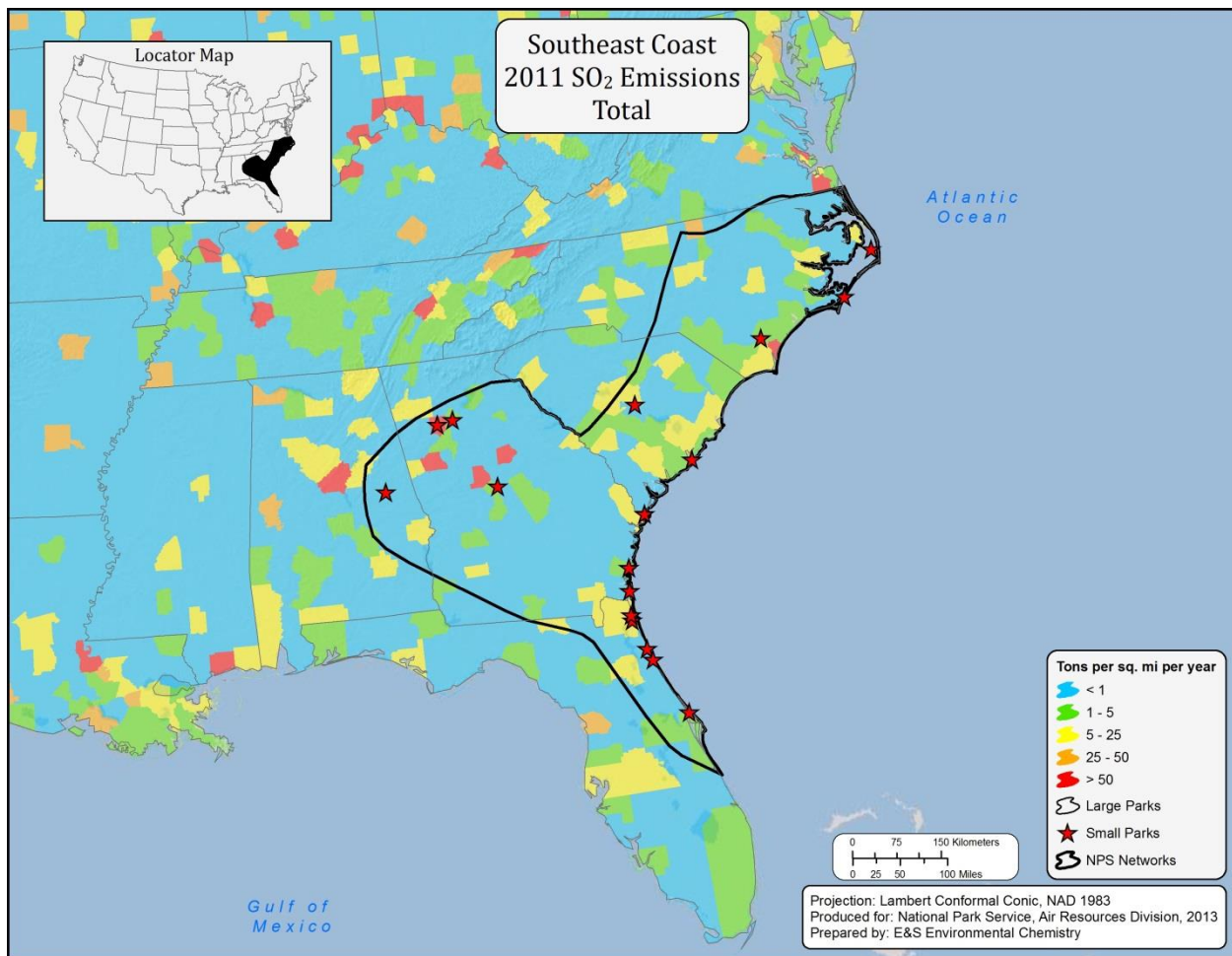
Schwede and Lear (2014) recently documented a hybrid approach developed by the National Atmospheric Deposition Program (NADP) Total Deposition (TDEP) Science Committee for estimating total N and S deposition. This approach combined monitoring and modeling data. Modeling was accomplished using the Community Multiscale Air Quality (CMAQ) model (Byun and Schere 2006). Priority was given to measured data near the locations of the monitors and to modeled data where monitoring data were not available. In addition, CMAQ data were used for N species that are not routinely measured in the monitoring programs: peroxyacetyl nitrate (PAN), N₂O₅, NO, NO₂, HONO, and organic NO₃. The total deposition estimates are considered to be dynamic, with updates planned as new information becomes available. TDEP data reported here were developed in late 2013 and are designated version 2013.02.

Atmospheric S deposition levels have declined at nearly all SECN parks since 2001, based on TDEP estimates (Table 1). Decreases in total S deposition over the previous decade for the parks in this network were commonly in the range of 30% to 40%. Oxidized and reduced N showed opposite patterns, with oxidized N decreasing and reduced N increasing at most of the parks in the network since the monitoring period 2000-2002.

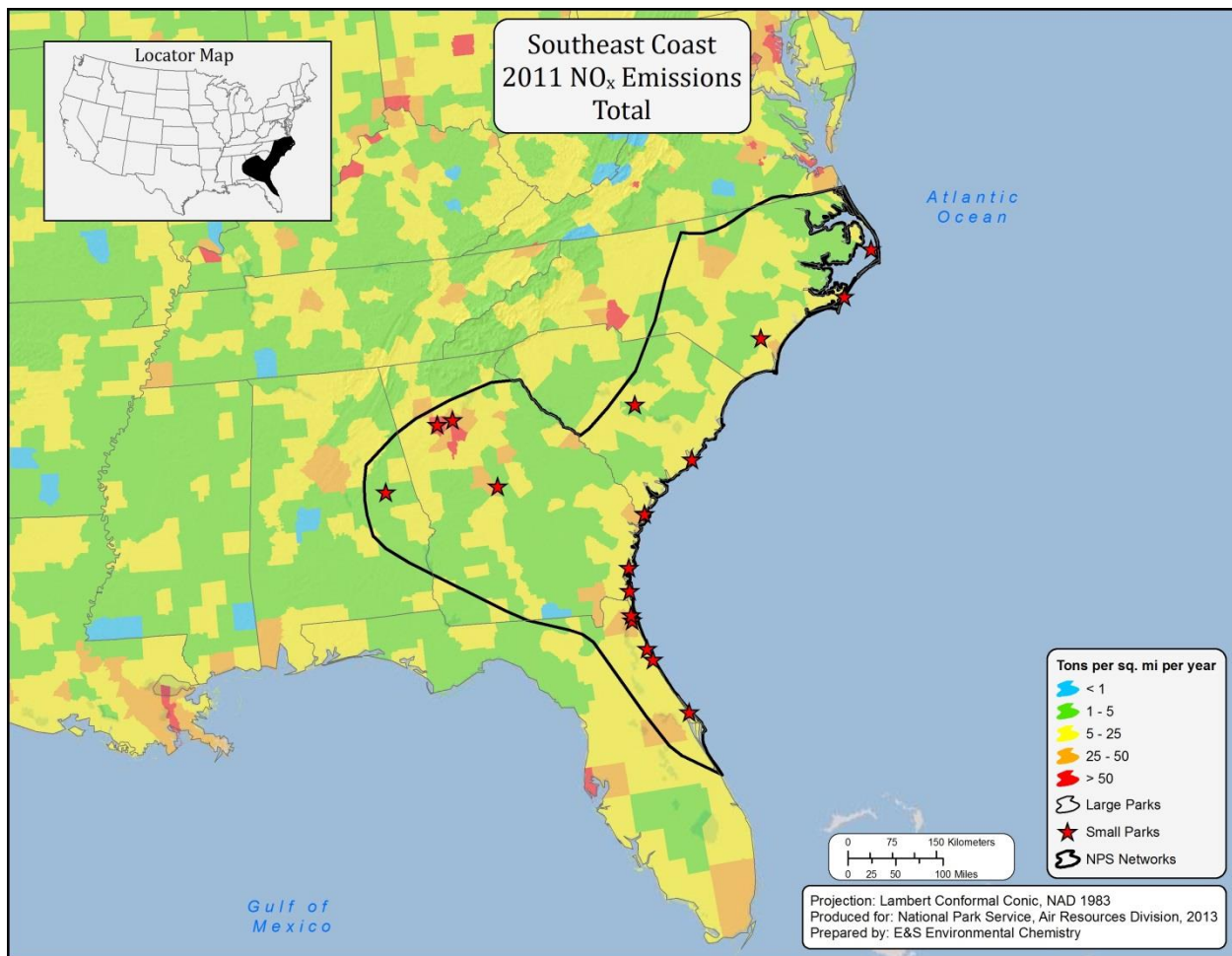
Total S deposition in and around the SECN for the period 2010-2012 was generally in the range of 5 to 10 kg S/ha/yr at park locations within the SECN (Map 5). Oxidized inorganic N deposition for the period 2010-2012 was less than 5 kg N/ha/yr throughout most of the park land within the SECN (Map 6). Estimates of reduced inorganic N from atmospheric deposition during this same period were variable (Map 7); some parklands received more than 10 kg N/ha/yr. Total N deposition was generally higher than 5 kg N/ha/yr at most park locations (Map 8).



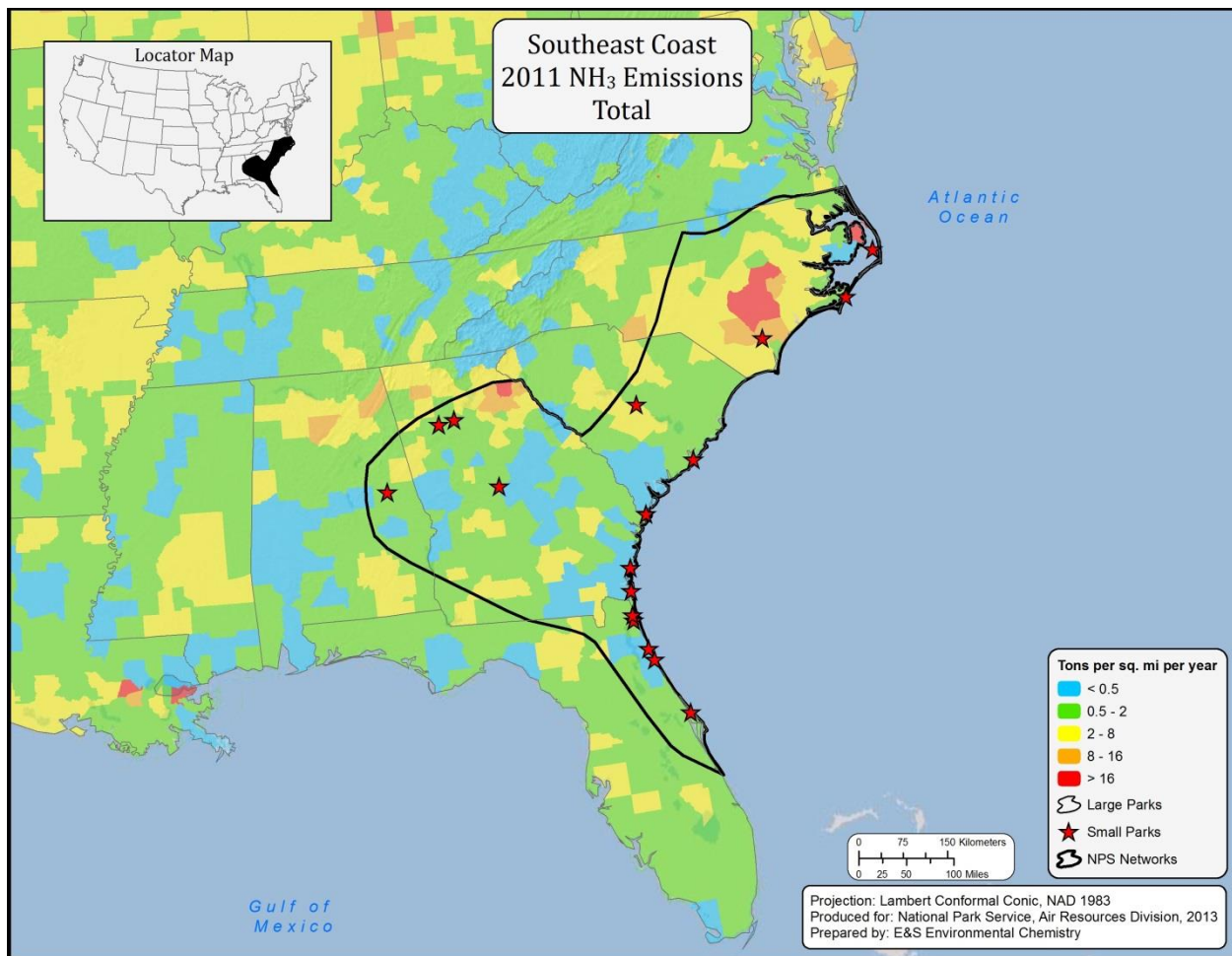
Map 1. Network boundary and locations of parks and population centers greater than 10,000 people within the SECN.



Map 2. Total SO₂ emissions, by county, near the SECN for the year 2011. Data from EPA's National Emissions Inventory.



Map 3. Total NO_x emissions, by county, near the SECN for the year 2011. Data from EPA's National Emissions Inventory.



Map 4. Total NH₃ emissions, by county, near the SECN for the year 2011. Data from EPA's National Emissions Inventory.

Acidification

The network rankings developed by Sullivan et al. (2011b) in a screening assessment for acid Pollutant Exposure, Ecosystem Sensitivity to acidification, and Park Protection yielded an overall network acidification Summary Risk ranking for the SECN that was relatively low among networks. The overall level of concern for acidification effects on Inventory and Monitoring (I&M) parks within this network was judged by Sullivan et al. (2011b) to be Low. While rankings are an indication of risk, park-specific data, particularly data on ecosystem sensitivity, are needed to fully evaluate risk from acidification.

Three parks in this network (CHAT, KEMO, and MOCR) were ranked by Sullivan et al. (2011b) in the highest quintile among I&M parks for acid Pollutant Exposure (Table 2), reflecting the relatively high levels of S and N deposition that occur across much of the network. The rest of the parks were ranked in the second highest quintile for this theme. Park rankings for Ecosystem Sensitivity to acidification were highly variable across the network, with rankings in the second highest quintile (High) for one park (CHAT) and Moderate for two parks (HOBE and KEMO). For the remaining parks, Ecosystem Sensitivity to acidification was in the lowest quintile for 11 parks and in the second lowest quintile for three parks (Table 2).

Ecosystem sensitivity to acidification rankings take into account elevation and land slope, which often influence the degree of acid neutralization provided by soils and bedrock within the watershed. The average slope for all but one (KEMO) of the parks in this network is less than 10°, suggesting a low potential for acid sensitivity of aquatic ecosystems. Available water quality data indicate that surface waters in SECN parks are generally well buffered against acidification. Acidification in response to atmospheric deposition of acidifying substances is not generally an important concern in this network.

Table 1. Average changes in S and N deposition between 2001 and 2011 across park grid cells at SECN parks. Deposition estimates were determined by the Total Deposition Project, TDEP, based on three-year averages centered on 2001 and 2011 for all ~4 km grid cells in each park. The minimum, maximum, and range of 2011 S and N deposition within each park are also shown.

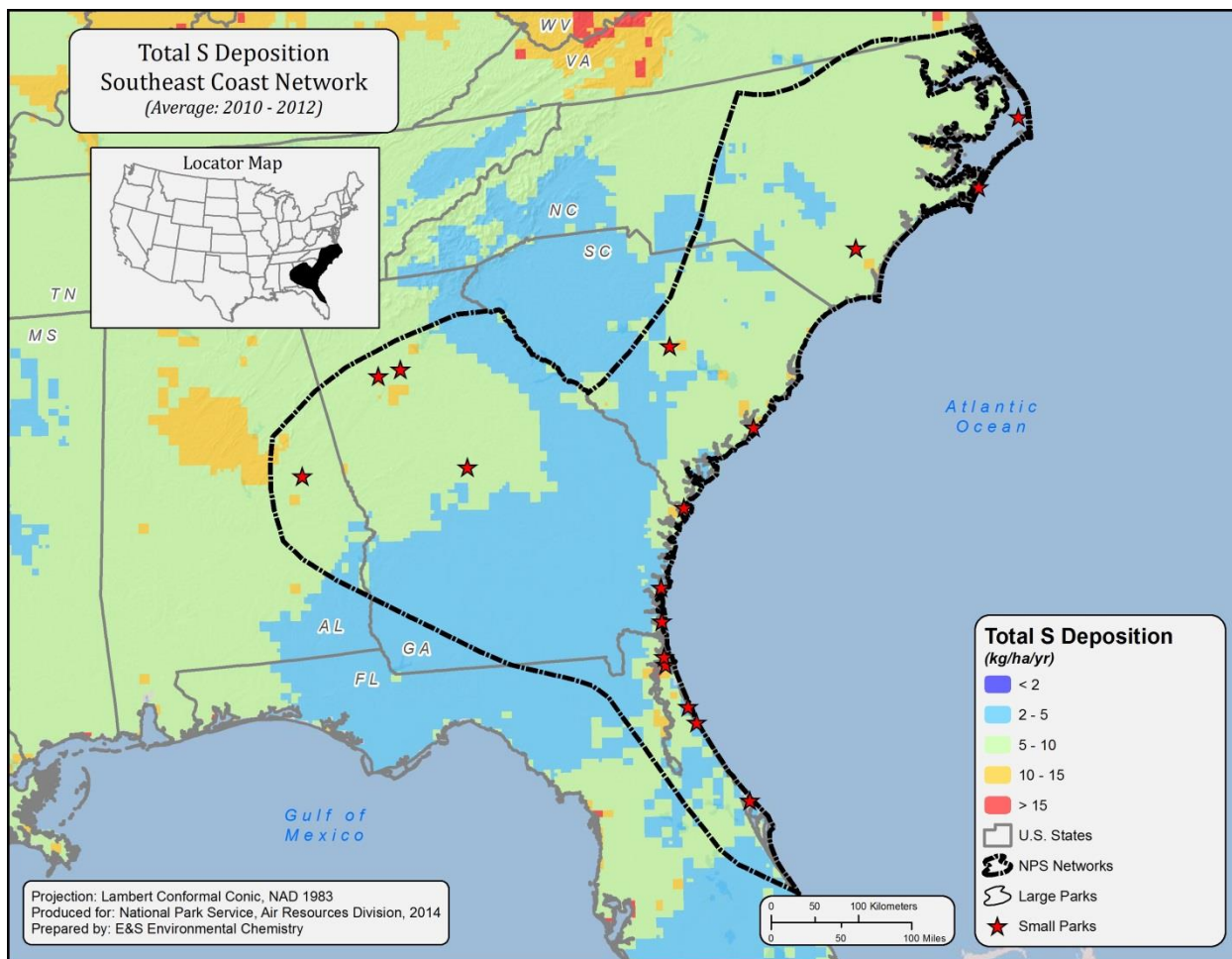
Park Code	Park Name	Parameter	2001 Average (kg/ha/yr)	2011 Average (kg/ha/yr)	Absolute Change (kg/ha/yr)	Percent Change	2011 Minimum (kg/ha/yr)	2011 Maximum (kg/ha/yr)	2011 Range (kg/ha/yr)
CAHA	Cape Hatteras	Total S	9.37	6.09	-3.27	-34.9%	5.67	6.61	0.94
		Total N	6.49	6.19	-0.30	-4.3%	5.29	6.87	1.58
		Oxidized N	4.40	3.15	-1.25	-28.5%	2.87	3.42	0.56
		Reduced N	2.09	3.04	0.95	48.6%	2.42	3.67	1.25
CALO	Cape Lookout	Total S	9.57	5.45	-4.12	-43.0%	5.30	5.70	0.40
		Total N	5.75	7.17	1.42	24.7%	7.07	7.33	0.25
		Oxidized N	4.00	2.89	-1.11	-27.7%	2.78	3.07	0.29
		Reduced N	1.75	4.28	2.53	144.4%	4.26	4.29	0.03
CANA	Canaveral	Total S	7.50	4.67	-2.82	-37.6%	4.50	4.71	0.22
		Total N	10.78	4.11	-6.63	-61.4%	3.87	4.88	1.01
		Oxidized N	9.24	2.75	-6.44	-69.7%	2.49	3.50	1.01
		Reduced N	1.54	1.36	-0.19	-12.2%	1.33	1.39	0.06
CASA	Castillo de San Marcos	Total S	7.80	4.62	-3.18	-40.8%	4.62	4.62	0.00
		Total N	10.10	3.62	-6.48	-64.2%	3.62	3.62	0.00
		Oxidized N	8.28	2.40	-5.88	-71.1%	2.40	2.40	0.00
		Reduced N	1.82	1.22	-0.60	-33.0%	1.22	1.22	0.00
CHAT	Chattahoochee River	Total S	10.45	9.71	-0.69	-5.6%	8.31	14.62	6.31
		Total N	14.12	12.13	-1.96	-13.9%	10.67	14.38	3.72
		Oxidized N	9.73	6.14	-3.59	-36.8%	5.44	7.26	1.81
		Reduced N	4.39	5.99	1.63	38.9%	5.12	8.51	3.40
COSW	Congaree	Total S	10.29	7.77	-2.56	-25.0%	5.78	12.34	6.56
		Total N	10.39	7.59	-2.80	-27.0%	7.50	7.68	0.18
		Oxidized N	6.97	4.16	-2.81	-40.3%	4.07	4.43	0.36
		Reduced N	3.43	3.43	0.00	0.1%	3.23	3.49	0.25

Table 1 (continued). Average changes in S and N deposition between 2001 and 2011 across park grid cells at SECN parks. Deposition estimates were determined by the Total Deposition Project, TDEP, based on three-year averages centered on 2001 and 2011 for all ~4 km grid cells in each park. The minimum, maximum, and range of 2011 S and N deposition within each park are also shown.

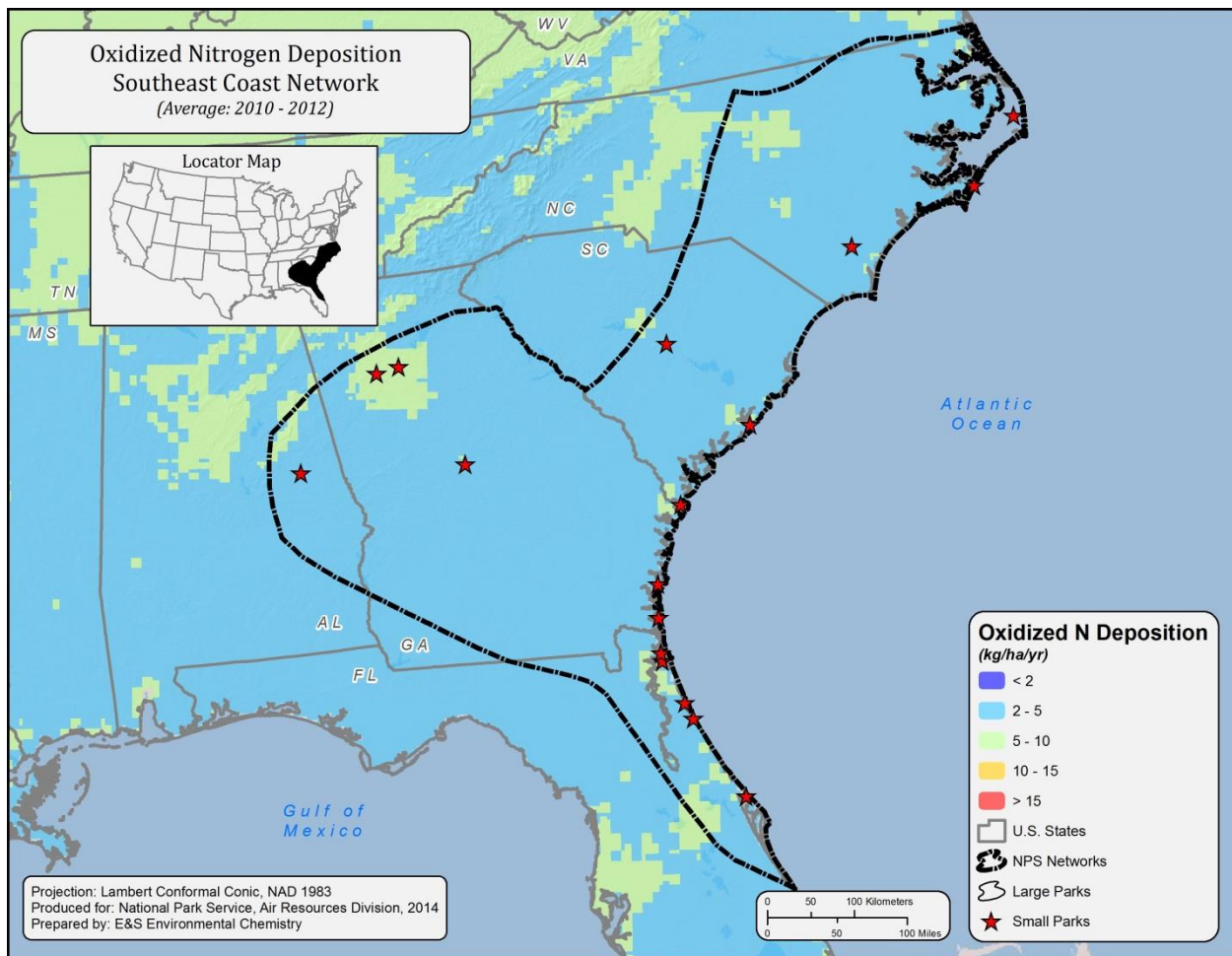
Park Code	Park Name	Parameter	2001 Average (kg/ha/yr)	2011 Average (kg/ha/yr)	Absolute Change (kg/ha/yr)	Percent Change	2011 Minimum (kg/ha/yr)	2011 Maximum (kg/ha/yr)	2011 Range (kg/ha/yr)
CUIS	Cumberland Island	Total S	6.51	4.82	-1.68	-25.9%	4.82	4.88	0.07
		Total N	5.12	4.33	-0.79	-15.4%	4.31	5.68	1.37
		Oxidized N	3.82	2.96	-0.86	-22.6%	2.94	3.99	1.05
		Reduced N	1.30	1.37	0.08	5.9%	1.37	1.69	0.32
FOCA	Fort Caroline	Total S	9.71	6.08	-3.63	-37.4%	6.08	6.08	0.01
		Total N	10.75	3.81	-6.94	-64.5%	3.73	4.34	0.61
		Oxidized N	8.90	2.50	-6.40	-71.9%	2.41	3.03	0.62
		Reduced N	1.85	1.31	-0.53	-28.9%	1.31	1.31	0.01
FOFR	Fort Frederica	Total S	6.35	4.77	-1.58	-24.8%	4.77	4.77	0.00
		Total N	5.04	5.73	0.68	13.5%	5.73	5.73	0.00
		Oxidized N	3.64	4.13	0.48	13.2%	4.13	4.13	0.00
		Reduced N	1.40	1.60	0.20	14.4%	1.60	1.60	0.00
FOMA	Fort Matanzas	Total S	7.51	4.64	-2.87	-38.2%	4.64	4.64	0.00
		Total N	10.44	3.72	-6.72	-64.4%	3.72	3.72	0.00
		Oxidized N	8.78	2.49	-6.29	-71.7%	2.49	2.49	0.00
		Reduced N	1.66	1.23	-0.43	-25.7%	1.23	1.23	0.00
FOPU	Fort Pulaski	Total S	7.23	7.74	0.63	10.8%	6.28	8.20	1.91
		Total N	7.80	6.32	-1.35	-16.2%	6.09	6.42	0.33
		Oxidized N	6.12	4.34	-1.68	-26.3%	4.25	4.39	0.14
		Reduced N	1.68	1.98	0.33	21.1%	1.84	2.03	0.19
FOSU	Fort Sumter	Total S	8.57	7.18	-1.39	-16.2%	7.18	7.18	0.00
		Total N	7.13	7.22	0.09	1.3%	7.22	7.22	0.00
		Oxidized N	5.16	5.06	-0.10	-1.9%	5.06	5.06	0.00
		Reduced N	1.97	2.16	0.19	9.7%	2.16	2.16	0.00

Table 1 (continued). Average changes in S and N deposition between 2001 and 2011 across park grid cells at SECN parks. Deposition estimates were determined by the Total Deposition Project, TDEP, based on three-year averages centered on 2001 and 2011 for all ~4 km grid cells in each park. The minimum, maximum, and range of 2011 S and N deposition within each park are also shown.

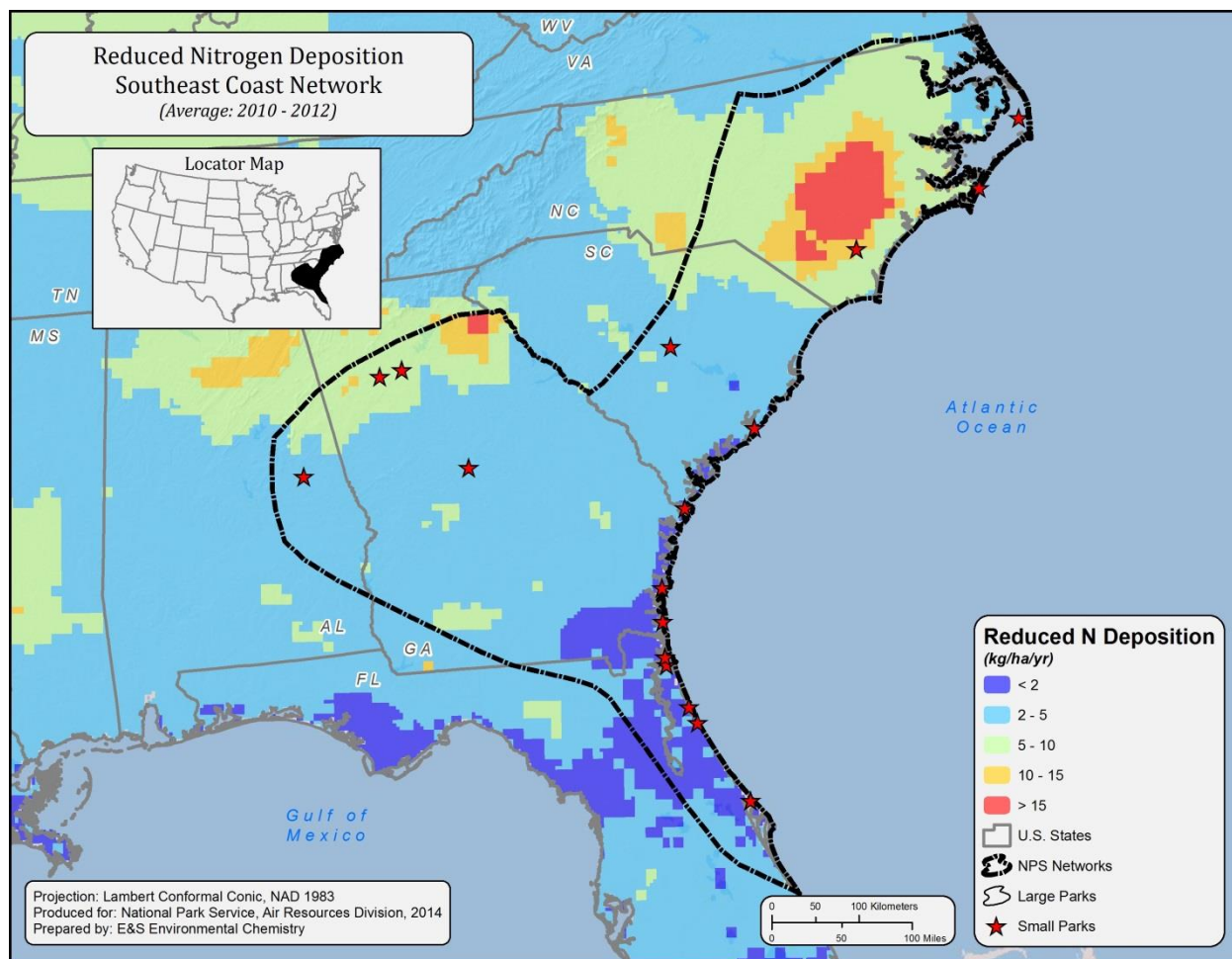
Park Code	Park Name	Parameter	2001 Average (kg/ha/yr)	2011 Average (kg/ha/yr)	Absolute Change (kg/ha/yr)	Percent Change	2011 Minimum (kg/ha/yr)	2011 Maximum (kg/ha/yr)	2011 Range (kg/ha/yr)
HOBE	Horseshoe Bend	Total S	10.91	6.82	-4.08	-37.4%	6.79	7.13	0.34
		Total N	11.20	7.31	-3.89	-34.7%	7.28	7.61	0.33
		Oxidized N	8.18	4.25	-3.92	-48.0%	4.24	4.39	0.15
		Reduced N	3.02	3.05	0.03	1.0%	3.04	3.22	0.18
KEMO	Kennesaw Mountain	Total S	12.10	9.40	-2.70	-22.3%	8.16	9.97	1.82
		Total N	15.48	12.59	-2.89	-18.7%	11.48	13.18	1.71
		Oxidized N	11.77	6.34	-5.43	-46.2%	5.56	6.62	1.05
		Reduced N	3.71	6.25	2.54	68.4%	5.90	6.63	0.73
MOCR	Moores Creek	Total S	10.50	5.81	-4.69	-44.7%	5.81	5.81	0.00
		Total N	14.33	16.45	2.12	14.8%	16.45	16.45	0.00
		Oxidized N	7.01	4.14	-2.87	-41.0%	4.14	4.14	0.00
		Reduced N	7.32	12.31	4.99	68.2%	12.31	12.31	0.00
OCMU	Ocmulgee	Total S	9.24	5.51	-3.80	-41.1%	5.30	5.98	0.68
		Total N	10.34	8.09	-2.21	-21.4%	7.61	8.22	0.61
		Oxidized N	7.55	4.87	-2.66	-35.2%	4.54	4.94	0.40
		Reduced N	2.79	3.22	0.45	16.1%	3.06	3.28	0.22
TIMU	Timucuan Ecological and Historical Preserve	Total S	8.41	5.77	-2.64	-30.2%	5.00	6.49	1.49
		Total N	8.21	4.69	-3.53	-40.0%	3.62	6.51	2.89
		Oxidized N	6.38	3.21	-3.18	-46.5%	2.36	4.62	2.26
		Reduced N	1.83	1.47	-0.35	-17.6%	1.26	1.89	0.63



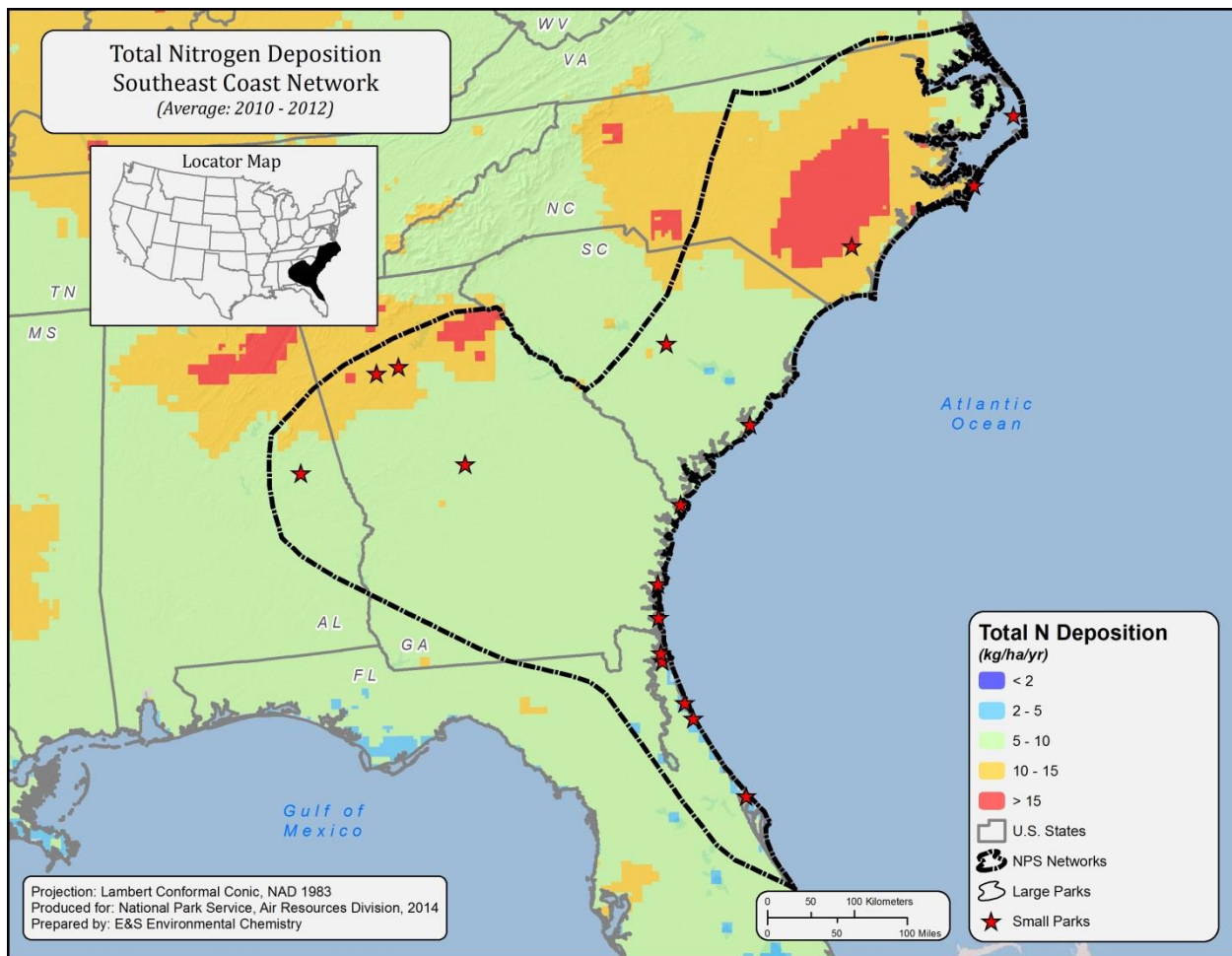
Map 5. Total S deposition for the three-year period centered on 2011 in and around the SECN. (Source: Schwede and Lear 2014)



Map 6. Total oxidized inorganic N deposition for the three-year period centered on 2011 in and around the SECN. (Source: Schwede and Lear 2014)



Map 7. Reduced inorganic N deposition for the three-year period centered on 2011 in and around the SECN. (Source: Schwede and Lear 2014)



Map 8. Total N deposition for the three-year period centered on 2011 in and around the SECN. (Source: Schwede and Lear 2014)

Table 2. Estimated I&M park rankings¹ according to risk of acidification impacts on sensitive receptors (Source: Sullivan et al. 2011a)

Park Name	Park Code	Estimated Acid Pollutant Exposure	Estimated Ecosystem Sensitivity to Acidification
Canaveral	CANA	High	Very Low
Cape Hatteras	CAHA	High	Very Low
Cape Lookout	CALO	High	Very Low
Castillo de San Marcos	CASA	High	Very Low
Chattahoochee River	CHAT	Very High	High
Congaree	COSW	High	Low
Cumberland Island	CUIS	High	Low
Fort Caroline	FOCA	High	Very Low
Fort Frederica	FOFR	High	Very Low
Fort Matanzas	FOMA	High	Very Low
Fort Pulaski	FOPU	High	Very Low
Fort Sumter	FOSU	High	Very Low
Horseshoe Bend	HOBE	High	Moderate
Kennesaw Mountain	KEMO	Very High	Moderate
Moore's Creek	MOCR	Very High	Very Low
Ocmulgee	OCMU	High	Very Low
Timucuan Ecological and Historical Preserve	TIMU	High	Low

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).

Nutrient Nitrogen Enrichment

The network rankings developed by Sullivan et al. (2011a) in a coarse screening study for nutrient N Pollutant Exposure, Ecosystem Sensitivity to nutrient N enrichment, and Park Protection yielded an overall network nutrient N enrichment Summary Risk ranking that was near the median among all networks. The overall level of concern for nutrient N enrichment effects on I&M parks within this network was judged by Sullivan et al. (2011a) to be Moderate, based on this screening assessment.

Twelve of the parks in the SECN were ranked in the second highest quintile in nutrient N Pollutant Exposure; three parks (CHAT, KEMO, and MOCR) were ranked in the highest quintile, and two (CUIS and FOPU) were ranked Moderate (Table 3). Thus, N pollutant exposures are generally high in SECN. Park rankings for Ecosystem Sensitivity to nutrient N enrichment were highly variable across the network; there were at least two parks in each quintile. FOPU and COSW were ranked in the highest quintile, CASA, FOSU, and KEMO were ranked in the lowest quintile, and seven parks were ranked in the second highest quintile. Although rankings provide an indication of risk, park-specific data, particularly regarding nutrient-enrichment sensitivity, are needed to fully evaluate risk from nutrient N addition.

Pardo et al. (2011b) compiled data on empirical critical loads (CL) for protecting sensitive resources in Level I ecoregions across the conterminous United States against nutrient enrichment effects caused by atmospheric N deposition. The lower end of the reported range was 3 to 5 kg N/ha/yr for protection of mycorrhizal fungi, lichens, and forest vegetation and 8 kg N/ha/yr for prevention of NO_3^- leaching in drainage water (Table 4). If current deposition is less than the CL for a given receptor, one would not expect harmful effects to occur. If current deposition exceeds the CL, the risk of harmful effects increases. Because of the NPS Organic Act mandate to preserve resources unimpaired for future generations, the appropriate CL would be the value at the lower end of the CL range, if a range is suspected. For example, available data suggest that a CL of 3 kg N/ha/yr would be most protective of forest health at CHAT. Ambient N deposition reported by Pardo et al. (2011b) was higher than the estimated empirical CL values at most parks in the network. This suggests the likelihood of CL exceedance for protection against nutrient enrichment effects at most parks in this network.

Table 3. Estimated park rankings¹ according to risk of nutrient enrichment impacts on sensitive receptors (Source: Sullivan et al. 2011b)

Park Name	Park Code	Estimated Nutrient N Pollutant Exposure	Estimated Ecosystem Sensitivity to Nutrient N Enrichment
Canaveral	CANA	High	Moderate
Cape Hatteras	CAHA	High	High
Cape Lookout	CALO	High	High
Castillo de San Marcos	CASA	High	Very Low
Chattahoochee River	CHAT	Very High	Low
Congaree	COSW	High	Very High
Cumberland Island	CUIS	Moderate	High
Fort Caroline	FOCA	High	Moderate
Fort Frederica	FOFR	High	High
Fort Matanzas	FOMA	High	High
Fort Pulaski	FOPU	Moderate	Very High
Fort Sumter	FOSU	High	Very Low
Horseshoe Bend	HOBE	High	Low
Kennesaw Mountain	KEMO	Very High	Very Low
Moore's Creek	MOCR	Very High	Moderate
Ocmulgee	OCMU	High	High
Timucuan Ecological and Historical Preserve	TIMU	High	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).

Ellis et al. (2013) estimated the CL for nutrient-N deposition to protect the most sensitive ecosystem receptors in 45 national parks. They estimated the N CL for COSW in the range of 3-8 kg N/ha/yr for protection of hardwood forests and 4-8 kg N/ha/yr for protection of lichens. Changes to lichen communities may signal the beginning of other changes to the ecosystem that might affect structure and function (Pardo et al. 2011a).

Table 4. Empirical critical loads for nitrogen in the SECN region, by ecoregion and receptor from Pardo et al. (2011b). Ambient N deposition reported by Pardo et al. (2011b) is compared to the lowest critical load for a receptor to identify potential exceedance, indicated by graying. A critical load exceedance suggests that the receptor is at increased risk for harmful effects.

NPS Unit	Ecoregion	N Deposition (kg N/ha/yr)	Critical Load (kg N/ha/yr)				Nitrate Leaching
			Mycorrhizal Fungi	Lichen	Herbaceous Plant	Forest	
Cape Hatteras NS	Eastern Temperate Forests	5.5	5 - 12	4 - 8	17.5	3 - 8	8
Cape Lookout NS	Eastern Temperate Forests	5.9	5 - 12	4 - 8	17.5	3 - 8	8
Canaveral NS	Eastern Temperate Forests	9.6	5 - 12	4 - 8	17.5	3 - 8	8
Chattahoochee River NRA	Eastern Temperate Forests	16.9	5 - 12	4 - 8	17.5	3 - 8	8
Congaree NP	Eastern Temperate Forests	10.1	5 - 12	4 - 8	17.5	3 - 8	8
Cumberland Island NS	Eastern Temperate Forests	5.7	5 - 12	4 - 8	17.5	3 - 8	8
Fort Caroline NMem	Eastern Temperate Forests	11.1	5 - 12	4 - 8	17.5	3 - 8	8
Fort Frederica NM	Eastern Temperate Forests	4.9	5 - 12	4 - 8	17.5	3 - 8	8
Fort Matanzas NM	Eastern Temperate Forests	8.2	5 - 12	4 - 8	17.5	3 - 8	8
Fort Pulaski NM	Eastern Temperate Forests	9.0	5 - 12	4 - 8	17.5	3 - 8	8
Fort Sumter NM	Eastern Temperate Forests	5.1	5 - 12	4 - 8	17.5	3 - 8	8
Horseshoe Bend NMP	Eastern Temperate Forests	9.7	5 - 12	4 - 8	17.5	3 - 8	8
Kennesaw Mountain NBP	Eastern Temperate Forests	16.2	5 - 12	4 - 8	17.5	3 - 8	8
Moores Creek NB	Eastern Temperate Forests	11.4	5 - 12	4 - 8	17.5	3 - 8	8
Ocmulgee NM	Eastern Temperate Forests	9.8	5 - 12	4 - 8	17.5	3 - 8	8
Timucuan Ecological and Historical Pres	Eastern Temperate Forests	11.1	5 - 12	4 - 8	17.5	3 - 8	8

Ozone Injury to Vegetation

The O₃-sensitive plant species that are known or thought to occur within the I&M parks in the SECN are listed in Table 5. Those considered to be bioindicators are designated by an asterisk. Each park in this network contained at least two O₃-sensitive and/or bioindicator species. Four parks contained 20 or more.

The W126 and SUM06 O₃ exposure indices calculated by NPS staff are given in Table 6, along with Kohut's (2007) O₃ risk ranking. The two ranking systems differ. The NPS (2010) ranking system is a quick assessment of O₃ condition and simply ranks O₃ exposure levels according to injury thresholds from the literature (Heck and Cowling 1997), using a 5-year average of the W126 (a measure of cumulative O₃ exposure that preferentially weights higher concentrations) or the SUM06 (a measure of cumulative O₃ exposure that includes only hourly concentrations over 60 ppb) metrics over a 3-month period.

Kohut's approach constitutes a more rigorous assessment of potential risk to plants. It considers both O₃ exposure and environmental conditions (soil moisture). Kohut also used injury thresholds from the literature, but evaluated a different O₃ metric (after Lefohn et al. 1997), the W126 over a 5-month period in conjunction with the N100 (number of hours over 100 ppb O₃). The rationale for the N100 statistic is that higher O₃ concentrations are most likely to cause plant injury. Kohut examined five individual years of O₃ exposure and soil moisture data and considered the effects of low soil moisture on O₃ uptake each year when assigning risk. Soil moisture is important because dry conditions induce stomatal closure in plants, which has the effect of limiting O₃ uptake and injury. In areas where low soil moisture levels correspond with high O₃ exposure, uptake and injury are limited by stomatal closure even when exposures are relatively high. Ozone condition, as rated by NPS, ranges from Low to High in SECN parks. Kohut's evaluation of risk to plants also ranges from Low to High, but more parks are rated Low because periods of higher O₃ exposure were generally associated with lower soil moisture during the time of the assessment (1995-1999), and the parks had few hours when O₃ concentrations exceeded 100 ppb. The results of both ranking systems should be considered when evaluating the potential for O₃ injury to park vegetation. The Kohut approach considered environmental conditions that affect plant response to O₃, but O₃ exposures have likely changed since the time of the assessment (1995-1999). The NPS approach considers more recent O₃ conditions (2005-2009), but not the modifying environmental conditions.

Atmospheric O₃ concentrations at 568 monitoring sites nationwide showed generally stable levels throughout the 1990s, but O₃ declined between 2002 and 2010, due largely to NO_x emissions reductions (<http://www.epa.gov/airtrends/ozone.html>; U.S. EPA 2008). Even though there have been widespread improvements in atmospheric O₃ levels, however, there were still 51 sites classified as nonattainment areas in 2007 because of failure to meet the O₃ NAAQ standard (U.S. EPA 2008). The highest O₃ concentrations in the United States in 2007 were located in Georgia and five other states (U.S. EPA 2008). There were 18 sites that showed O₃ levels that 1) were above the new O₃ standard (fourth highest daily maximum 8-hour concentration equal to 0.075 ppm) in 2007, and 2) showed an

Table 5. Ozone-sensitive and bioindicator plant species known or thought to occur in the I&M parks of the SECN. (Data Source: E. Porter, National Park Service, pers. comm., August 30, 2012; lists are periodically updated at <https://irma.nps.gov/NPSpecies/Report>.)

Species	Common Name	Park																
		CAHA	CALO	CANA	CASA	CHAT	COSW	CUIS	FOCA	FOFR	FOMA	FOPU	FOSU	HOBE	KEMO	MOCR	OCMU	TIMU
<i>Ailanthus altissima</i> *	Tree-of-heaven		x			x		x							x		x	
<i>Apios americana</i> *	Groundnut	x	x	x		x	x							x				
<i>Apocynum cannabinum</i>	Dogbane, Indian hemp	x	x			x	x								x			
<i>Artemisia ludoviciana</i> *	Silver wormwood	x																
<i>Asclepias incarnata</i>	Swamp milkweed	x																
<i>Asclepias syriaca</i> *	Common milkweed	x													x			
<i>Cercis canadensis</i> *	Redbud	x				x	x	x	x	x				x	x		x	x
<i>Clematis virginiana</i>	Virgin's bower	x				x	x		x					x	x		x	x
<i>Corylus americana</i> *	American hazelnut					x									x			
<i>Eupatorium rugosum</i> *	White snakeroot							x						x	x			
<i>Fraxinus americana</i> *	White ash					x	x		x						x			x
<i>Fraxinus pennsylvanica</i>	Green ash					x	x							x	x		x	
<i>Gaylussacia baccata</i> *	Black huckleberry	x																
<i>Liquidambar styraciflua</i>	Sweetgum	x		x	x	x	x	x	x	x		x		x	x	x	x	x
<i>Liriodendron tulipifera</i> *	Yellow-poplar	x				x	x							x	x	x	x	
<i>Lyonia ligustrina</i> *	Maleberry	x				x	x		x							x		x
<i>Parthenocissus quinquefolia</i>	Virginia creeper	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Pinus rigida</i>	Pitch pine														x			
<i>Pinus taeda</i>	Loblolly pine	x	x			x	x	x	x	x			x	x	x	x	x	x
<i>Pinus virginiana</i>	Virginia pine					x									x			
<i>Platanus occidentalis</i> *	American sycamore	x				x	x	x	x	x		x		x	x	x	x	x
<i>Prunus serotina</i> *	Black cherry	x	x			x	x	x	x	x		x	x	x	x		x	x
<i>Rhus copallina</i>	Winged sumac	x	x	x			x	x	x					x	x		x	x
<i>Robinia pseudoacacia</i>	Black locust	x	x			x				x					x			
<i>Rubus allegheniensis</i> *	Allegheny blackberry		x															
<i>Rubus canadensis</i> *	Thornless blackberry						x										x	
<i>Rubus cuneifolius</i>	Sand blackberry	x					x	x	x							x		x
<i>Rudbeckia laciniata</i> *	Cutleaf coneflower					x								x	x			
<i>Sambucus canadensis</i> *	American elder	x		x		x	x	x	x			x		x	x	x	x	x
<i>Sapium sebiferum</i> *	Chinese tallowtree				x													

* Bioindicator species

Table 5 (continued). Ozone-sensitive and bioindicator plant species known or thought to occur in the I&M parks of the SECN. (Data Source: E. Porter, National Park Service, pers. comm., August 30, 2012; lists are periodically updated at <https://irma.nps.gov/NPSpecies/Report>.)

Species	Common Name	Park																
		CAHA	CALO	CANA	CASA	CHAT	COSW	CUIS	FOCA	FOFR	FOMA	FOPU	FOSU	HOBE	KEMO	MOCR	OCMU	TIMU
<i>Sassafras albidum</i>	Sassafras	x	x			x	x	x		x		x		x	x	x	x	
<i>Solidago altissima</i>	Goldenrod	x					x								x	x		
<i>Spartina alterniflora</i>	Smooth cordgrass	x	x	x				x	x	x	x	x	x					x
<i>Triadica sebifera</i> *	Chinese tallowtree								x	x		x						x
<i>Verbesina occidentalis</i> *	Crownbeard	x				x	x	x		x				x			x	
<i>Vitis labrusca</i> *	Northern fox grape	x	x			x									x			

* Bioindicator species

Table 6. Ozone assessment results for I&M parks in the SECN based on estimated average 3-month W126 and SUM06 ozone exposure indices for the period 2005-2009 and Kohut's (2007) ozone risk ranking for the period 1995-1999¹.

Park Name	Park Code	W126		Sum06		Kohut O ₃ Risk Ranking
		Value (ppm-hr)	Ranking	Value (ppm-hr)	Ranking	
Canaveral	CANA	8.24	Moderate	9.62	Moderate	Low
Cape Hatteras	CAHA	11.29	Moderate	14.65	Moderate	Moderate
Cape Lookout	CALO	9.96	Moderate	12.53	Moderate	Moderate
Castillo de San Marcos	CASA	8.70	Moderate	10.41	Moderate	Low
Chattahoochee River	CHAT	16.69	High	22.49	High	High
Congaree	COSW	11.62	Moderate	16.23	High	Low
Cumberland Island	CUIS	7.45	Moderate	8.81	Moderate	Low
Fort Caroline	FOCA	8.86	Moderate	10.77	Moderate	Low
Fort Frederica	FOFR	6.66	Low	7.83	Low	Low
Fort Matanzas	FOMA	8.35	Moderate	9.79	Moderate	Low
Fort Pulaski	FOPU	7.30	Moderate	9.27	Moderate	Low
Fort Sumter	FOSU	8.65	Moderate	11.28	Moderate	Low
Horseshoe Bend	HOBE	12.15	Moderate	16.37	High	Moderate
Kennesaw Mountain	KEMO	16.57	High	22.36	High	High
Moore's Creek	MOCR	10.98	Moderate	14.45	Moderate	Moderate
Ocmulgee	OCMU	14.81	High	20.22	High	High
Timucuan Ecological and Historical Preserve	TIMU	8.68	Moderate	10.53	Moderate	Low

¹ Parks are classified into one of three ranks (Low, Moderate, High), based on comparison with other I&M parks.

increase of more than 0.005 ppm. Two of these sites were located in or near Jacksonville, FL and Columbus, GA, within the SECN region.

Visibility Degradation

Natural Background and Ambient Visibility Conditions

The Clean Air Amendments (CAA) set a specific goal for visibility protection in Class I areas: “the prevention of any future, and the remedying of any existing, impairment of visibility¹ in mandatory Class I federal areas which impairment results from manmade air pollution” (42 U.S.C. 7491).

Although SECN does not contain any Class I parks, emissions controls targeting improvements in air quality throughout Class I areas in the wider southeastern United States region (i.e., Everglades, Great Smoky Mountains, Mammoth Cave, and Virgin Islands national parks) would be expected to also benefit parks in the SECN. In 1999, EPA passed the Regional Haze Rule (RHR), which requires each state to develop a plan to improve visibility in Class I areas, with the goal of returning visibility to natural conditions in 2064. Natural background visibility, or natural haze, assumes no human-caused pollution, but varies with natural processes such as windblown dust, fire, volcanic activity and biogenic emissions. Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Network and typically reported using the haze index deciview² (dv).

There were no IMPROVE sites located within any of the I&M parks within the SECN. However, data are available that are considered to be representative of visibility conditions in five of the parks in this network. A monitoring site is considered by IMPROVE to be representative of an area if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area. Natural background and ambient visibility conditions have been estimated by IMPROVE for these parks for the 20% clearest visibility days, the 20% haziest visibility days, and average days (Table 7).

The parks in the SECN had relatively high natural haze in comparison with other I&M parks for the 20% clearest natural haze conditions (5.4-5.9 dv), 20% haziest natural haze conditions (11.4-12.1 dv), and for the average of all natural haze conditions (8.1-8.6 dv; Table 7). Even in the absence of anthropogenic air pollution, the parks in the SECN would be hazy at times because of biogenic and other natural emissions, and in some parks, sea salt.

Current visibility estimates from representative monitors reflect current pollution levels and were used to rank conditions at parks (within 100 km) in order to provide park managers with information on spatial differences in visibility and air pollution. Rankings for parks across the United States range from very low haze (very good visibility) to very high haze (very poor visibility). Only parks with

¹ Visibility impairment means any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions.

² The *deciview* visibility metric expresses uniform changes in haziness in terms of common increments across the entire range of visibility conditions, from pristine to extremely hazy conditions. Because each unit change in deciview represents a common change in perception, the deciview scale is like the decibel scale for sound. A one deciview change in haziness is a small but noticeable change in haziness under most circumstances when viewing scenes in Class I areas.

Table 7. Estimated natural haze and measured ambient haze in I&M parks averaged over the period 2004 through 2008¹ in national parks in the SECN. Representative monitors are located at Okefenokee or Cape Romain National Wildlife Refuges.

Park Name	Park Code	Site ID	Estimated Natural Haze (dv)		
			20% Clearest Days	20% Haziest Days	Average Days
Canaveral	CANA	No Site			
Cape Hatteras	CAHA	No Site			
Cape Lookout	CALO	No Site			
Castillo de San Marcos	CASA	No Site			
Chattahoochee River	CHAT	No Site			
Congaree	COSW	No Site			
Cumberland Island ²	CUIS	OKEF1	5.42	11.44	8.07
Fort Caroline ²	FOCA	OKEF1	5.42	11.44	8.07
Fort Frederica ²	FOFR	OKEF1	5.42	11.44	8.07
Fort Matanzas	FOMA	No Site			
Fort Pulaski	FOPU	No Site			
Fort Sumter	FOSU	ROMA1	5.93	12.12	8.63
Horseshoe Bend	HOBE	No Site			
Kennesaw Mountain	KEMO	No Site			
Moores Creek	MOCR	No Site			
Ocmulgee	OCMU	No Site			
Timucuan Ecological and Historical Preserve ²	TIMU	OKEF1	5.42	11.44	8.07

Park Name	Park Code	Site ID	Measured Ambient Haze (For Years 2004 through 2008)					
			20% Clearest Days		20% Haziest Days		Average Days	
			dv	Ranking	dv	Ranking	dv	Ranking
Canaveral	CANA	No Site						
Cape Hatteras	CAHA	No Site						
Cape Lookout	CALO	No Site						
Castillo de San Marcos	CASA	No Site						
Chattahoochee River	CHAT	No Site						
Congaree	COSW	No Site						
Cumberland Island ²	CUIS	OKEF1	14.90	Very High	26.88	Very High	20.17	Very High
Fort Caroline ²	FOCA	OKEF1	14.90	Very High	26.88	Very High	20.17	Very High
Fort Frederica ²	FOFR	OKEF1	14.90	Very High	26.88	Very High	20.17	Very High
Fort Matanzas	FOMA	No Site						
Fort Pulaski	FOPU	No Site						
Fort Sumter ²	FOSU	ROMA1	15.29	Very High	27.40	Very High	20.98	Very High
Horseshoe Bend	HOBE	No Site						
Kennesaw Mountain	KEMO	No Site						
Moores Creek	MOCR	No Site						
Ocmulgee	OCMU	No Site						
Timucuan Ecological and Historical Preserve ²	TIMU	OKEF1	14.90	Very High	26.88	Very High	20.17	Very High

¹ Parks are classified into one of five haze ranks (Very Low, Low, Moderate, High, or Very High haze).

² Data are borrowed from a nearby IMPROVE site. A monitoring site is considered by IMPROVE to be representative of an area if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area.

representative monitoring data were used in generating the baseline visibility ranking. Table 7 gives the relative ambient park haze rankings on the 20% clearest, 20% haziest, and average days. Measured ambient haze for the period 2004 through 2008 was considerably (about 9 to 15 dv) higher than the estimated natural condition. Measured ambient haze in all parks in this network was ranked Very High for the 20% clearest, 20% haziest, and average days.

The IMPROVE data from Okefenokee National Wildlife Refuge (NWR; representative of CUIS, FOCA, FOFR, and TIMU) showed that pollution had reduced average visual range (VR) from 100 miles to 25 miles (161 km to 40 km). On the haziest days, VR has been reduced from 75 to 15 miles (121 km to 24 km). Severe haze episodes occasionally reduce visibility in these parks to 5 miles (8 km). At Cape Romain NWR (representative of FOSU) pollution has reduced average VR from 100 miles to 30 miles (161 km to 48 km). On the haziest days, VR has been reduced from 70 to 15 miles (113 km to 24 km). Severe haze episodes occasionally reduce visibility in FOSU (as represented by Cape Romain NWR) to 6 miles (10 km).

Composition of Haze

Various pollutants make up the haze that causes visibility degradation. IMPROVE measures these pollutants and reports them as ammonium sulfate, ammonium nitrate, elemental carbon, coarse mass, organic mass, sea salt, and soil. Sulfates form in the atmosphere from SO₂ emissions from coal-burning power plants, smelters, and other industrial facilities. Nitrates form in the atmosphere from NO_x emissions from combustion sources including vehicles, power plants, industry, and fires. Organic compounds are emitted from a variety of both natural (biogenic) and anthropogenic sources, including agriculture, industry, and fires. Atmospheric sea salt concentrations are higher in coastal areas. Soil can enter the atmosphere through both natural processes and human disturbance.

Figure 1 shows estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze and its composition for parks with representative monitoring data in the SECN. The figure illustrates that over 50% of the total particulate light extinction (b_{ext}) in all of the monitored parks is attributable to SO₄²⁻ for the 20% clearest days, 20% haziest days, and annual average days. Organics contribute about 14% to the haze in FOSU for all groups (20% clearest, average, and 20% haziest days); in CUIS, FOCA, FOFR, and TIMU, the contribution of organics ranges from 16.5% to 22.6%. Nitrates, carbon, coarse mass and sea salt also contribute to the haze in these parks.

Trends in Visibility

Representative monitoring data for the parks in the SECN are shown in Figure 2. There is little evidence of improvement in visibility over most of the period of record. However, haze has decreased markedly since about 2005 at the representative monitors, especially on the 20% haziest days.

Development of State Implementation Plans

According to the RHR, states and tribes must establish and meet reasonable progress goals for each federal Class I area to improve visibility on the 20% haziest days and to prevent visibility degradation on the 20% clearest days. The national goal is to return visibility in Class I areas to

natural background levels in 2064. States must evaluate progress by 2018 (and every 10 years thereafter) based on a baseline period of 2000 to 2004 (Air Resource Specialists 2007).

Progress to date in meeting the national visibility goal is illustrated in Figure 3 using a uniform rate of progress glideslope. On the 20% haziest days, ambient haze levels have decreased at all of the monitored parks sufficiently to fall below the calculated glideslopes required for RHR compliance during the three most recent years of monitoring data. On the clearest 20% of days, recent progress has been made at Okefenokee NWR (representing CUIS, FOCA, FOFR, and TIMU), but not at Cape Romain NWR (representing FOSU). Additional data will be needed to ensure continued compliance with requirements of the RHR.

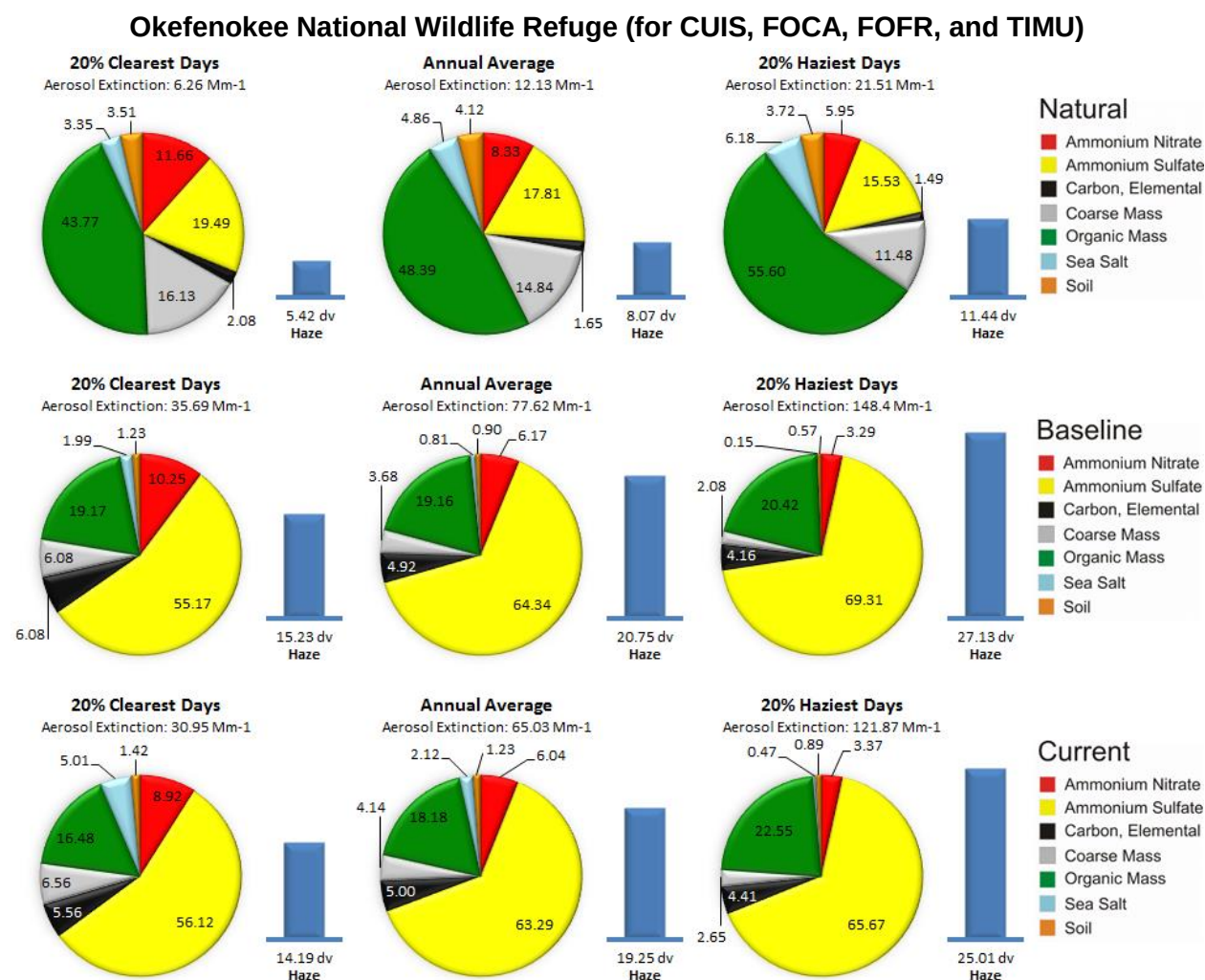


Figure 1a. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for CUIS, FOCA, FOFR, TIMU. Data for all of these parks were taken from nearby sites, including Okefenokee National Wildlife Refuge (NWR) for CUIS, FOCA, FOFR, and TIMU, and Cape Romain NWR for FOSU. Data Source: NPS-ARS

Cape Romain National Wildlife Refuge (for FOSU)

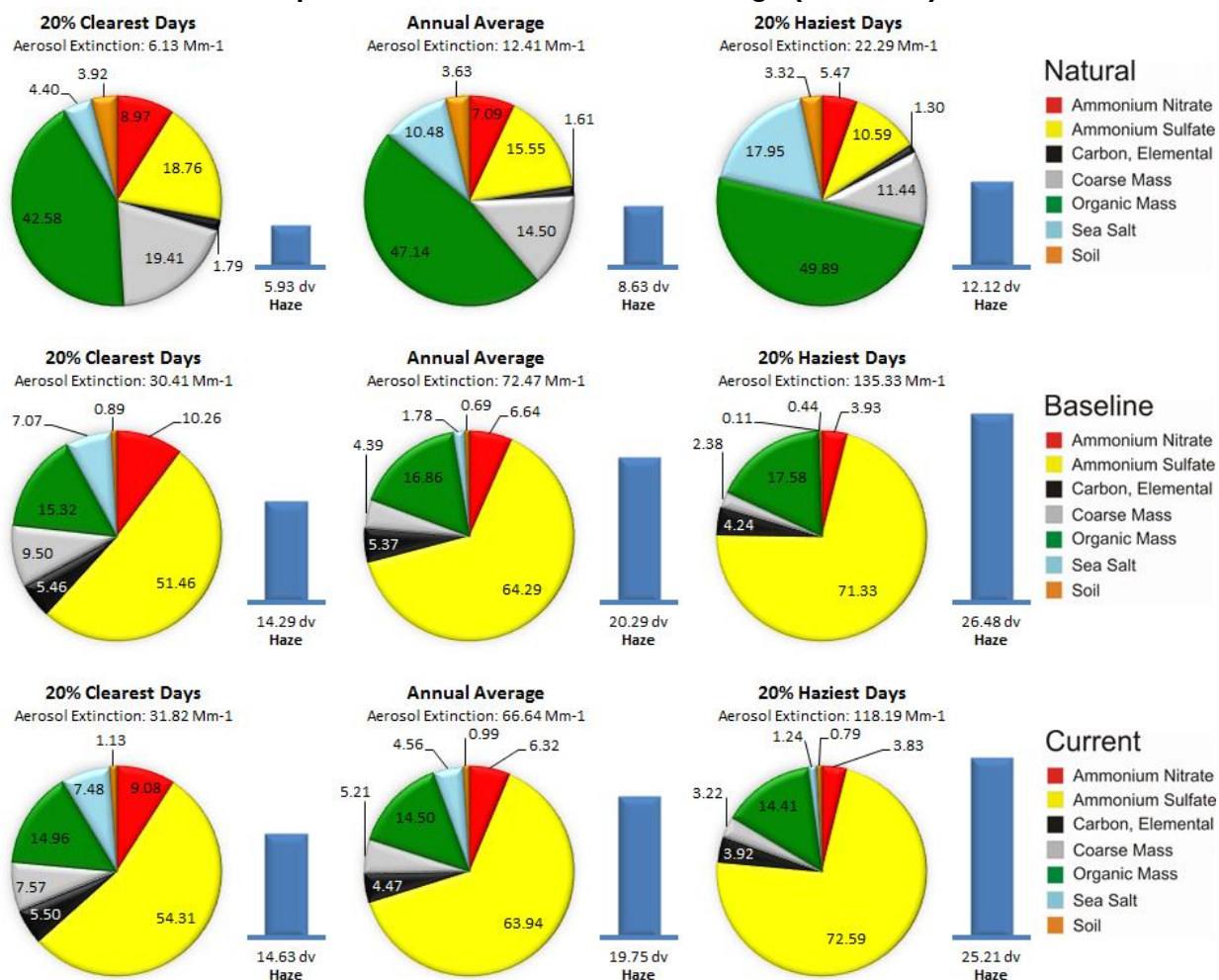


Figure 1b. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for FOSU. Data for all of these parks were taken from nearby sites, including Okefenokee National Wildlife Refuge (NWR) for CUIS, FOCA, FOFR, and TIMU, and Cape Romain NWR for FOSU. Data Source: NPS-ARS

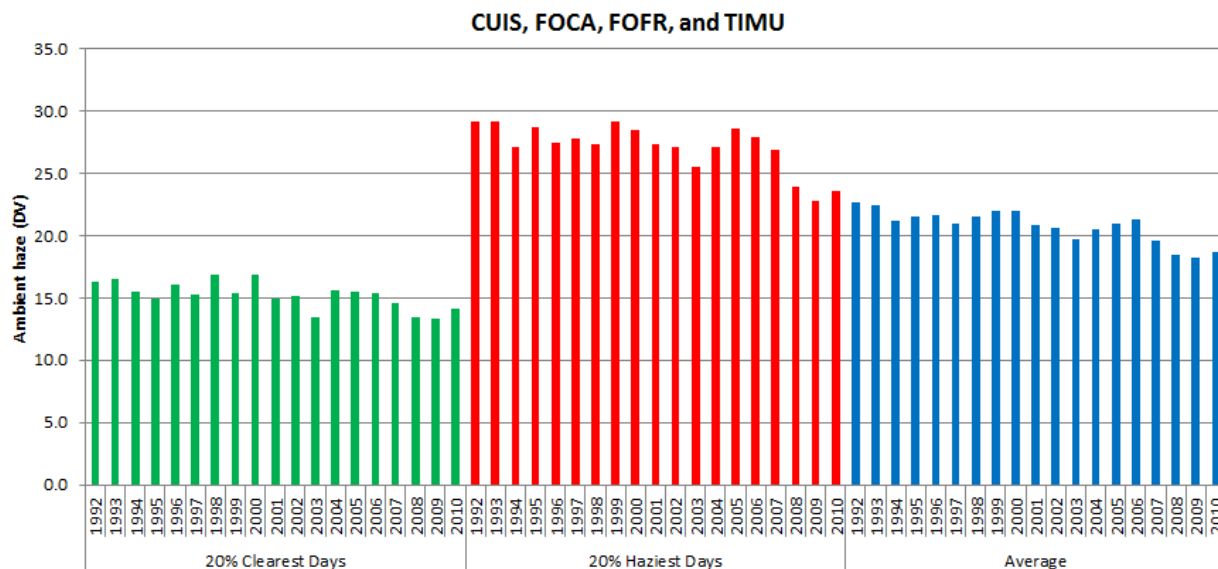


Figure 2. Trends in ambient haze levels at CUIS, FOCA, FOFR, TIMU, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for all of these parks were taken from nearby sites, including Okefenokee National Wildlife Refuge (NWR) for CUIS, FOCA, FOFR, and TIMU, and Cape Romain NWR for FOSU. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

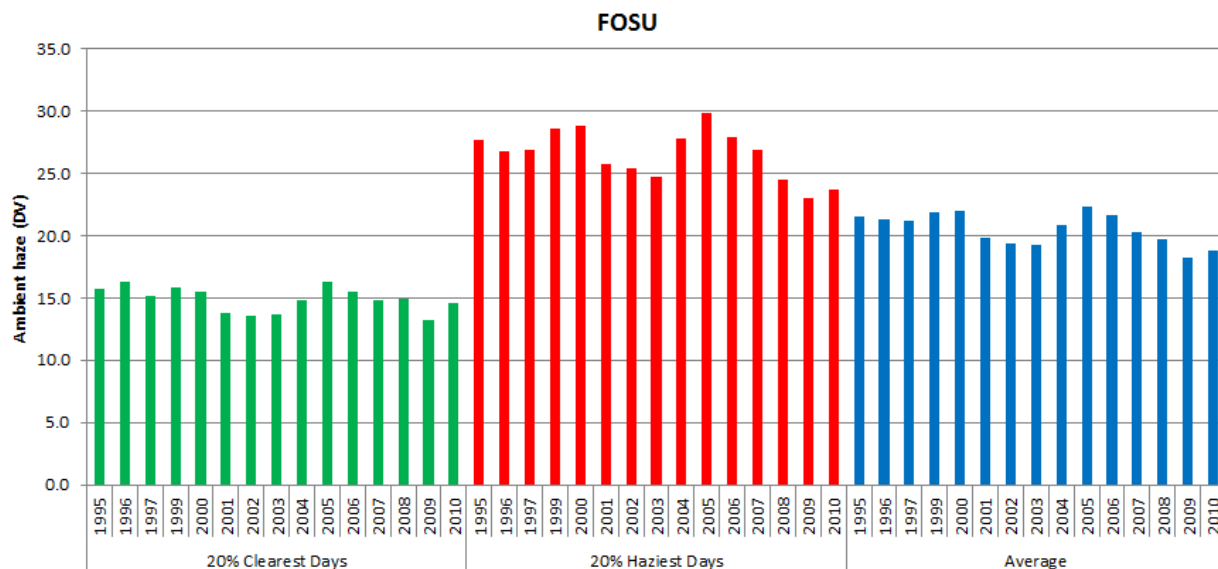


Figure 2. Trends in ambient haze levels at FOSU, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for all of these parks were taken from nearby sites, including Okefenokee National Wildlife Refuge (NWR) for CUIS, FOCA, FOFR, and TIMU, and Cape Romain NWR for FOSU. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

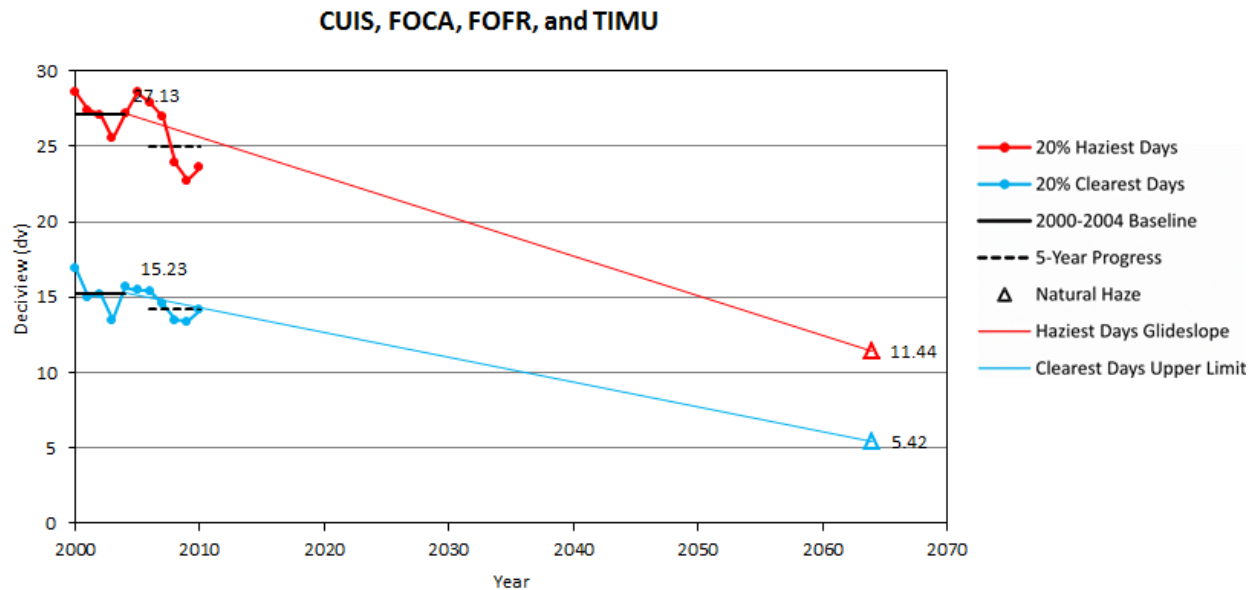


Figure 3a. Glideslopes to achieving natural visibility conditions in 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days in Okefenokee National Wildlife Refuge (NWR), representing CUIS, FOCA, FOFR, and TIMU. The regional haze rule does not require a uniform rate of progress glideslope on the clearest days; the rule only requires that the clearest days do not get any worse than the baseline period. Also shown are measured values during the period 2000 to 2010. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm



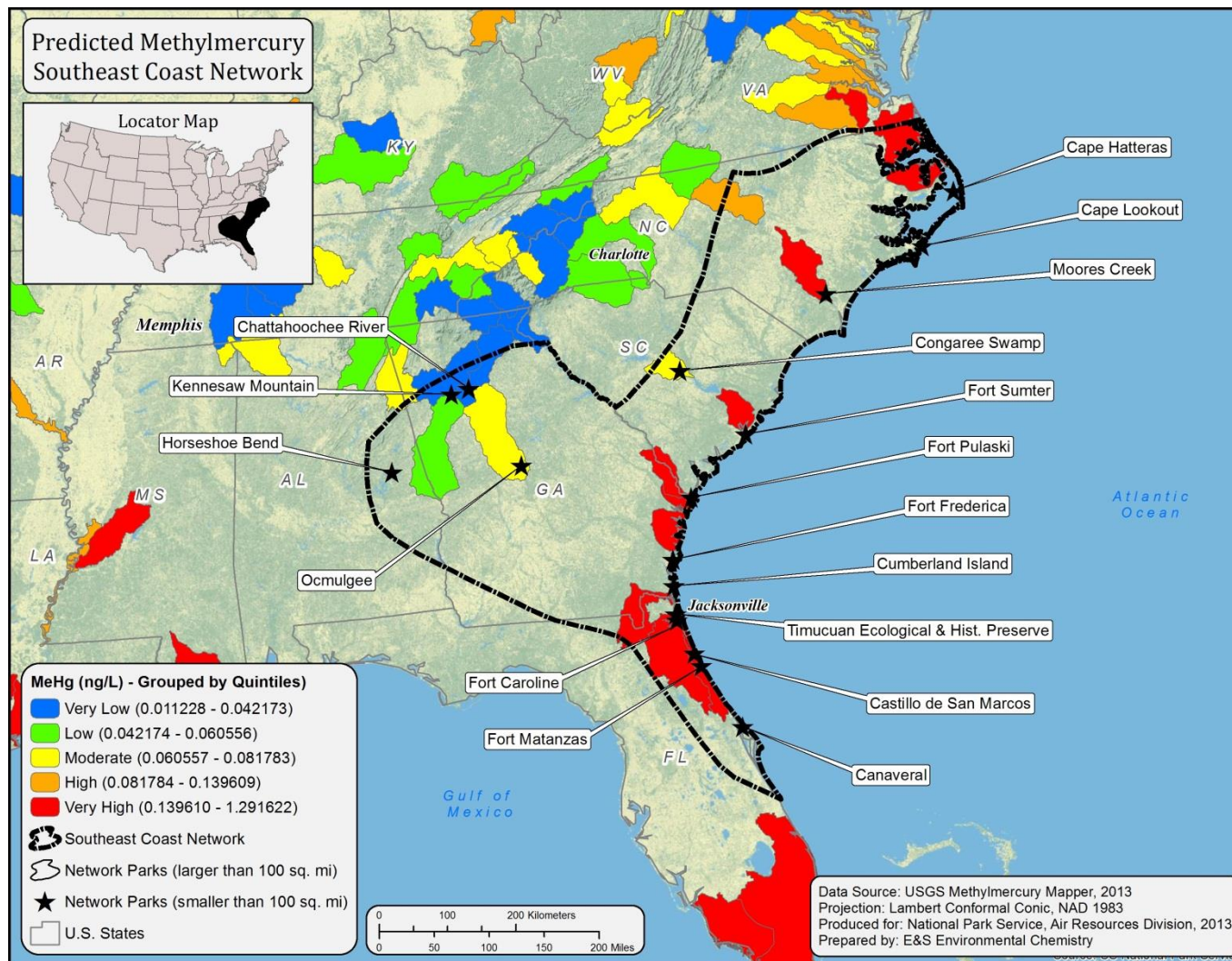
Figure 3b. Glideslopes to achieving natural visibility conditions in 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days in Okefenokee National Wildlife Refuge (NWR), representing Cape Romain NWR, representing FOSU. The regional haze rule does not require a uniform rate of progress glideslope on the clearest days; the rule only requires that the clearest days do not get any worse than the baseline period. Also shown are measured values during the period 2000 to 2010. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

Toxic Airborne Contaminants

Airborne toxics include a variety of compounds, such as pesticides, herbicides, and industrial by-products, and also heavy metals such as mercury (Hg). Mercury is emitted by power plants, incinerators, and other human-caused and natural sources and deposited by rain, snow, and dryfall into ecosystems, usually in an inorganic form. In ecosystems, Hg can be transformed biologically to a highly toxic organic form, methylmercury (MeHg). Certain ecosystems are conducive to methylation of Hg, including wetlands and reservoirs, and high levels of organic carbon drive the methylation process. Myers et al. (2007) and USGS (Last modified February 20, 2015) proposed a national map showing the relative sensitivity of aquatic ecosystems to Hg methylation. Areas showing the highest estimated sensitivity were mainly confined to the East Coast, Gulf Coast, and Upper Midwest, with scattered small areas in other regions. The SECN is generally within the region of high sensitivity. Estimates of Hg methylation potential generated by USGS (Last modified February 20, 2015) for watershed boundaries (based on eight-digit hydrologic unit codes [HUCs]) containing national park lands in the SECN suggested high methylation potential at most parks considered in this analysis (Map 9). This result is likely driven mainly by relatively high concentrations of total organic carbon in the surface waters in this network.

Although these maps are useful for identifying areas potentially at most risk, on-site sampling of biota is generally recommended to assess the extent of Hg contamination in ecosystems. Research in COSW (predicted to have moderate MeHg levels) found that Hg concentrations in fish were somewhat elevated (0.2 microgram per gram [$\mu\text{g/g}$]), but below levels recommended to protect public health (0.3 $\mu\text{g/g}$). Much higher levels were found in the nearby Edisto River, where some fish contained approximately 2 $\mu\text{g/g}$ of Hg, an order of magnitude higher than at COSW. These results suggest that some combination of geochemical and hydrologic factors may limit Hg methylation in COSW as opposed to the Edisto River, reinforcing the general belief that site-specific conditions greatly influence methylation and uptake of Hg (Bradley et al. 2009).

Other airborne toxics include pesticides and industrial contaminants and by-products. Agricultural pesticides like chlorpyrifos, malathion, and atrazine can volatilize and be deposited through atmospheric processes into ecosystems, potentially harming birds, fish, and other wildlife in the SECN.



Map 9. Predicted MeHg concentrations in surface waters by HUCs that contain national parklands in the Southeast Coast Network. Estimates were generated by USGS (Last modified February 20, 2015). Rankings are based on quintile distributions across all I&M parks having estimates by USGS.

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