



Air Quality Related Values (AQRVs) for South Florida/Caribbean Network (SFCN) Parks

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

Natural Resource Report NPS/SFCN/NRR—2016/1194



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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Natural Resource Report NPS/SFCN/NRR—2016/1194

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April 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Sullivan, T. J. 2016. Air quality related values (AQRVs) for South Florida/Caribbean Network (SFCN) parks: Effects from ozone; visibility reducing particles; and atmospheric deposition of acids, nutrients and toxics. Natural Resource Report NPS/SFCN/NRR—2016/1194. National Park Service, Fort Collins, Colorado.

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Summary

This report describes the Air Quality Related Values (AQRVs) of the South Florida/Caribbean Network (SFCN). AQRVs are those resources sensitive to air quality and include streams, lakes, soils, vegetation, fish and wildlife, and visibility. The SFCN parks that are included in the NPS Inventory and Monitoring (I&M) Program and discussed in this report are Big Cypress National Preserve (BICY), Biscayne National Park (BISC), Buck Island Reef National Monument (BUIS), Dry Tortugas National Park (DRTO), Everglades National Park (EVER), Salt River Bay National Historical Park and Ecological Preserve (SARI), and Virgin Islands National Park (VIIS). EVER and VIIS are Class I air quality areas; the rest of the parks are Class II areas. There are almost no data available for SARI; EVER is relatively data-rich. Assessments are presented here for acidification, eutrophication, ozone (O_3) exposure, visibility impairment, and mercury (Hg) bioaccumulation. However, because most of the air quality and AQRV data have been collected in the two Class I areas, those parks will be the main focus of this report.

Sullivan et al. (2011a, 2011b) and Kohut (2007) conducted risk assessments for acidification, eutrophication, and O_3 for all of the SFCN parks; their results are described in this report. This report also describes air pollutant emissions and air quality, and their effects on AQRVs in the SFCN. 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).

Some parks in the SFCN, especially EVER, are heavily influenced by human activities. Much of the historical Everglades ecosystem has been lost or degraded as a consequence of human activities (McCormick et al. 2009). Atmospheric deposition is only part of that complicated story. Other parks (especially DRTO, VIIS, and BUIS) in the SFCN are relatively remote from major human-caused pollutant emissions sources. There are many population centers in the range of 50,000 to 500,000 people scattered along the south Florida coastline. Miami, Fort Lauderdale, Key West, and Naples are all within 50 miles of both EVER and BICY; Fort Meyers is within 50 miles of BICY. Emissions of S and N are high in some areas.

Total estimated S deposition within the network was relatively high in 2002, generally between 5 and 10 kg S/ha/yr. There were areas of lower and higher estimated S deposition in the Florida portion of the network, ranging from 2 to 5 kg S/ha/yr in the south to more than 30 kg S/ha/yr in the northwest. Total estimated N deposition in 2002 ranged from as low as 5 to 10 kg N/ha/yr to as high as 10 to 15 kg N/ha/yr across broad areas of the network. Both S and N deposition decreased substantially between 2001 and 2011 at most SFCN parks. Nevertheless, reduced N deposition actually increased at all parks, in all cases by more than 10%. These increases in reduced N deposition partly counteracted concurrent decreases in oxidized N (NO_x) deposition.

Atmospheric S and N can cause acidification of streams, lakes and soils. Most SFCN parks are relatively insensitive to acidification because of generally low relief, strong buffering capacity of some soils, and ample contact between drainage water and weatherable soils and geologic materials.

Nitrogen can cause undesirable nutrient enrichment of natural ecosystems, leading to changes in plant species distribution and diversity. The overall level of concern for nutrient N enrichment effects on I&M parks within this network was judged by Sullivan et al. (2011a) in a coarse screening assessment to be Very High. The predominant vegetation type found within three of the larger parks in the SFCN (BICY, BISC, and EVER) that is thought to be especially sensitive to eutrophication effects from nutrient N addition is wetland. This vegetation type is especially prevalent in BICY and EVER. Because of their substantial wetland coverage, BICY and EVER were ranked Very High in ecosystem sensitivity to nutrient N enrichment. Ambient levels of N deposition in these parks in some areas are comparable to those found to cause species shifts in wetlands elsewhere in the United States (Greaver et al. 2011). However, phosphorus (P) limitation is an important issue in South Florida wetlands, in part because many tropical wetland plants fix N through symbiotic relationships with bacteria. Thus, N addition may have limited impact on the nutrient status of wetlands in SFCN except where there are also elevated P inputs. Ecosystem sensitivity to nutrient N enrichment in the other parks in the SFCN was ranked much lower. Estuaries are also highly sensitive to N addition from both atmospheric and land-based sources. Seagrass communities are especially vulnerable. However, evaluation of effects on estuaries is beyond the scope of this assessment.

Ozone pollution can harm human health, reduce plant growth, and cause visible injury to foliage. In general, however, O₃ exposure from sources of NO_x and volatile organic compounds and risk to plant foliage are considered to be low in this network. Nevertheless, O₃ is also produced by lightning, which is very prevalent in south Florida. Furthermore, many of the plants that occur in south Florida do not occur at more northern locations and have not been evaluated for O₃ sensitivity.

Particulate pollution can cause haze, reducing visibility. Haze has been monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Network at EVER and VIIS. Visibility is impaired in those parks, and is likely impaired in some of the other SFCN parks that have not been monitored. Although some of the haze is natural (e.g., caused by sea salt and marine SO₄²⁻), a substantial portion is caused by anthropogenic emissions of air pollutants. The largest contributor to total particulate light extinction (b_{ext}) in EVER is SO₄²⁻, followed by organics. Atmospheric SO₄²⁻ in the SFCN parks is derived from both human-caused and natural (marine) sources. On the 20% haziest days at EVER, atmospheric SO₄²⁻ at this park contributed more than half of the light extinction. In VIIS, the majority of the light extinction was attributable to a combination of SO₄²⁻, sea salt and coarse mass. On the 20% haziest days in VIIS, SO₄²⁻ accounted for 24.1% of light extinction.

Airborne toxics, including Hg and other heavy metals, can accumulate in, and is evident at, all levels of the food web. These contaminants can reach toxic levels in mid-level and top predators. South Florida is considered to be a region of high Hg methylation potential. The issue has been well-studied in EVER. Atmospheric deposition accounts for an estimated 95% of all Hg inputs in EVER (Landing et al. 1995). South Florida, including the parks and preserve, has some of the highest wet deposition

levels of Hg in the United States (NADP 2008), because of a combination of high concentrations of Hg in precipitation, and high amounts of precipitation in the region.

High Hg and S deposition rates, coupled with elevated concentrations of dissolved organic carbon (DOC) and the high reducing capacity of soils in the EVER wetlands, support rapid transformation of Hg to the biologically available and significantly more toxic methylmercury form (MeHg; Chen et al. 2012), which contributes to high Hg bioaccumulation in many species, including fish, panthers, alligators, and wading birds. Mercury can biomagnify at higher trophic levels to concentrations that can potentially damage the nervous system of sensitive species of biota. This issue is of particular concern to people and wildlife that consume large quantities of Hg contaminated fish and shellfish. Body burdens of Hg in sunfish, largemouth bass, and bluegill in northern EVER exceeded the human and wildlife criteria levels established by U.S. EPA (Chen et al. 2012, U.S. EPA 2007). Exposure to MeHg above the levels that cause adverse effects have been estimated for great egret (*Ardea alba*), bald eagle (*Haliaeetus leucocephalus*), and wood stork (*Mycteria americana*) in the northern part of the park. There is also concern regarding how Hg exposure may impact the reproductive success of the endangered Florida panther (*Puma concolor coryi*; U.S. EPA 2007). To protect humans from adverse effects associated with Hg contamination, the state of Florida has issued fish consumption advisories that ban or limit consumption by humans of nine fish species over two million acres in EVER (U.S. EPA 2007). Mercury methylation in EVER is linked to S in wetland ecosystems, which is partly a legacy pollution issue caused by past use of agrochemicals.

The wading bird population in Florida has declined dramatically compared to its original size (Runde 1991). Habitat loss has been an important contributor to that decline. However, Hg contamination of their food supplies may also be an important factor (Sundlof et al. 1994). Toxicity to birds from MeHg exposure can be expressed as damage to nervous, excretory, immune, or reproductive systems (Wiener et al. 2003). Embryos and hatchlings are especially vulnerable (Heinz and Hoffman 2003).

Background

In the United States, the tropical and subtropical humid forest ecoregion occurs in southern Florida, Puerto Rico, and Hawaii. Biodiversity is very high in this ecoregion, which contains many species of epiphytes. Within the SFCN, Puerto Rico contains some very diverse humid subtropical forests in protected forest reserves and secondary forest growth on former agricultural land. The tropical humid forest zone of southern Florida is biologically one of the most diverse vegetation zones in the United States. Wetlands are widespread, both saltwater and freshwater, including mangrove swamps and tropical tree islands.

There are four parks in the SFCN that are larger than 100 square miles: Big Cypress National Preserve (BICY), Biscayne National Park (BISC), Dry Tortugas National Park (DRTO), and Everglades National Park (EVER). In addition, there are three smaller parks: Buck Island Reef National Monument (BUIS), Salt River Bay National Historical Park and Ecological Preserve (SARI), and Virgin Islands National Park (VIIS), of which BUIS and VIIS are considered here. Larger parks generally have more available data with which to evaluate air pollution sensitivities and effects. In addition, the larger parks generally contain more extensive resources in need of protection against the adverse impacts of air pollution.

There are many human population centers in the range of 50,000 to 500,000 people in the vicinity of the SFCN, scattered along the south Florida coastline, but BUIS, DRTO, and VIIS are more remote. Map 1 shows a map of the network boundaries along with locations of each park and the population centers having more than 10,000 people.

Atmospheric Emissions and Deposition

Annual county-level sulfur (S) emissions in 2002 generally ranged from less than 1 ton of sulfur dioxide (SO₂) per square mile per year (ton/mi²/yr) to 20 tons/mi²/yr in the SFCN. There were two areas in the network that had higher emissions, in particular in the northwest corner of the network where emissions were as high as 50 to 100 tons/mi²/yr (Sullivan et al. 2011b). Point source emissions of SO₂ were located in the Florida portion of the network and were mostly sources that emitted less than 5,000 tons of SO₂ per year. There were a few larger SO₂ point sources that emitted between 5,000 and 20,000 tons per year.

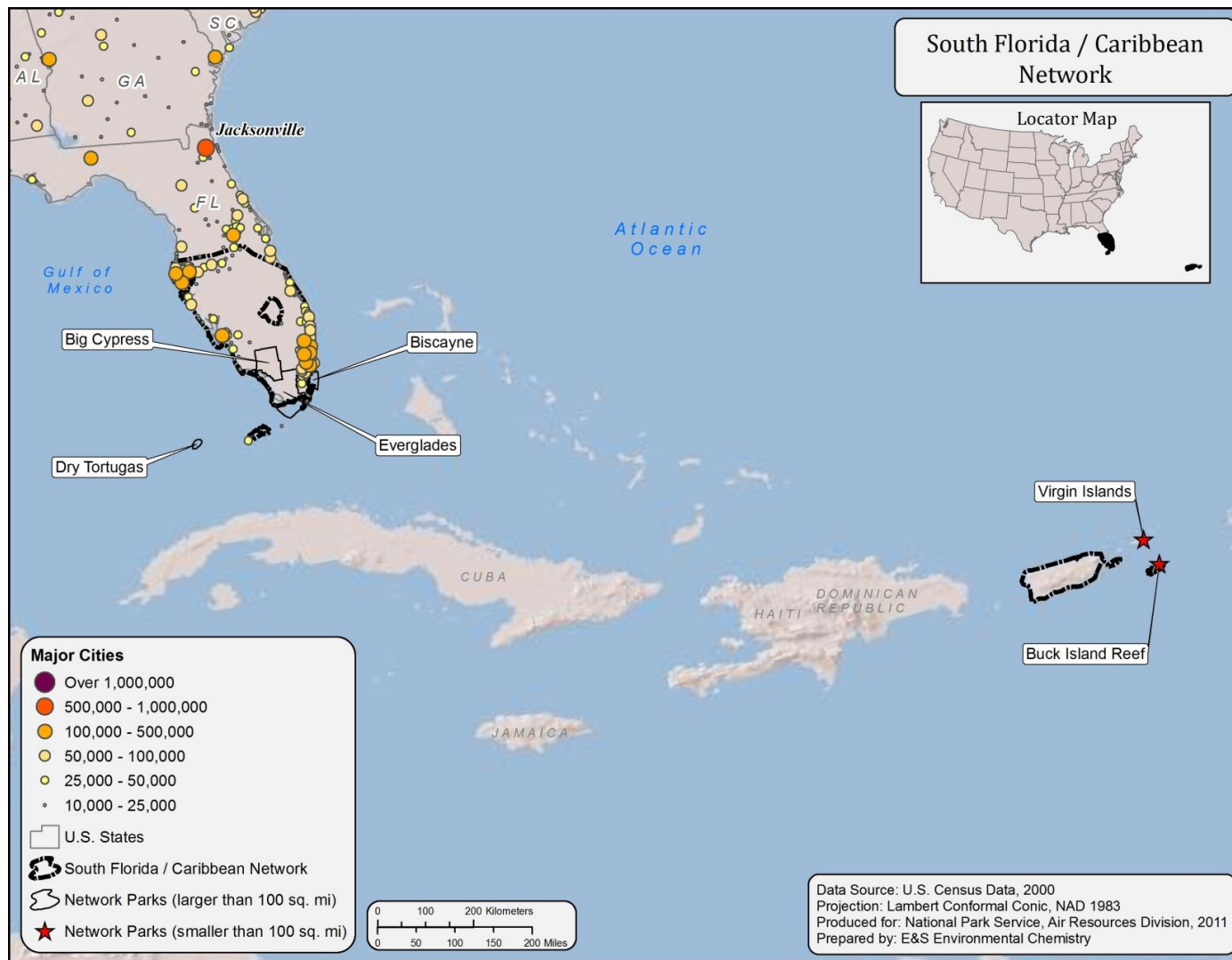
Annual county-level nitrogen (N) emissions in 2002 within the network generally ranged from less than 1 ton/mi²/yr to more than 20 tons/mi²/yr. In general, annual county N emissions were between 1 and 20 tons/mi²/yr throughout most of the network, with higher and lower values in a few areas. There were many relatively large (larger than 2,000 tons/yr) point sources of N scattered throughout the portion of the network in Florida. The largest point sources were sources of oxidized N, although there were also some moderate size sources of reduced N.

County-level emissions near SFCN, based on data from the EPA's National Emissions Inventory (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. The counties near the SFCN parks had relatively low SO₂

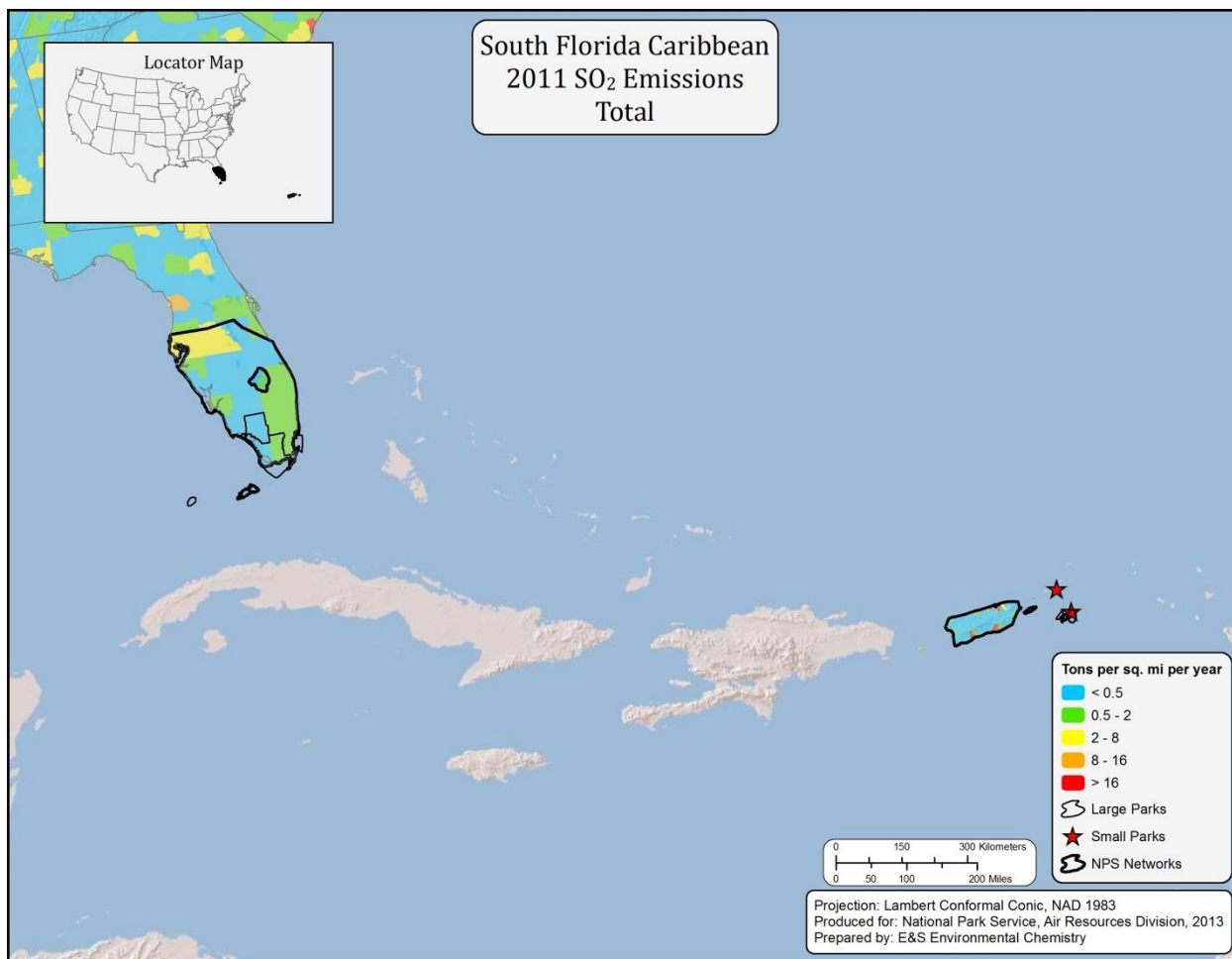
emissions (< 2 tons/mi²/yr; Map 2). Patterns in NO_x emissions were generally higher, with highest values in the range of 2 to 16 tons/mi²/yr (Map 3). Emissions of NH₃ near SFCN parks were somewhat lower, with most counties showing emissions levels below 2 tons/mi²/yr (Map 4).

Total estimated S deposition within the network was generally between 5 and 10 kg S/ha/yr in 2002 (Sullivan et al. 2011b). There were areas of lower and higher estimated S deposition in the Florida portion of the network, ranging from 2 to 5 kg S/ha/yr in the south to more than 30 kg S/ha/yr in the northwest. Total estimated N deposition in 2002 ranged from as low as 5 to 10 kg N/ha/yr to as high as 10 to 15 kg N/ha/yr across broad areas of the network. Smaller areas receiving both lower (2 to 5 kg/ha/yr) and higher (more than 15 kg/ha/yr) estimated atmospheric N deposition also occurred in limited portions of the network.

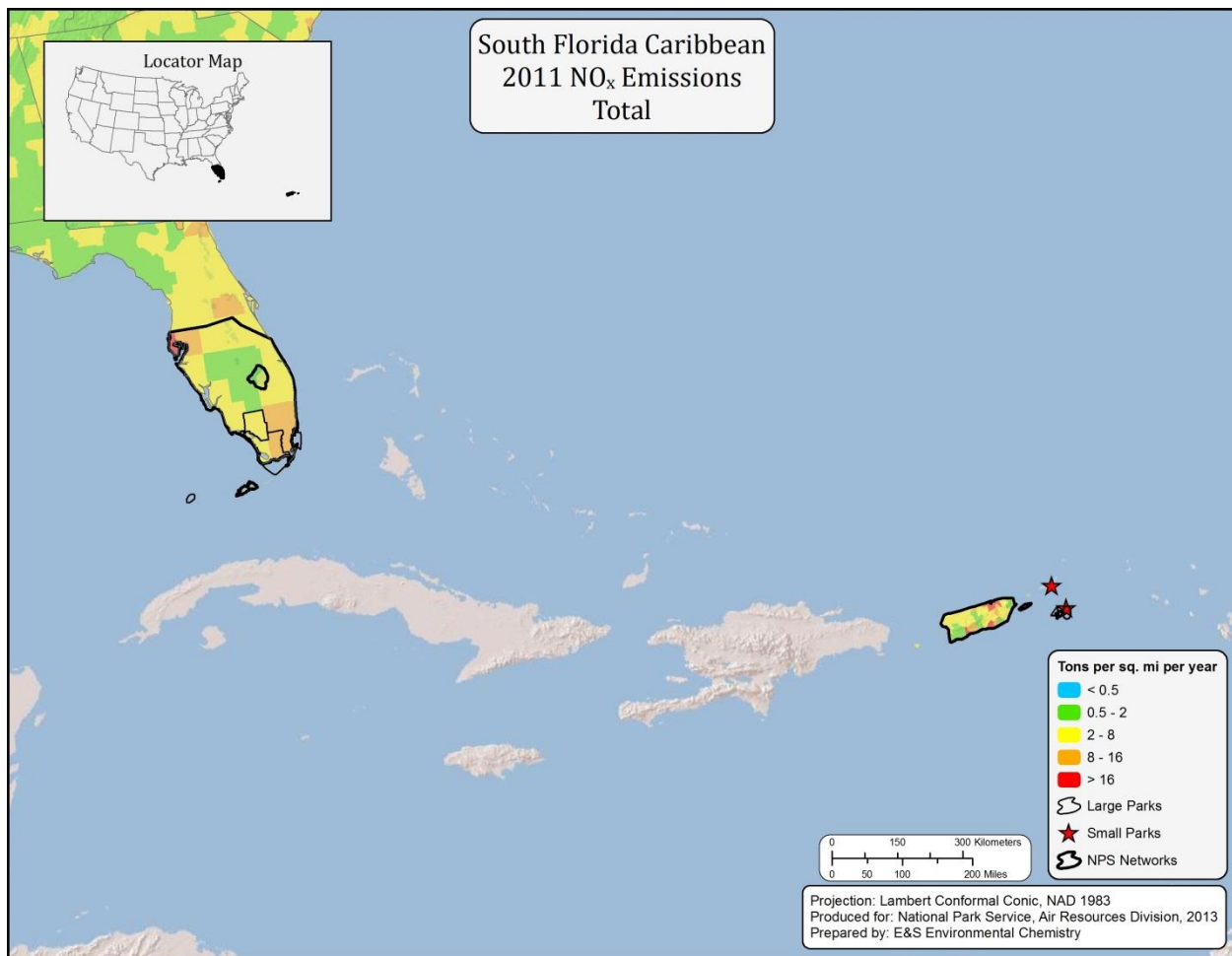
Recently, Schwede and Lear (2014) documented a hybrid approach developed by the National Atmospheric Deposition Program (NADP) Total Deposition (TDEP) Science Committee for estimating total N and S deposition. This approach combined monitoring and modeling data.



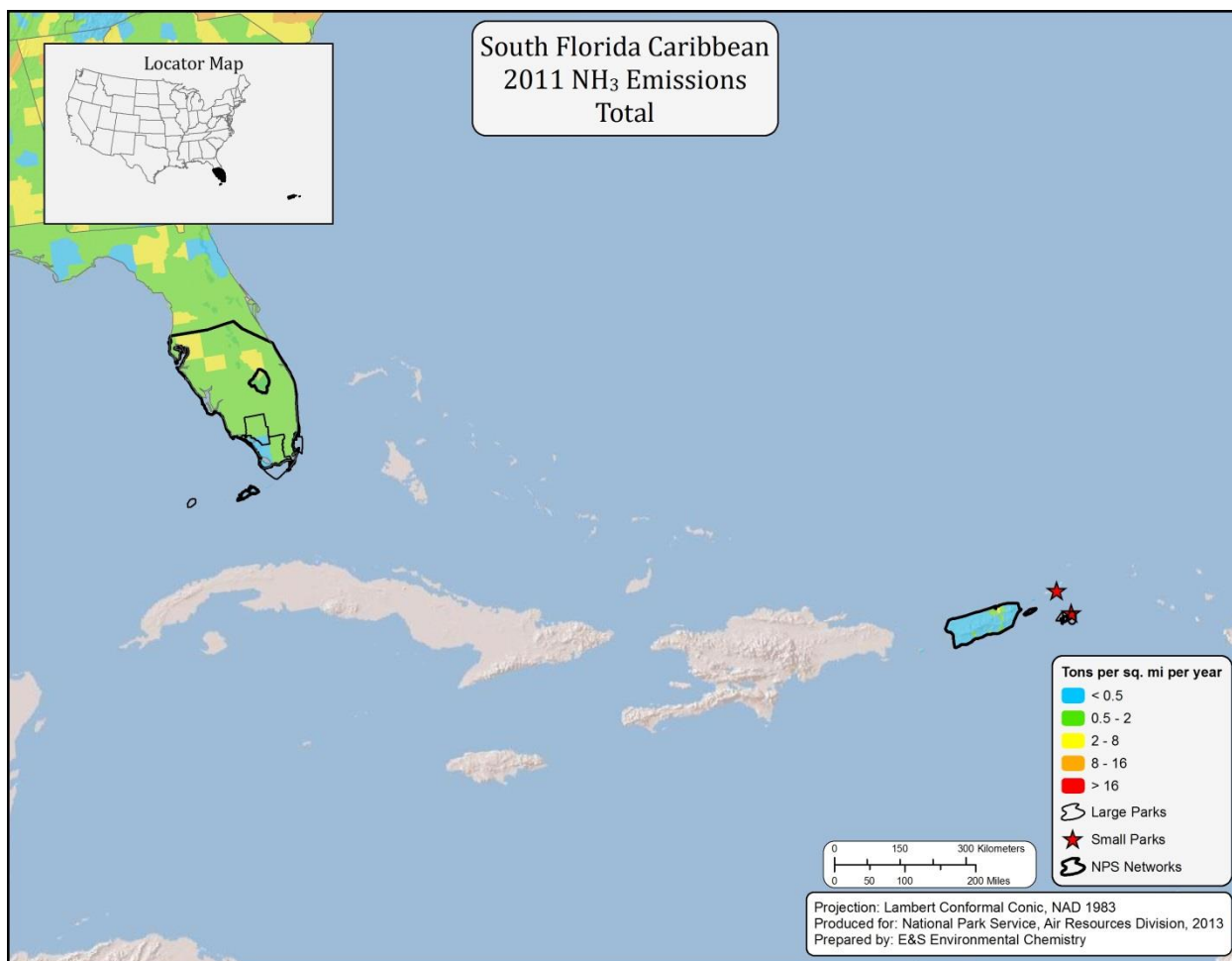
Map 1. Network boundary and locations of national parks and human population centers near the SFCN.



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



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



Map 4. Total NH_3 emissions, by county, near SFCN for the year 2011. Data from EPA's National Emissions Inventory.

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), N_2O_5 , NO, NO_2 , HONO, and organic NO_3 . 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.

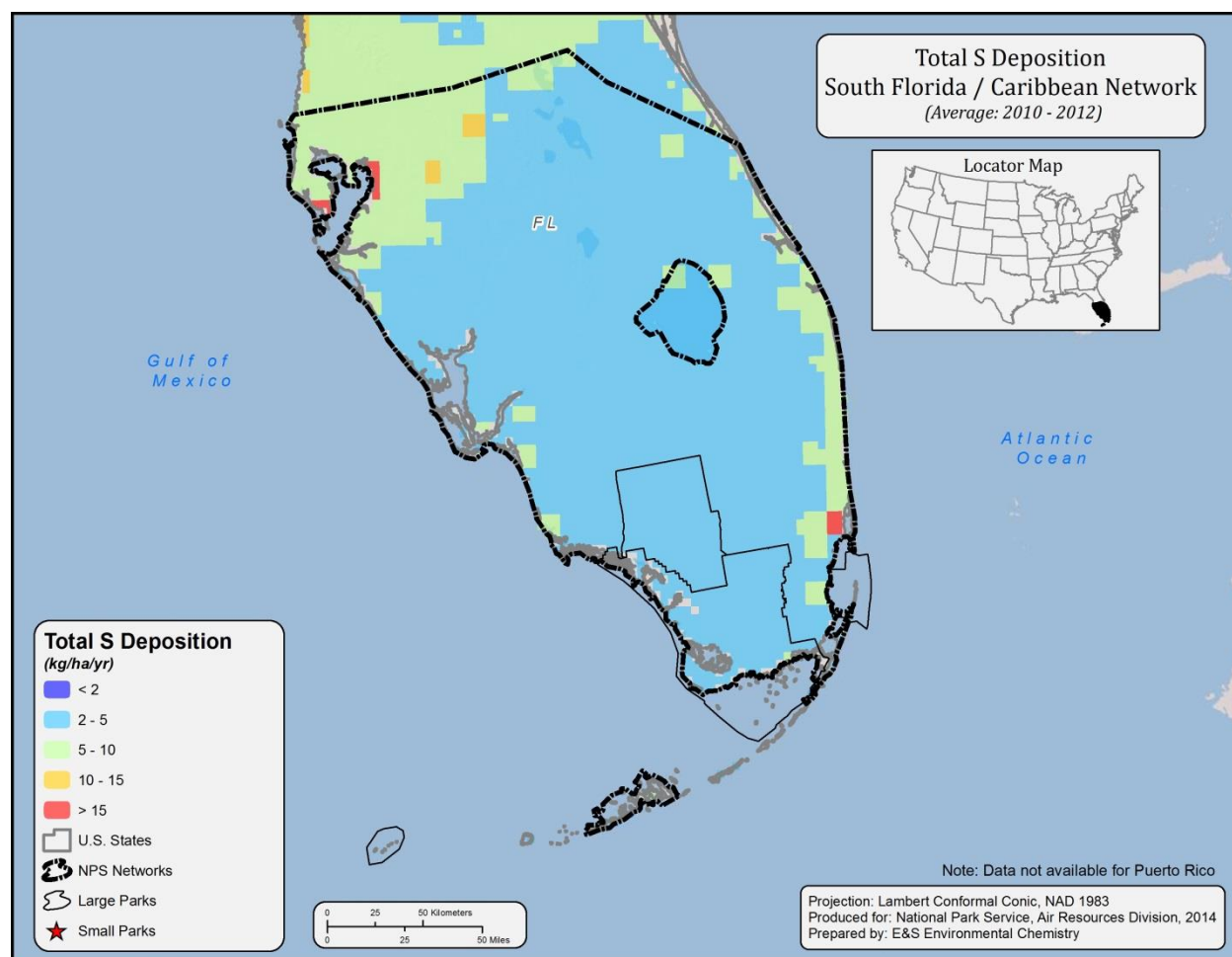
Atmospheric S and N deposition levels have declined at SFCN parks since 2001, based on TDEP estimates (Table 1). Some of the decreases have been sizeable (> 20% change). Oxidized and reduced N showed opposite patterns, with NO_x decreasing and NH_3 increasing at all of the parks in the network since the monitoring period 2000-2002.

Table 1. Average changes in S and N deposition between 2001 and 2011 across park grid cells at SFCN 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.

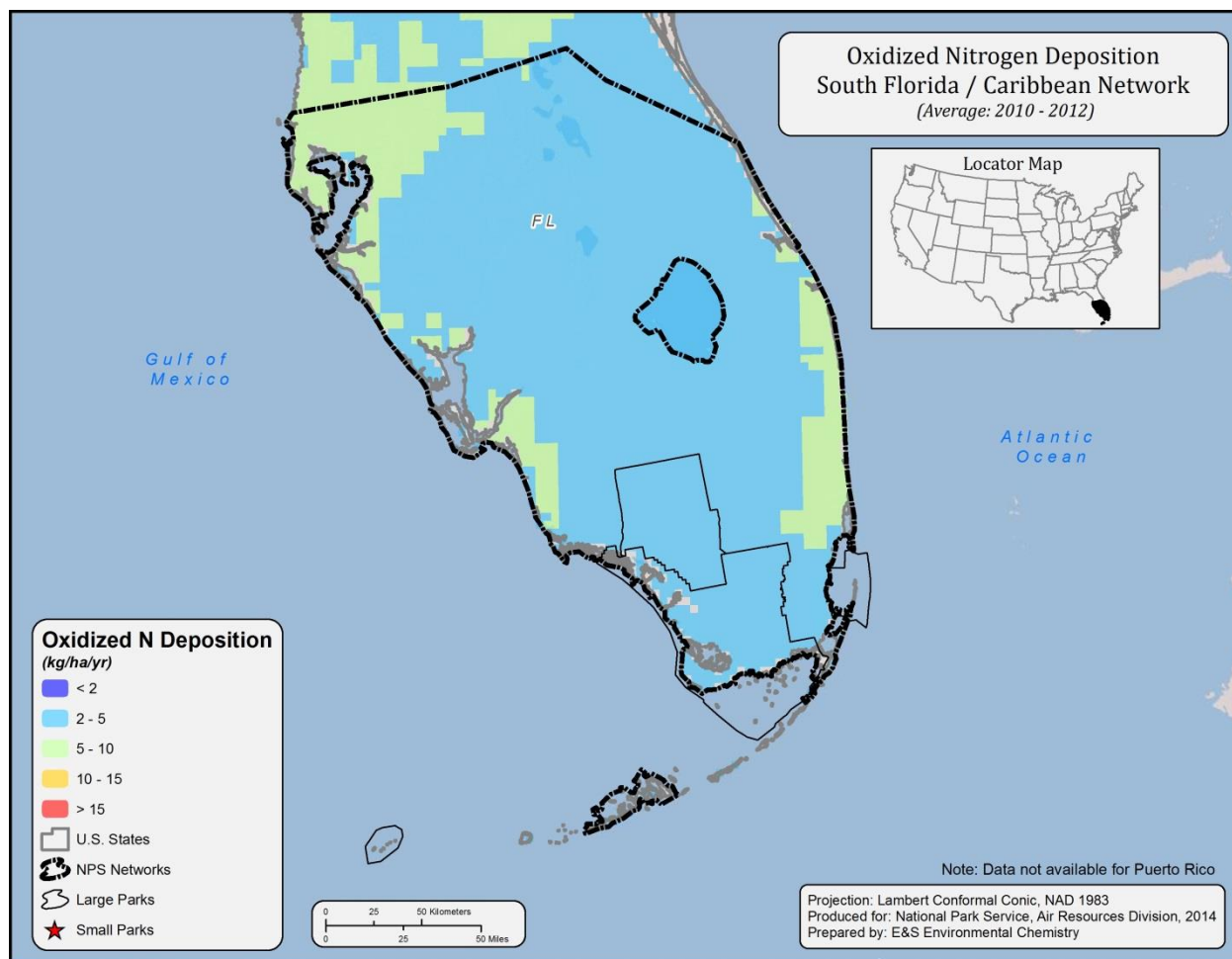
Park Code	Park Name	Parameter	2001 Average (kg/ha/yr)	2011 Average (kg/ha/yr)	Absolute Change (kg/ha/yr)	Percent Change	2011 Minimum (kg/ha/yr)	2011 Maximum (kg/ha/yr)	2011 Range (kg/ha/yr)
BICY	Big Cypress	Total S	4.98	3.82	-1.15	-23.1%	3.52	4.07	0.55
		Total N	6.79	5.04	-1.75	-24.7%	4.42	5.52	1.10
		Oxidized N	5.33	3.40	-1.93	-35.1%	2.80	3.83	1.03
		Reduced N	1.45	1.64	0.18	13.0%	1.43	1.78	0.35
BISC	Biscayne	Total S	5.37	5.30	-0.06	-1.2%	4.11	6.00	1.88
		Total N	7.70	5.58	-2.12	-27.4%	4.06	6.58	2.52
		Oxidized N	5.66	3.19	-2.46	-43.4%	2.41	3.79	1.38
		Reduced N	2.05	2.39	0.34	16.5%	1.65	2.80	1.15
DRTO	Dry Tortugas	Total S	4.22	3.59	-0.63	-15.0%	3.59	3.59	0.00
		Total N	5.51	3.39	-2.13	-38.6%	3.39	3.39	0.00
		Oxidized N	4.54	2.31	-2.23	-49.1%	2.31	2.31	0.00
		Reduced N	0.97	1.07	0.10	10.4%	1.08	1.08	0.00
EVER	Everglades	Total S	5.00	3.84	-1.15	-22.7%	3.37	5.05	1.68
		Total N	5.49	4.94	-0.55	-7.7%	3.32	6.85	3.53
		Oxidized N	4.06	3.02	-1.04	-23.0%	2.03	4.74	2.71
		Reduced N	1.43	1.92	0.49	35.2%	1.29	2.60	1.31

Total S deposition in and around the SFCN for the period 2010-2012 was generally in the range of 2 to 5 kg S/ha/yr at park locations within the network area (Map 5). Oxidized inorganic N deposition for the period 2010-2012 was less than 5 kg N/ha/yr throughout most of the park lands within SFCN (Map 6). Most areas also received less than 5 kg N/ha/yr of reduced inorganic N from atmospheric deposition during this same period (Map 7). Total N deposition was less than 10 kg N/ha/yr at most park locations (Map 8)

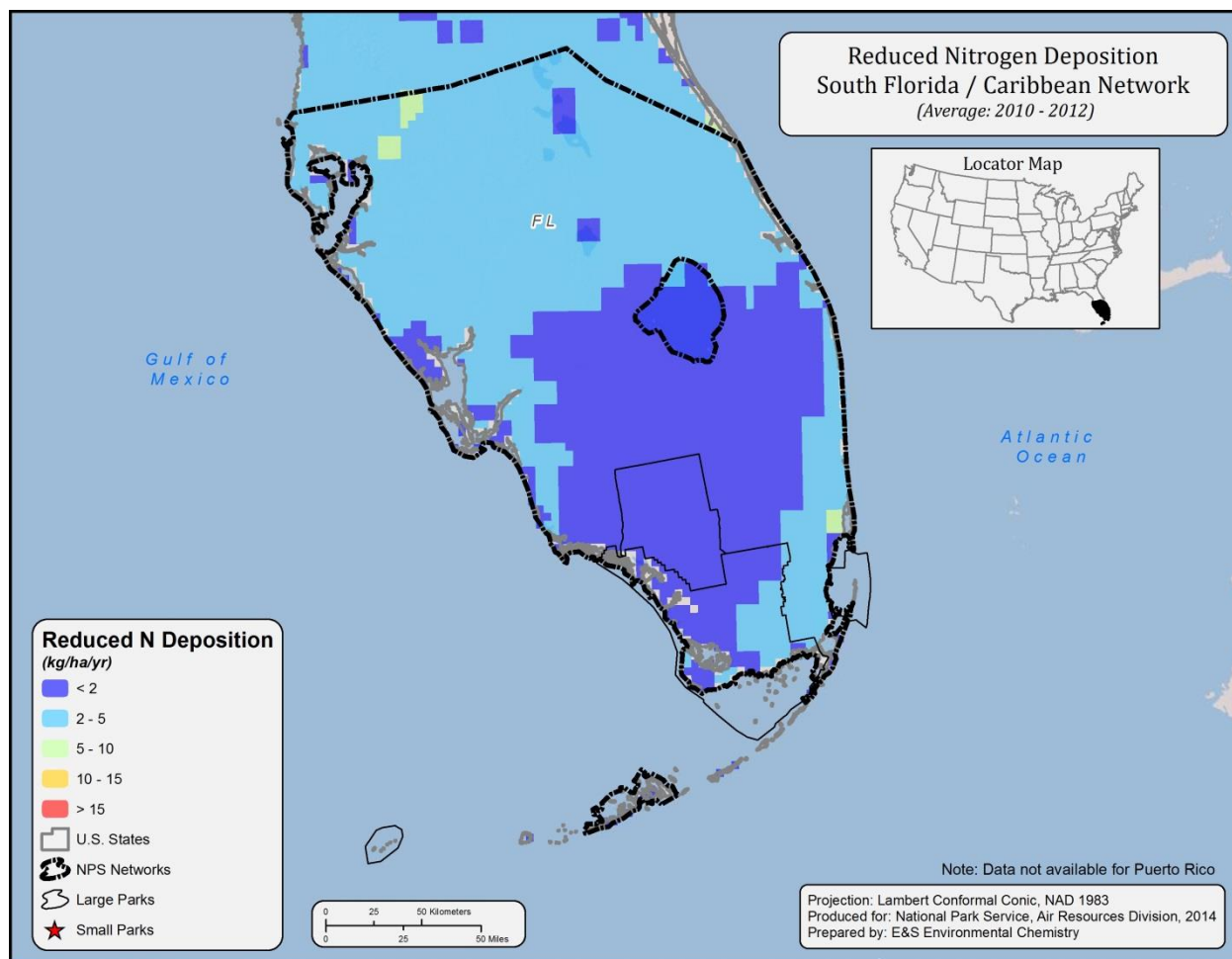
NPS (2010) reported long-term trends in concentrations of mercury (Hg) in wet deposition in EVER during the period beginning in 1996 and running through 2008. Three-year means of annual Hg concentration in wet deposition were reported for 13 parks that had at least two years of valid data during the period 2006-2008. The highest Hg concentration in precipitation was reported for EVER. In fact, south Florida has one of the nation's highest rates of atmospheric Hg deposition, originating from both local and international sources (material provided by Jed Redwine, NPS, from the National Resource Condition Assessment under development, July, 2014).



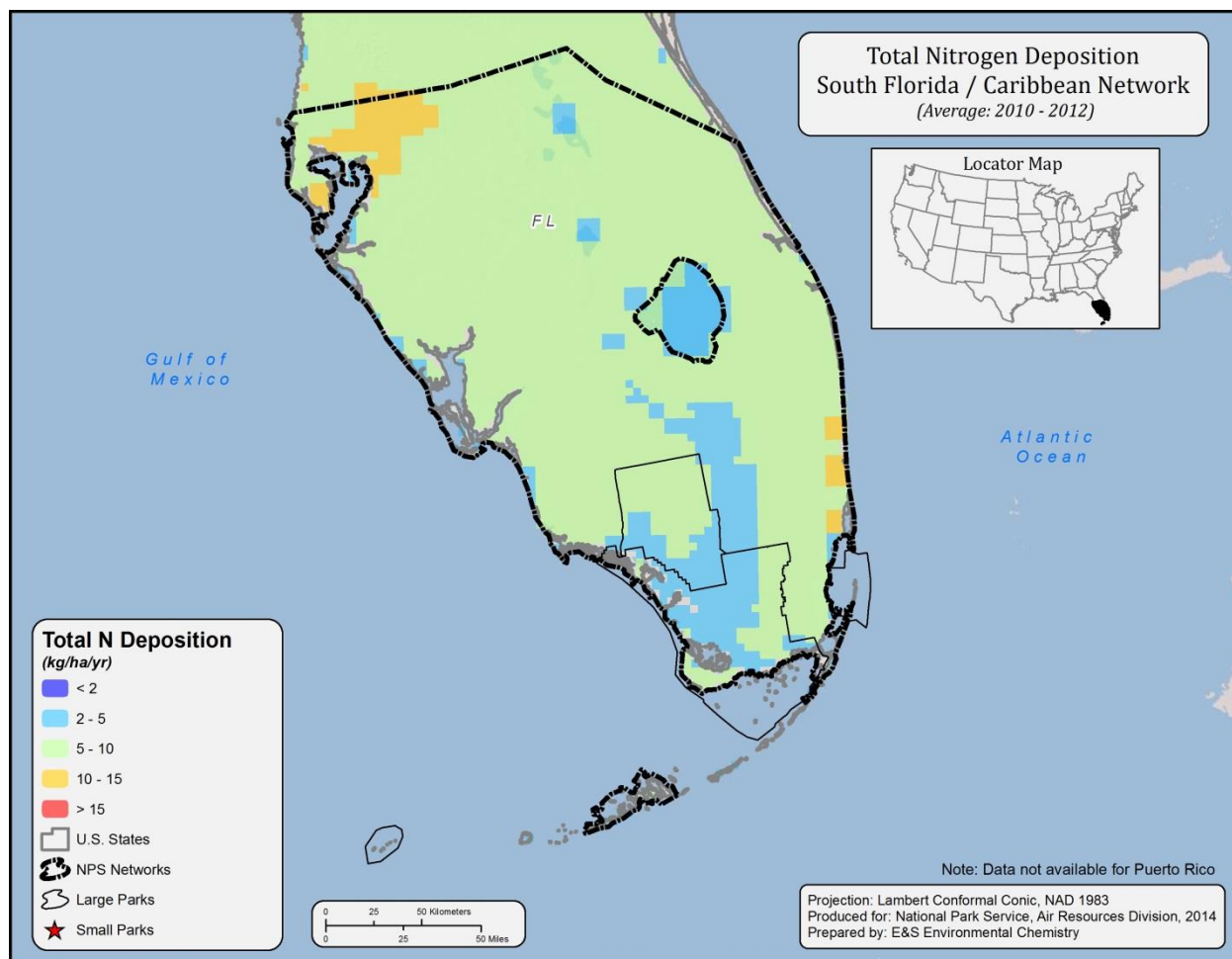
Map 5. Total S deposition for the three-year period centered on 2011 in and around the Florida section of the SFCN. (Source: Schwede and Lear 2014)



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



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



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

Data on atmospheric Hg deposition collected at Davie, Florida showed Hg concentrations in precipitation more than twice as high during spring and summer, as compared with winter samples. Tracer studies suggested that air parcels arriving at the study site during winter incorporated more local urban emissions. Results of this study supported the belief that local human-caused sources of Hg emissions play a dominant role in the overall wet deposition to south Florida and the Everglades (Dvonch et al. 2005).

Acidification

The network rankings developed by Sullivan et al. (2011b) in a coarse screening assessment of acid Pollutant Exposure, Ecosystem Sensitivity to acidification, and Park Protection yielded an overall Network Risk ranking for the SFCN that was near the middle of the distribution among networks. All of the parks in this network were ranked in the second highest quintile in acid Pollutant Exposure (Table 2). Rankings for Ecosystem Sensitivity to acidification varied somewhat, four parks ranked Very Low, one park ranked Low, and one park (VIIS) ranked Moderate (Table 2).

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

Park Name ²	Park Code	Estimated Acid Pollutant Exposure	Estimated Ecosystem Sensitivity to Acidification
<i>Big Cypress</i>	BICY	High	Very Low
<i>Biscayne</i>	BISC	High	Very Low
Buck Island Reef	BUIS	High	Very Low
<i>Dry Tortugas</i>	DRTO	High	Very Low
<i>Everglades</i>	EVER	High	Low
Virgin Islands	VIIS	High	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 names are printed in bold italic for parks larger than 100 mi².

While rankings are an indication of risk, park-specific data, particularly data on ecosystem sensitivity, are needed to fully evaluate risk from acidification. We are not aware of any data documenting acid sensitivity of either aquatic or terrestrial resources in southern Florida. Based on the geology and low topographic relief of this region, resources are likely not highly sensitive to, or affected by, acidification. There may be a greater likelihood of acid sensitivity or effects in VIIS, where slopes are somewhat steeper than in southern Florida. Nevertheless, human impacts on surface waters in the Everglades have been substantial. These have included, in particular, alterations to regional hydrology and changes in land use (McCormick et al. 2011).

Alkaline soils in southern Florida can effectively buffer acidic inputs from the atmosphere (Hall 2011). There are also peat soils in southern Florida. These soils may under certain conditions be more sensitive to acidification from S or N deposition. However, the calcium supply to network wetlands is high due to the prevalence of calcium carbonate geology (Jed Redwine, NPS, personal communication, July, 2014).

Nutrient Nitrogen Enrichment

The predominant vegetation types found within three of the larger parks in the SFCN (EVER, BICY, and BISC) that are thought to be especially sensitive to eutrophication effects from nutrient N addition are wetland and seagrass. Wetlands are especially prevalent in BICY and EVER. Wetlands covered much of south Florida prior to human alterations of the hydrologic system, which began more than a century ago. The quantity, timing, location, and quality of freshwater flows to estuaries and wetlands have been dramatically modified (Science Subgroup 1996). These hydrologic changes interact in complex ways with nutrient inputs. Harmful effects from dehydration and nutrient loading (mostly phosphorus [P]) have been documented on Everglades ecosystem structure and function (Gaiser et al. 2006, Wright et al. 2008).

Based on a coarse screening analysis by Sullivan et al. (Sullivan et al. 2011a), the network rankings 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 in the highest quintile 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 Very High.

Five of the parks in this network considered here (all except DRTO) were ranked in the highest (BUIS, EVER, VIIS) or second highest quintile in nutrient N Pollutant Exposure. Because of their substantial wetland coverage, two of the parks (BICY and EVER) were ranked Very High (i.e., in the highest quintile among parks) or High (in the second highest quintile) in Ecosystem Sensitivity to nutrient N enrichment. Ecosystem Sensitivity to nutrient N enrichment in the other parks was ranked much lower. 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.

Tropical and subtropical forests are often relatively rich in N, and other nutrients are more often limiting (Chadwick et al. 1999). Such ecosystems commonly show high rates of N leaching and denitrification, irrespective of atmospheric deposition (Davidson et al. 2007, Hall 2011, Lewis et al. 1999). On tropical or subtropical sites where N is not limiting, atmospheric N deposition would not be expected to alter productivity or plant species composition. However, loss of N to the atmosphere as gasses produced by denitrification or to drainage water as NO_3^- may be stimulated by increased N deposition (Hall and Matson 1999, Hall 2011, Herbert and Fownes 1995, Lohse and Matson 2005, Templer et al. 2008). On sites where the N supply is limiting, added N would be expected to increase plant growth and perhaps change plant community composition, eventually leading to N-saturation (Erickson et al. 2001, Feller et al. 2007, Hall and Matson 1999).

Nitrogen retention in tropical and subtropical forests differs from retention in temperate forests. Evergreen tropical forests have high leaf area throughout the year, and therefore retain more N in their canopies. This prevents N from reaching the microbial and plant communities that develop on the soil surface (Bakwin et al. 1990, Hall 2011, Sparks et al. 2001).

Data are not available with which to evaluate the extent to which wetlands in the SFCN have been affected by nutrient enrichment from N deposition. The levels of N deposition found in the SFCN

have been relatively high and may or may not have been sufficiently high to cause species shifts in wetland plants. The risk of species composition change is important, in part because wetland ecosystems often contain large numbers of rare plant species.

One of the adverse impacts of eutrophication on estuarine and coastal ecosystems is a decrease in the extent of seagrasses such as turtle grass (*Thalassia testudinum*) and other submerged aquatic vegetation that provide habitat for a wide range of estuarine and marine species. Investigators in some parks are delineating the extent of submerged aquatic vegetation in park estuaries to provide data needed for more effective resource management. The U.S. Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) have partnered with NPS to map submerged resources in nine coastal parks in several locations, including VIIS (Cross and Curdts 2011). In addition, NPS has mapped submerged vegetation in DRTO and BISC and the Florida Fish and Wildlife Conservation Commission has mapped Florida Bay (Matt Patterson, NPS, personal communication, July, 2014).

Florida Bay has experienced major seagrass die-offs and noxious algal blooms attributable to nutrient inputs and hydrological changes (Philips et al. 1999, Science Subgroup 1996). Long-term management plans are aimed at restoring to the extent feasible the natural hydrological conditions of this system (Glibert et al. 2004). There has also been substantial degradation of the Florida Reef Tract, an offshore coral barrier reef system.

Ellis et al. (2013) estimated the CL for nutrient-N deposition to protect the most sensitive ecosystem receptors in 45 national parks. The lowest terrestrial CL of N is generally estimated for protection of lichens (Geiser et al. 2010). Changes to lichen communities may signal the beginning of other changes to the ecosystem that might affect structure and function (Pardo et al. 2011a). Ellis et al. (2013) estimated the N CL for BISC and EVER in the range of 5-10 kg N/ha/yr for protection of forest/trees.

Pardo et al. (2011b) compiled data on empirical CL for protecting sensitive resources in Level I ecoregions across the conterminous United States against nutrient enrichment effects caused by atmospheric N deposition. Data compiled by Pardo et al. (2011b) suggest that ambient N deposition may exceed the lower limit of the expected CL to protect against nutrient enrichment effects in two of the parks in the SFCN. These potential exceedances were reported for the protection of mycorrhizal fungi, lichens, and forest vegetation in BICY and for forest vegetation in EVER (Table 3).

Ozone Injury to Vegetation

The O₃-sensitive plant species that are known or thought to occur within the I&M parks in the SFCN are listed in Table 4. Those considered to be bioindicators because they exhibit distinctive symptoms when injured (e.g., dark stipple), are designated by an asterisk. BUIS, DRTO and VIIS did not contain any O₃-sensitive and/or bioindicator species at the time of this analysis. BICY and EVER contained four and five sensitive species, respectively. Two sensitive species (groundnut [*Apios americana*] and American elder [*Sambucus canadensis*]) that occur in BICY and EVER are recognized as bioindicators. BISC contained only one species, which was not a bioindicator.

The W126 (a measure of cumulative O₃ exposure that preferentially weights higher concentrations) and SUM06 (a measure of cumulative exposure that includes only hourly concentrations over 60 ppb O₃) exposure indices calculated by NPS staff are given in Table 5, along with Kohut's (2007) O₃ risk ranking. The NPS and Kohut ranking systems differ. The NPS ranking system (NPS 2010) is a quick assessment of O₃ condition that ranks O₃ exposure levels according to injury thresholds from the literature (Heck and Cowling 1997), using a 5-year average of either the W126 or SUM06 index. Both metrics are calculated over a 3-month period. The W126 was classified as Moderate exposure at values between 7 and 13 ppm-hr, as defined by NPS (2010). Values higher than 13 ppm-hr were classified as High exposure, and values lower than 7 ppm-hr were classified as Low exposure. The SUM06 was classified as Moderate at values between 8 and 15 ppm-hr. Higher and lower values were classified as High and Low, respectively, as defined by NPS (2010). Using these criteria, O₃ levels at the SFCN parks for 2005-2009 are generally rated Low to Moderate. Monitoring was discontinued at VIIS in 2003. Estimates were not available for BUIS and VIIS due to insufficient data.

Kohut's approach constitutes a more rigorous assessment of potential O₃ 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.

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 significantly affect plant response to O₃, but exposures have likely changed since the time of the assessment (1995-1999). The NPS approach considers more recent O₃ conditions (2005-2009), but not environmental conditions.

Table 3. Empirical critical loads for nitrogen in the SFCN, 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	
Big Cypress NPres	Eastern Temperate Forests	7.1	5 - 12	4 - 8	17.5	3 - 8	8
Big Cypress NPres	Tropical Humid Forests	7.1	NA	NA	NA	5 - 10	NA
Biscayne NP	Tropical Humid Forests	4.3	NA	NA	NA	5 - 10	NA
Dry Tortugas NP	NA	NA	-	-	-	-	-
Everglades NP	Tropical Humid Forests	9.8	NA	NA	NA	5 - 10	NA

Kohut's (2007) ranking was Low across all parks in this network with the exception of DRTO, which was not ranked because there were no on-site or nearby O₃ monitors to provide data at the time of the assessment.

Table 4. Ozone-sensitive and bioindicator plant species known or thought to occur in the I&M parks of the SFCN. (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 ¹					
		<i>BICY</i>	<i>BISC</i>	BUIS	<i>DRTO</i>	<i>EVER</i>	VIIS
No Species Present				x	x		x
<i>Apios americana</i> *	Groundnut	x				x	
<i>Asclepias incarnata</i>	Swamp milkweed	x				x	
<i>Parthenocissus quinquefolia</i>	Virginia creeper	x	x			x	
<i>Sambucus canadensis</i> *	American elder	x				x	
<i>Spartina alterniflora</i>	Smooth cordgrass					x	

¹ Park acronyms are printed in bold italic for parks larger than 100 mi².

* Bioindicator species

Table 5. Ozone assessment results for I&M parks in the SFCN 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 ²	Park Code	W126		Sum06		Kohut O ₃ Risk Ranking
		Value (ppm-hr)	Ranking	Value (ppm-hr)	Ranking	
<i>Big Cypress</i>	BICY	6.48	Low	7.48	Low	Low
<i>Biscayne</i>	BISC	6.40	Low	7.30	Low	Low
Buck Island Reef	BUIS	No Data	No Rank	No Data	No Rank	Low
<i>Dry Tortugas</i>	DRTO	7.94	Moderate	9.46	Moderate	No Rank
<i>Everglades</i>	EVER	6.50	Low	7.50	Low	Low
Virgin Islands	VIIS	No Data	No Rank	No Data	No Rank	Low

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

² Park names are printed in bold italic for parks larger than 100 mi².

Visibility Degradation

Natural Background and Ambient Visibility Conditions

The Clean Air Act 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). In 1999, EPA passed the Regional Haze Rule, 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. EVER and VIIS are Class I parks; the other SFCN parks are Class II parks but are expected to benefit from visibility improvements at Class I areas.

Natural background visibility 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 deciview (dv)².

Haze is monitored by IMPROVE for EVER and VIIS. Data are also available that are considered to be representative of visibility conditions in three of the other parks, BICY, BISC, and BUIS. 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. These parks have relatively high levels of natural haze (Table 6) caused by sea salt and to some extent by marine sources of SO_4^{2-} because of their proximity to the ocean. Current haze levels are substantially elevated above the estimated natural levels and are considered impaired at times from anthropogenic pollution.

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 SO_2 emissions from 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.

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 6. Estimated natural haze and measured ambient haze in I&M parks averaged over the period 2004 through 2008.

Park Name ¹	Park Code	Site ID	Estimated Natural Haze (dv)		
			20% Clearest Days	20% Haziest Days	Average Days
<i>Big Cypress</i> ²	BICY	EVER1	5.22	12.15	7.77
<i>Biscayne</i> ²	BISC	EVER1	5.22	12.15	7.77
Buck Island Reef ²	BUIS	VIIS1	4.41	10.68	7.10
<i>Dry Tortugas</i>	DRT0	No Site			
<i>Everglades</i>	EVER	EVER1	5.22	12.15	7.77
Virgin Islands	VIIS	VIIS1	4.41	10.68	7.10
Park Name	Park Code	Site ID	Measured Ambient Haze (For Years 2004 through 2008; dv)		
			20% Clearest Days	20% Haziest Days	Average Days
<i>Big Cypress</i> ²	BICY	EVER1	12.14	21.43	16.17
<i>Biscayne</i> ²	BISC	EVER1	12.14	21.43	16.17
Buck Island Reef ²	BUIS	VIIS1	9.16	18.08	13.23
<i>Dry Tortugas</i>	DRT0	No Site			
<i>Everglades</i>	EVER	EVER1	12.14	21.43	16.17
Virgin Islands	VIIS	VIIS1	9.16	18.08	13.23

¹ Park names are printed in bold italic for parks larger than 100 mi².

² Data are borrowed from nearby IMPROVE sites. 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.

Figure 1 shows estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze and its composition for the monitored parks in the SFCN. The largest contributor to total particulate light extinction (b_{ext}) in BICY, BISC, and EVER was SO_4^{2-} , followed by organics (Figure 1). The contribution of SO_4^{2-} was highest on the 20% haziest days (57.4%). The contribution of organics was about 14% on the 20% clearest and 20% haziest days. Nitrates, coarse mass, and sea salt also contributed to haze in these parks.

In BUIS and VIIS, the majority of b_{ext} was attributable to SO_4^{2-} , sea salt and coarse mass (Figure 1). On an annual average basis, SO_4^{2-} contributed 29.5% of b_{ext} , sea salt 26.5%, and coarse mass 24.1%. On the 20% haziest days, SO_4^{2-} accounted for 25.3% of b_{ext} , sea salt 19.3% and the contribution of coarse mass increased slightly to 27.2%. On the 20% clearest visibility days, the contribution of SO_4^{2-} increased to 35.2% of b_{ext} , sea salt contributed 27.8%, and the contribution of coarse mass decreased to 21.6%.

Trends in Visibility

EPA monitors visibility in 155 national parks through the IMPROVE program. Over the period 1996 to 2006, visibility on the 20% clearest days improved (decreased haze) or remained constant at all monitored sites in the conterminous United States except EVER (U.S. EPA 2008).

Available IMPROVE data suggest that haze may be decreasing in more recent years at BICY, BISC, and EVER, especially on the 20% haziest days (Figure 2). There has been a continuous decline in

haze at these parks by more than 6 dv since 2003. In marked contrast, ambient haze at BUIS and VIIS has generally increased since monitoring began in 2001, especially on the 20% haziest days.

Development of State Implementation Plans

The Visibility Improvement State and Tribal Association of the Southeast (VISTAS) is a collaborative effort among state governments, tribal governments, and federal agencies involved in management of visibility and regional haze in the Southeast. The VISTAS region includes the southeastern United States from Virginia and West Virginia in the north, south to Florida, and west

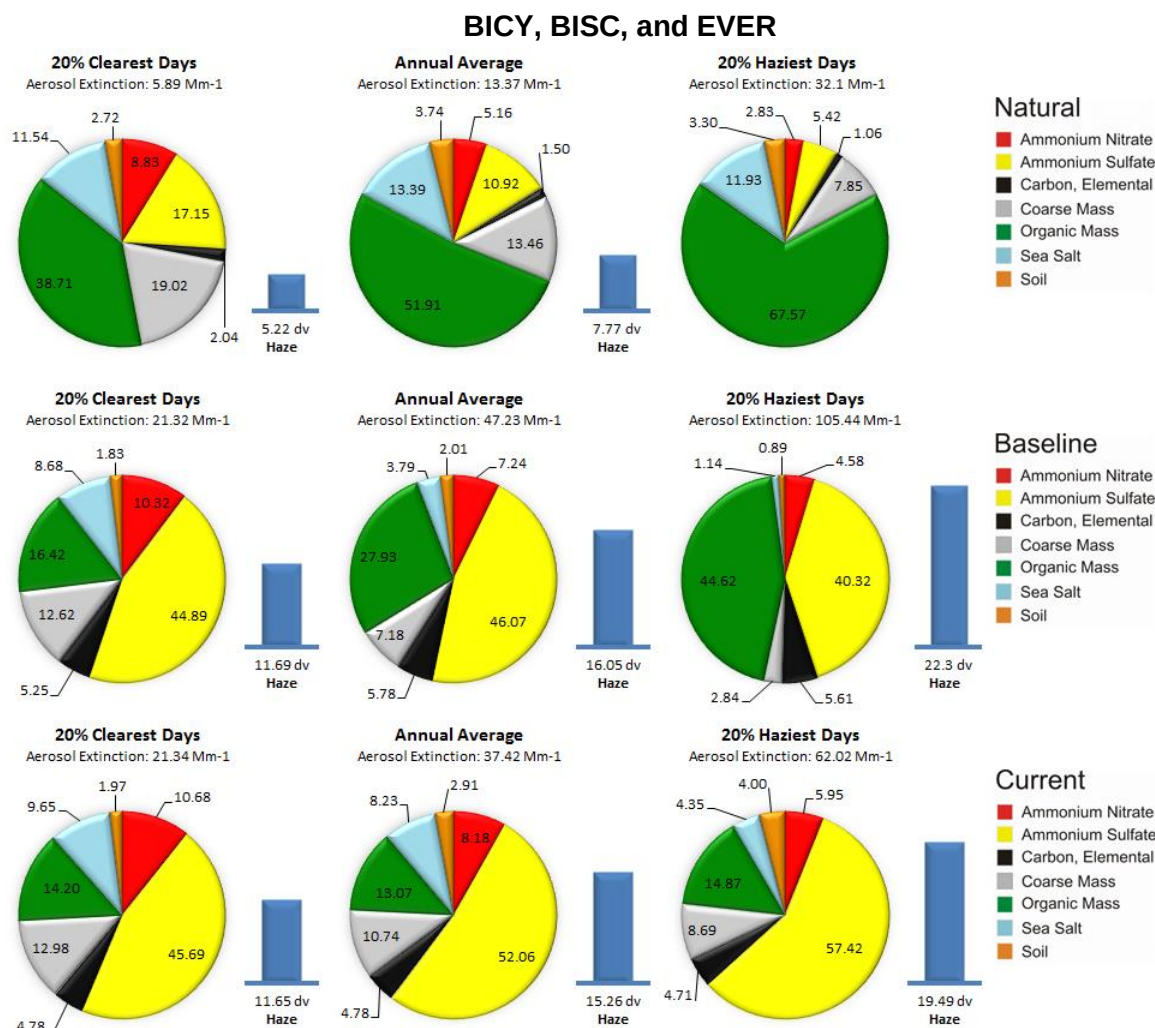


Figure 1a. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for BICY, BISC, and EVER. Data for BICY, BISC, and BUIS were taken from nearby sites. BICY, BISC, and EVER have no data for the year 2000. BUIS and VIIS have no data for the year 2000 and 2007. Ammonium sulfate is the most important non-natural substance that causes haze in southern Florida's NPS units. Data Source: NPS-ARD

BUIS and VIIS

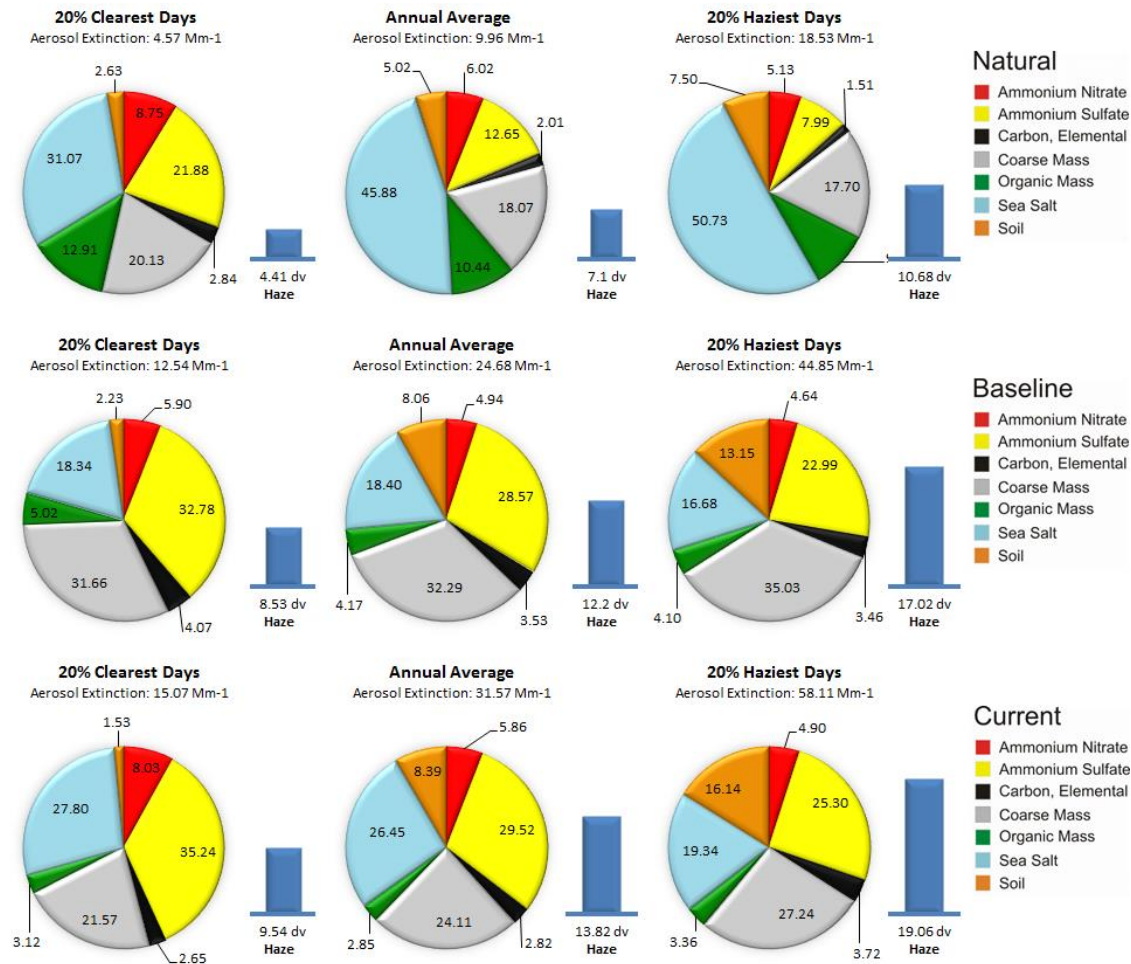


Figure 1b. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for BUIS and VIIS. Data for BICY, BISC, and BUIS were taken from nearby sites. BICY, BISC, and EVER have no data for the year 2000. BUIS and VIIS have no data for the year 2000 and 2007. Ammonium sulfate is the most important non-natural substance that causes haze in southern Florida's NPS units. Data Source: NPS-ARD

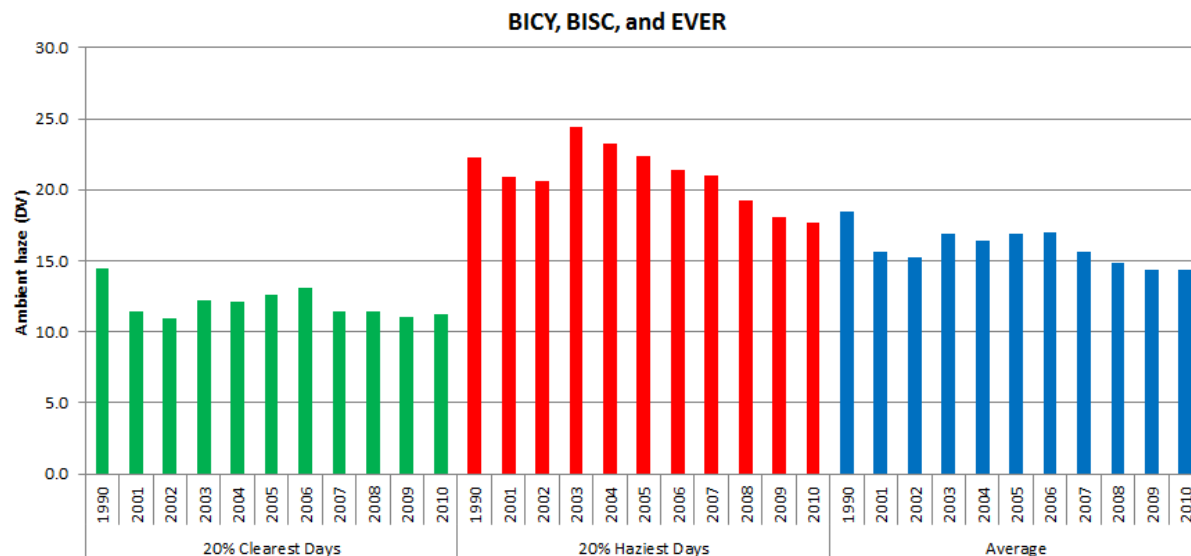


Figure 2a. Trends in ambient haze levels at BICY, BISC, and EVER, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for BICY, BISC, and BUIS were taken from nearby sites. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm.

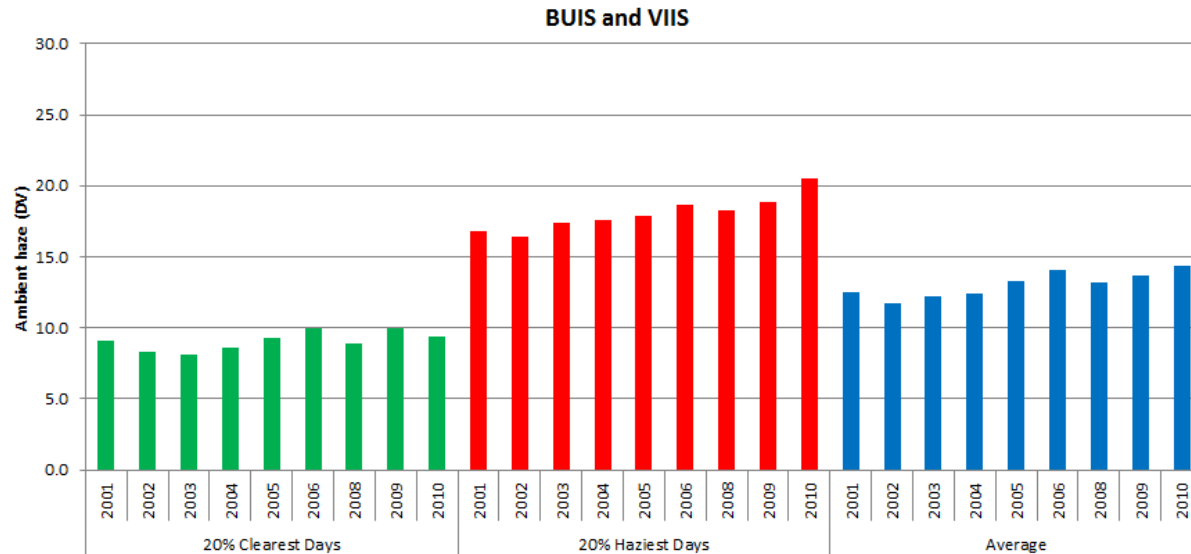


Figure 2b. Trends in ambient haze levels at BUIS and VIIS, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for BICY, BISC, and BUIS were taken from nearby sites. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm.

to Kentucky, Tennessee, and Mississippi. According to the Regional Haze Rule (RHR), promulgated in 1999, 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 by 2064. States must evaluate progress by 2018 (and every 10 years thereafter) based on a baseline period of 2000 to 2004 (Air Resource Specialists [ARS] 2007). Analyses conducted on behalf of VISTAS in the southeastern United States have included determination of baseline visibility conditions, calculation of the glide slope from the baseline necessary to achieve background conditions in 2064, and determination of air pollutant source areas. Back trajectory analyses identified the areas most likely to contribute to visibility degradation on the 20% haziest days at the Class I areas in the VISTAS region. The method basically followed a parcel of air over the Class I area backwards in space and time for a specified period of time. Trajectories were generated by ARS (2007) using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed by NOAA.

Progress to date in meeting the national visibility goal is illustrated in Figure 3 using a uniform rate of progress glideslope. Results of this analysis suggest that improvements to date at BICY, BISC, and EVER in visibility on the 20% haziest days exceeded the glideslope required for RHR compliance. This has clearly not been the case at BUIS and VIIS. On the clearest 20% of days, ambient haze appears to be increasing at BUIS and VIIS; data for the 20% clearest days for the other parks are inclusive. Additional monitoring is needed.

Toxic Airborne Contaminants

Airborne toxics include various semi-volatile organics (e.g., pesticides, industrial by-products) and heavy metals (e.g., Hg). Pesticide residues likely contribute to adverse impacts on sensitive species in the SFCN. However, there are no available data to suggest that atmospheric contributions of pesticides constitute an important part of the total pesticide loading to sensitive surface waters in this network. However, there is evidence of high levels of atmospheric deposition of endosulfan (Potter et al. 2014). 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 SFCN 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 this network, coupled with relatively high atmospheric deposition of Hg and S.

Wetlands, which are common in parts of the SFCN, act as important sources of biologically available methylmercury (MeHg) to fresh water ecosystems. This is likely due in large part to three characteristics of south Florida wetlands: 1) high availability of DOC, 2) common occurrence of anaerobic conditions in sediments, and 3) high atmospheric S deposition. All enhance Hg methylation rates. The abundance of DOC also enhances the transport of MeHg to downstream receiving waters. As a consequence of these wetland influences on Hg methylation and transport, the percentage of wetland areas within watersheds is commonly correlated with MeHg flux (Grigal 2002). Both BICY and EVER have extensive wetland coverage. Lake types that are generally associated with Hg bioaccumulation are poorly buffered, low in pH and productivity, and have forested watersheds and little human development within the watershed (Chen et al. 2005). The review of Evers (2005) classified Hg-sensitive surface waters as those having:

- high SO_4^{2-} concentrations
- extensive associated wetlands
- fluctuating water levels
- low nutrient concentration

Surface waters throughout much of southern Florida often exhibit many of these characteristics.

It appears that S enrichment of wetlands in the Everglades, in response to both atmospheric S deposition and agricultural inputs (Bates et al. 2001), has increased Hg methylation in wetland ecosystems (McCormick et al. 2011). For example, a mesocosm experiment by Gilmour et al. (2003) showed increased methylation in response to SO_4^{2-} addition.

Atmospheric deposition accounts for an estimated 95% of all Hg inputs in EVER (Landing et al. 1995). The park receives some of the highest wet deposition levels of Hg in the United States (NADP 2008), largely the result of high precipitation in the park. High precipitation, coupled with elevated concentrations of DOC in surface waters, availability of S, and the high reducing capacity of the EVER wetlands, support rapid transformation of Hg to the biologically-available MeHg (Chen et al. 2012), which contributes to high Hg bioaccumulation in fish. Mercury can biomagnify, especially at

higher trophic levels, to concentrations that can potentially damage the nervous system of sensitive species of biota. This issue is of particular concern to people and wildlife that consume large quantities of fish. Body burdens of Hg in sunfish (*Lepomis* spp.), largemouth bass (*Micropterus salmoides*), and bluegill (*Lepomis macrochirus*) in northern EVER exceeded the wildlife criteria levels established by U.S. EPA (Chen et al. 2012, U.S. EPA 2007). Exposure to MeHg above the levels that cause adverse effects have been estimated for great egret (*Ardea alba*), bald eagle (*Haliaeetus leucocephalus*), and wood stork (*Mycteria americana*) in the northern part of the park. There is also concern for how Hg exposure may impact the reproductive success of the endangered Florida panther (*Puma concolor coryi*; U.S. EPA 2007). To protect humans from adverse effects associated with Hg contamination, the state of Florida has issued fish consumption advisories that ban or limit consumption by humans for nine fish species over two million acres in EVER (U.S. EPA 2007).

In the Everglades Water Conservation areas adjacent to EVER, MeHg concentrations in fish have been declining since the early 1990s; nevertheless, they still generally exceed the U.S. EPA thresholds for human consumption and for wildlife (Axelrad et al. 2007).

In 1999, a survey was conducted of 28 American alligators (*Alligator mississippiensis*) along a transect through the Everglades by a multi-agency team including researchers from the USGS, USFWS, and the Florida Fish and Wildlife Conservation Commission. Results showed that alligators in EVER had Hg body burdens that were roughly twice as high as the Everglades-wide average

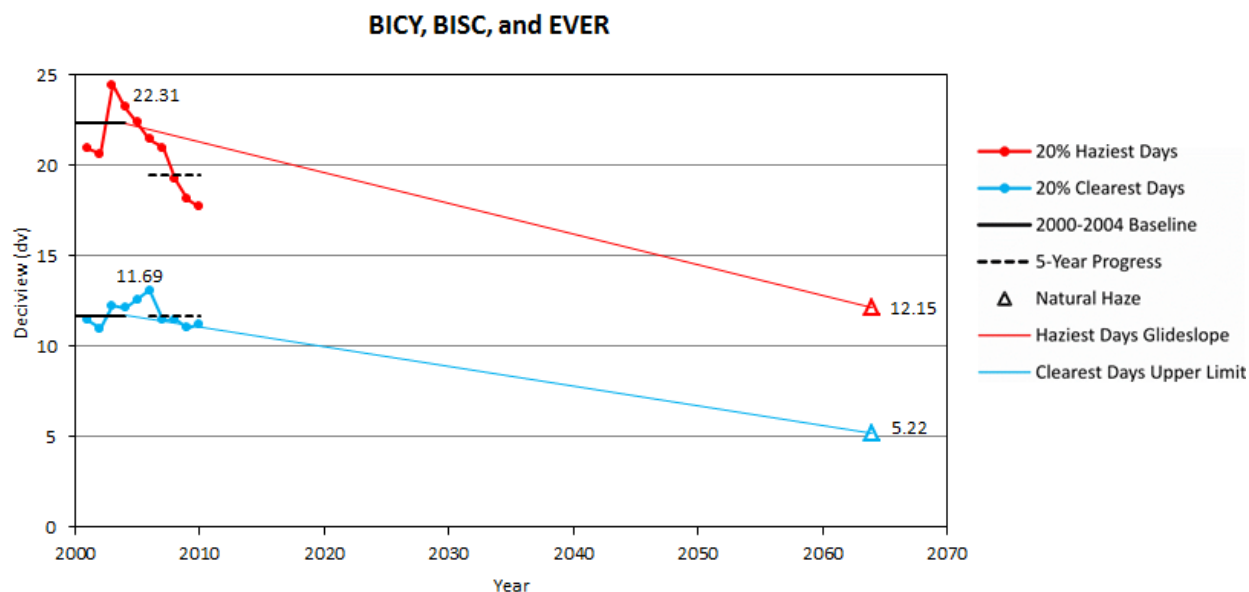


Figure 3a. Glideslopes to achieving natural visibility conditions in 2064 for the 20% hazeiest (red line) and the 20% clearest (blue line) days in BICY, BISC, and EVER. In the regional haze rule, the clearest days do not have a uniform rate of progress glideslope; the rule only requires that the clearest days do not get any worse than the baseline period. Also shown are measured values during the period 2000 to 2010. Data for BICY, BISC, and BUIS were taken from nearby sites. BICY, BISC, and EVER have no data for the year 2000. BUIS and VIIS have no data for the year 2000 and 2007. Data Source:

http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

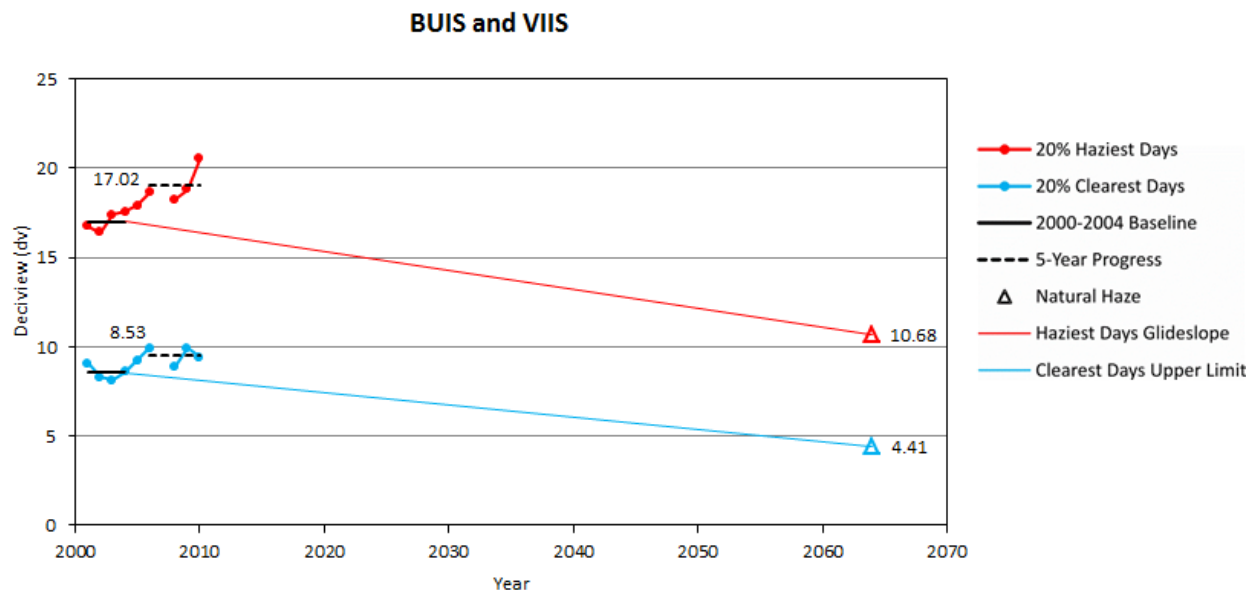
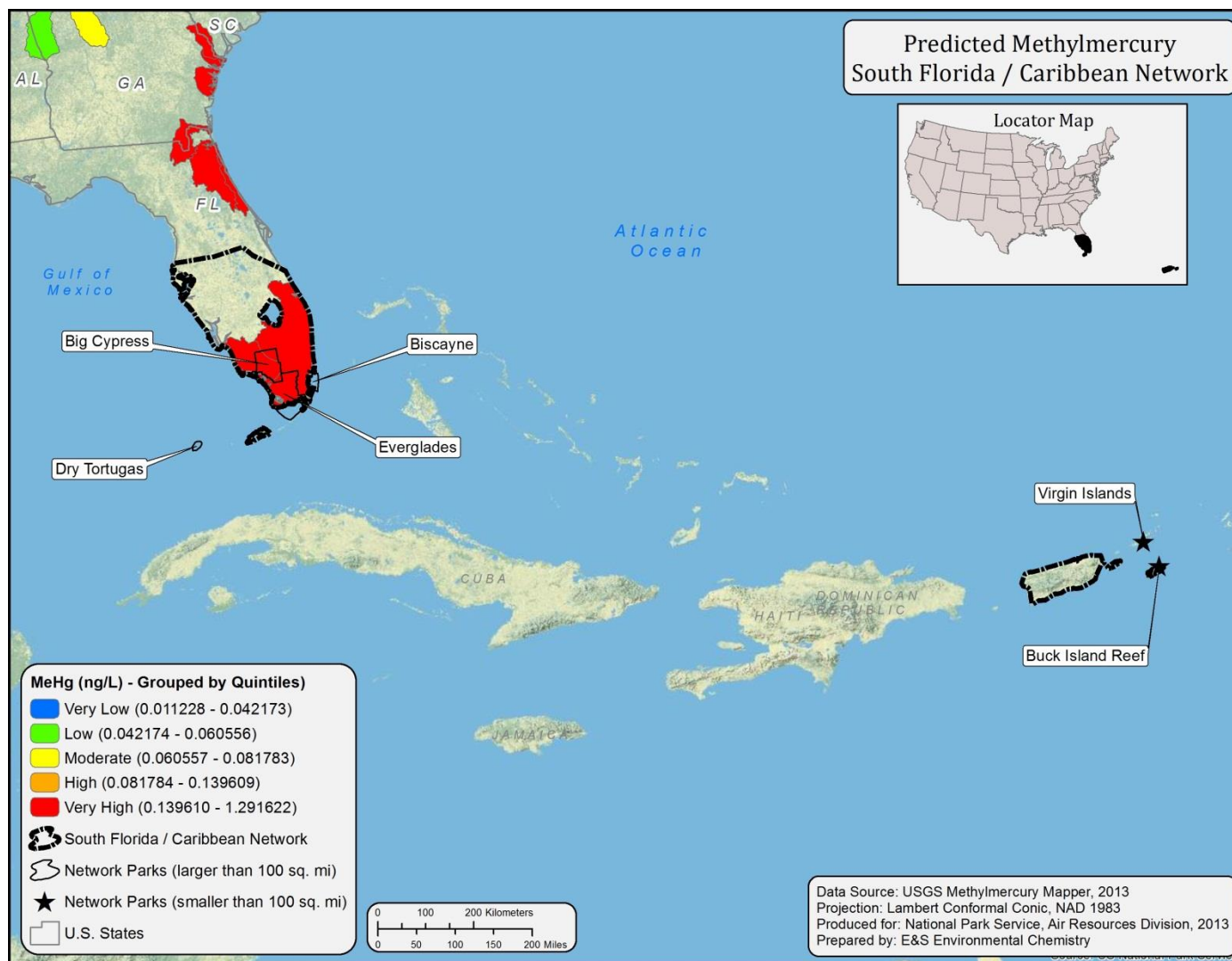


Figure 3b. Glideslopes to achieving natural visibility conditions in 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days in BUIS and VIIS. In the regional haze rule, the clearest days do not have a uniform rate of progress glideslope; the rule only requires that the clearest days do not get any worse than the baseline period. Also shown are measured values during the period 2000 to 2010. Data for BICY, BISC, and BUIS were taken from nearby sites. BICY, BISC, and EVER have no data for the year 2000. BUIS and VIIS have no data for the year 2000 and 2007. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm



Map 9. Predicted MeHg concentrations in surface waters by HUCs that contain national parklands in the South Florida/Caribbean 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.

(10.4 mg/kg and 1.2 mg/kg versus 4.0 mg/kg and 0.64 mg/kg in the liver and tail, respectively; Rumbold et al. 2002). When compared with a survey by Yanochko et al. (1997), Hg levels in alligators in EVER appear to have declined since 1994 (Rumbold et al. 2002). Monitoring of Hg levels in pig frogs (*Rana grylio*) in EVER is important because this amphibian is an abundant intermediary component of the Everglades food web and because the frogs are harvested for human consumption. In a survey by Ugarte et al. (2005), the highest Hg concentrations in frog legs were found in EVER, where harvesting is prohibited; however, frog legs collected at some sites in the Everglades outside EVER had Hg levels that exceeded the U.S. EPA 0.3 mg/kg fish tissue residue criterion. The role played by frogs in the transfer of Hg through the wetland system in EVER may be significant, as Hg levels measured in some frogs were higher than the threshold values for piscivorous wildlife. Spatial patterns in Hg concentrations in the frog samples generally corresponded with results for other wildlife species (Ugarte et al. 2005).

Wading birds (order ciconiiformes) include herons, egrets, ibis, and spoonbills. These are upper trophic level aquatic feeders that may be at risk from high levels of Hg exposure in portions of the SFCN having high ambient Hg in surface water. Populations of these birds have declined in southern Florida (Ogden 1994). Sundlof et al. (1994) compared Hg concentrations in livers of young ciconiiforme birds collected across southern Florida, including within and adjacent to EVER and BICY. Mercury was measured in the livers of 144 birds. Hepatic Hg concentration varied by location, age, diet, and body fat content. Birds collected from the central Everglades and eastern Florida Bay had significantly higher hepatic Hg concentration than birds collected in other areas. Species that had a prey base of larger fish had about four times the hepatic Hg concentration compared with species that consumed small fish or crustaceans. Four great blue heron (*Ardea herodias*) collected in the central Everglades had livers containing Hg concentrations commonly associated with neurologic symptoms ($\geq 30 \mu\text{g/g}$). Between 30% and 80% of potential breeding age birds collected from the central Everglades had hepatic Hg concentrations that have previously been associated with reproduction impairment in ducks and pheasants (Sundlof et al. 1994).

The wading bird population in Florida has declined dramatically since the 1910's (Runde 1991). Habitat loss, altered regional hydrology, and P pollution have been important contributing factors to the observed decline. Hg contamination of their food supply may also be an important factor (Sundlof et al. 1994). Toxicity to birds from MeHg exposure can be expressed as damage to nervous, excretory, immune, or reproductive systems (Wiener et al. 2003). Embryos and hatchlings are especially vulnerable (Heinz and Hoffman 2003).

Julian et al. (2014) provided an assessment of the Hg and S status during water year 2013 of the Everglades Protection Area. The reported total Hg concentration in largemouth bass ranged from 0.02 to 2.0 mg/kg, with a median concentration of 0.4 mg/kg. In the trophic level 3 sunfish species (*Lepomis* spp.) surveyed, total Hg concentration ranged from 0.1 to 0.25 mg/kg, which exceeded the federal MeHg criterion of 0.077 mg/kg for trophic level 3 fish in order to protect piscivorous wildlife.

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NPS 910/132244, April 2016

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