Appendix C

Monitoring, Meteorological, and Other Data Acquisition and Preparation

Appendix C-1: Southeastern VISTAS II Regional Haze Analysis Project: Task 4 Report October 17, 2018

Appendix C-2: 2000-2018 Clearest and Most Impaired Charts

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Southeastern VISTAS II Regional Haze Analysis Project: Task 4 Report

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Abbreviations/Acronym List

AIRMoN	Atmospheric Integrated Research Monitoring Network
AMNet	Atmospheric Mercury Network
AMoN	Ammonia Monitoring Network
AQS	Air Quality System
ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
Ca^{2+}	Calcium
CART	Classification And Regression Tree
CASTNET	Clean Air Status and Trends Network
CBSA	Core-Based Statistical Area
CIRA	Cooperative Institute for Research in the Atmosphere
Cl^-	Chloride
EPA	United States Environmental Protection Agency
ERG	Eastern Research Group, Inc.
FAA	Federal Aviation Administration
FIPS	Federal Information Processing System
GMT	Greenwich Mean Time
H^+ as pH	Free acidity
HAL	Mercury (Hg) Analytical Laboratory
Hg	Total mercury
HgP	Particulate mercury
HNO_3	Nitric acid
ID	Identifier
IMPROVE	Interagency Monitoring of Protected Visual Environments
K^+	Potassium
km	Kilometers
kts	Knots
LC	Local conditions
µg	Microgram
m	Meters
m^3	Cubic meters
MDN	Mercury Deposition Network
Mg^{2+}	Magnesium
Mm^{-1}	Inverse megameters
MPE	Model performance evaluation
mph	Miles per hour
Na^+	Sodium
NADP	National Atmospheric Deposition Program
NCEI	National Centers for Environmental Information
NH_3	Ammonia
NH_4^+	Ammonium
NO_3^-	Nitrate
NTN	National Trends Network
NWS	National Weather Service
PM	Particulate matter

$PM_{2.5}$	Fine particle; primary particulate matter less than or equal to 2.5 microns in aerodynamic diameter
QA	Quality assurance
QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	Quality control
RH	Relative humidity
RHR	Regional Haze Rule
RRF	Relative Response Factor
SESARM	Southeastern States Air Resource Managers, Inc.
SO_2	Sulfur dioxide
SO_4^{2-}	Sulfate
SOP	Standard Operating Procedure
TAMIS	Texas Air Monitoring Information System
USCRN	U.S. Climate Reference Network
USRCRN	U.S. Regional Climate Reference Network
VISTAS	Visibility Improvement - State and Tribal Association of the Southeast
WBAN	Weather Bureau Army-Navy
YYYY-MM-DD	Year -month-day format

1. INTRODUCTION

This report documents the work completed under Task 4 (Data Acquisition and Preparation) and Subtask 4.1 (Collecting Weekly Wet and Weekly Dry Deposition Data) for the Southeastern Visibility Improvement - State and Tribal Association of the Southeast Phase II (VISTAS II) Regional Haze Analysis Project. Eastern Research Group, Inc. (ERG) used existing data sets to develop databases containing the air quality, deposition, and meteorological data for use in the study. The air quality, deposition, and meteorological data are provided in three separate Microsoft Access databases. A data dictionary containing descriptions of the fields in each Access table is provided in Excel format.

These databases cover the VISTAS II study period of 2009-2016 for concentrations and deposition data, and 2011-2016 for wind information (wind speed and wind direction). At a minimum, databases include data all the states that fall within the VISTAS 12km modeling domain (Figure 1-1). When not inhibited by file size limitations, additional states have been included in the database. These databases provide a permanent record of the set of data used to support the model performance evaluation (MPE) and the regional haze calculations conducted throughout the study.

These databases also have a use beyond this study, as the ambient air quality, meteorological and deposition data can fulfill the data gathering phase of any additional studies the Southeastern States Air Resource Managers, Inc. (SESARM) partners might wish to conduct. For example, the weekly wet deposition and weekly dry deposition data was collected under Subtask 4.1 for potential use by SESARM's partners to support other projects that evaluate acid deposition in watersheds. Having this data set in hand will facilitate any evaluation, save time and resources for extending beyond the scope of this study, state could use the meteorology and air quality database for a multivariate regression model or Classification And Regression Tree (CART) analysis to examine the meteorological conditions that lead to impair visibility and high concentrations of particulate matter or other pollutants.

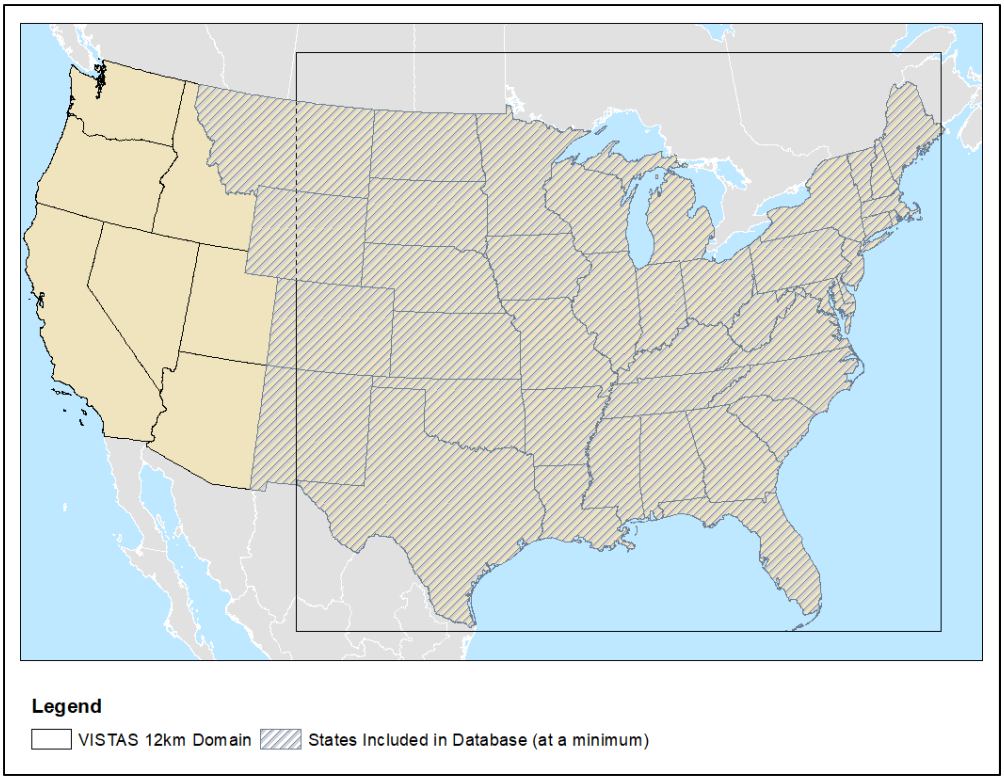

Figure 1-1. States Included in Task 4 Databases

2. AIR QUALITY DATABASES

The primary goal of Task 4 was to collect ambient air quality information for use across the VISTAS II projects and other analysis associated with the SESARM partners regional haze SIP submittals. ERG developed a comprehensive ambient air quality database to serve as a master database of available ambient data for the 2011 to 2016 study period. Additionally, concentration data from 2009 and 2010 were obtained for calculation of Relative Response Factors (RRFs) for Task 9. The database includes data from the following monitoring networks:

- Interagency Monitoring of Protected Visual Environments (IMPROVE),
- U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS)

These networks are discussed in the following sections. The data was retrieved from the Cooperative Institute for Research in the Atmosphere (CIRA) IMPROVE website and EPA's AQS.

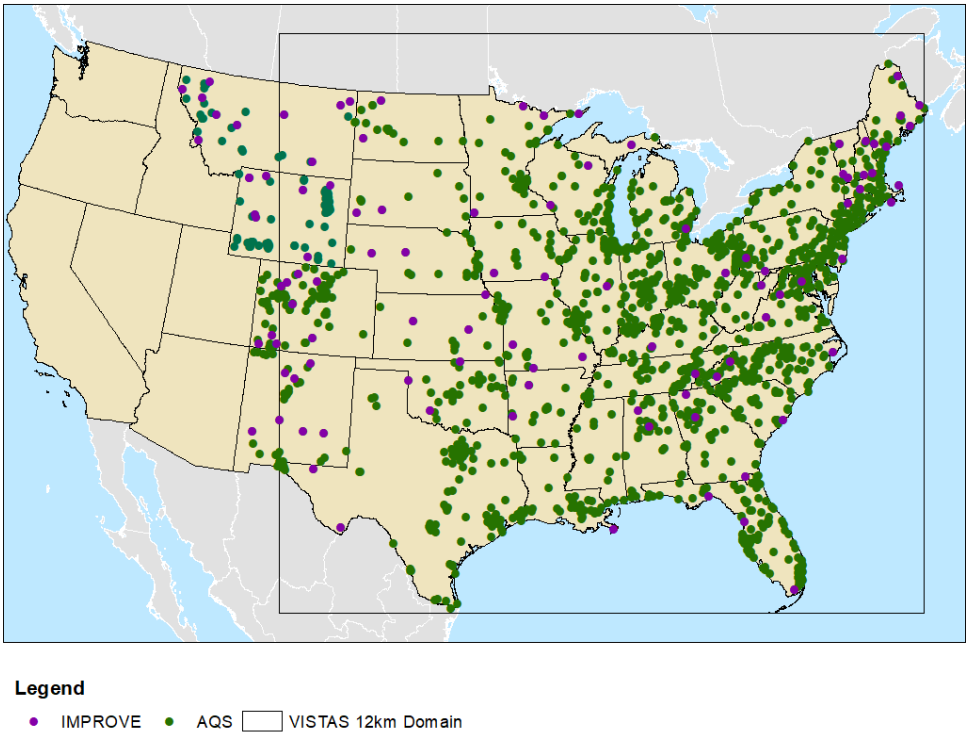

Figure 2-1. Air Quality Monitoring Sites Included in the Database

2.1 Monitoring Networks

2.1.1 IMPROVE

The IMPROVE network is overseen by a collaborative association of state, tribal, and federal agencies, and international partners. EPA is the primary funding source, with contracting and research support from the National Park Service. Collectively, this group is known as CIRA. The Air Quality Group at the University of California, Davis is the central analytical laboratory, with ion analysis provided by Research Triangle Institute, and carbon analysis provided by Desert Research Institute.

During the implementation of the Regional Haze Rule (RHR), IMPROVE was designated as the visibility network to fulfill the monitoring requirements of the RHR. The existing network expanded to 110 monitoring sites representative of 155 of the 156 mandatory Class I areas. The IMPROVE network also includes protocol sites to expand the spatial coverage of the network. The IMPROVE monitoring network has a rigorous quality assurance (QA) program and extensive quality control (QC) and assessment procedures. This includes requiring adherence to the network quality assurance project plan (QAPP)[1] and standard operating procedures (SOPs)[2] for monitoring equipment. Each member of the analytics team submits quality assurance reports[3] annually to affirm adherence to the quality documentation, compliance with the Quality Assurance Plans and Data Quality Objects.

IMPROVE monitors collect 24-hour samples every three days. Filters from the monitoring sites are analyzed for total $PM_{2.5}$ mass, mass of individual $PM_{2.5}$ species (e.g., organic carbon, elemental carbon, sulfate ion, nitrate ion), light absorption, and PM_{10} mass. Select sites also include a nephelometer for optical monitoring. Table 2-1 provides a detailed list of IMPROVE monitoring network measurements included in the database for the VISTAS II project.

[1] http://vista.cira.colostate.edu/improve/wp-content/uploads/2017/01/IMPROVE-QAPP-Signed_3_2016.pdf
[2] Available at: http://vista.cira.colostate.edu/Improve/sops/
[3] IMPROVE quality assurance documentation can be found at: http://vista.cira.colostate.edu/Improve/quality-assurance/

Table 2-1. IMPROVE Monitoring Network Measurements

AQS Parameter Code	Parameter Description	Units[a]
42401	Sulfur Dioxide	µg/m^3 LC
81103	Mass, $PM_{2.5}$ - PM_{10} (Coarse)	µg/m^3 LC
85101	Mass, PM_{10} (Total)	µg/m^3 LC
88101	Mass, $PM_{2.5}$ (Fine)	µg/m^3 LC
88103	Arsenic (Fine)	µg/m^3 LC
88104	Aluminum (Fine)	µg/m^3 LC
88109	Bromine (Fine)	µg/m^3 LC
88111	Calcium (Fine)	µg/m^3 LC
88112	Chromium (Fine)	µg/m^3 LC
88114	Copper (Fine)	µg/m^3 LC
88115	Chlorine (Fine)	µg/m^3 LC
88126	Iron (Fine)	µg/m^3 LC
88128	Lead (Fine)	µg/m^3 LC
88132	Manganese (Fine)	µg/m^3 LC
88136	Nickel (Fine)	µg/m^3 LC
88140	Magnesium (Fine)	µg/m^3 LC
88152	Phosphorus (Fine)	µg/m^3 LC
88154	Selenium (Fine)	µg/m^3 LC
88161	Titanium (Fine)	µg/m^3 LC
88164	Vanadium (Fine)	µg/m^3 LC
88165	Silicon (Fine)	µg/m^3 LC
88167	Zinc (Fine)	µg/m^3 LC
88168	Strontium (Fine)	µg/m^3 LC
88169	Sulfur (Fine)	µg/m^3 LC
88176	Rubidium (Fine)	µg/m^3 LC
88180	Potassium (Fine)	µg/m^3 LC
88184	Sodium (Fine)	µg/m^3 LC
88185	Zirconium (Fine)	µg/m^3 LC
88203	Chloride (Fine)	µg/m^3 LC
88301	Ammonium Ion (Fine)	µg/m^3 LC
88306	Total Nitrate (Fine)	µg/m^3 LC
88307	Carbon, Elemental Total (Fine)	µg/m^3 LC
88320	Carbon, Organic Total (Fine)	µg/m^3 LC
88329	Carbon, Elemental Fraction 1 (Fine)	µg/m^3 LC
88330	Carbon, Elemental Fraction 2 (Fine)	µg/m^3 LC
88331	Carbon, Elemental Fraction 3 (Fine)	µg/m^3 LC
88332	Carbon, Organic Fraction 1 (Fine)	µg/m^3 LC
88333	Carbon, Organic Fraction 2 (Fine)	µg/m^3 LC
88334	Carbon, Organic Fraction 3 (Fine)	µg/m^3 LC
88335	Carbon, Organic Fraction 4 (Fine)	µg/m^3 LC
88336	Carbon, Organic Pyrolized (Fine), by Reflectance	µg/m^3 LC
88337	Hydrogen (Fine)	µg/m^3 LC

Table 2-1. IMPROVE Monitoring Network Measurements

AQS Parameter Code	Parameter Description	Units[a]
88338	Nitrite (Fine)	µg/m^3 LC
88339	Ammonium Sulfate (Fine)	µg/m^3 LC
88344	Ammonium Nitrate (Fine)	µg/m^3 LC
88348	Soil (Fine)	µg/m^3 LC
88350	Carbon, Organic Mass (Fine) (1.8*OC)	µg/m^3 LC
88395	Sea Salt (Fine)	µg/m^3 LC
88401	Mass, $PM_{2.5}$ Reconstructed (Fine)	µg/m^3 LC
88403	Sulfate (Fine)	µg/m^3 LC

[a] LC: local conditions

For the database, total and speciated light extinction (in inverse megameters (Mm^{-1})) and meteorological measurements from the IMPROVE monitoring location were collected via the IMPROVE website.[4] The initial measurements are made in micrograms per cubic meter and converted to local conditions (LC), meaning the volumetric measurements are adjusted based on the temperature and humidity conditions at the observation site. These measurements are then used in the "IMPROVE Equation"[5] to estimate light extinction at each site. The locations of the IMPROVE monitoring sites included in the database are pictured in Figure 2-2.

[4] IMPROVE data is available at: http://views.cira.colostate.edu/fed/DataWizard/Default.aspx

[5] http://vista.cira.colostate.edu/Improve/the-improve-algorithm/

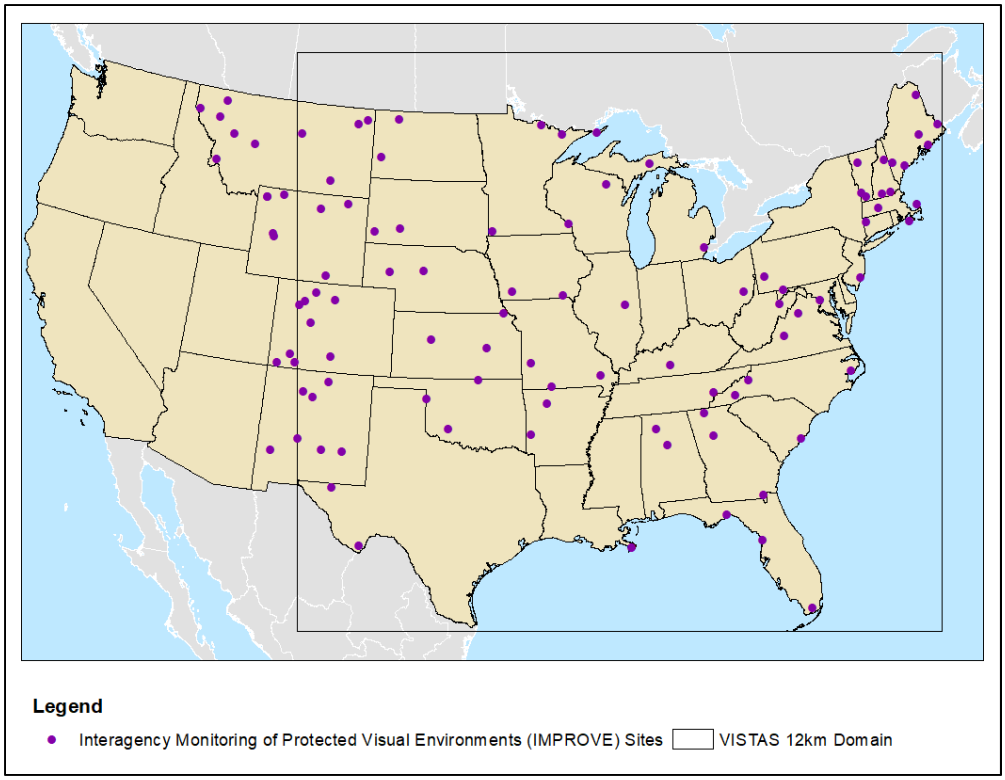

Figure 2-2. IMPROVE Monitoring Sites Included in the Database

2.1.2 EPA's Air Quality System (AQS)

The Air Quality System (AQS)[6] contains ambient air pollution data collected by EPA, state, local, and tribal air pollution control agencies from thousands of monitors across the United States. $PM_{2.5}$ and $PM_{2.5}$ component species information from these sites were aggregated into the air quality databases.

Overall, nearly 1,800 monitors throughout the United States were active during the VISTAS II study period of 2009-2016 and are include in the ambient monitoring database. Figure 2-3 shows the location of these within the VISTAS 12km domain and included in the database. Data were collected from the AQS system.

[6] https://www.epa.gov/aqs

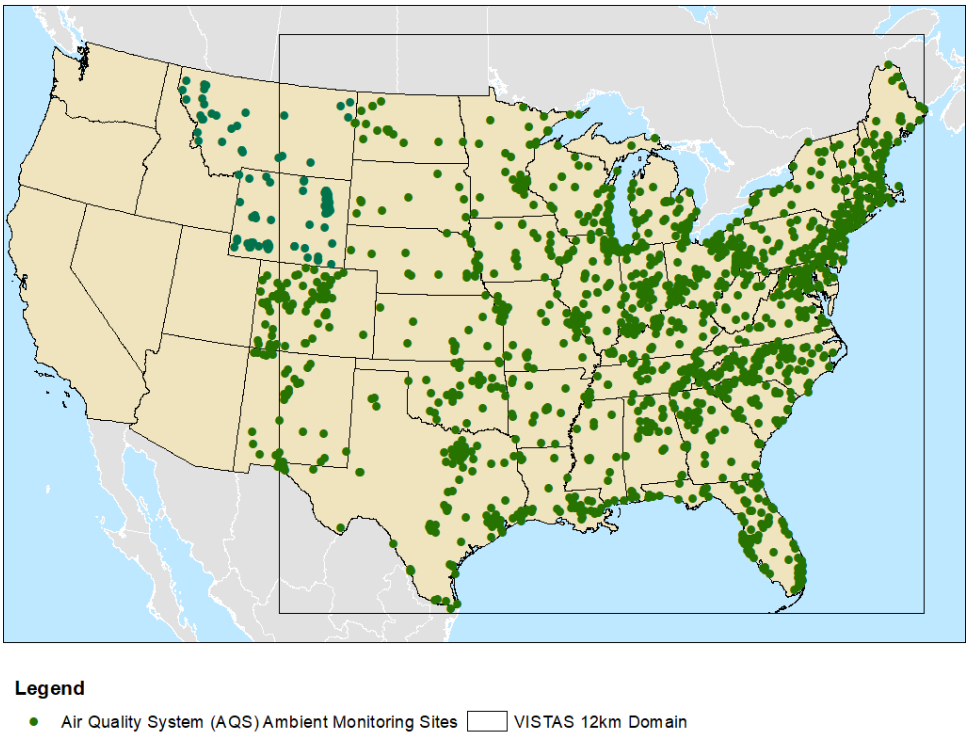

Figure 2-3. AQS Ambient Air Quality Monitoring Sites Included in the Database

2.2 Database Development

Due to its size, the ambient air quality data is split between several databases based on monitor type. The databases are further divided by whether the monitor was in one of the SESARM partner's jurisdictions (SESARM) or outside (Non-SESARM).

The primary data source for the database was from AQS, which contains data from multiple programs, including IMPROVE and Clean Air Status and Trends Network (CASTNET). As such, the IMPROVE and CASTNET data were subsequently removed from the AQS data and placed into their own separate databases.

The SESARM AQS data were split into six zipped Access databases:

- TASK_4_0_AMBIENT_DATABASE_SESARM_2009.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2010.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2011.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2012.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2013.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2014.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2015.zip
- TASK_4_0_AMBIENT_DATABASE_SESARM_2016.zip

Each database includes a single table, AMBIENT_DATABASE_SESARM_STATES, that include all the AQS ambient monitoring data for the year.

For AQS data for NONSESARM states, there are eighteen zipped Access databases, which is made up of three files for each year:

- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2009_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2009_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2009_3.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2010_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2010_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2010_3.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2011_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2011_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2011_3.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2012_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2012_2.zip
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- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2013_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2013_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2013_3.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2014_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2014_2.zip
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- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2015_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2015_3.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2016_1.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2016_2.zip
- TASK_4_0_AMBIENT_DATABASE_NON_SESARM_2016_3.zip

File #1 include the data for January 1 through April 30. File #2 include data for May 1 through August 31. File #3 includes data for September 1 through December 31. Each database includes a single table, AMBIENT_DATABASE_NON_SESARM_STATES, which include all the AQS ambient monitoring data for the calendar period.

The supplemental databases include:

- CASTNET databases (2 zipped database)
  - TASK_4_0_AMBIENT_DATABASE_CASTNET_NON_SESARM_SUPP.zip
  - TASK_4_0_AMBIENT_DATABASE_CASTNET_SESARM_SUPP.zip
- IMPROVE Data (2 zipped databases)

- TASK_4_0_AMBIENT_DATABASE_IMPROVE_SESARM_SUPP.zip
- TASK_4_0_AMBIENT_DATABASE_IMPROVE_NON_SESARM_SUPP.zip

The CASTNET databases contain one table, which holds all the data for the specified area for the entire study period. Similarly, the IMPROVE databases contain one table, which holds all the data for the specified area for the entire study period.

Consistent with the project QAPP, a data definitions tables that describes the contents of each field and unit, where applicable has been provided (AQ_Data_Dictionary.xlsx). ERG also provided a site list, (Air_Quality_Monitoring_Site_Descriptions.xlsx), which includes station metadata such as location information (e.g., latitude, longitude, elevation), site duration, and type. The site list includes also information on the nearest NWS site for coupling meteorological and air quality data. The field names and descriptions of the site list are detailed in Table 2-2.

2.3 Database Quality Assurance

Since CIRA may not have the most recent IMPROVE data uploaded to AQS, ERG download the latest information from CIRA's IMPROVE website to ensure a complete database. The ambient database was screened to ensure no duplicative IMPROVE values were included in the database. Furthermore, each data record has primary keys assigned to ensure that no duplication of data is permissible or that record growth occurs when running queries and assure that there are no duplicate entries. That is, the primary keys prevent erroneous one to many pairs that could create extra row in the data table that are not actual observations. Data entered into these systems have passed QA/QC procedures employed by EPA and the data owners.

All data retrieval will follow data acquisition and handling procedures outlined in the project QAPP.

Table 2-2. Field Names and Descriptions for "Air_Quality_Monitoring_Site_Descriptions"

Field Name	Description
AMA_SITE_CODE	Unique site identifier consisting of 5-digit Federal Information Processing System (FIPS) code and 4-digit site identifier (ID)
STATE_FIPS	2-digit FIPS code for the state
COUNTY_FIPS	3-digit FIPS code for the county
STATE_COUNTY_FIPS	Combined 5-digit FIPS coded for State and County
COUNTY_NAME	Name of the county where the monitor is located
LOCAL_SITE_ID	Site ID designated by the agency maintaining the monitor
SITE_NAME	Site name
ADDRESS	Street address for the site
CITY	City where the site is located
STATE_ABBR	State postal abbreviation
ZIP_CODE	Zip Code where the site is located
EPA_REGION	EPA region (1 through 10) where the monitor is located
SUPPORT_AGENCY_CODE	Code for the Support Agency
SUPPORT_AGENCY	Name of the agency maintaining the monitor
MONITOR_LATITUDE	Site latitude (decimal degrees)
MONITOR_LONGITUDE	Site Longitude (decimal degrees)
DATUM	Coordinate data system
ELEVATION	Elevation of the monitoring site, in meters
LOCATION_TYPE	Type of location
LAND_USE	Land Use Type
DATE_SITE_ESTABLISHED	Date in which the site began operation
DATE_SITE_CLOSED	Date in which the site ceased operations
CBSA_NAME	Core-Based Statistical Area (CBSA) name
CBSA_TYPE	CBSA type (metropolitan or micropolitan)
CLOSEST_NWS_STATION	Name of closest National Weather Service (NWS) meteorological station
CLOSEST_NWS_STATION_WBAN	Weather Bureau Army Navy (WBAN) ID of closest NWS meteorological station

Table 2-2. Field Names and Descriptions for "Air_Quality_Monitoring_Site_Descriptions"

Field Name	Description
CLOSEST_NWS_STATION_DISTANCE_MILES	Distance to closest NWS station in miles
CLOSEST_NWS_STATION_BEARING_FROM_EAST	Bearing angle from the east of the monitoring site and the closest NWS station
SECOND_CLOSEST_NWS_STATION	Name of next closest NWS meteorological station
SECOND_CLOSEST_NWS_STATION_WBAN	Closest NWS station identifier
SECOND_CLOSEST_NWS_STATION_DISTANCE_MILES	Distance to next closest NWS station in miles
SECOND_CLOSEST_NWS_STATION_BEARING_FROM_EAST	Bearing angle from the east of the monitoring site and the second closest NWS station
COMMENT	General comment

3. DEPOSITION DATABASE

Under Subtask 4.1 weekly wet deposition and weekly dry deposition data were organized into a database for potential use by SESARM states or other parties (e.g., Federal Land Managers) to support other projects such as evaluation of acid deposition in watersheds. This following section provides a summary of the monitoring networks and data included in the database.

3.1 Monitoring Networks

ERG aggregated deposition information from the various monitoring networks into a single database for SESARM states. This data can be used to assess the deposition of various pollutant on land and waterways. The primary source for deposition data is the National Atmospheric Deposition Program (NADP).[7] The NADP consists of the following monitoring networks:

- National Trends Network (NTN)
- Atmospheric Integrated Research Monitoring Network (AIRMon)
- Mercury Deposition Network (MDN)
- Atmospheric Mercury Network (AMNet)
- Ammonia Monitoring Network (AMoN)

Additional dry deposition information is available from the CASTNET Network (CASTNET). This data was also collected and is available in the deposition database.

Figure 3-1 shows the spatial distribution of these deposition networks across the United States. All the NADP sites in Figure 3-1 were included in the VISTAS II database. Table 3-1 summarizes the measurements available from each deposition monitoring network. Each network is discussed separately in the following sections.

[7] National Atmospheric Deposition Program (NRSP-3). 2018. NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, Madison, WI 53706. http://nadp.slh.wisc.edu/

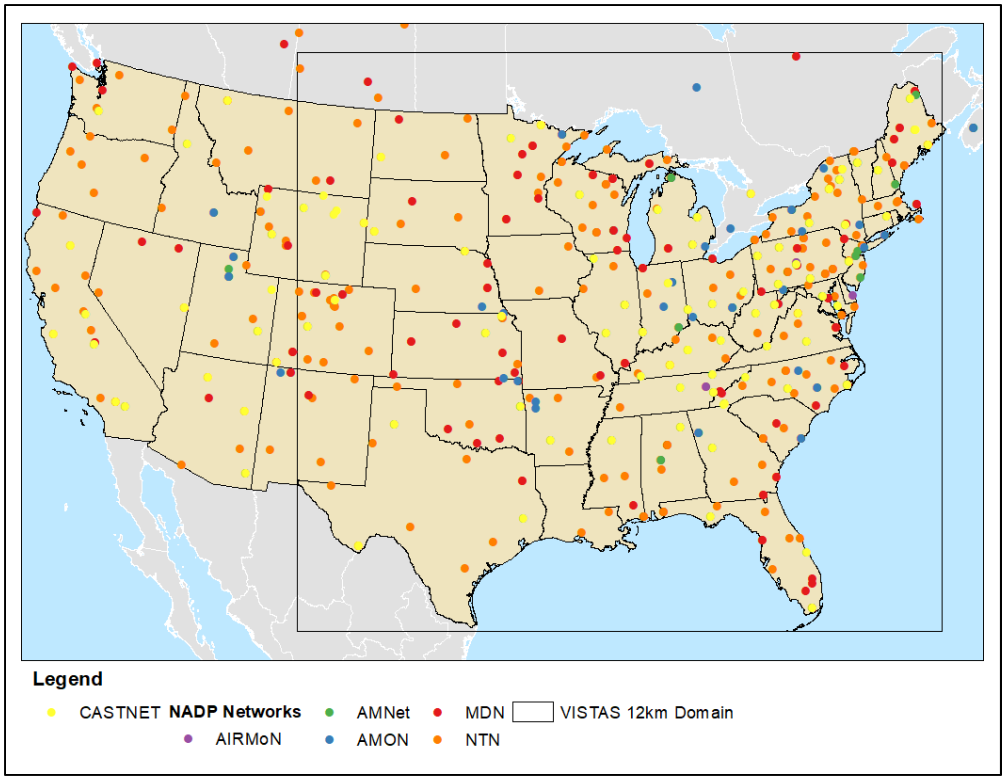

Figure 3-1. Deposition Monitors Included in the VISTAS II Database

Table 3-1. Wet and Dry Deposition Monitoring Network Measurements

Measurement	Wet Deposition			Dry Deposition		
	NTN	MDN	AIRMoN	AMNet	AMoN	CASTNET
Free acidity (H^+ as pH)	✓		✓			
Conductance	✓		✓			
Calcium (Ca^{2+})	✓		✓			✓
Magnesium (Mg^{2+})	✓		✓			✓
Sodium (Na^+)	✓		✓			✓
Potassium (K^+)	✓		✓			✓
Sulfate (SO_4^{2-})	✓		✓			✓
Nitrate (NO_3^-)	✓		✓			✓
Chloride (Cl^-)	✓		✓			✓
Ammonium (NH_4^+)	✓		✓			
Total mercury (Hg) total concentration		✓				✓
Total mercury (Hg) total deposition		✓				
Ammonia (NH_3)					✓	
Particulate Bound Mercury (HgP) concentration				✓		
Average Gaseous Oxidized Mercury				✓		

3.1.1 National Atmospheric Deposition Program (NADP)

The NADP is a clearing house for national deposition data. All networks have quality assurance plans:[8] and SOPs[9] in place to help ensure data comparability and representativeness. Each network is reviewed annually to note operation and equipment changes, as well as perform a QA/QC review to ensure compliance with the Quality Assurance Plans and Data Quality Objects laid out for each network. These QA reports are published on NADP website.[10]

3.1.1.1 National Trends Network (NTN)

The NTN[11] provides a long-term record of wet deposition across the United States. The earliest NTN monitors were brought online in the summer of 1978, with new monitors installed almost every year since. There were 285 active monitors throughout the United States and Canada for at least part of the VISTAS II study period of 2011-2016. All 285 of the monitors were included in the VISTAS II database. Figure 3-2 shows the location of these 285 monitors. Data were collected from the NADP's NTN website.[12]

NTN sites are located away from urban areas and point sources of pollution. Each site has an automated precipitation chemistry collector, which ensures that the sample is exposed only during precipitation (wet-only-sampling). Samples are collected on Tuesday mornings and are sent to the Central Analytical Laboratory (CAL) at the Illinois State Water Survey (ISWS) for analysis, data entry, verification, and screening. Measurements collected include free acidity (H^+ as pH), conductance, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and ammonium (NH_4^+). The CAL conducts additional review of field and lab notes, and flags samples that were mishandled, compromised, or contaminated. Once the data is delivered to NADP, a final review is conducted before data are made available.

[8] QAPP is available at: http://nadp.slh.wisc.edu/lib/qaPlans.aspx
[9] SOPs are available at: http://nadp.slh.wisc.edu/lib/manualsSOPs.aspx
[10] Quality assurance reports are available at: http://nadp.slh.wisc.edu/lib/qaReports.aspx
[11] http://nadp.slh.wisc.edu/NTN/
[12] Data is available for download at: http://nadp.slh.wisc.edu/data/NTN/

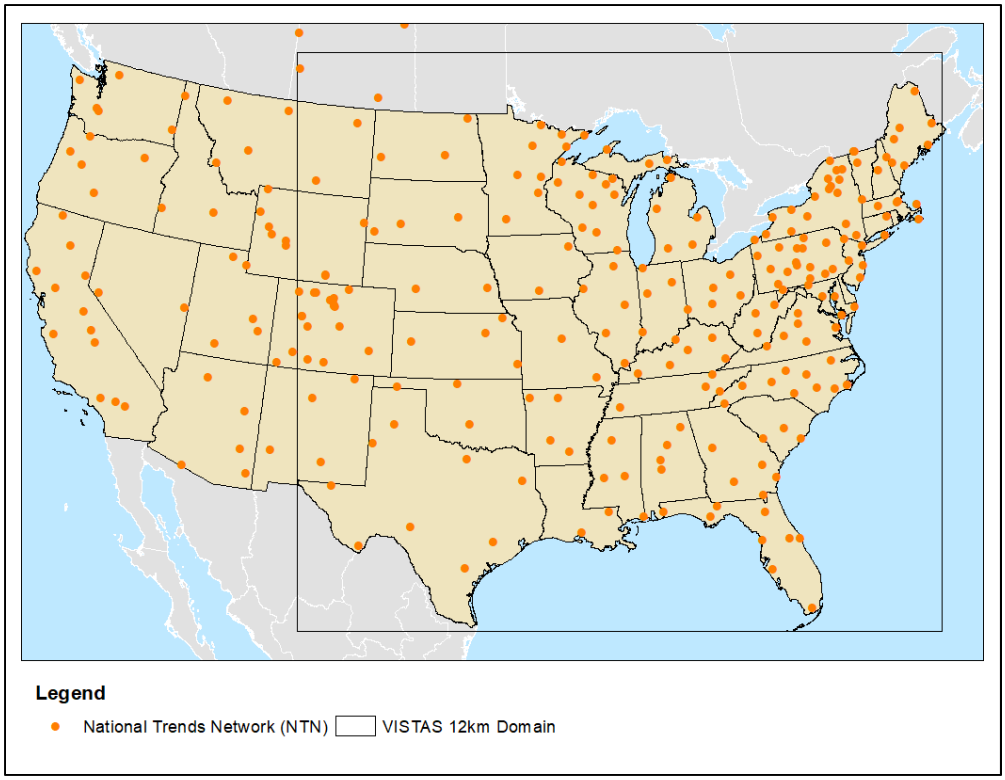

Figure 3-2. NTN Sites in the VISTAS II Deposition Database

3.1.1.2 Atmospheric Integrated Research Monitoring Network (AIRMoN)

AIRMoN[13] was incorporated into NADP in 1992. The AIRMoN sites have the same equipment used at NTN sites. Samples are analyzed by CAL and follow similar handling procedures. The main difference is low volume AIRMoN samples are not diluted to accommodate complete analysis like NTN.

The AIRMon sites collects weekly wet deposition data, include free acidity (H^+ as pH), conductance, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and ammonium (NH_4^+). Data were downloaded from the AIRMoN page on the NADP website.[14] There were 7 active monitors throughout the United States and Canada during the study period, which are included in the deposition database. Figure 3-3 shows the location of the 7 monitors included in the deposition database.

[13] http://nadp.slh.wisc.edu/AIRMoN/
[14] Data are available for download at: http://nadp.slh.wisc.edu/data/AIRMoN/

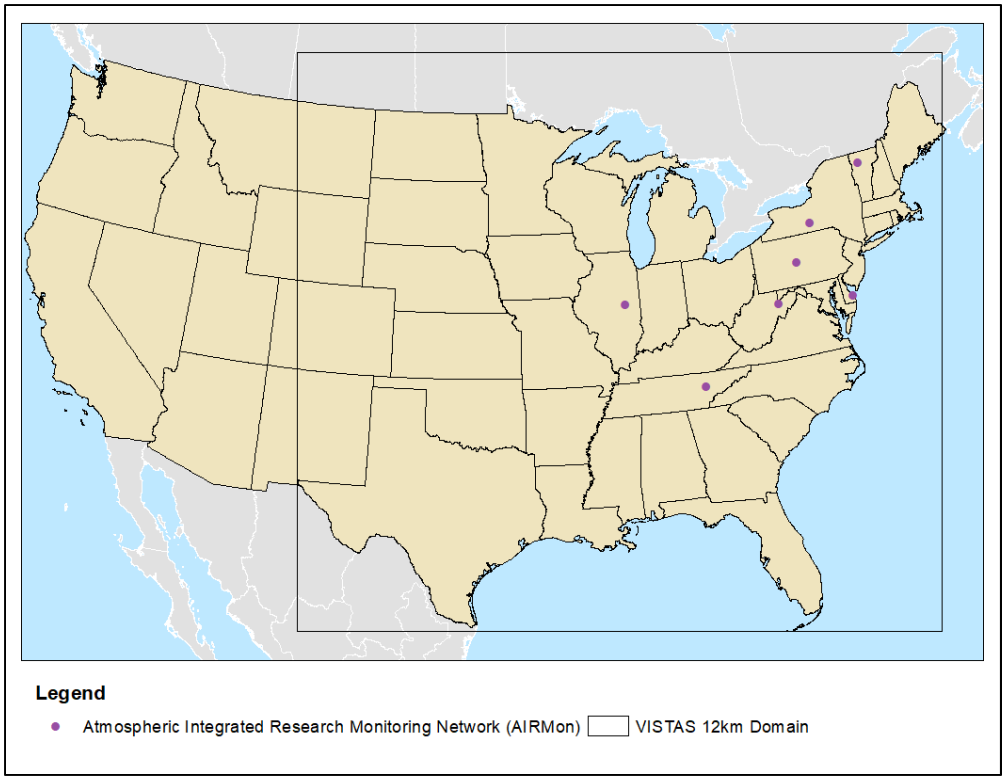

Figure 3-3. AIRMon Sites in the VISTAS II Deposition Database

3.1.1.3 Mercury Deposition Network (MDN)

The MDN[15] provides weekly dry and wet deposition measurement of mercury. MDN site utilize an automated collector similar to the NTN sites, but that has been modified to preserve Mercury. Samples are collected on Tuesdays, or within 24-hours of the start of a precipitation event. Samples are analyzed by the Mercury Analytical Laboratory (HAL) at Eurofins Frontier Global Sciences, Inc., Seattle, Washington. MDN sites follow stringent sampling protocols that enable sites to report mercury concentrations below 1 part per trillion (<1 nanogram/liter). The analysis includes all forms of mercury, which is reported as total mercury concentration.

After analyzing the samples, the HAL conducts additional review of field and lab notes, and flags samples that were mishandled, compromised, or contaminated. Once the data is delivered to NADP, a final review is conducted before data are made available on the NADP website.[16]

[15] http://nadp.slh.wisc.edu/MDN/
[16] Data are available for download at: http://nadp.slh.wisc.edu/data/MDN/

The location of the 138 MDN monitors located across the continental united states are included in the deposition database, and are shown in Figure 3-4.

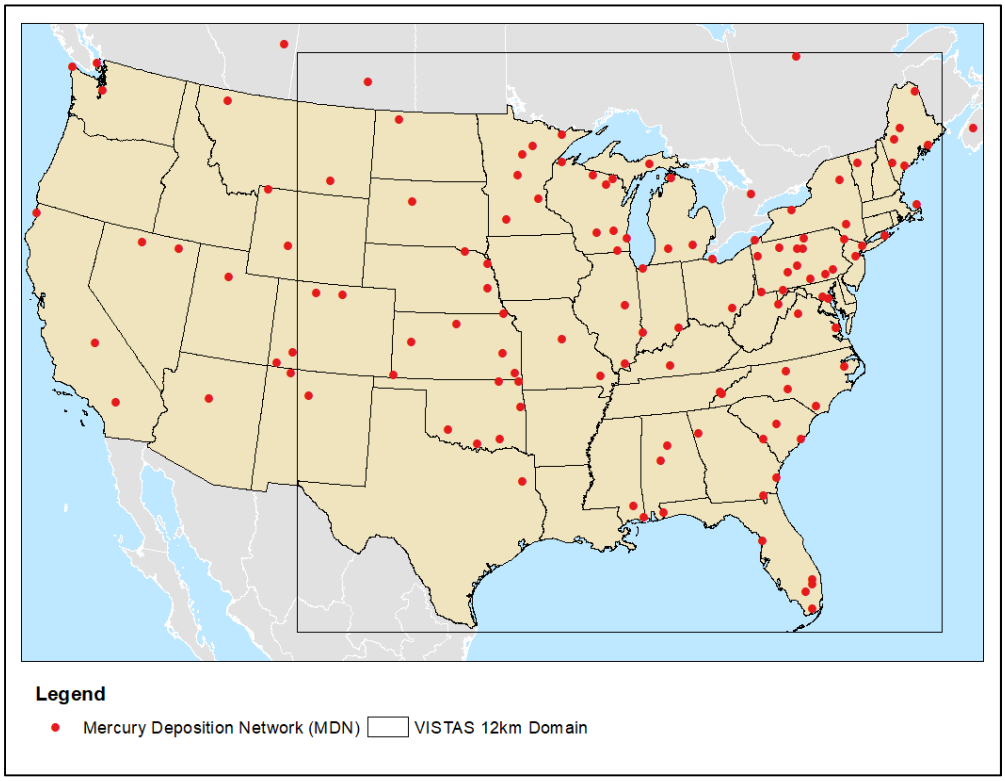

Figure 3-4. MDN Sites in the VISTAS II Deposition Database

3.1.1.4 Atmospheric Mercury Network (AMNet)

AMNet[17] started collecting atmospheric mercury fraction data to estimate dry and total deposition of mercury. Automated continuous measuring system collect concentrations of atmospheric mercury species, total mercury in precipitation, and meteorological measurements. Data are collected using standardized instrumentation, methods, and QA procedures.[18] Data are made available on the NADP website.[19]

There were 33 active monitors throughout the United States and Canada for at least part of the VISTAS II study period of 2011-2016. Figure 3-5 shows the location of the all 33 AMNet monitors, which are included in the database.

[17] http://nadp.slh.wisc.edu/AMNet/
[18] Quality documents and SOPs are available at: http://nadp.slh.wisc.edu/AMNet/docs.aspx
[19] Data are available at: http://nadp.slh.wisc.edu/data/AMNet/

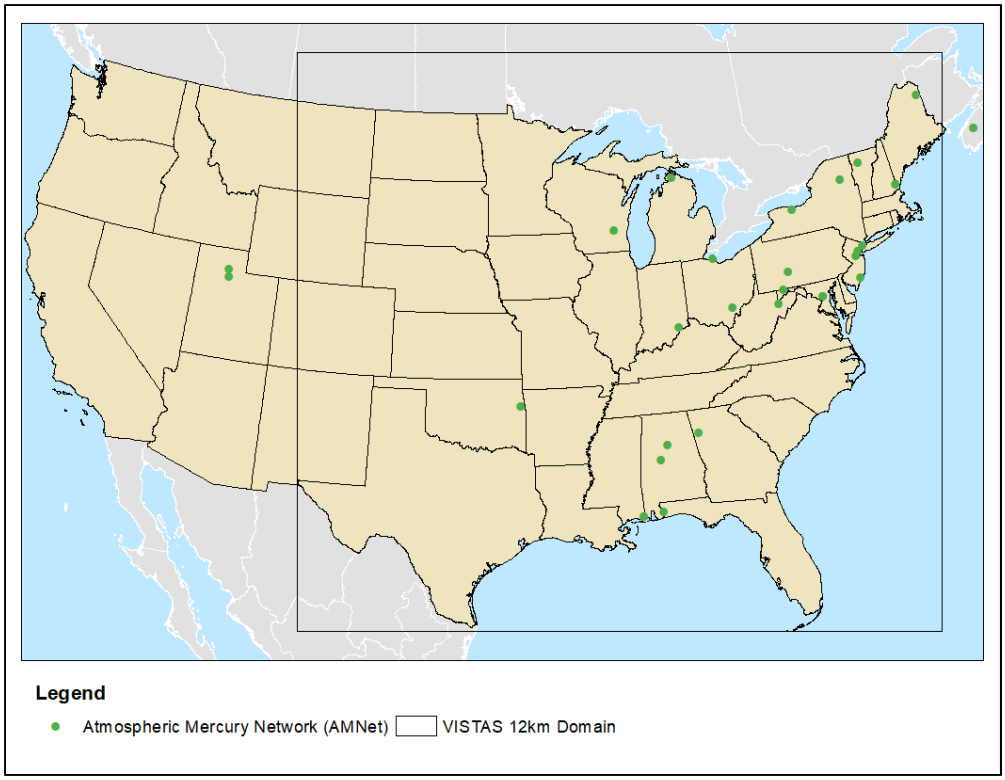

Figure 3-5. AMNet Sites in the VISTAS II Deposition Database

3.1.1.5 Ammonia Monitoring Network (AMoN)

NADP deployed AMoN.[20] sites at most CASNET sites, which record biweekly concentrations of ambient ammonia gas (NH_3^-). With monitoring sites established in 2007, AMoN provides long-term ammonia gas. AMoN utilizes passive samplers, which are deployed for two weeks at a time. AMoN samples are prepared, extracted and analyzed at the NADP's CAL following strict SOPs[21] are available. Data are made available on the NADP website.[22] AMoN site collect multiple, or replicate, samples for each sampling period. The database includes the individual replicate values and the NADP processed average of the samples.

There were 105 active monitors throughout the United States and Canada between 2011-2016. Figure 3-6 shows the location of the 105 AMoN site, which are included in the VISTAS II deposition database.

[20] http://nadp.slh.wisc.edu/AMoN/
[21] Available at: http://nadp.slh.wisc.edu/AMoN/amon-standardoperatingprocedures.pdf
[22] Data available at: http://nadp.slh.wisc.edu/data/AMoN/

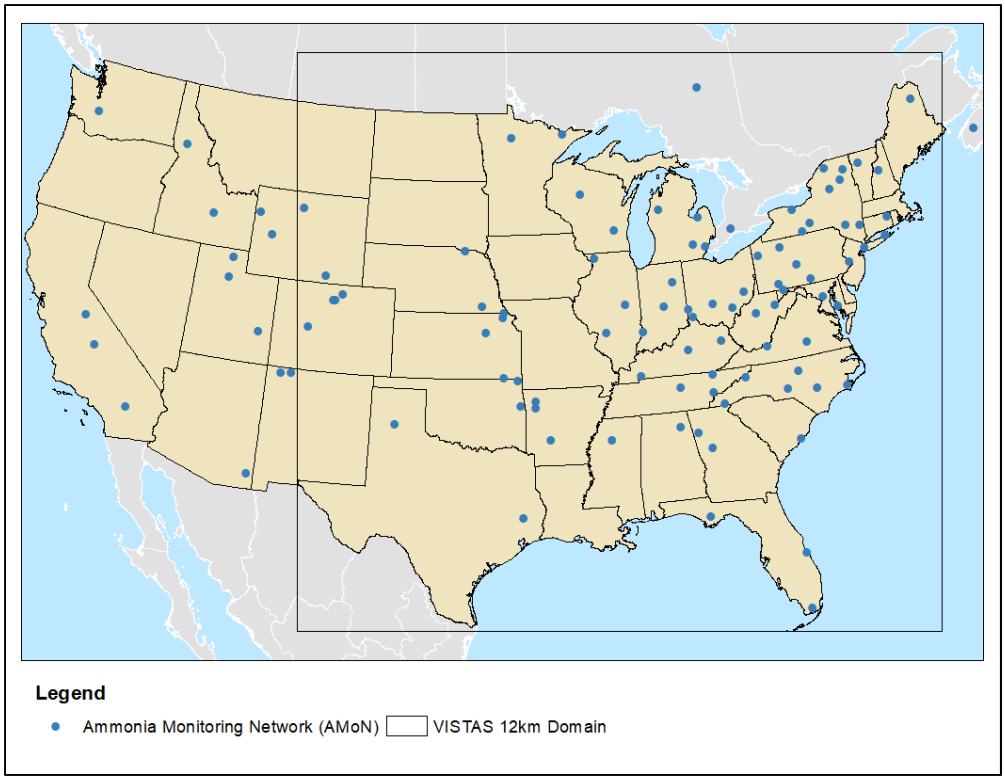

Figure 3-6. AMoN Sites in the VISTAS II Deposition Database

3.1.2 Clean Air Status and Trends Network (CASTNET)

CASTNET[23] is a long-term rural monitoring network with 95 sites located throughout the United States and Canada. The network was established under the 1991 Clean Air Act Amendments to assess the trends in acidic deposition due to emission reduction programs.

The CASTNET, provides weekly measurements of sulfur dioxide (SO_2), nitric acid (HNO_3), particulate sulfate (SO_4^{-2}), nitrate (NO_3^-), ammonium (NH_4^+), base cations (Mg^{+2}, Ca^{+2}, K^+, and Na^+), and chloride ion (Cl^-) for deposition analysis, as well as several ambient concentrations on an hourly basis. Data collection and analysis follow QAPP and SOPs, which are available on the CASTNET website.[24] Data are available through AQS and the CASTNET website.[25]

[23] https://www.epa.gov/castnet
[24] Quality documents are available on: https://java.epa.gov/castnet/documents.do
[25] Data are available at: https://java.epa.gov/castnet/clearsession.do

Figure 3-7 shows the location of the CASTNET sites included in the database. There were 98 active monitors throughout the United States and Canada for at least part of the VISTAS II study period of 2011-2016, which are all included in the database.

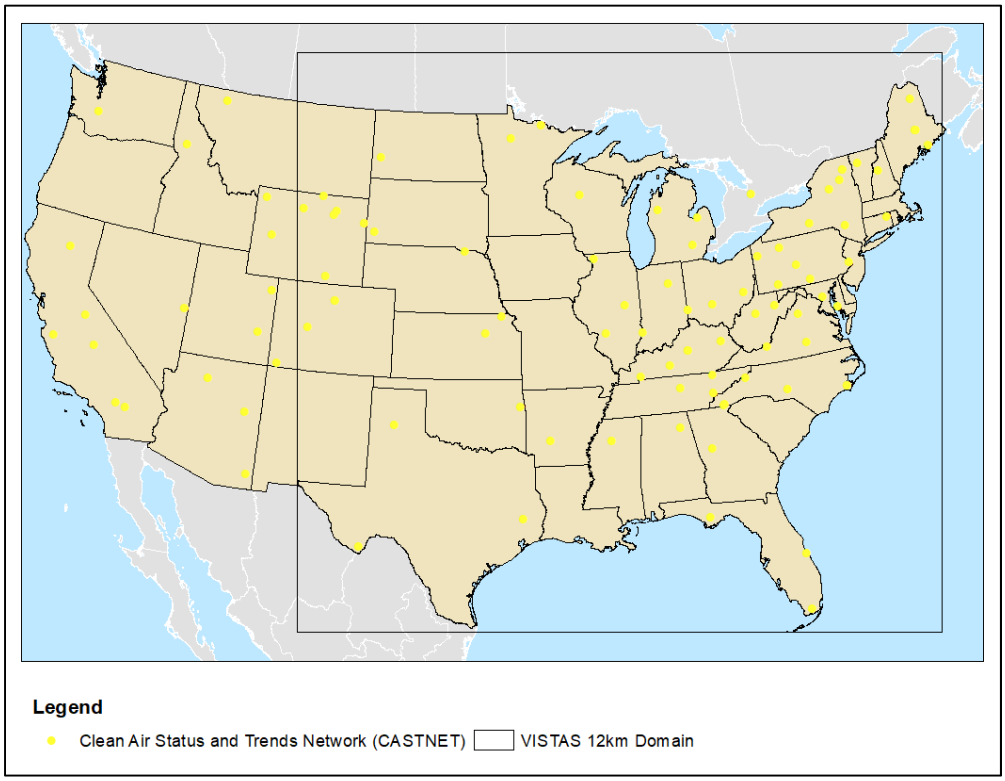

Figure 3-7. CASTNET Sites in the VISTAS II Deposition Database

3.2 Database Development

The deposition database (DepositionData_2011-2016.accdb) consists of eight tables:

- **AIRMoN_2011-2016**: Weekly AIRMoN data collected between 2011 and 2016
- **AMNet_2011-2016**: Weekly AMNet data collected between 2011 and 2016
- **2016AMoN_AVE_2011-2016**: Weekly average of replicate sample from AMoN sites collected between 2011 and 2016
- **AMoN_REP_2011-2016**: Weekly individual replicate samples collected at AMoN sites between 2011 and 2016
- **MDN_2011-2016**: Weekly MDN data collected between 2011 and 2016
- **NTN_2011-2016**: Weekly NTN data collected between 2011 and 2016
- **CASTNET_2011-2016**: data collected between 2011 and 2016
- **Deposition_Sites**: comprehensive list of the sites in each monitoring network.

All data were downloaded directly from the NADP and CASTNET website and uploaded into an Access database. The "start" and "stop" dates of the samples were used to filter the table

to the 2011 to 2016 VISTAS II study period. Those entries that were collected after 12/31/2010 and before 01/01/2017 were extracted into separate tables.

Consistent with the project QAPP, a data dictionary containing descriptions of the fields in each table is provided (Deposition_Data_Dictionary.xlsx).

Consistent with the project QAPP, the database includes table (Deposition_Sites) with all the sites in the database and pertinent metadata. The field names and descriptions of the site list are detailed in Table 3-2.

Table 3-2. Field Names and Descriptions for Table "Deposition_Sites"

Field Name	Description
network	Monitoring network name. (e.g., NTN, MDN)
siteid	4 digit site ID (first two digits are the state abbreviation, followed by a two digit number).
siteName	Site name
county	County name
state	State postal abbreviation
latitude	Site latitude (decimal degrees)
longitude	Site Longitude (decimal degrees)
elevation	site elevation (in meters)
status	Operational Status (A= Active, I = inactive)
startdate	Start date for the site, reported in Greenwich Mean Time (GMT); YYYY-MM-DD hh:mm format
stopdate	End date for the site, reported in Greenwich Mean Time (GMT); YYYY-MM-DD hh:mm format
start	Start date, without time
stop	End date, without time

3.3 Database Quality Assurance

Consistent with the QAPP, all original files (i.e., data downloaded from network websites) was sequestered from the project working files to preserve the original data. Data sheet were imported into Access for filtering. When additional fields were added (i.e., start, stop), the working database preserved the queries used to generate the fields for QA/QC review. Review was conducted by a second analyst, who was not part of the deposition field gathering and database development.

Fields from the original source were preserved throughout the process and are present in the final data table. Additionally, each data record has primary keys assigned to ensure that no duplication of data is permissible or that record growth occurs when running queries.

4. METEOROLOGICAL DATABASE

Hourly meteorological measurements obtained from the National Centers for Environmental Information (NCEI) for the Weather Bureau Army-Navy (WBAN) sites, which include National Weather Service (NWS) Automated Surface Observing Systems (ASOS) and Federal Aviation Administration (FAA) Automated Weather Observing System (AWOS) sites. Hourly data from EPA's AQS sites are also included in the database.

Meteorological data is provided to support additional analysis by states that may arise when developing regional haze SIPs. Figure 4-1 shows the spatial distribution of the meteorological networks across the United States. Table 4-1 summarizes the measurements provided from each meteorological monitoring network. Each network is discussed separately in the following sections.

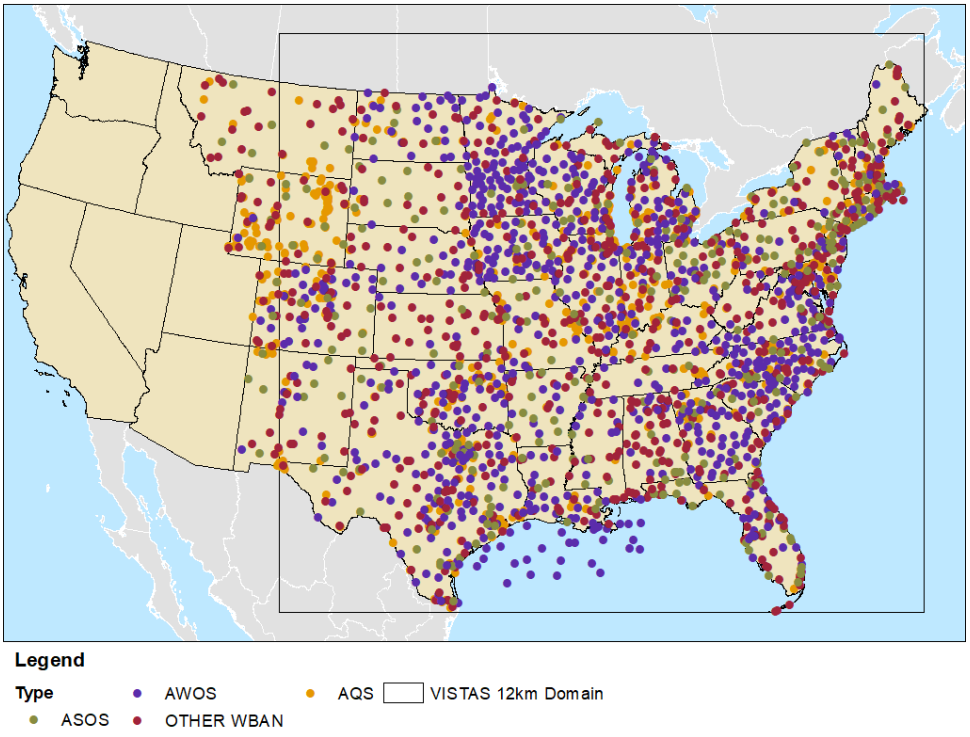

Figure 4-1. Meteorological Monitoring Sites Included in the VISTAS II Database

Table 4-1. Meteorological Monitoring Network Measurements Included

Observation	Parameter Code	AQS*	NWS*	TAMIS*
Wind Speed (mph or kts)	61101	✓	✓	✓
Wind Direction (degrees)	61102	✓	✓	✓
Resultant Speed (mph or kts)	61103	✓		
Resultant Direction (degrees)	61104	✓		
Sky Condition	--		✓	
Visibility	--		✓	
Weather Type	--		✓	
Temperature (F)	--		✓	
Dew Point (F)	--		✓	
Station Pressure (in Hg)	--		✓	
Sea Level Pressure (mb)	--		✓	
Hourly precipitation (in)	--		✓	

* Air Quality System (AQS), National Weather Service (NWS), Texas Air Monitoring Information System (TAMIS)

4.1 Monitoring Networks

4.1.1 AQS

In addition to ambient concentrations, EPA's AQS contains meteorological data from collocated towers. These data are reported by the agency operating the monitor to AQS. Operators adhere to collection and quality standards established by EPA. Figure 4-2 shows the location of the AQS meteorological sites included in the database. There were 681 active AQS meteorological monitors throughout the United States during the study period.

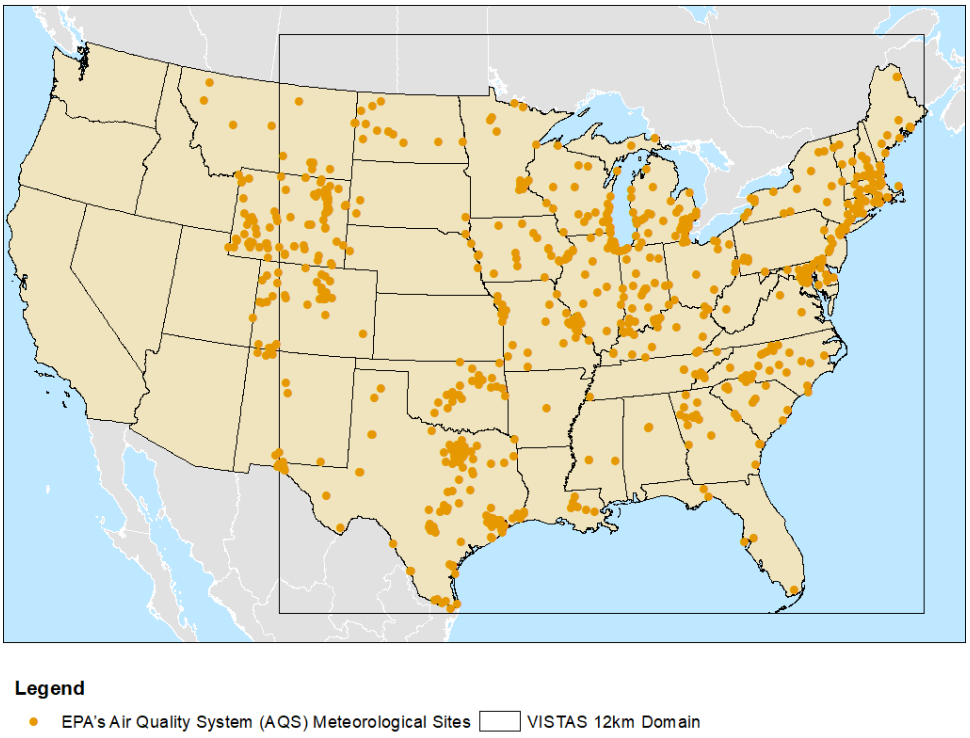

Figure 4-2. AQS meteorological Monitoring Sites Included in the VISTAS II Database

4.1.2 Weather Bureau Army-Navy (WBAN) Sites

WBAN number were the first attempt at a standardized station numbering system across various weather reporting agencies. The WBAN site list is comprised of ASOS, AWOS, and various other observation sites. For the database, only hourly data was included form the various WBAN networks. For summary purposes, the ASOS and AWOS sites were identified separately from the other networks and are described below.

4.1.2.1 Automated Surface Observing Systems (ASOS)

ASOS sites are managed by the National Weather Service and serve meteorological and aviation observing needs. Sites are typically collocated with airports but can be sited at other strategic locations. ASOS sites report hourly observations and special observations during rapid shift in weather and for changing aviation needs. Figure 4-3 shows the location of the ASOS

sites included in the database. There were 309 active monitors throughout the United States during the study period. Hourly data was obtained from NCEI.[26]

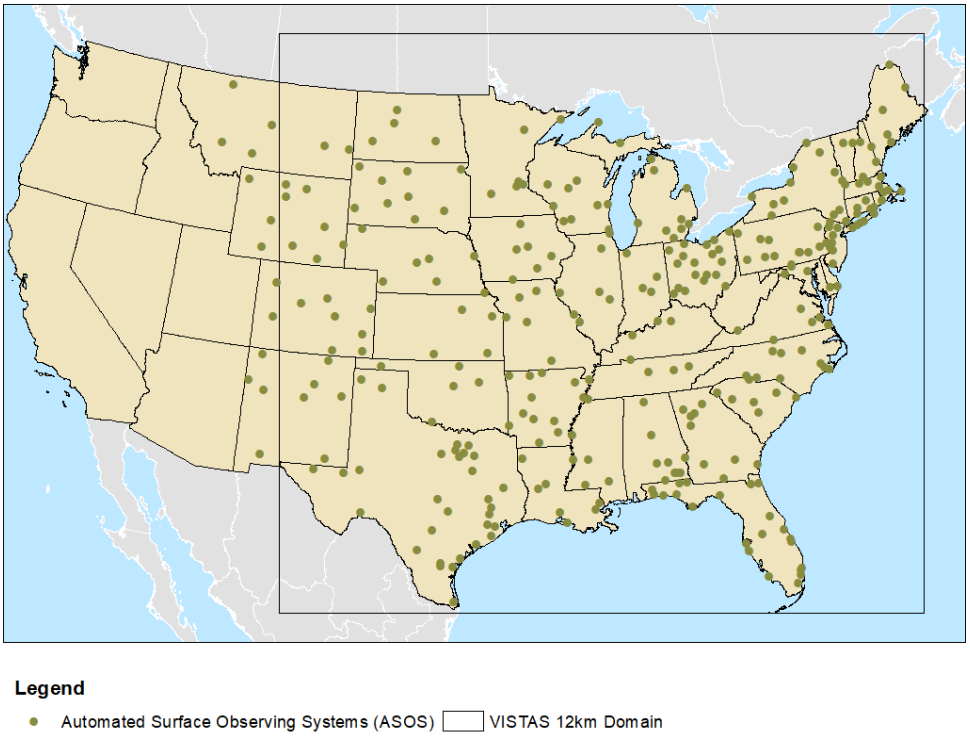

Figure 4-3. ASOS Meteorological Monitoring Sites Included in the VISTAS II Database

4.1.2.2 Automated Weather Observing System (AWOS)

AWOS sites are operated by the FAA, and generally fulfill observational needs for aviation. AWOS provides a similar suite of measurements as the ASOS sites, but report at 20-minute intervals. Figure 4-4 shows the location of the AWOS sites included in the database. There were 777 active monitors throughout the United States during the study period. Hourly data was obtained from NCEI.[27]

[26] Data available at: https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/automated-surface-observing-system-asos

[27] Data are available at: https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/automated-weather-observing-system-awos

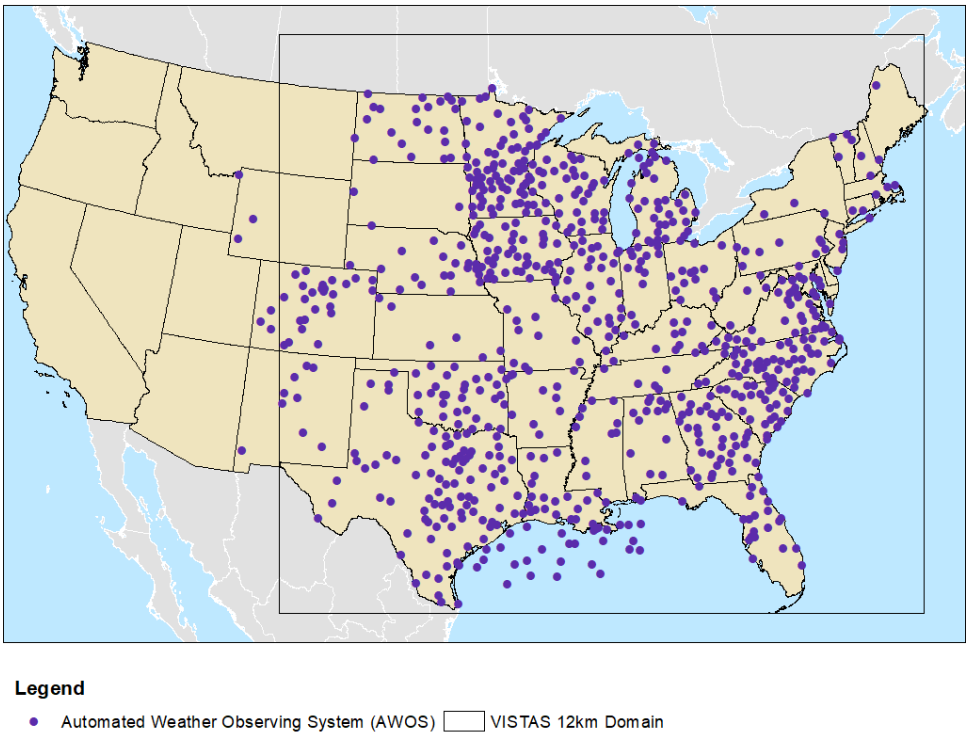

Figure 4-4. AWOS Meteorological Monitoring Sites Included in the VISTAS II Database

4.1.2.3 Additional Weather Bureau Army-Navy (WBAN)

The additional WBAN sites include the U.S. Historical Climatology Network (USHCN), U.S. Climate Reference Network (USCRN), U.S. Regional Climate Reference Network (USRCRN), and other various Military, Weather Service, Airways sites.[28] In all, there were 660 additional WBAN active monitors throughout the United States during the study period. Hourly data was obtained from NCEI.[29] Figure 4-5 shows the location of the other WBAN sites included in the database.

[28] https://www.ncdc.noaa.gov/homr/
[29] https://www.ncdc.noaa.gov/homr/reports/platforms

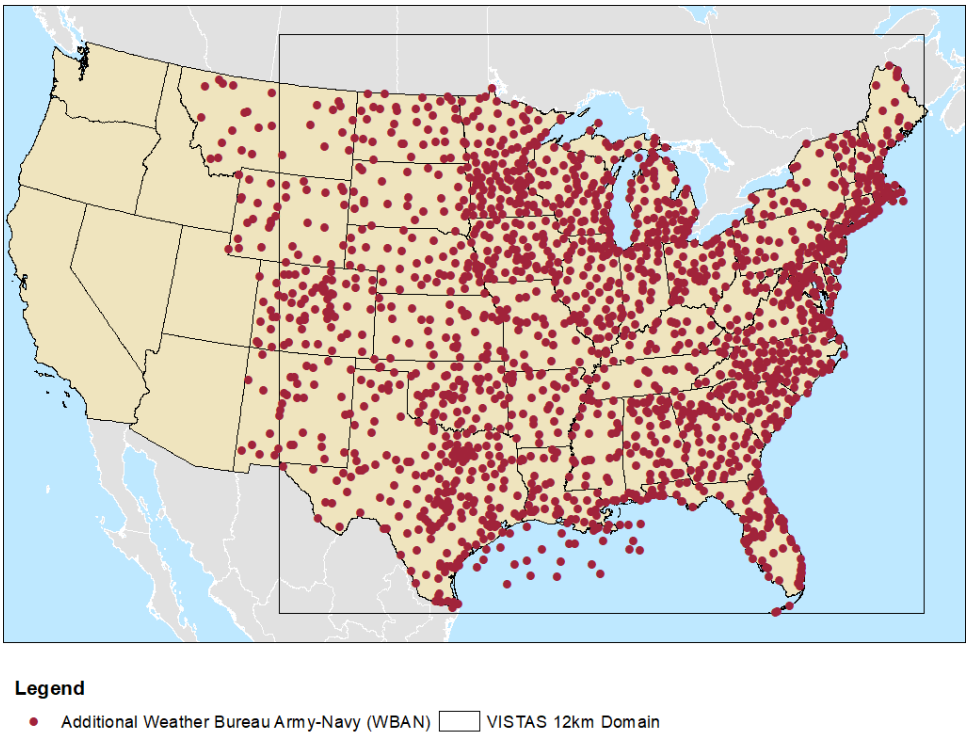

Figure 4-5. Other WBAN Meteorological Monitoring Sites Included in the VISTAS II Database

4.2 Database Development

Due to its size, the meteorological data is split between several databases. Similar to the ambient databases, the meteorological databases are divided by network (i.e, NWS, AQS, TAMIS) and then further divided by whether the monitor was in one of the SESARM partner's jurisdictions (SESARM) or outside (Non-SESARM).

For the NWS data, the data within the SESARM states are presented in six zipped Access databases:

- NWS_SESARM_10_States_2011.zip
- NWS_SESARM_10_States_2012.zip
- NWS_SESARM_10_States_2013.zip
- NWS_SESARM_10_States_2014.zip
- NWS_SESARM_10_States_2015.zip
- NWS_SESARM_10_States_2016.zip

Each database includes one table, NWS_SESARM_10_STATES**,** which holds all the meteorological data for the year.

For NWS data for NONSESARM states, there are eighteen zipped Access databases, which is made up of three files for each year:

- NWS_VISTAS_NON_SESARM_2011_1.zip
- NWS_VISTAS_NON_SESARM_2011_2.zip
- NWS_VISTAS_NON_SESARM_2011_3.zip
- NWS_VISTAS_NON_SESARM_2012_1.zip
- NWS_VISTAS_NON_SESARM_2012_2.zip
- NWS_VISTAS_NON_SESARM_2012_3.zip
- NWS_VISTAS_NON_SESARM_2013_1.zip
- NWS_VISTAS_NON_SESARM_2013_2.zip
- NWS_VISTAS_NON_SESARM_2013_3.zip
- NWS_VISTAS_NON_SESARM_2014_1.zip
- NWS_VISTAS_NON_SESARM_2014_2.zip
- NWS_VISTAS_NON_SESARM_2014_3.zip
- NWS_VISTAS_NON_SESARM_2015_1.zip
- NWS_VISTAS_NON_SESARM_2015_2.zip
- NWS_VISTAS_NON_SESARM_2015_3.zip
- NWS_VISTAS_NON_SESARM_2016_1.zip
- NWS_VISTAS_NON_SESARM_2016_2.zip
- NWS_VISTAS_NON_SESARM_2016_3.zip

Each database includes a single table, NWS_NON_SESARM_VISTAS_DOMAIN, which include all the meteorology data for the calendar period. File #1 include the data for January 1 through April 30. File #2 include data for May 1 through August 31. File #3 includes data for September 1 through December 31.

For the AQS Data, all states, that is SESARM and NONSESARM, are contained in separate zipped Access databases for each year:

- TASK_4_0_MET_DATABASE_AQS_2011.zip
- TASK_4_0_MET_DATABASE_AQS_2012.zip
- TASK_4_0_MET_DATABASE_AQS_2013.zip
- TASK_4_0_MET_DATABASE_AQS_2014.zip
- TASK_4_0_MET_DATABASE_AQS_2015.zip
- TASK_4_0_MET_DATABASE_AQS_2016.zip

All database contains a single table, MET_DATABASE_AQS_VISTAS_DOMAIN, with all the data for the year.

The Texas Air Monitoring Information System (TAMIS) provides additional meteorological data for the state of Texas. This additional Texan data is provided in a separate

zipped Access database file, TASK_4_0_MET_DATABASE_TAMIS_2011_2016.zip. The database has a single table, MET_DATABASE_TAMIS_2011_2016, which holds all the data for the 2011-2016 for all the TAMIS sites.

Lastly, Florida DEP provided relative humidity (RH) data at the St. Marks, FL IMPROVE site (SAMA1.txt).

Consistent with the project QAPP, a data dictionary containing description of the fields in each table is provided (METEOROLOGY_Data_Dictionary.xlsx). Additionally, the spreadsheet (Meteorological_Site_list.xlsx) contains information on all the meteorological sites included in the databases. The AQS site list includes information on the nearest NWS site for data substitution/replacement purposes. The field names and descriptions of the site list are detailed in Table 4-2.

Table 4-2. Field Names and Descriptions for Table "Meteorological_Site_List"

Field Name	Description
AMA_SITE_CODE	Unique site identifier consisting of 5-digit FIPS code and 4-digit site id
STATE_FIPS	2-digit FIPS code for the state
COUNTY_FIPS	3-digit FIPS code for the county
STATE_COUNTY_FIPS	Combined 5-digit FIPS coded for State and County
COUNTY_NAME	Name of the county where the monitor is located
LOCAL_SITE_ID	Site ID designated by the agency maintaining the monitor
SITE_NAME	Site name
ADDRESS	Street address for the site
CITY	City where the site is located
STATE_ABBR	State postal abbreviation
ZIP_CODE	Zip Code where the site is located
EPA_REGION	EPA region (1 through 10) where the monitor is located
SUPPORT_AGENCY_CODE	Code for the Support Agency
SUPPORT_AGENCY	Name of the agency maintaining the monitor
MONITOR_LATITUDE	Site latitude (decimal degrees)
MONITOR_LONGITUDE	Site Longitude (decimal degrees)
DATUM	Coordinate data system
ELEVATION	Elevation of the monitoring site, in meters
LOCATION_TYPE	Type of location

Table 4-2. Field Names and Descriptions for Table "Meteorological_Site_List"

Field Name	Description
LAND_USE	Land Use Type
DATE_SITE_ESTABLISHED	Date in which the site began operation
DATE_SITE_CLOSED	Date in which the site ceased operations
CBSA_NAME	Core-Based Statistical Area name
CBSA_TYPE	CBSA type (metropolitan or micropolitan)
CLOSEST_NWS_STATION	Name of closest NWS meteorological station
CLOSEST_NWS_STATION_WBAN	WBAN ID of closest NWS meteorological station
CLOSEST_NWS_STATION_DISTANCE_MILES	Distance to closest NWS station in miles
CLOSEST_NWS_STATION_BEARING_FROM_EAST	Bearing angle from the east of the monitoring site and the closest NWS station
SECOND_CLOSEST_NWS_STATION	Name of next closest NWS meteorological station
SECOND_CLOSEST_NWS_STATION_WBAN	Closest NWS station identifier
SECOND_CLOSEST_NWS_STATION_DISTANCE_MILES	Distance to next closest NWS station in miles
SECOND_CLOSEST_NWS_STATION_BEARING_FROM_EAST	Bearing angle from the east of the monitoring site and the second closest NWS station
COMMENT	General comment

4.3 Database Quality Assurance

Consistent with the QAPP, all original files (i.e., data downloaded from original sources) were sequestered from the project working files to preserve the original data. When additional fields were added (i.e., alternate units), ERG's comprehensive environmental database retains the original fields for QA/QC review. Review was conducted by a second analyst, who was not part of the deposition field gathering and database development. Each data record has primary keys assigned to ensure that no duplication of data is permissible or that record growth occurs when running queries.

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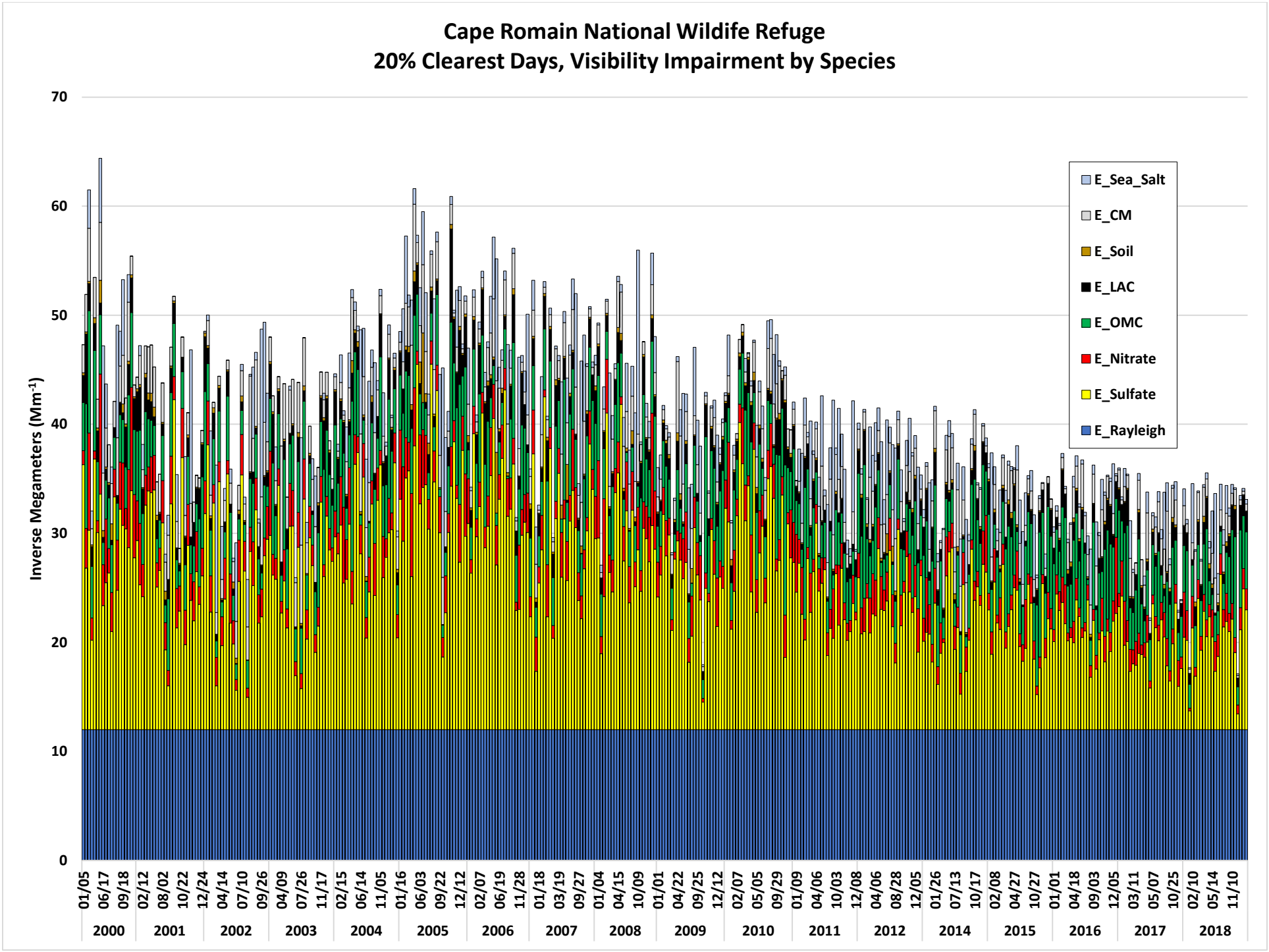
Cape Romain National Wildife Refuge
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
01/05
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09/18
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08/02
10/22
12/24
04/14
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04/09
07/26
11/17
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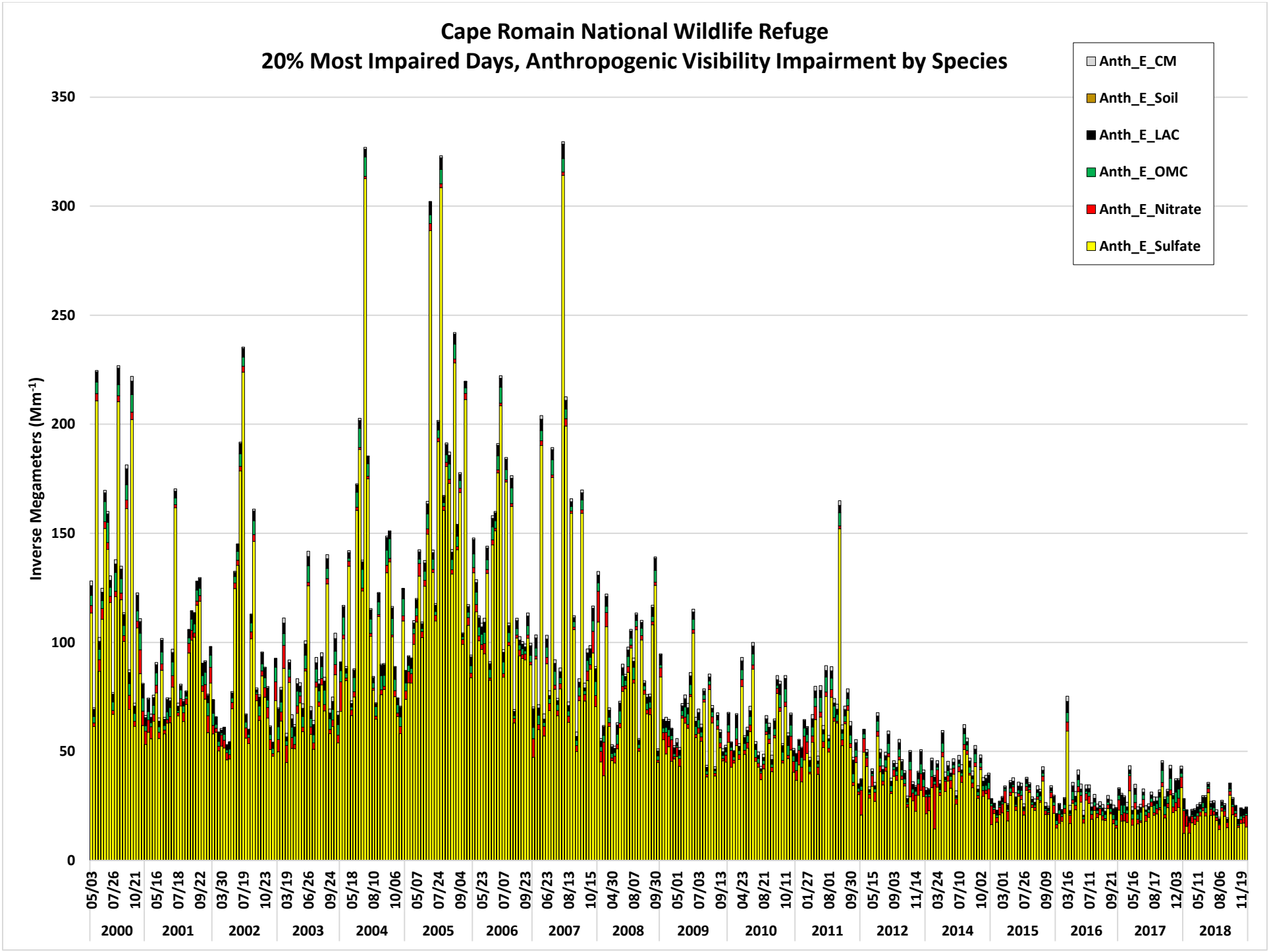
Cape Romain National Wildlife Refuge
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
Inverse Megameters (Mm-1)
350
300
250
200
150
100
50
0
05/03
07/26
10/21
05/16
07/18
09/22
03/30
07/19
10/23
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04/30
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05/01
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01/27
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09/30
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11/14
03/24
07/10
10/02
03/01
07/26
09/09
03/16
07/11
09/21
05/16
08/17
12/03
05/11
08/06
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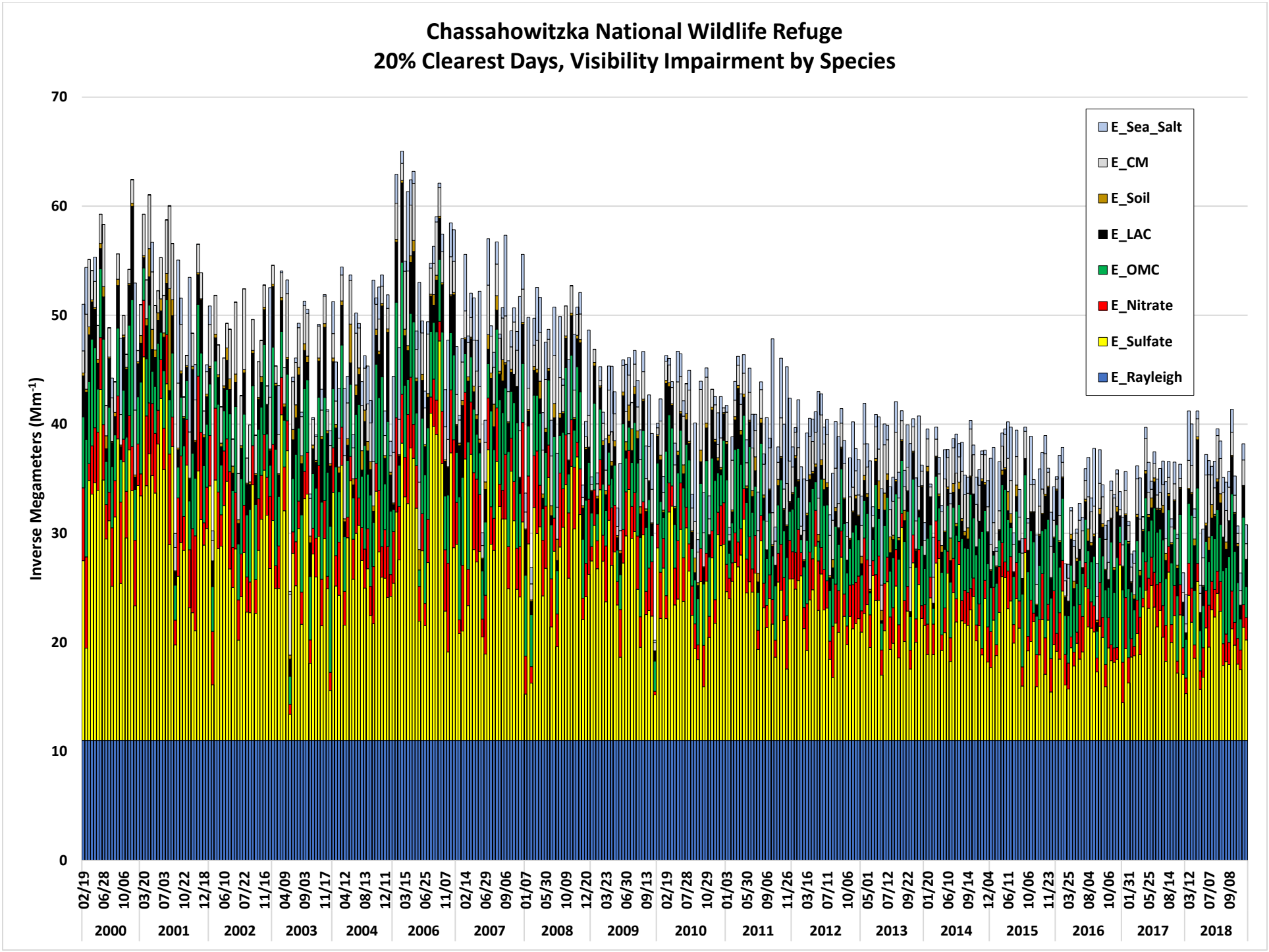
2012
2014
2015
2016
2017
2018


Chassahowitzka National Wildlife Refuge
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
02/19
06/28
10/06
03/20
07/03
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12/18
06/10
07/22
11/16
04/09
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03/15
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03/23
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01/03
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09/06
11/26
03/16
07/11
10/06
05/01
07/12
09/22
01/20
06/10
09/14
12/04
06/11
10/06
11/23
03/25
08/04
10/06
01/31
05/25
08/14
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07/07
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2017
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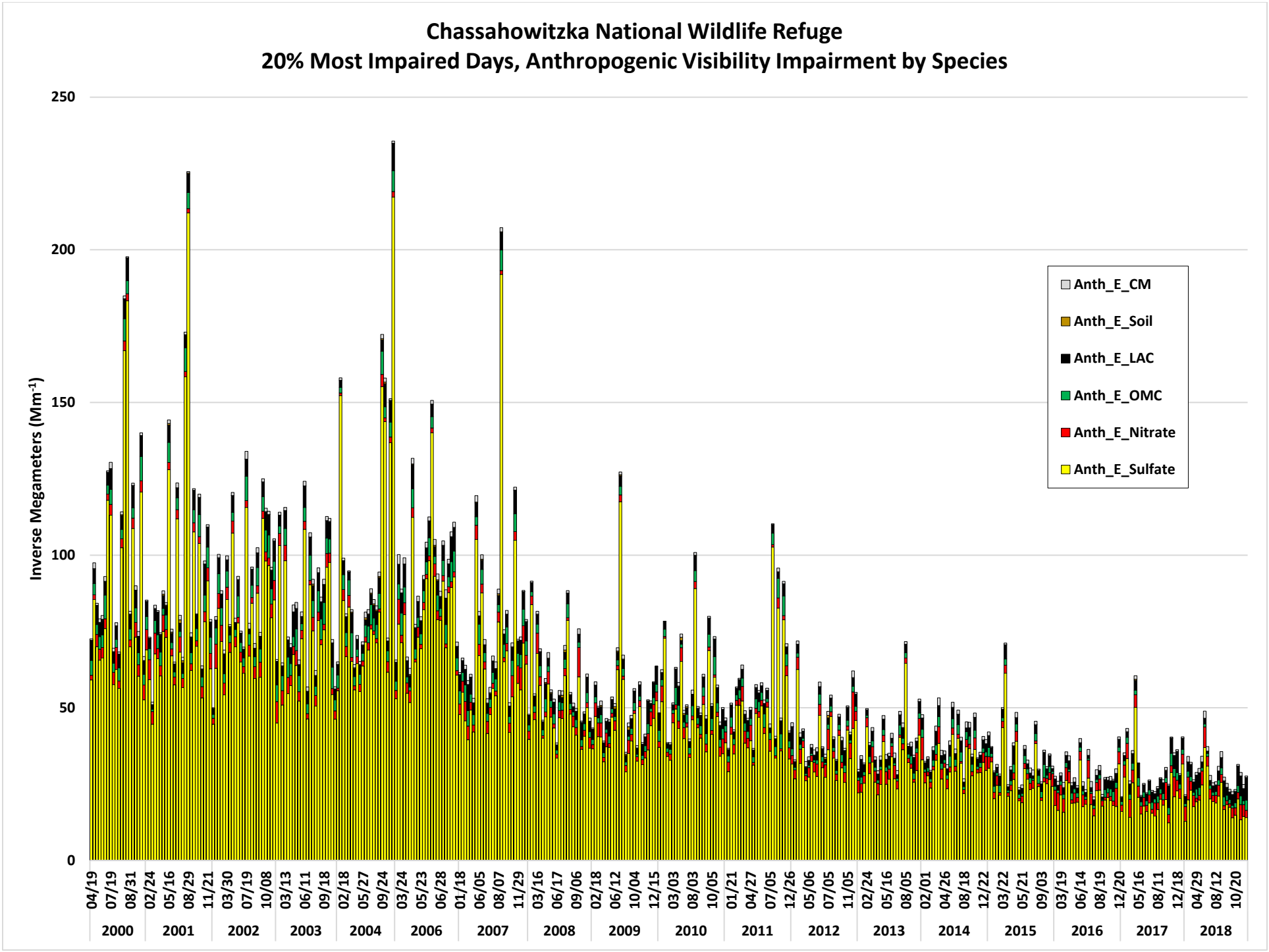
Chassahowitzka National Wildlife Refuge
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
04/19
07/19
08/31
02/24
05/16
08/29
11/21
03/30
07/19
10/08
03/13
06/11
09/18
02/18
05/27
09/24
03/24
05/23
06/28
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06/05
08/07
11/29
03/16
06/17
09/06
02/18
06/12
10/04
12/15
03/03
08/03
10/05
01/21
04/27
07/05
12/26
05/06
07/05
11/05
02/24
05/16
08/05
02/01
04/26
08/18
12/22
03/22
05/21
09/03
03/19
06/14
08/19
12/20
05/16
08/11
12/18
04/29
08/12
10/20
2000
2001
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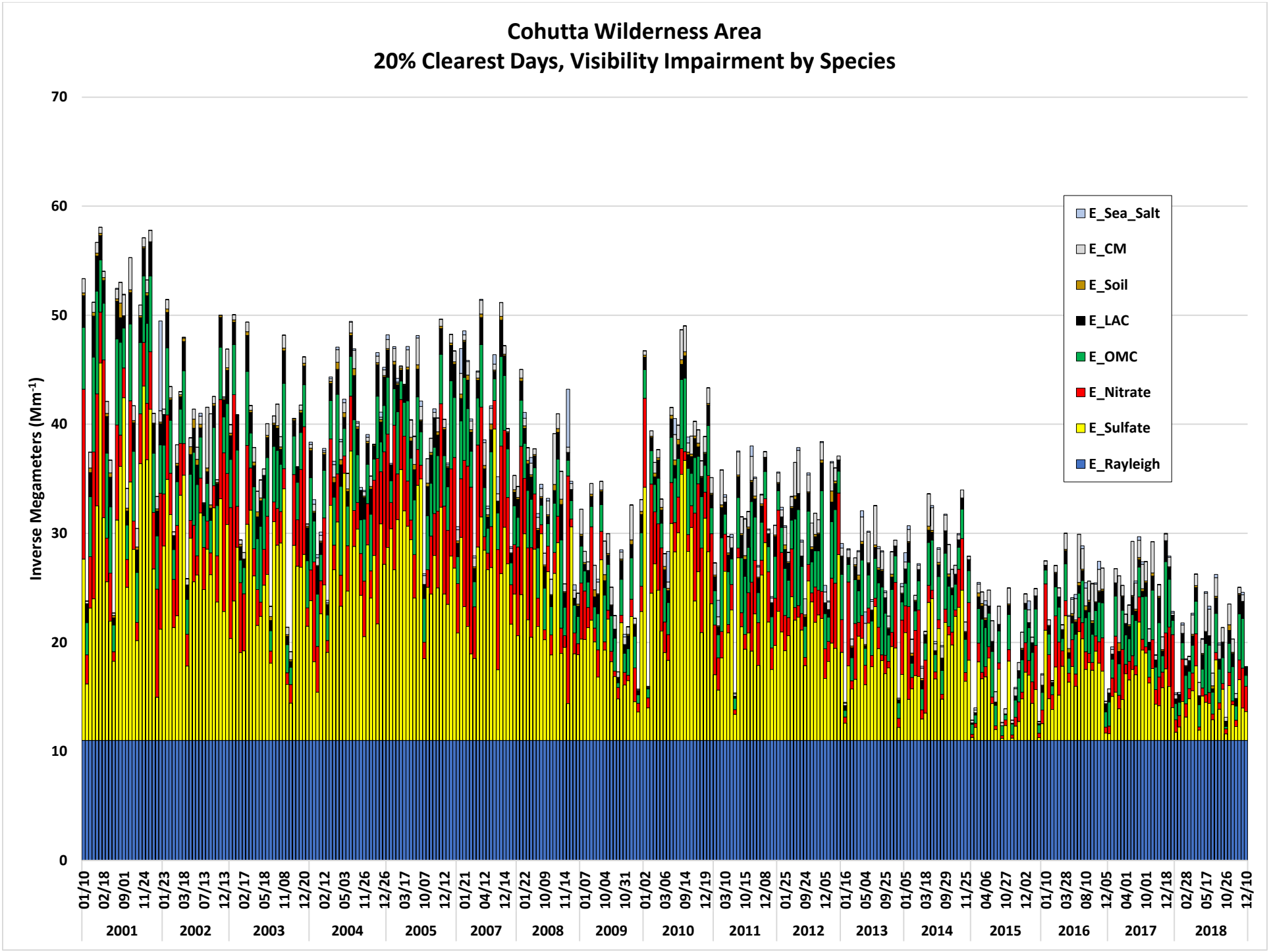
2015
2016
2017
2018


Cohutta Wilderness Area
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
01/10
02/18
09/01
11/24
01/23
03/18
07/13
12/13
02/17
05/18
11/08
12/20
02/12
05/03
11/26
12/26
03/17
10/07
12/12
01/21
04/12
12/14
01/22
10/09
11/14
01/07
10/04
10/31
01/02
03/06
09/14
12/19
03/10
10/15
12/08
01/25
09/24
12/05
01/16
05/04
09/25
01/05
03/18
09/29
11/25
04/06
10/27
12/02
01/10
03/28
08/10
12/05
04/01
10/01
12/18
02/28
05/17
10/26
12/10
2001
2002
2003
2004
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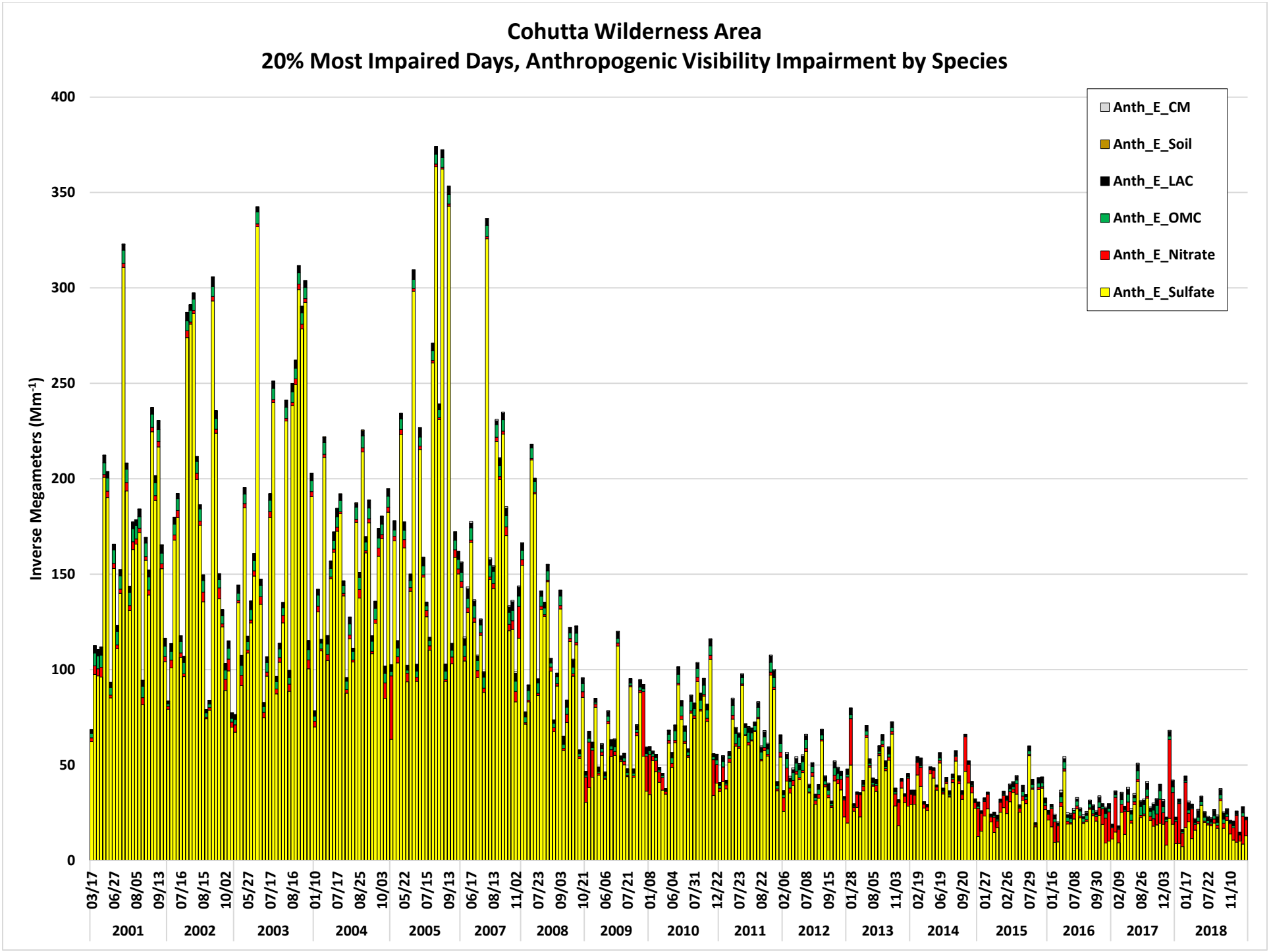
2014
2015
2016
2017
2018


Cohutta Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
03/17
06/27
08/05
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07/16
08/15
10/02
05/27
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08/16
01/10
07/17
08/25
10/03
05/22
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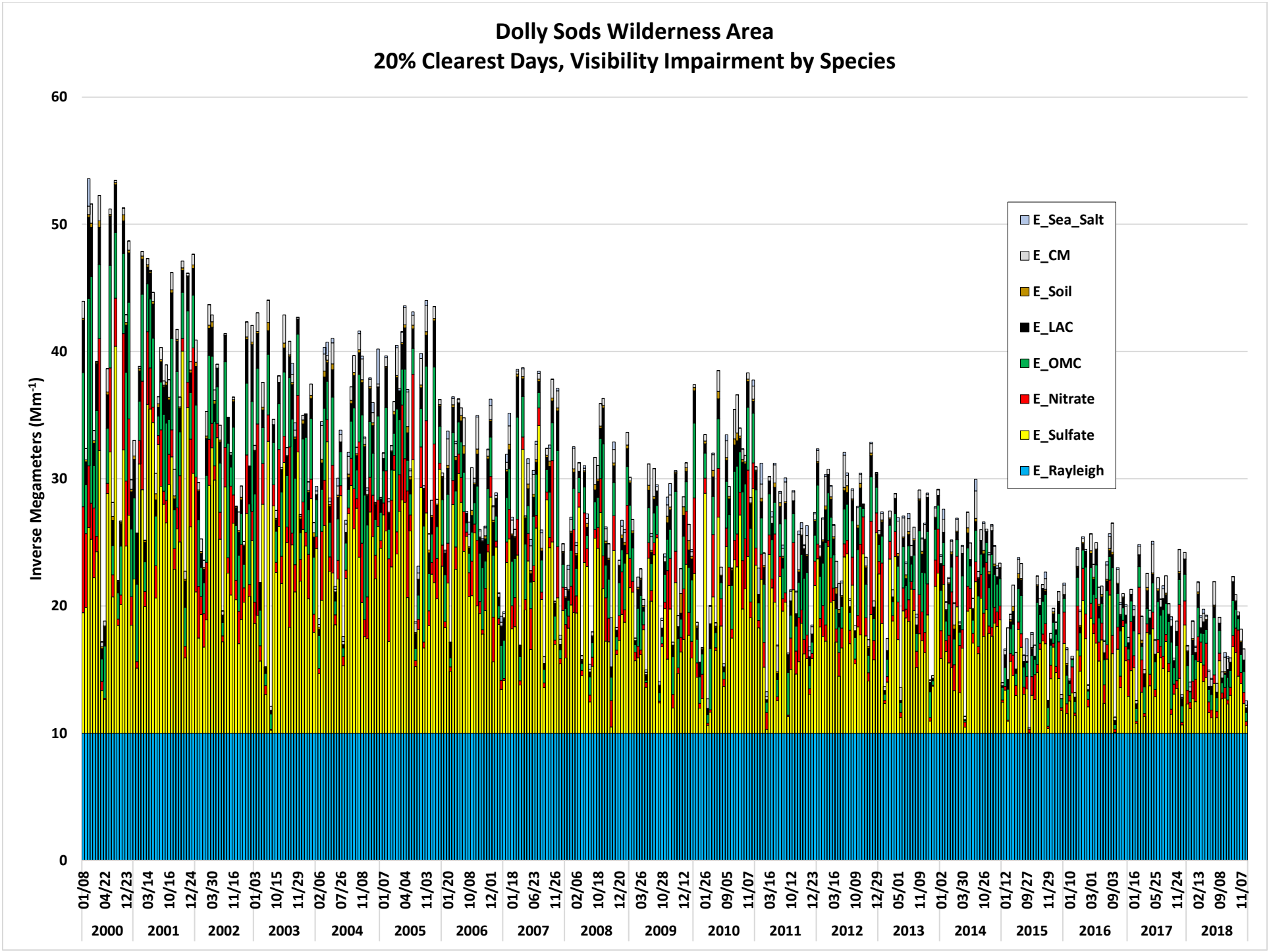
06/17
08/13
11/02
07/23
09/03
10/21
06/06
07/21
01/08
06/04
07/31
12/22
07/23
08/22
02/06
07/08
09/15
01/28
08/05
11/03
02/19
06/19
09/20
01/27
02/26
07/29
01/16
07/08
09/30
02/09
08/26
12/03
01/17
07/22
11/10
2001
2002
2003
2004
2005
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


Dolly Sods Wilderness Area
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
01/08
04/22
12/23
03/14
10/16
12/24
03/30
11/16
01/03
10/15
11/29
02/06
07/26
11/08
01/07
04/04
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10/08
12/01
01/18
06/23
11/26
02/06
10/18
12/20
03/26
10/28
12/12
01/26
09/05
11/07
03/16
10/12
12/23
03/16
10/09
12/29
05/01
11/09
01/02
03/30
10/26
01/12
09/27
11/29
01/10
03/01
09/03
01/16
05/25
11/24
02/13
09/08
11/07
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2015
2016
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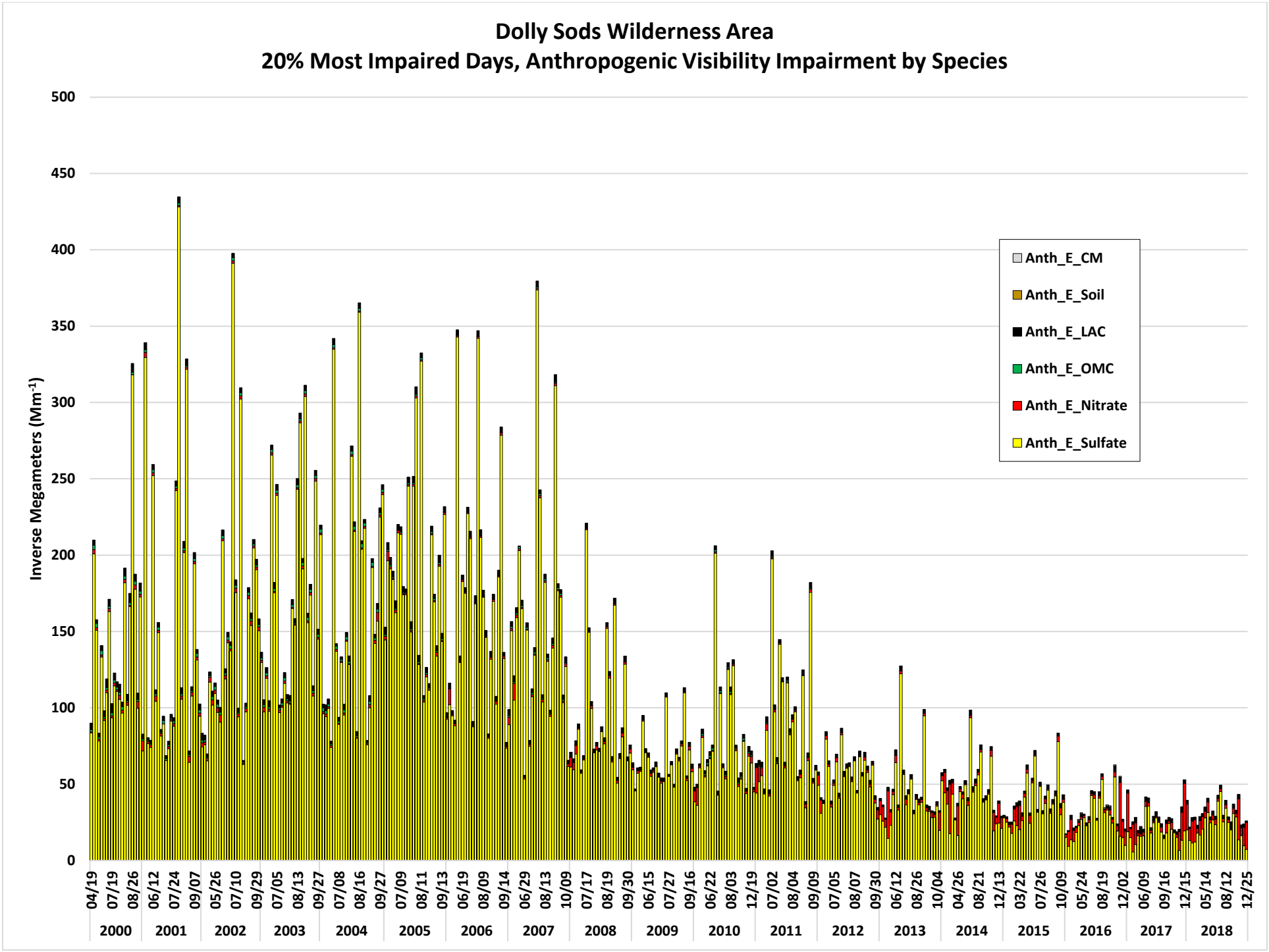
2018


Dolly Sods Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
500
450
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
04/19
07/19
08/26
06/12
07/24
09/07
05/26
07/10
09/29
07/05
08/13
09/27
07/08
08/16
09/27
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07/17
08/19
09/30
06/15
07/27
09/16
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08/26
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04/26
08/21
12/13
03/22
07/26
10/09
05/24
08/19
12/02
06/09
09/16
12/15
05/14
08/12
12/25
2000
2001
2002
2003
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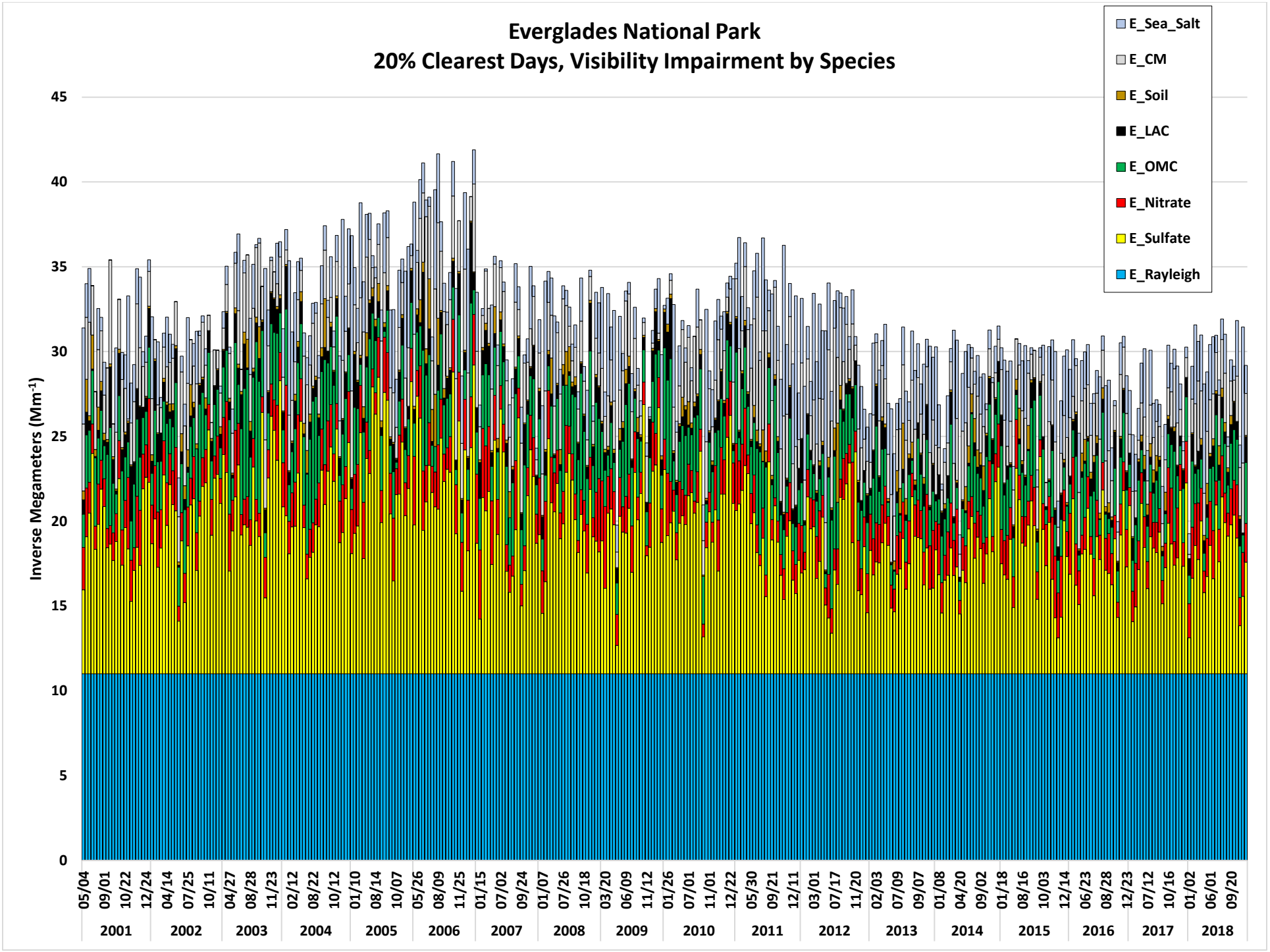
2011
2012
2013
2014
2015
2016
2017
2018


Everglades National Park
20% Clearest Days, Visibility Impairment by Species
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
Inverse Megameters (Mm-1)
45
40
35
30
25
20
15
10
5
0
05/04
09/01
10/22
12/24
04/14
07/25
10/11
04/27
08/28
11/23
02/12
08/22
10/12
01/10
08/14
10/07
05/26
08/09
11/25
01/15
07/02
09/24
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07/26
10/18
03/20
06/09
11/12
01/26
07/01
11/01
12/22
05/30
09/21
12/11
03/01
07/17
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02/03
07/09
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04/20
09/02
01/18
08/16
10/03
12/14
06/23
08/28
12/23
07/12
10/16
01/02
06/01
09/20
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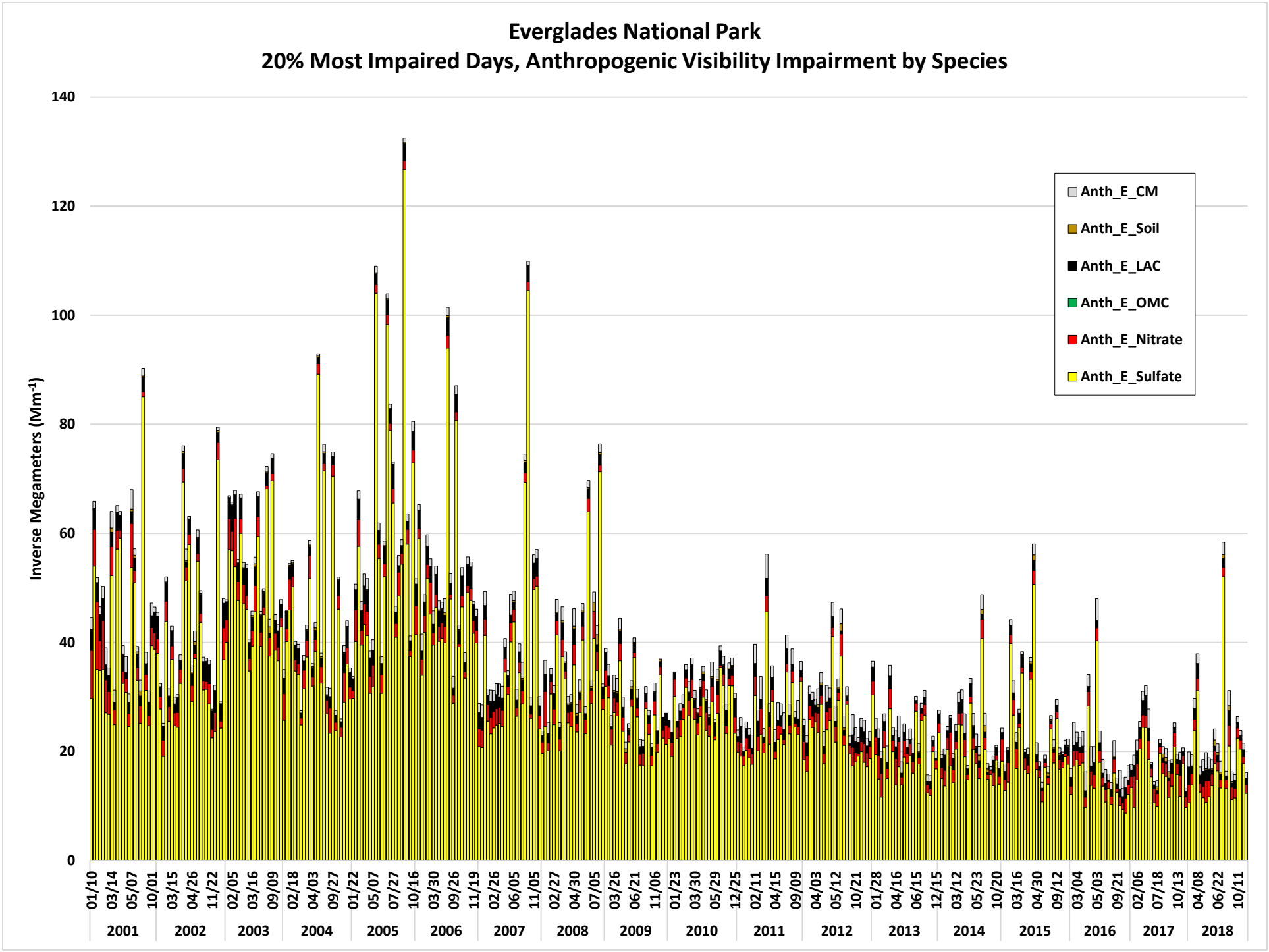
2013
2014
2015
2016
2017
2018


Everglades National Park
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
140
120
100
80
60
40
20
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
01/10
03/14
05/07
10/01
03/15
04/26
11/22
02/05
03/16
09/09
02/18
04/03
09/27
01/22
05/07
07/27
10/16
03/30
09/26
11/19
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06/15
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05/23
10/20
03/16
04/30
09/12
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02/06
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2001
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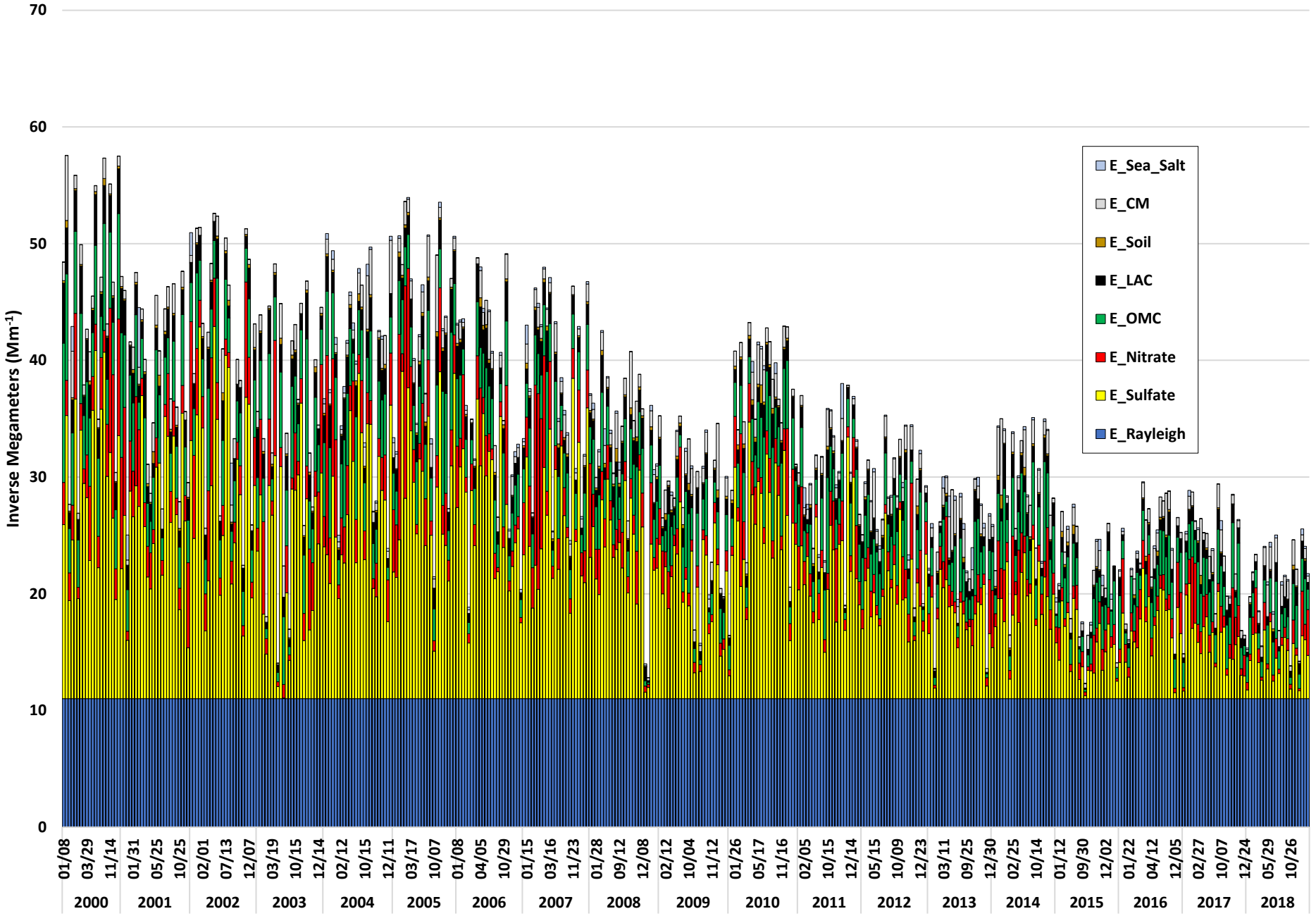
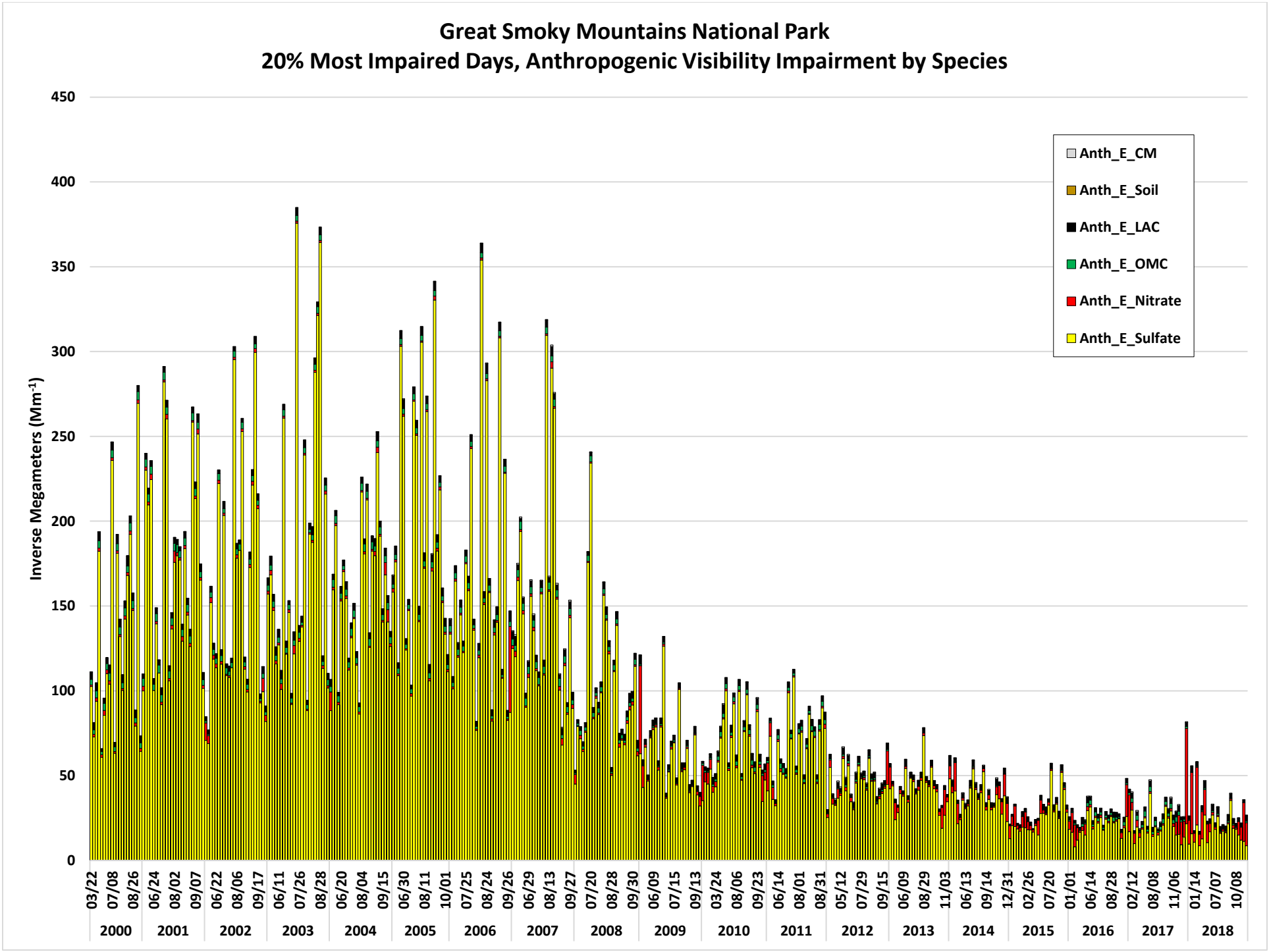
Great Smoky Mountains National Park
20% Clearest Days, Visibility Impairment by Species




Great Smoky Mountains National Park
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
450
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
03/22
07/08
08/26
06/24
08/02
09/07
06/22
08/06
09/17
06/11
07/26
08/28
06/20
08/04
09/15
06/30
08/11
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09/27
07/20
08/28
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07/15
09/13
03/24
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09/23
06/14
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08/31
05/12
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09/15
06/09
08/29
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09/14
12/31
02/26
07/20
01/01
06/14
08/28
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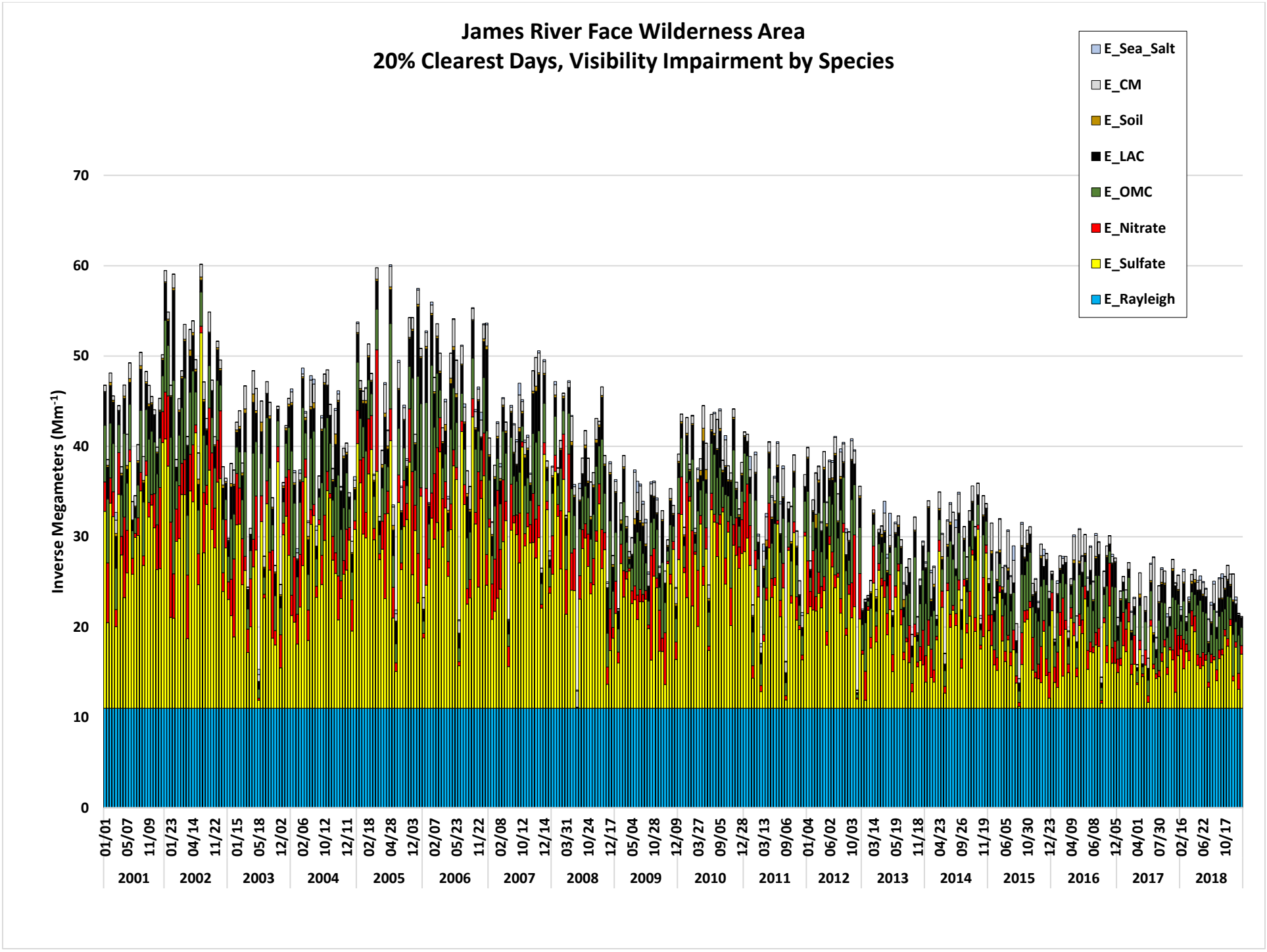
2015
2016
2017
2018


James River Face Wilderness Area
20% Clearest Days, Visibility Impairment by Species
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
01/01
05/07
11/09
01/23
04/14
11/22
01/15
05/18
12/02
02/06
10/12
12/11
02/18
04/28
12/03
02/07
05/23
11/22
02/08
10/12
12/14
03/31
10/24
12/17
05/04
10/28
12/09
03/27
09/05
12/28
03/13
09/06
01/04
06/02
10/03
03/14
05/19
11/18
04/23
09/26
11/19
06/05
10/30
12/23
04/09
06/08
12/05
04/01
07/30
02/16
06/22
10/17
2001
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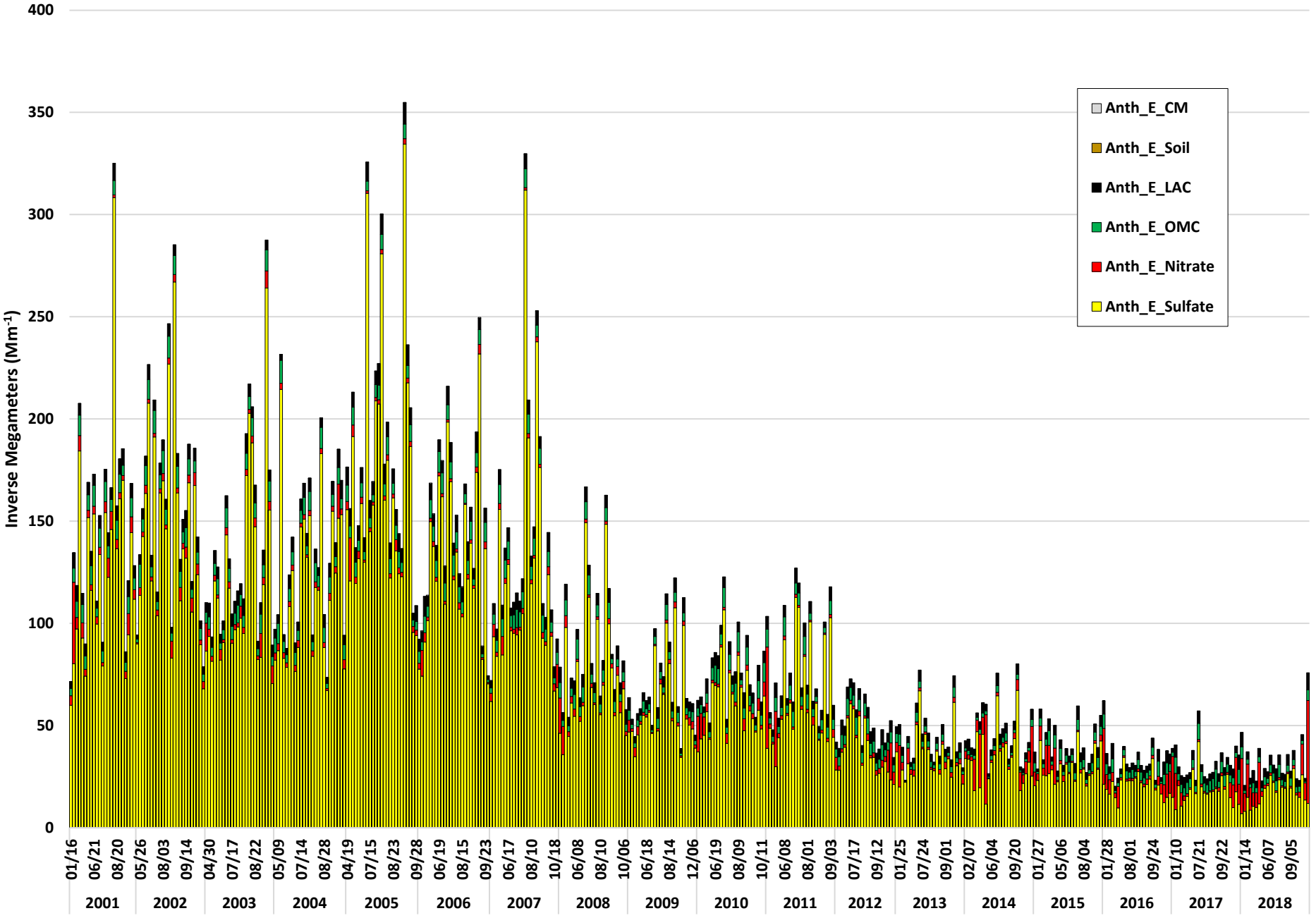
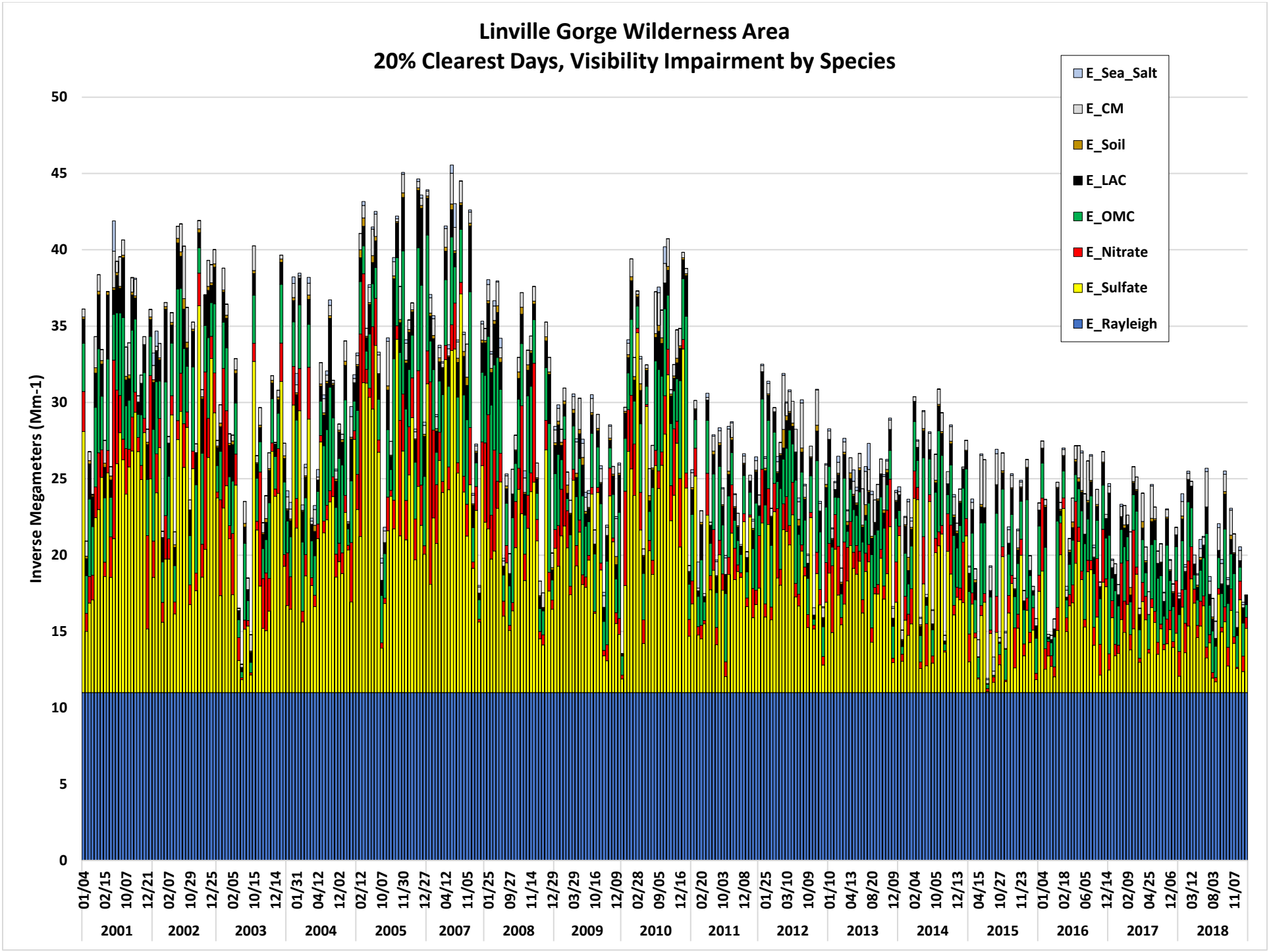
2014
2015
2016
2017
2018

James River Face Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species




Linville Gorge Wilderness Area
20% Clearest Days, Visibility Impairment by Species
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
Inverse Megameters (Mm-1)
0
5
10
15
20
25
30
35
40
45
50
01/04
02/15
10/07
12/21
02/07
10/29
12/25
02/05
10/15
12/14
01/31
04/12
12/02
02/12
10/07
11/30
12/27
04/12
11/05
01/25
09/27
11/14
12/29
03/29
10/16
12/09
02/28
09/05
12/16
02/20
10/03
12/08
01/25
03/10
10/09
01/10
04/13
08/20
12/09
02/04
10/05
12/13
04/15
10/27
11/23
01/04
02/18
06/05
12/14
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04/25
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11/07
2001
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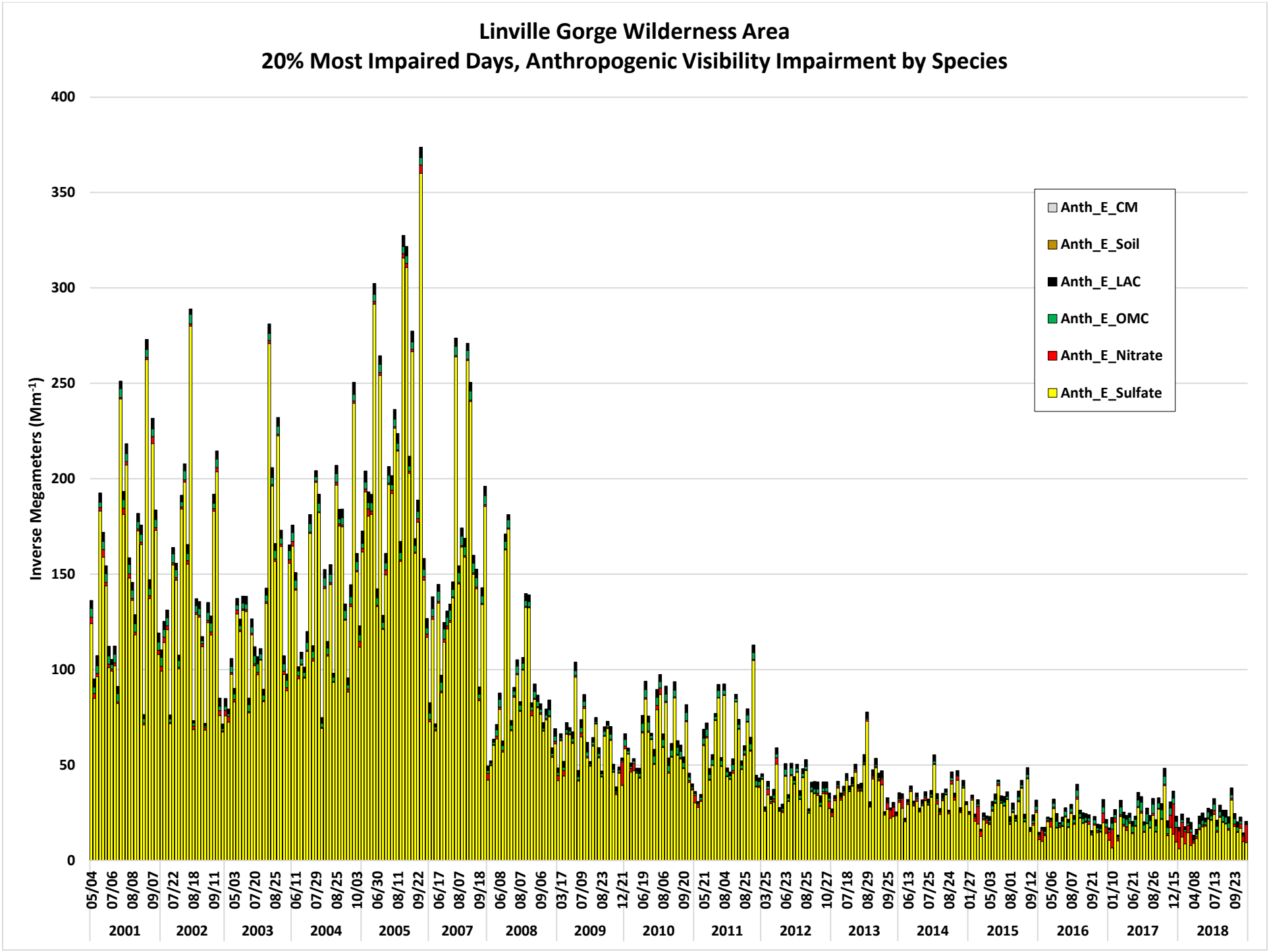
2018


Linville Gorge Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
05/04
07/06
08/08
09/07
07/22
08/18
09/11
05/03
07/20
08/25
06/11
07/29
08/25
10/03
06/30
08/11
09/22
06/17
08/07
09/18
06/08
08/07
09/06
03/17
07/09
08/23
12/21
06/19
08/06
09/20
05/21
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08/25
03/25
06/23
08/25
10/27
07/18
08/29
09/25
06/13
07/25
08/24
01/27
05/03
08/01
09/12
05/06
08/07
09/21
01/10
06/21
08/26
12/15
04/08
07/13
09/23
2001
2002
2003
2004
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2008
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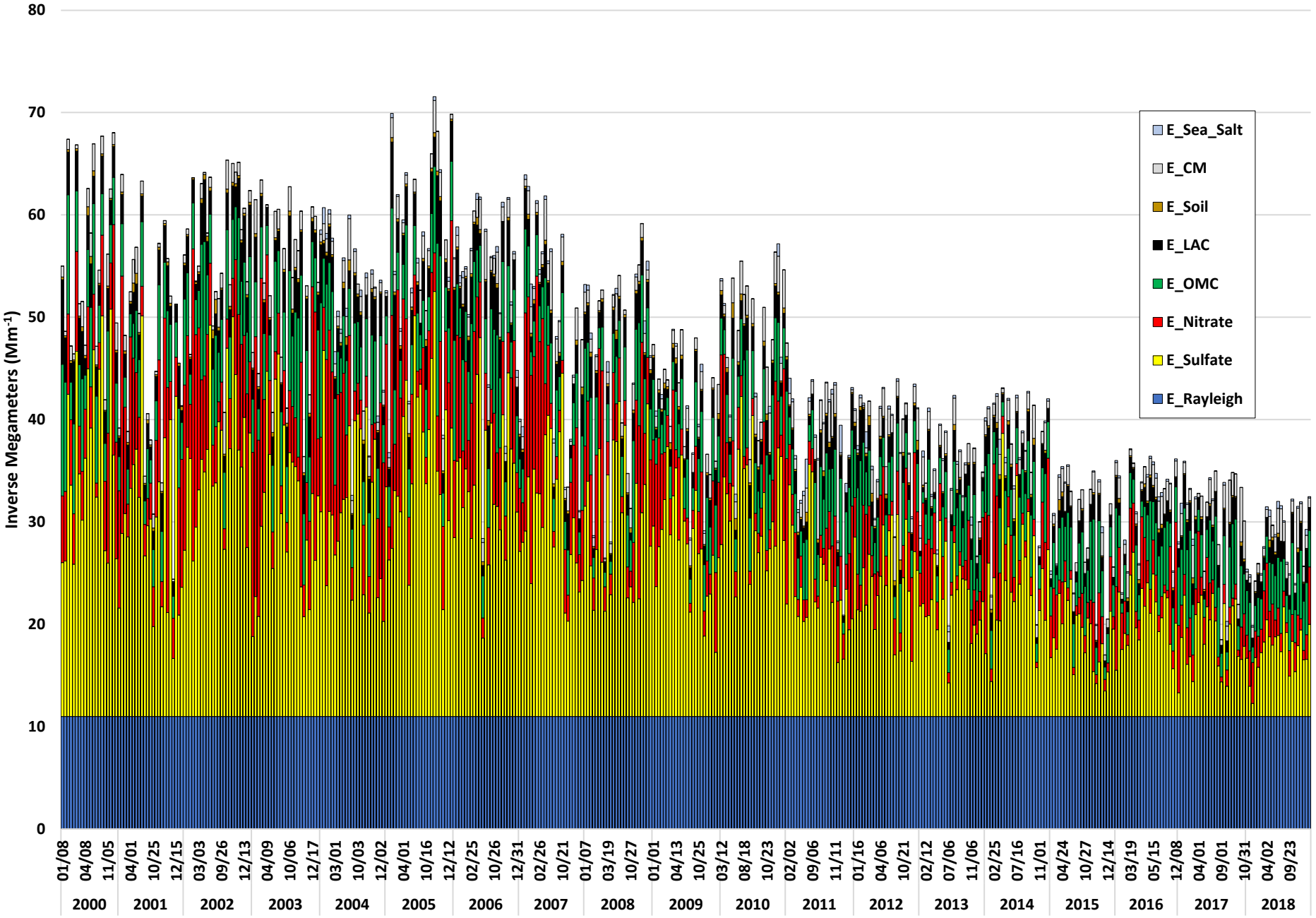
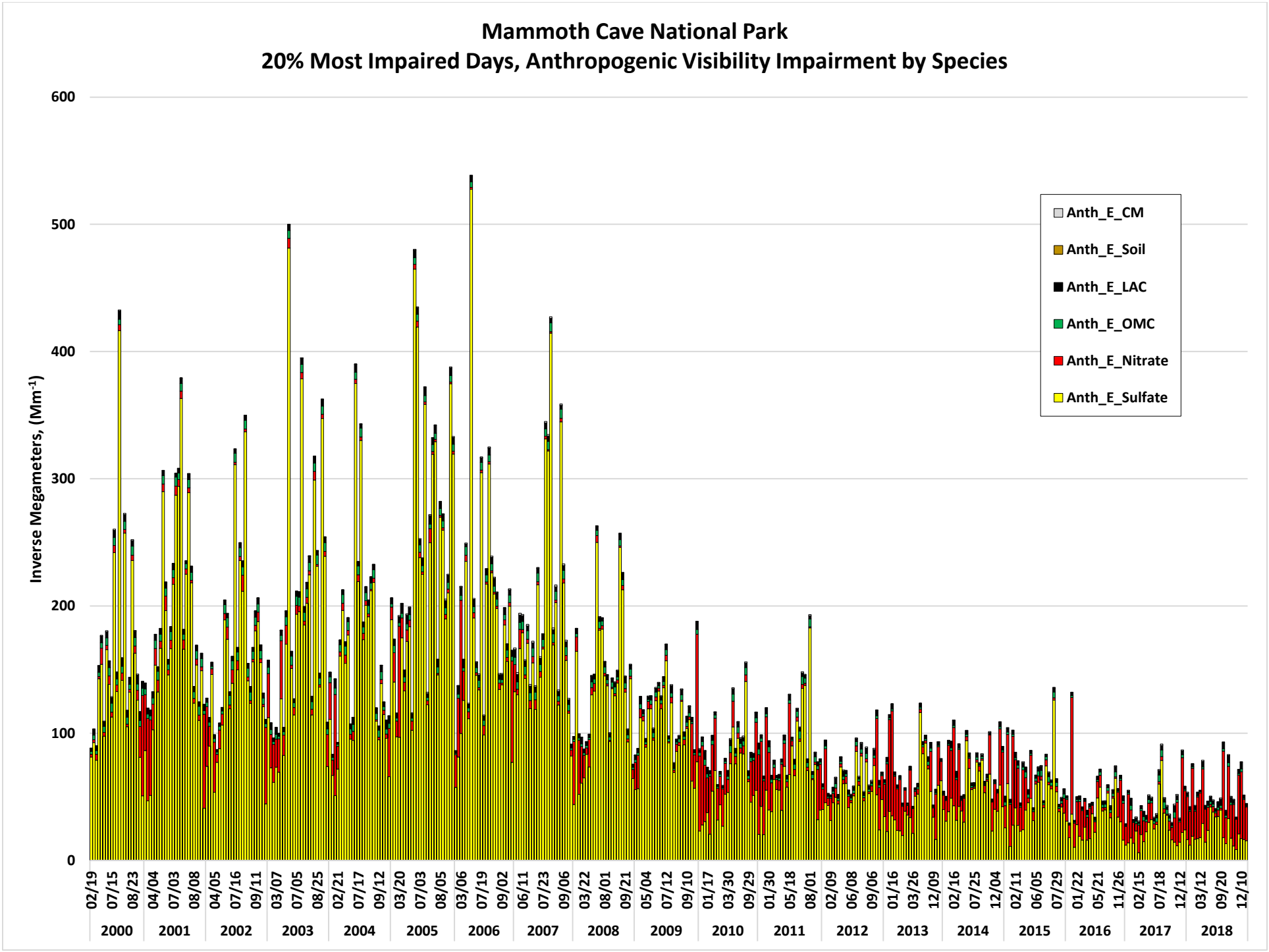
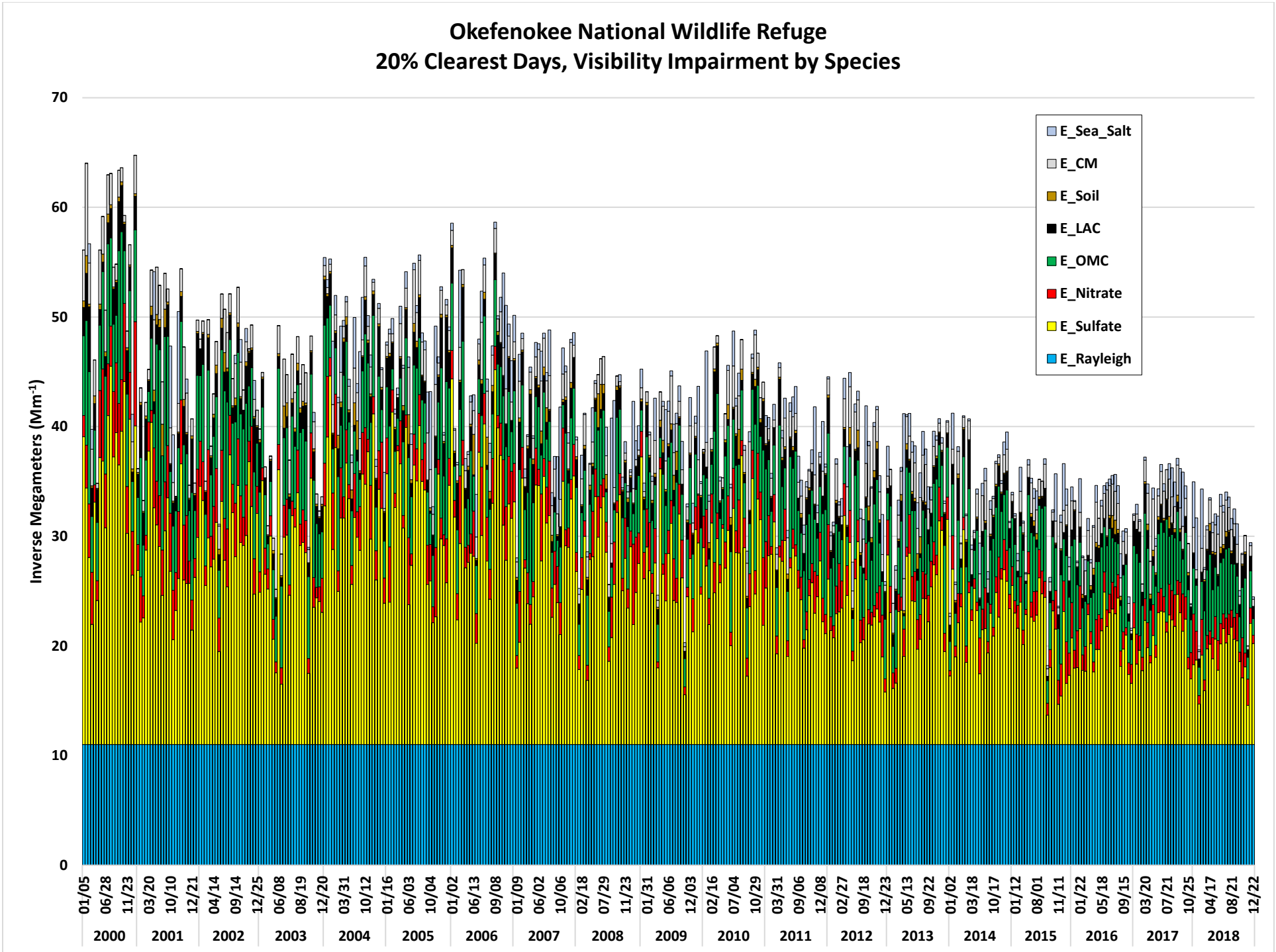
2010
2011
2012
2013
2014
2015
2016
2017
2018

Mammoth Cave National Park
20% Clearest Days, Visibility Impairment by Species




Mammoth Cave National Park
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters, (Mm-1)
600
500
400
300
200
100
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
02/19 07/15 08/23
04/04 07/03 08/08
04/05 07/16 09/11
03/07 07/05 08/25
02/21 07/17 09/12
03/20 07/03 08/05
03/06 07/19 09/02
06/11 07/23 09/06
03/22 08/01 09/21
05/04 07/12 09/10
01/17 03/30 09/29
01/30 05/18 08/01
02/09 06/08 09/06
01/16 03/26 12/09
02/16 07/25 12/04
02/11 06/05 07/29
01/22 05/21 11/26
02/15 07/18 12/12
03/12 09/20 12/10
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


Okefenokee National Wildlife Refuge
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
01/05
06/28
11/23
03/20
10/10
12/21
04/14
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12/20
03/31
10/12
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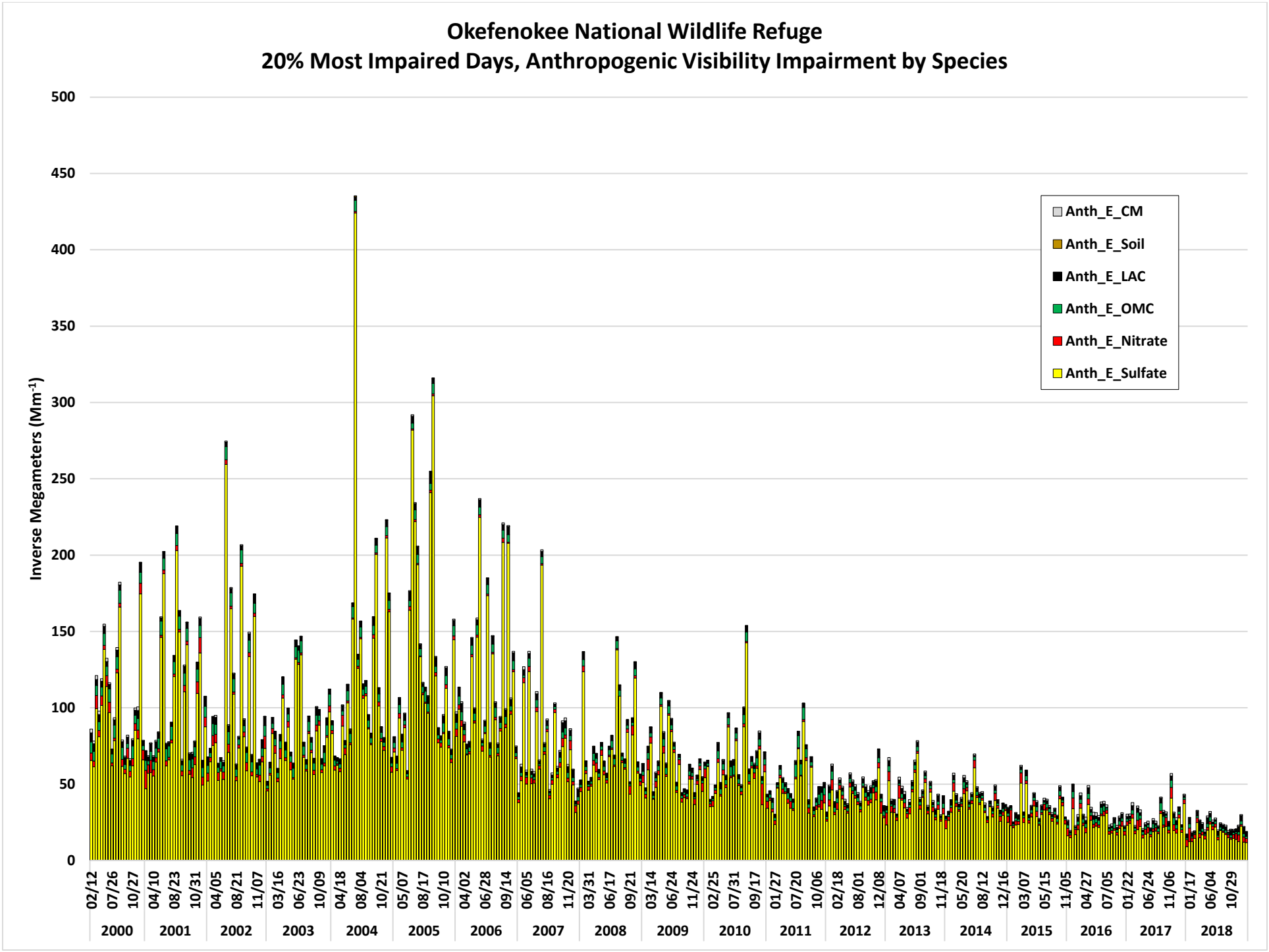
2018


Okefenokee National Wildlife Refuge
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
500
450
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
02/12
07/26
10/27
04/10
08/23
10/31
04/05
08/21
11/07
03/16
06/23
10/09
04/18
08/04
10/21
05/07
08/17
10/10
04/02
06/28
09/14
06/05
08/16
11/20
03/31
06/17
09/21
03/14
06/24
11/24
02/25
07/31
09/17
01/27
07/20
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08/12
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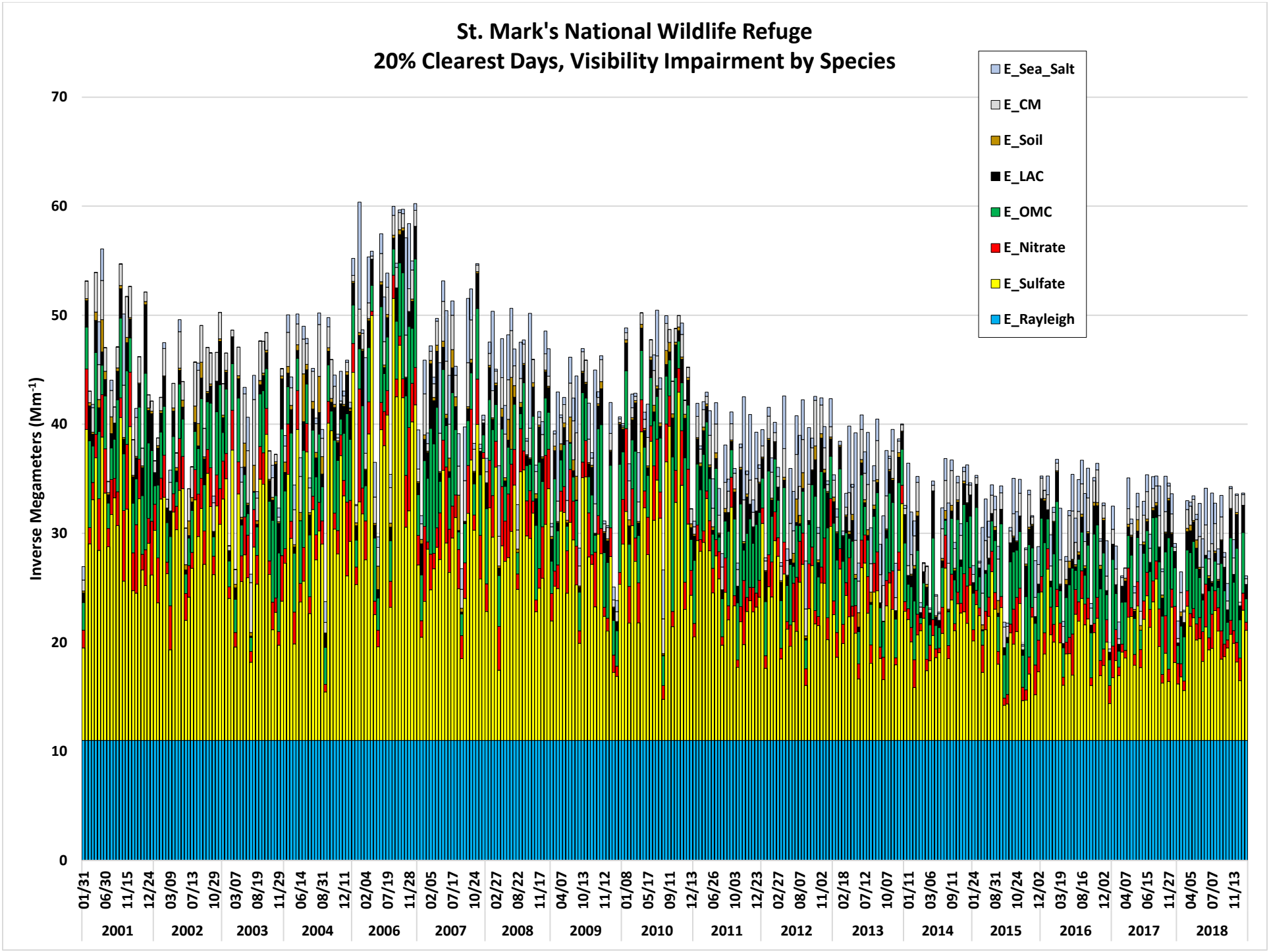
2018


St. Mark's National Wildlife Refuge
20% Clearest Days, Visibility Impairment by Species
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
01/31
06/30
11/15
12/24
03/09
07/13
10/29
03/07
08/19
11/29
06/14
08/31
12/11
02/04
07/19
11/28
02/05
07/17
10/24
02/27
08/22
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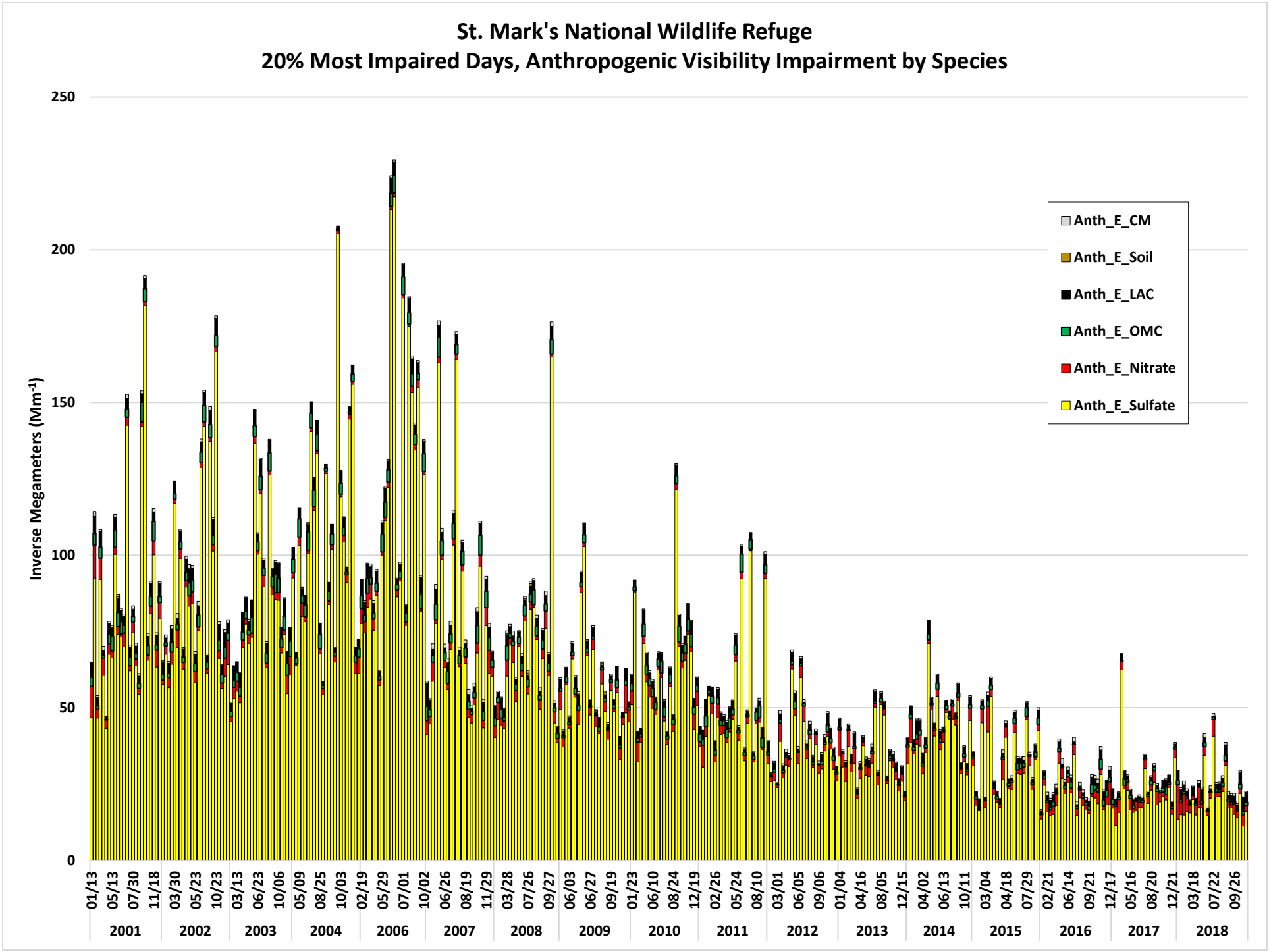
St. Mark's National Wildlife Refuge
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
01/13
05/13
07/30
11/18
03/30
05/23
10/23
03/13
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05/09
08/25
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02/19
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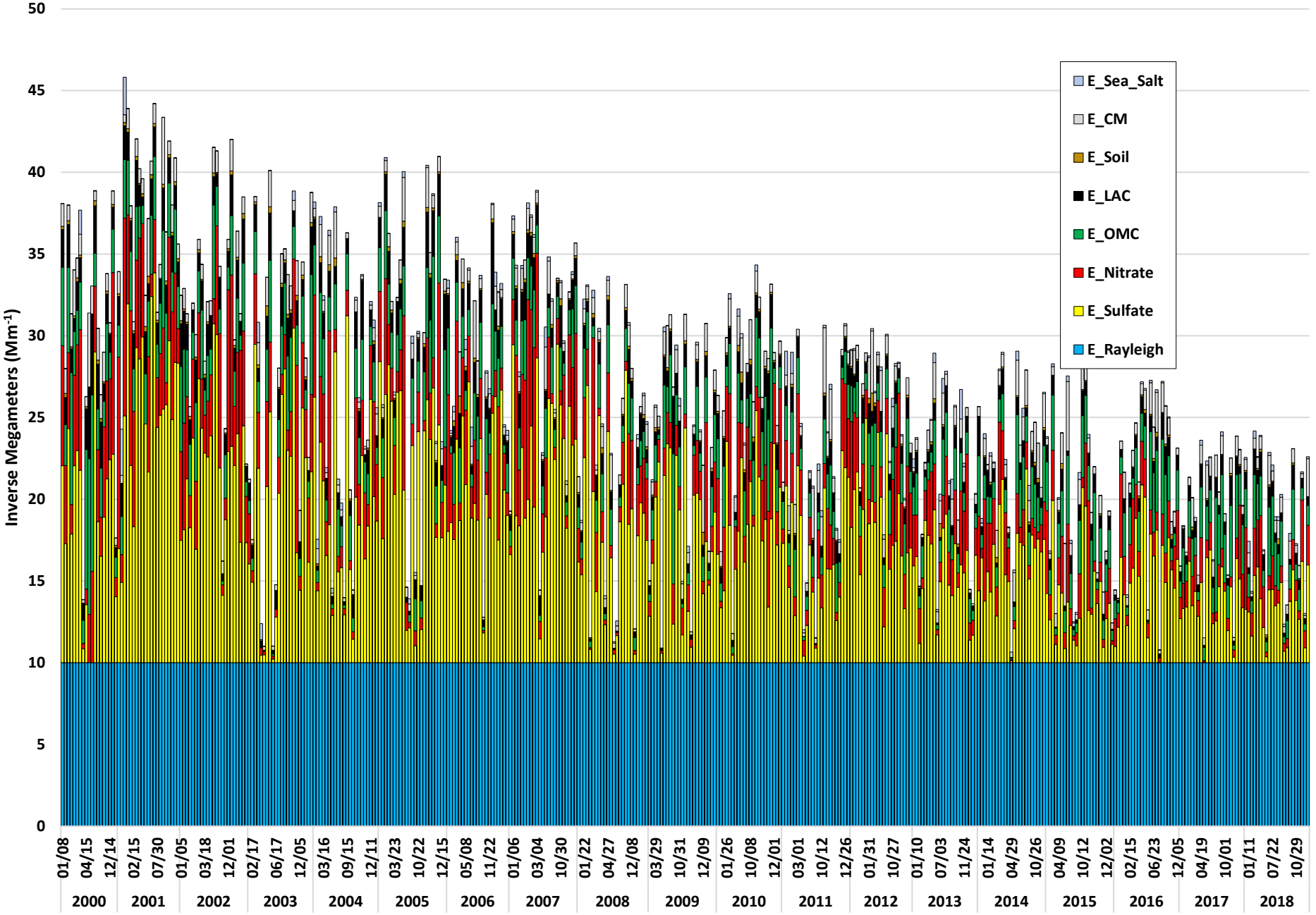
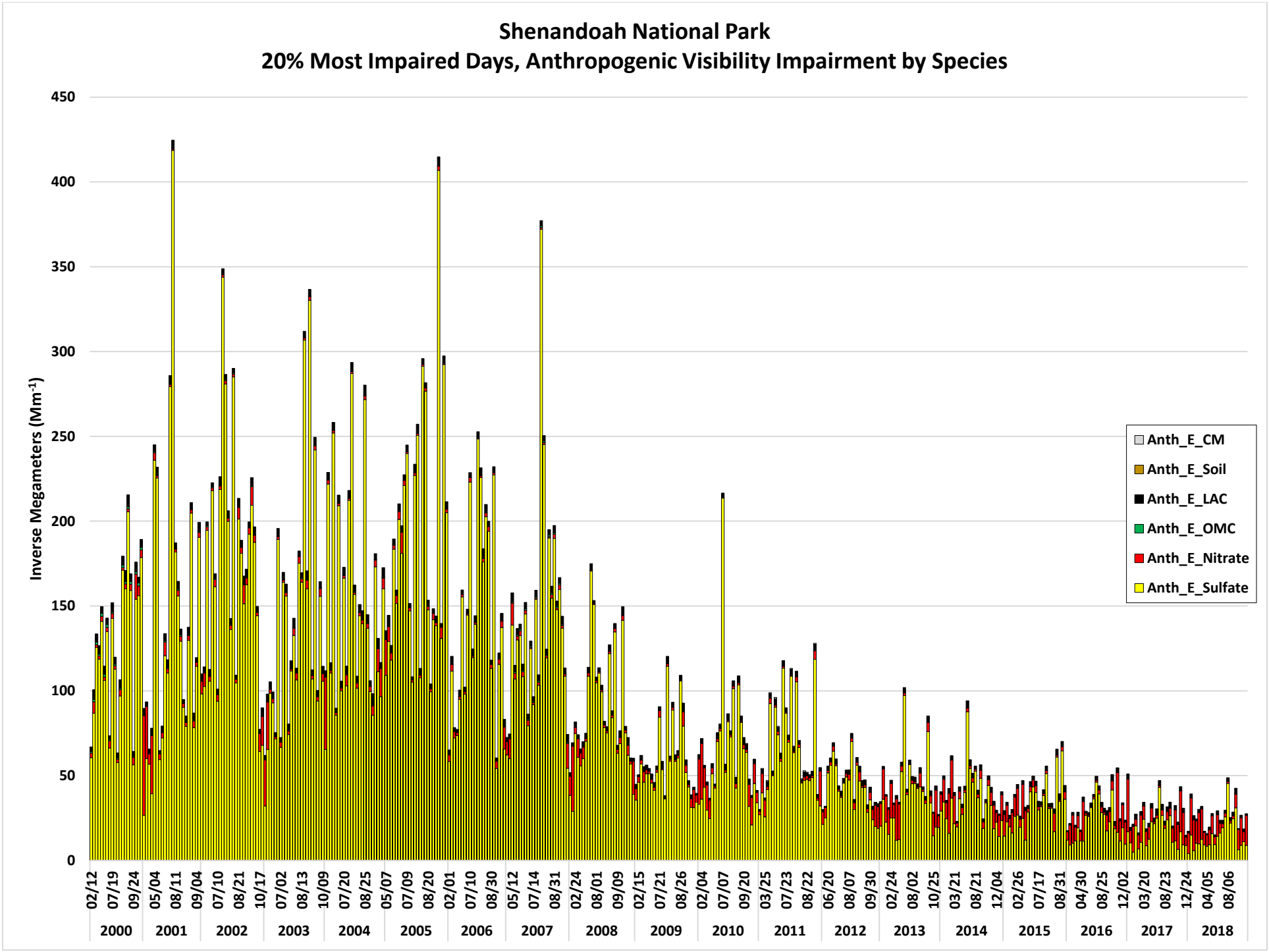
Shenandoah National Park
20% Clearest Days, Visibility Impairment by Species




Shenandoah National Park
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
450
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
02/12
07/19
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08/21
12/04
02/26
07/17
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04/30
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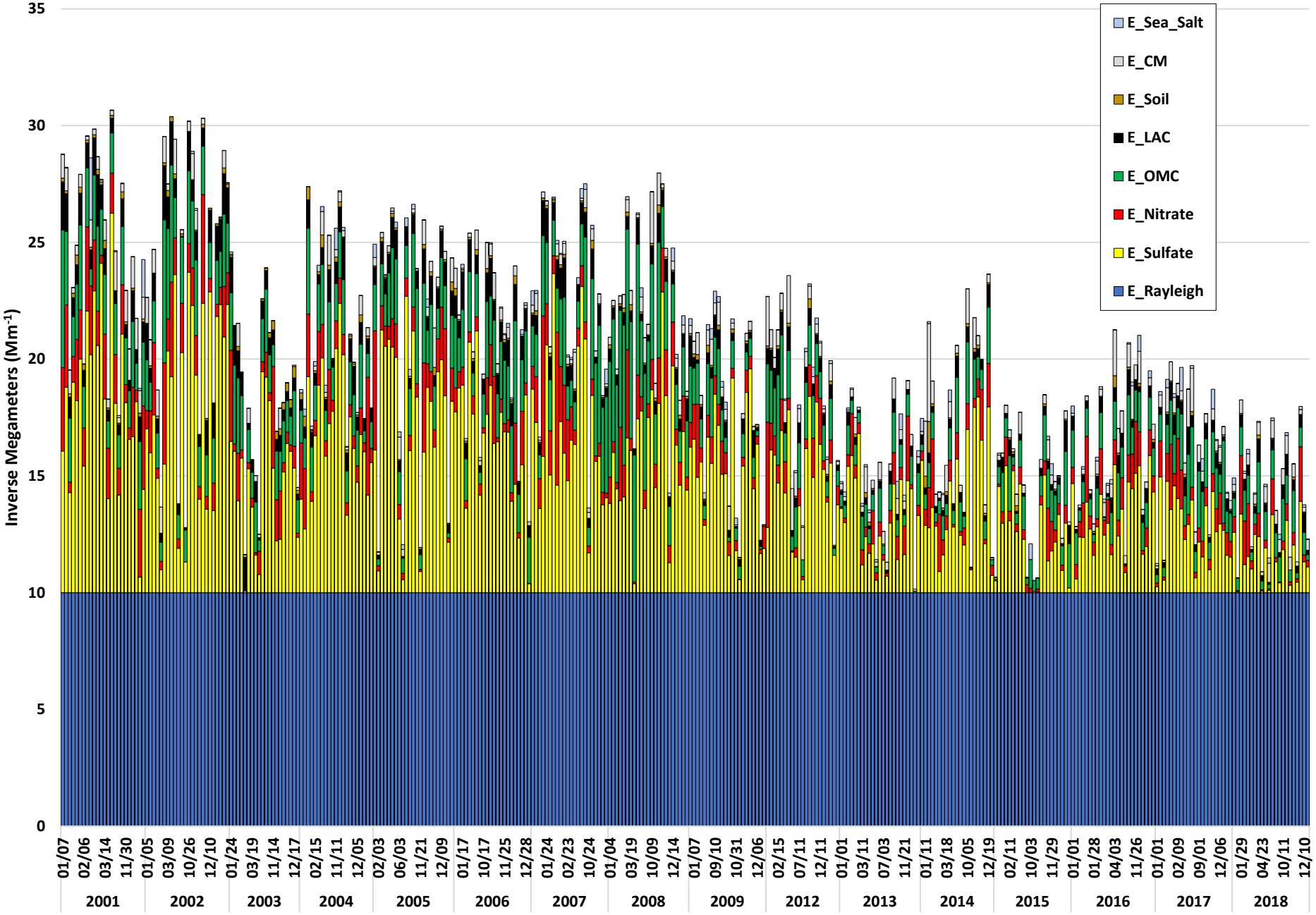
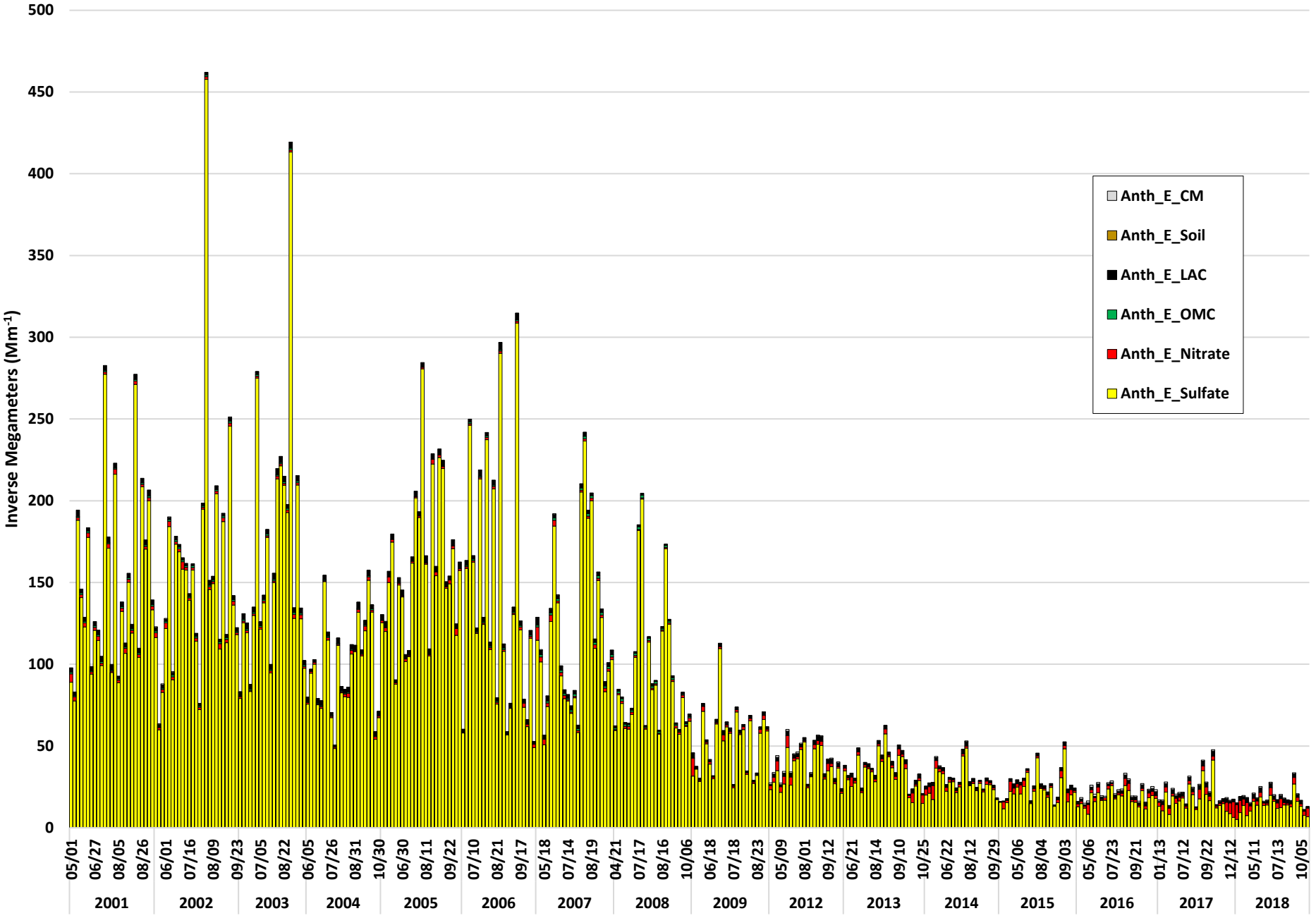
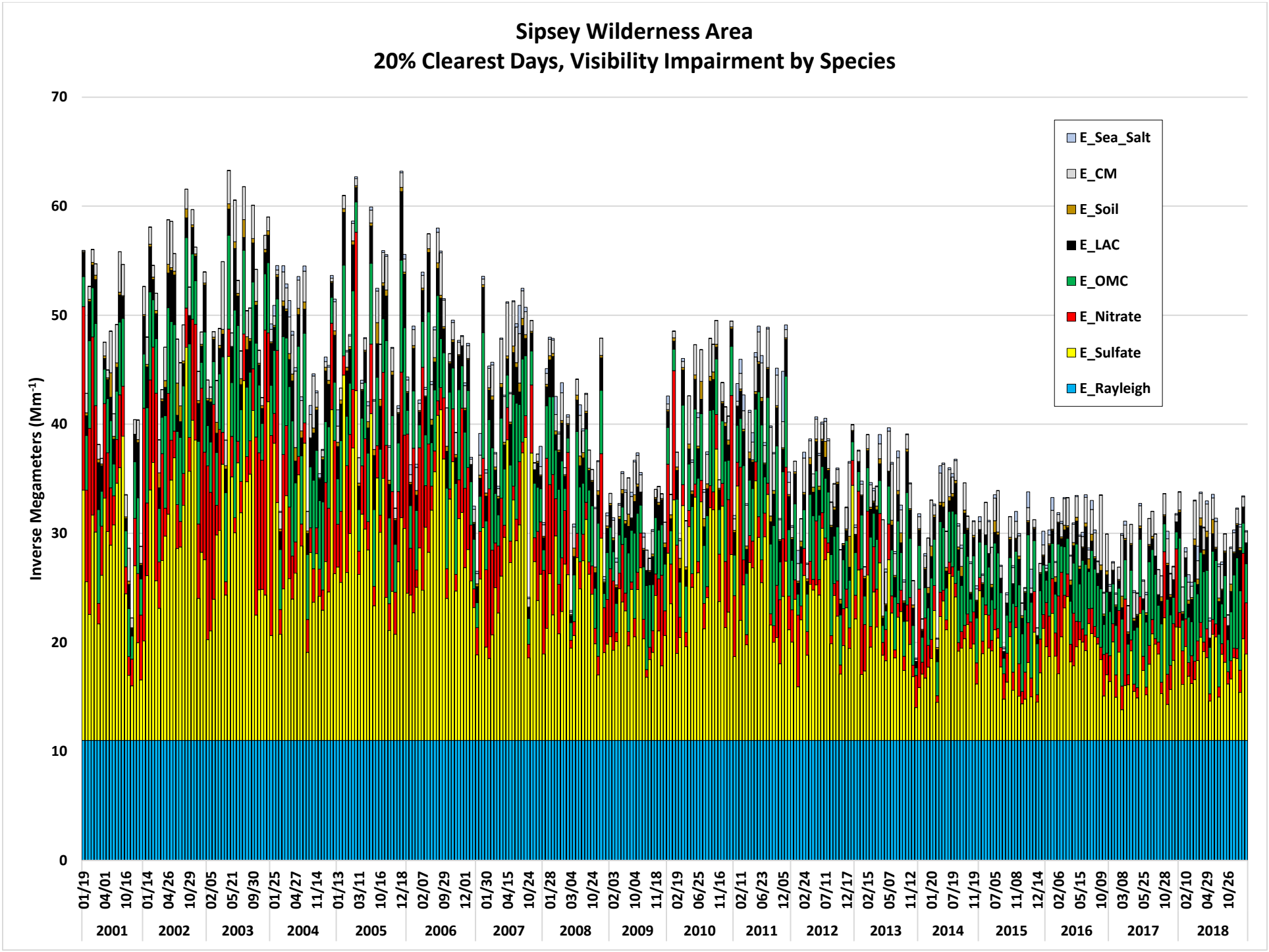
Shining Rock Wilderness Area
20% Clearest Days, Visibility Impairment by Species



Shining Rock Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species




Sipsey Wilderness Area
20% Clearest Days, Visibility Impairment by Species
Inverse Megameters (Mm-1)
70
60
50
40
30
20
10
0
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
01/19
04/01
10/16
01/14
04/26
10/29
02/05
05/21
09/30
01/25
04/27
11/14
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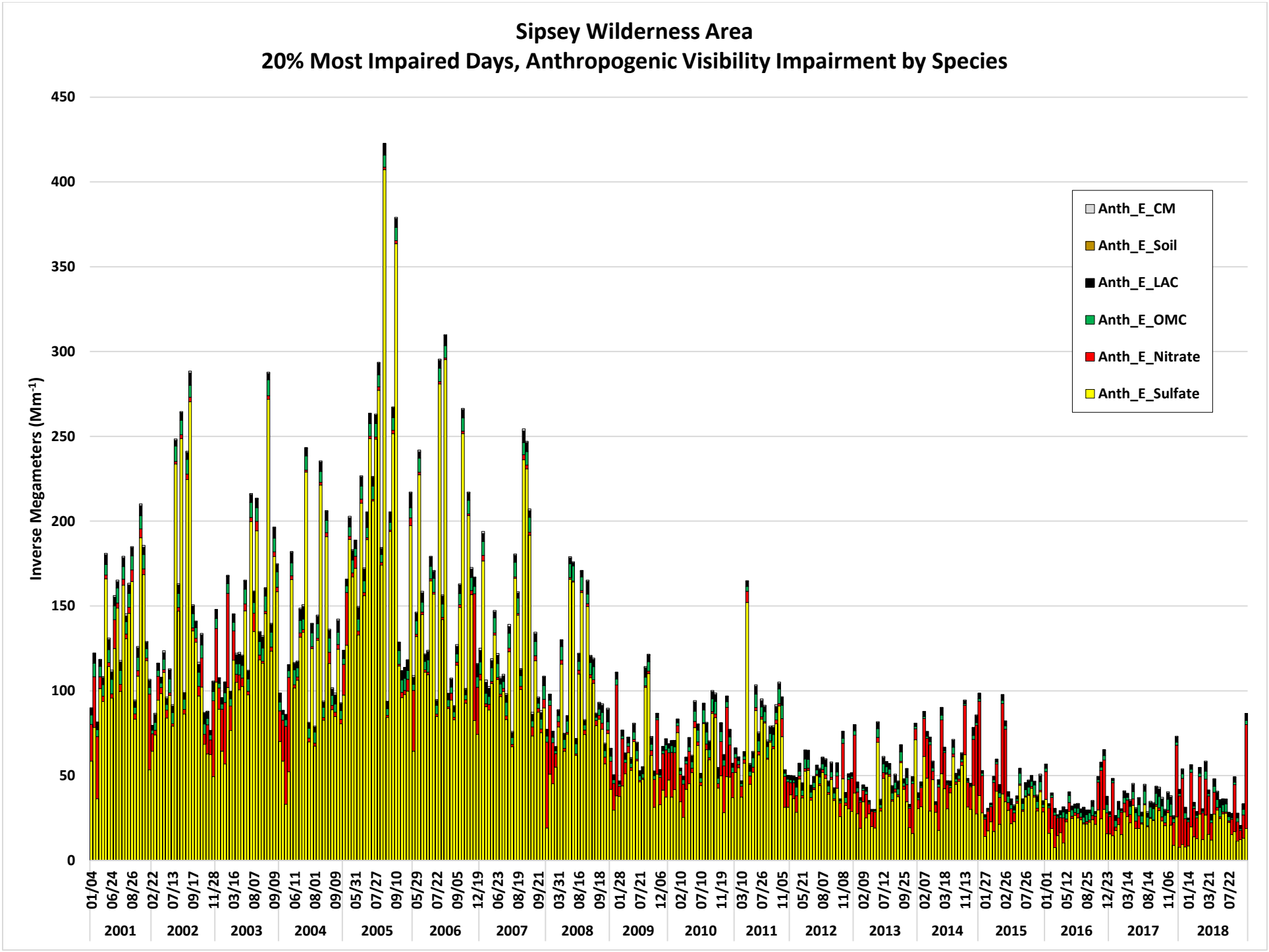
Sipsey Wilderness Area
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species
Inverse Megameters (Mm-1)
450
400
350
300
250
200
150
100
50
0
Anth_E_CM
Anth_E_Soil
Anth_E_LAC
Anth_E_OMC
Anth_E_Nitrate
Anth_E_Sulfate
01/04
06/24
08/26
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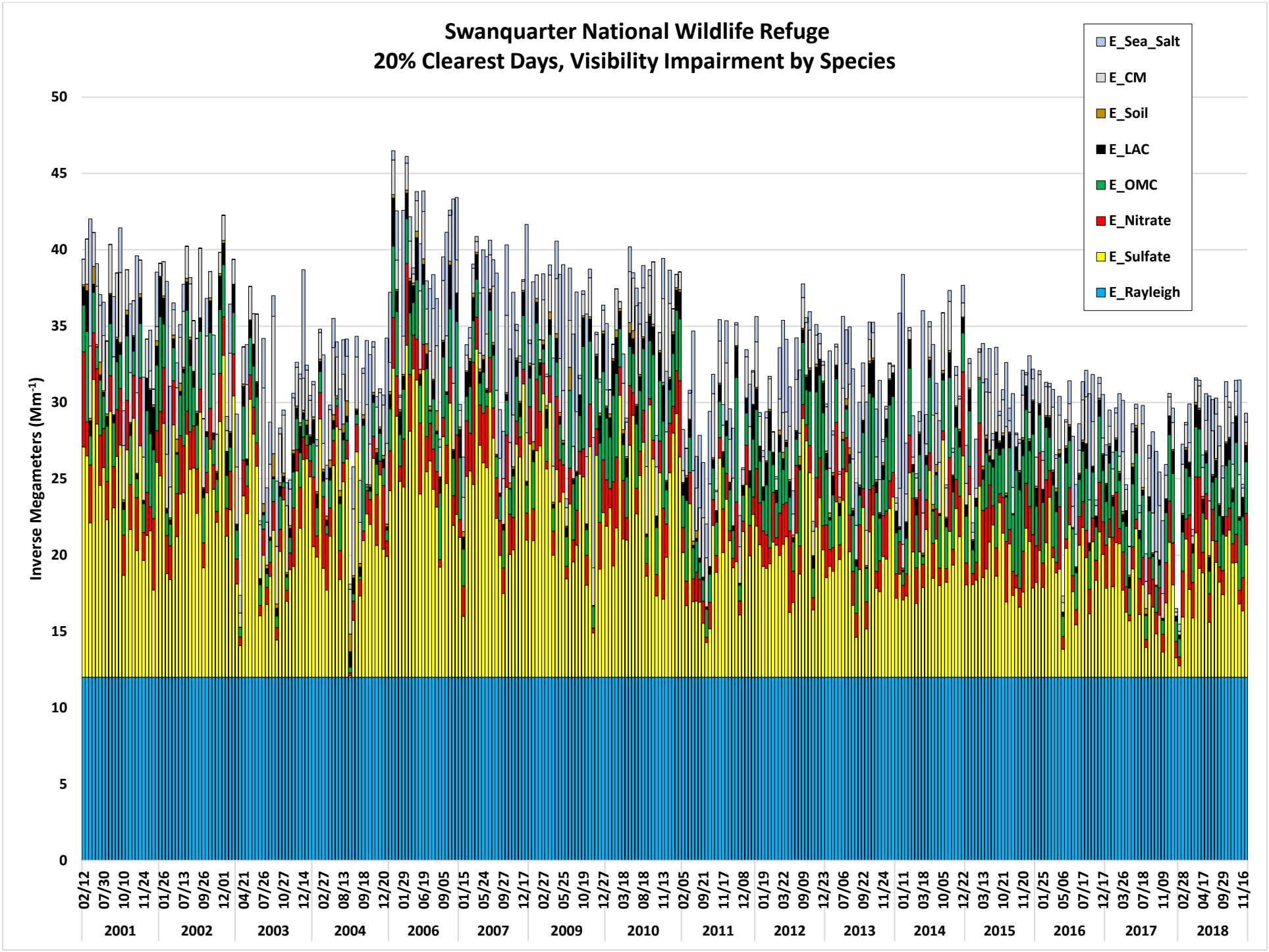
Swanquarter National Wildlife Refuge
20% Clearest Days, Visibility Impairment by Species
E_Sea_Salt
E_CM
E_Soil
E_LAC
E_OMC
E_Nitrate
E_Sulfate
E_Rayleigh
Inverse Megameters (Mm-1)
50
45
40
35
30
25
20
15
10
5
0
02/12
07/30
10/10
11/24
01/26
07/13
09/26
12/01
04/21
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10/27
12/14
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01/25
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12/17
03/26
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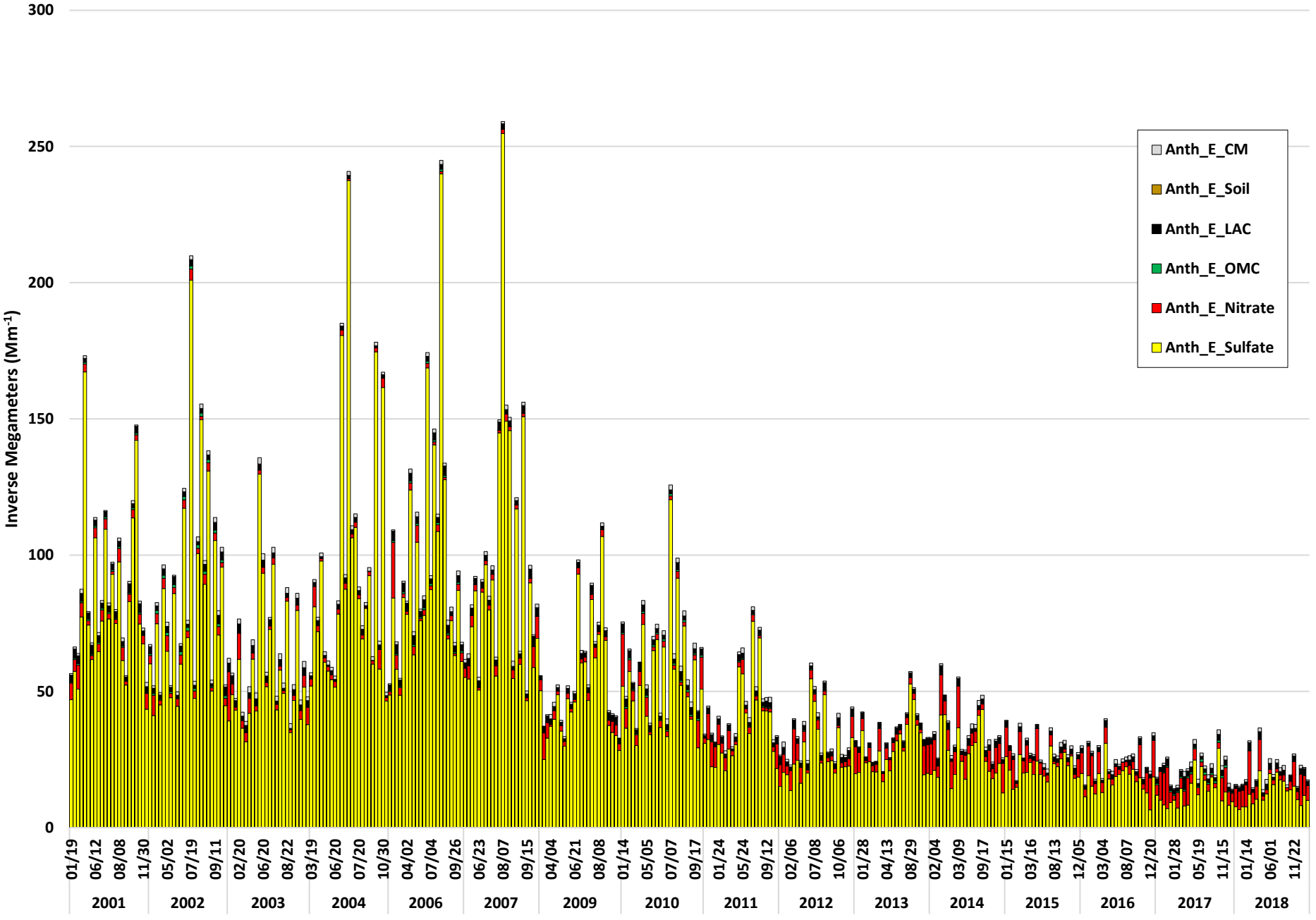
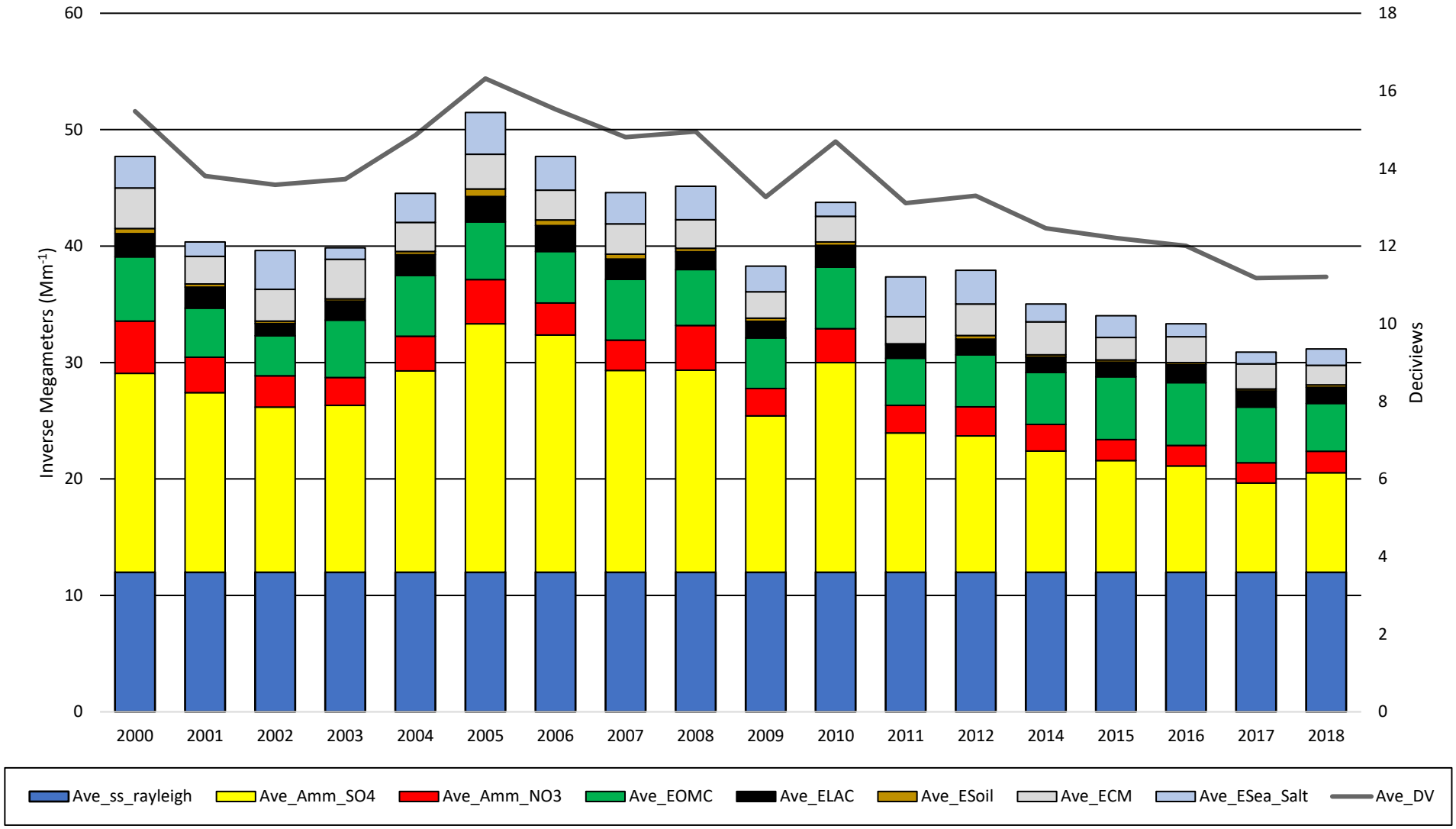
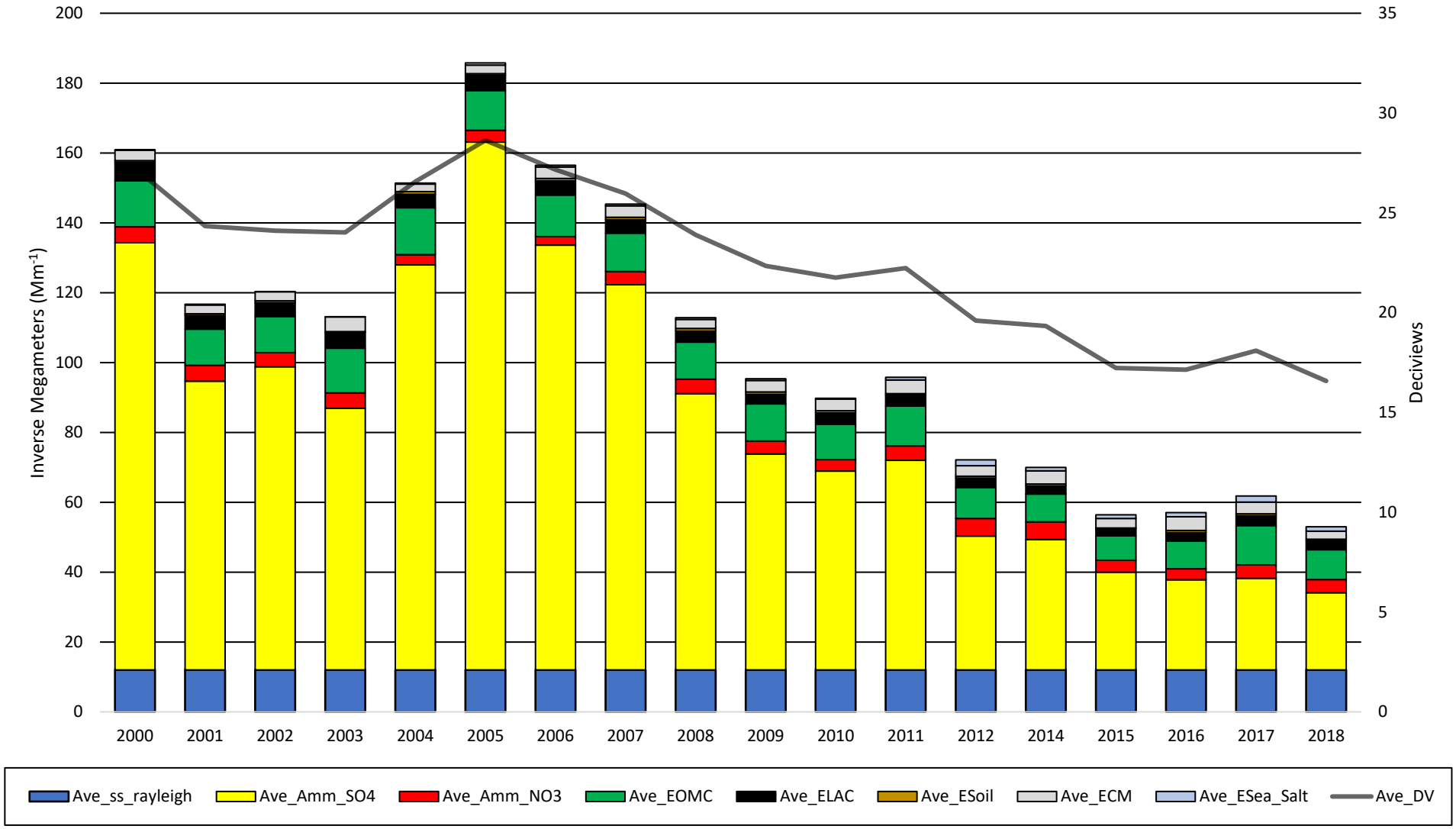
Swanquarter National Wildlife Refuge
20% Most Impaired Days, Anthropogenic Visibility Impairment by Species



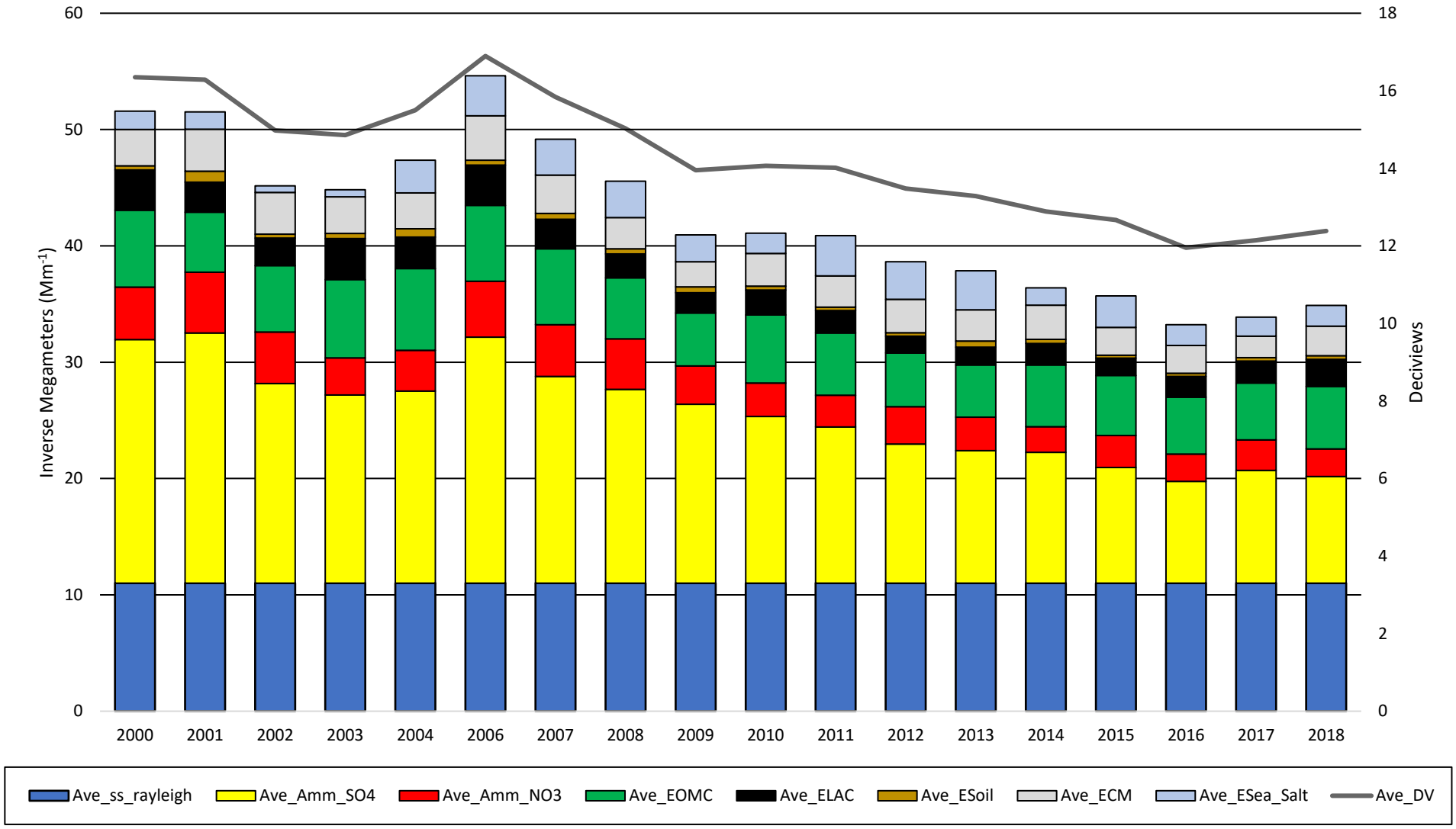
Cape Romain National Wildife Refuge
Annual Average of 20% Clearest Days, Visibility Impairment by Species



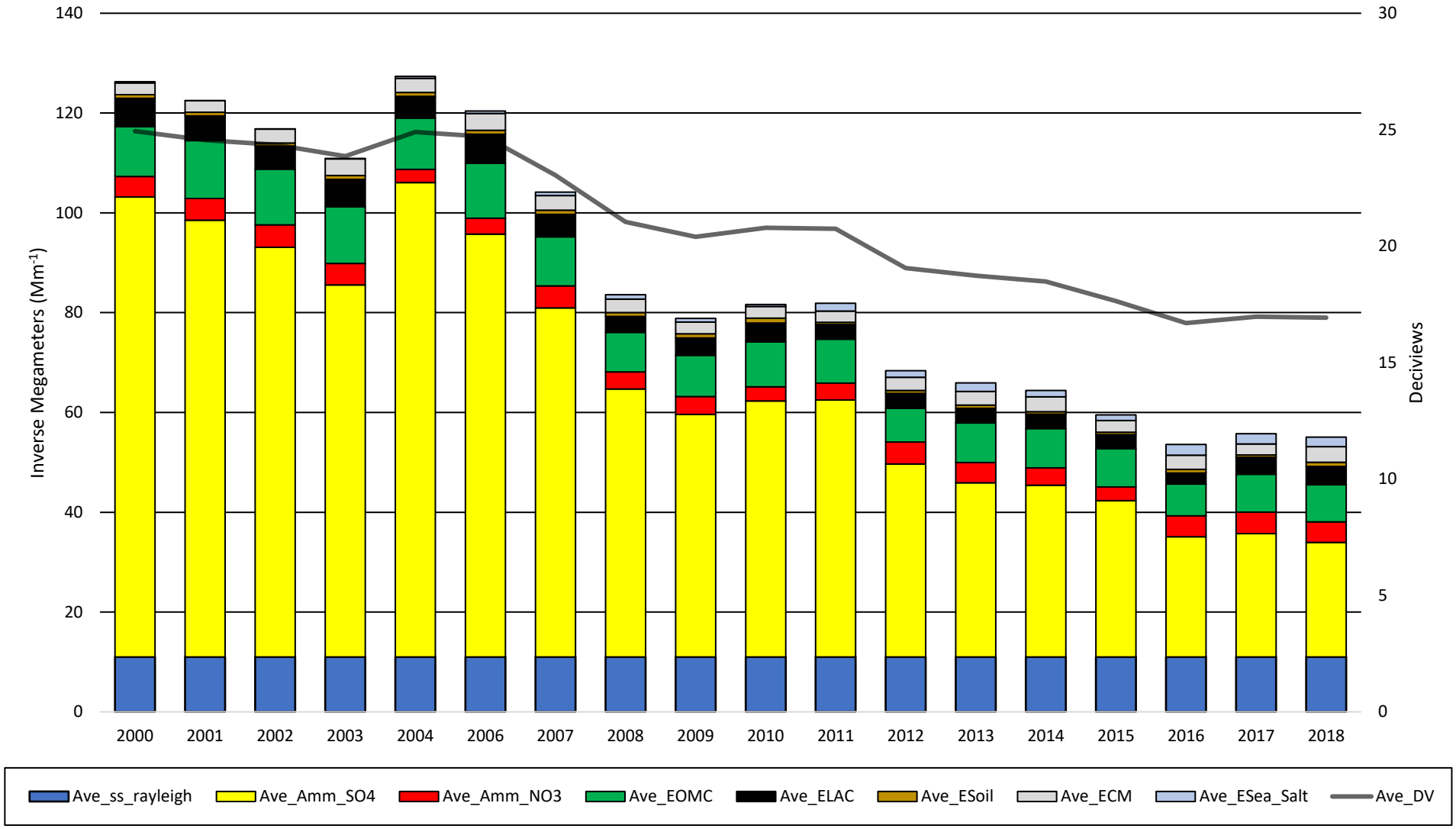
Cape Romain National Wildife Refuge
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



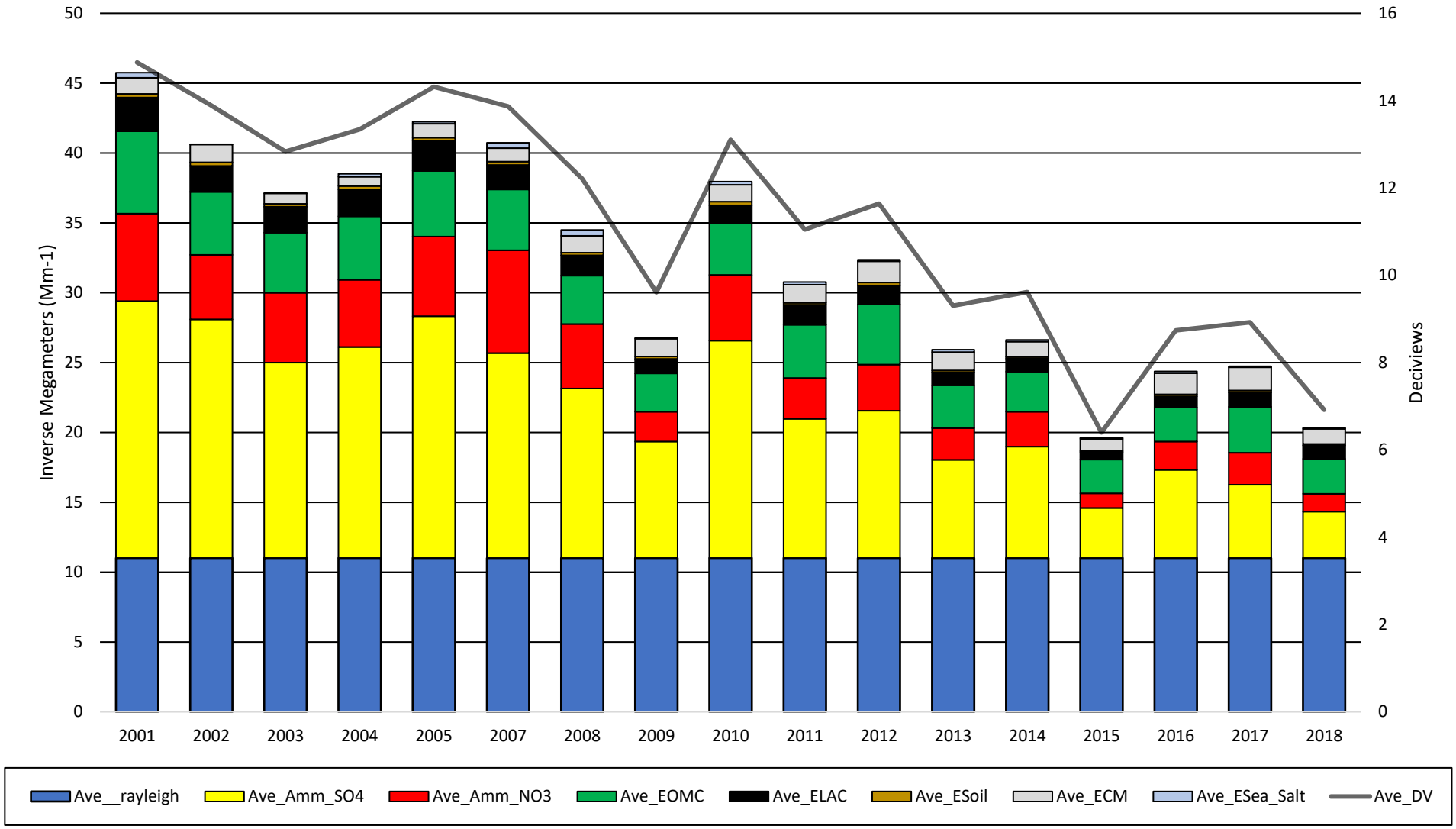
Chassahowitzka National Wildlife Refuge
Annual Average of 20% Clearest Days, Visibility Impairment by Species



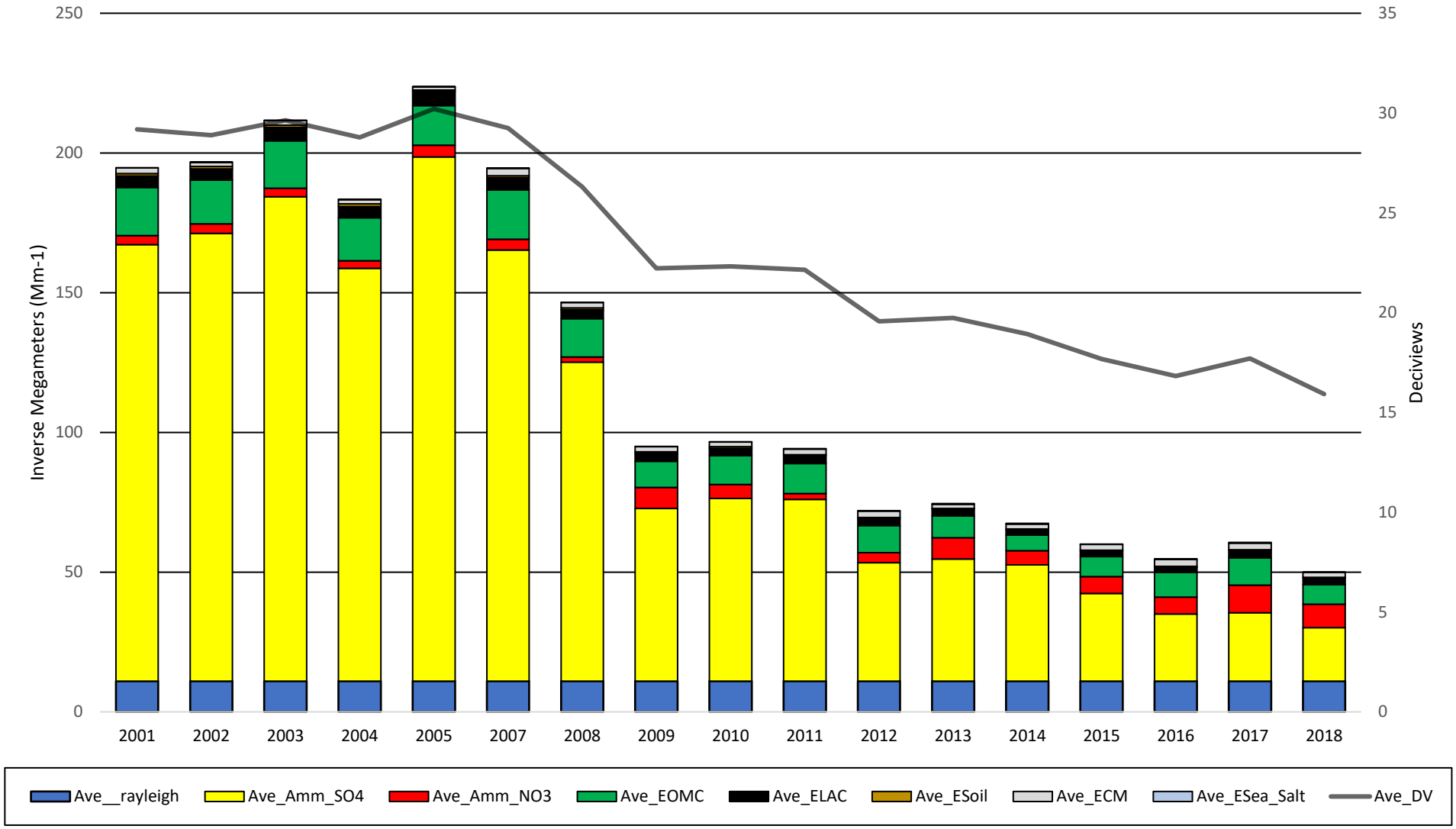
Chassahowitzka National Wildlife Refuge
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



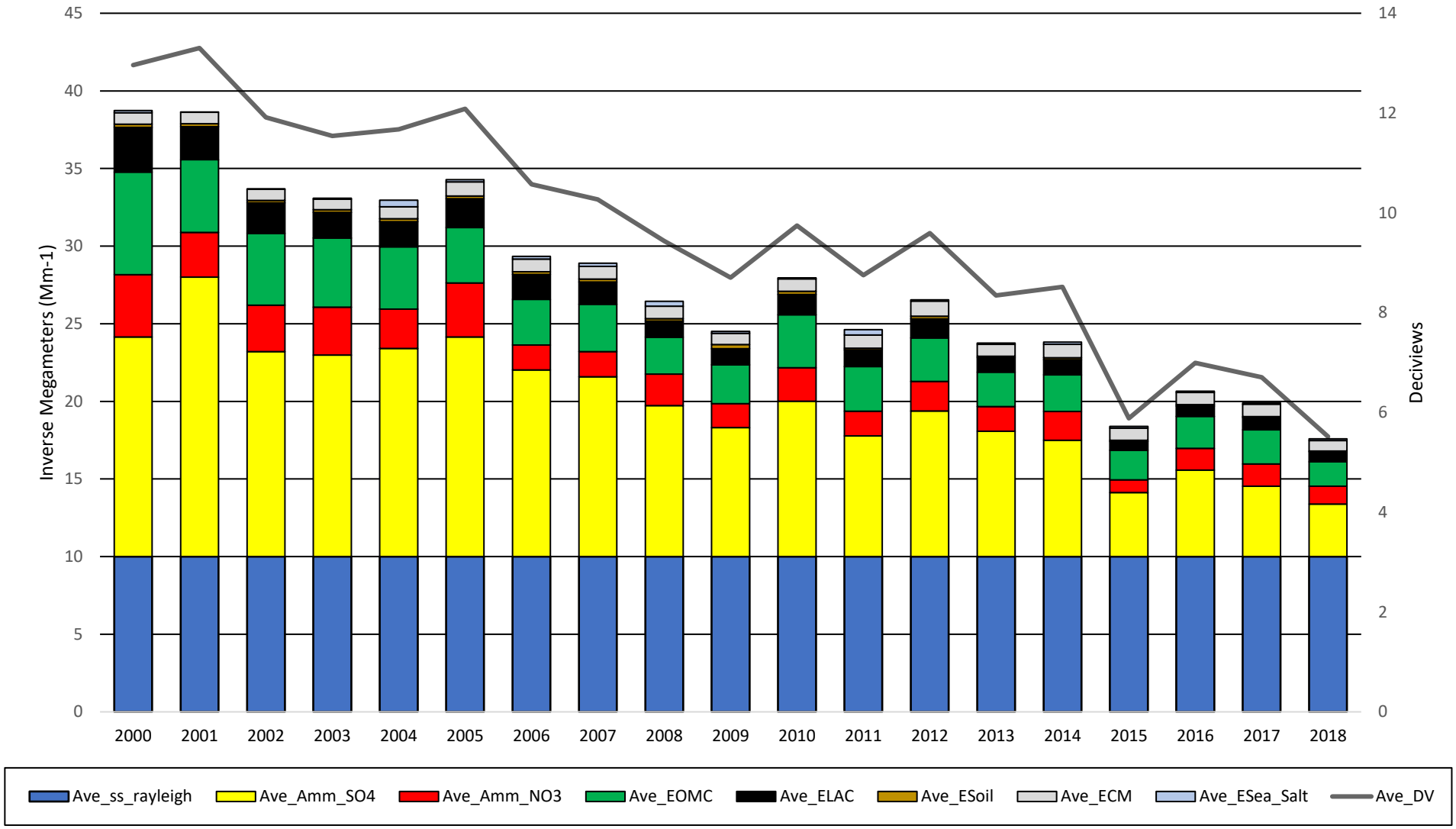
Cohutta Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



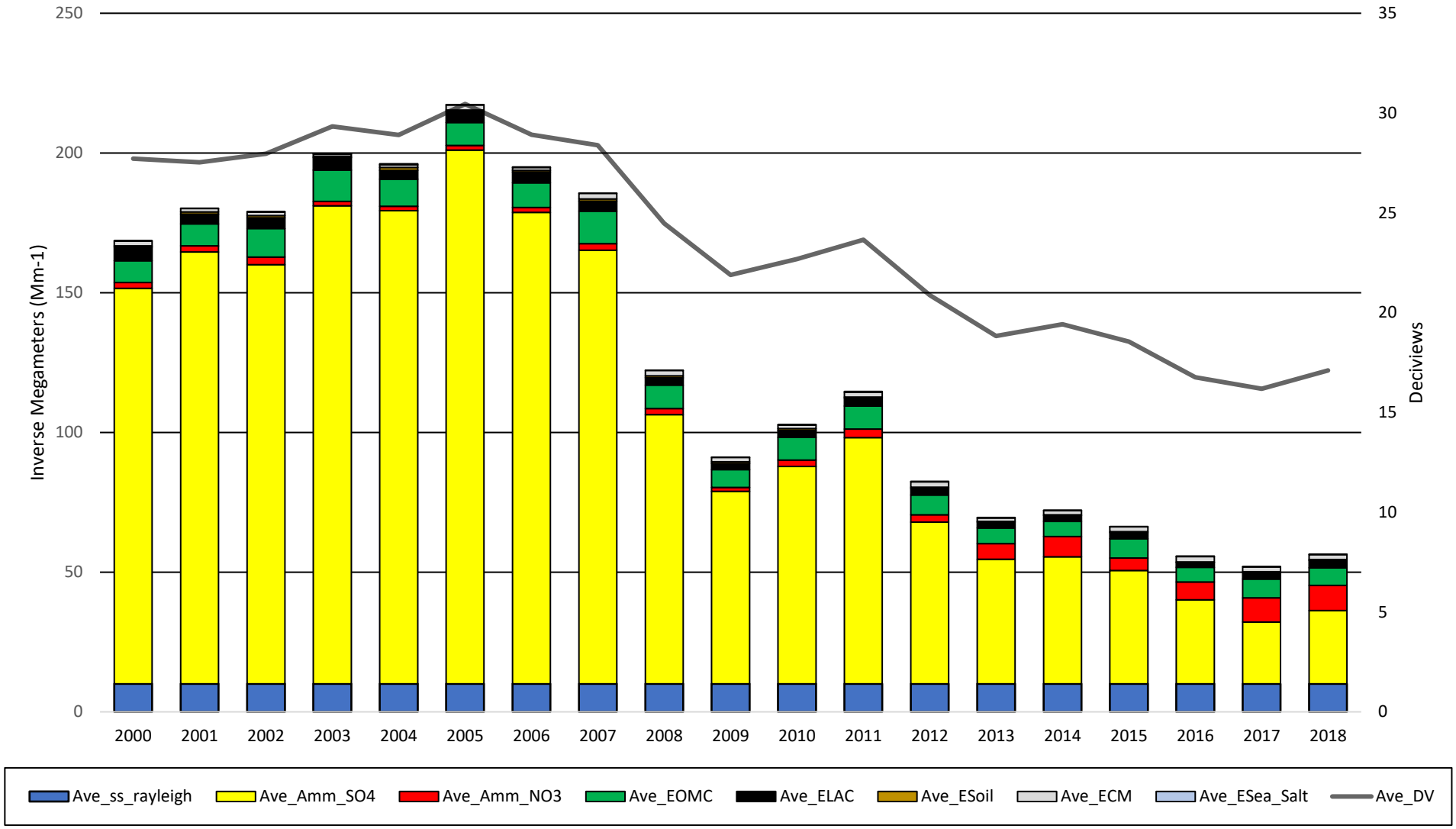
Cohutta Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



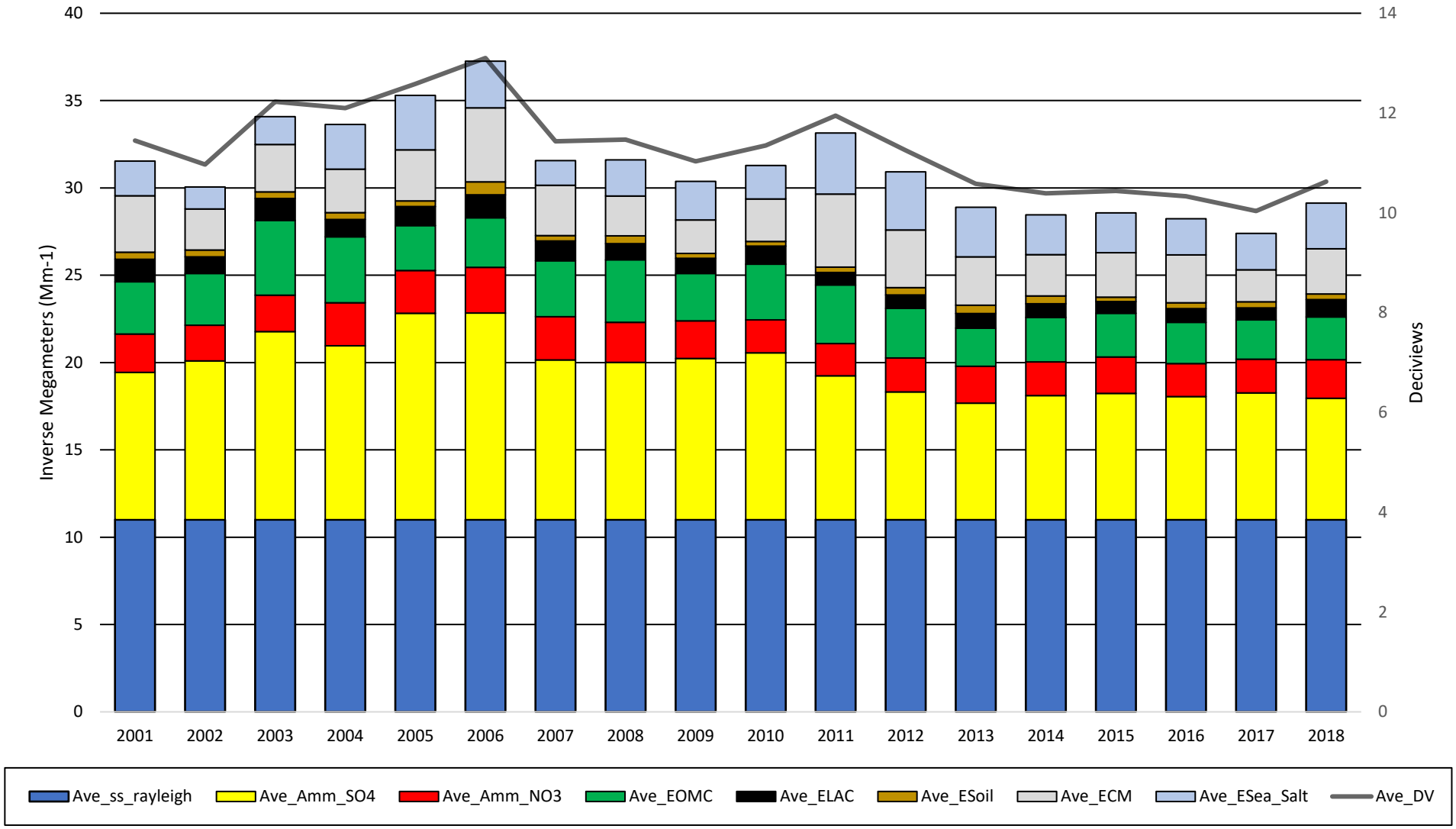
Dolly Sods Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



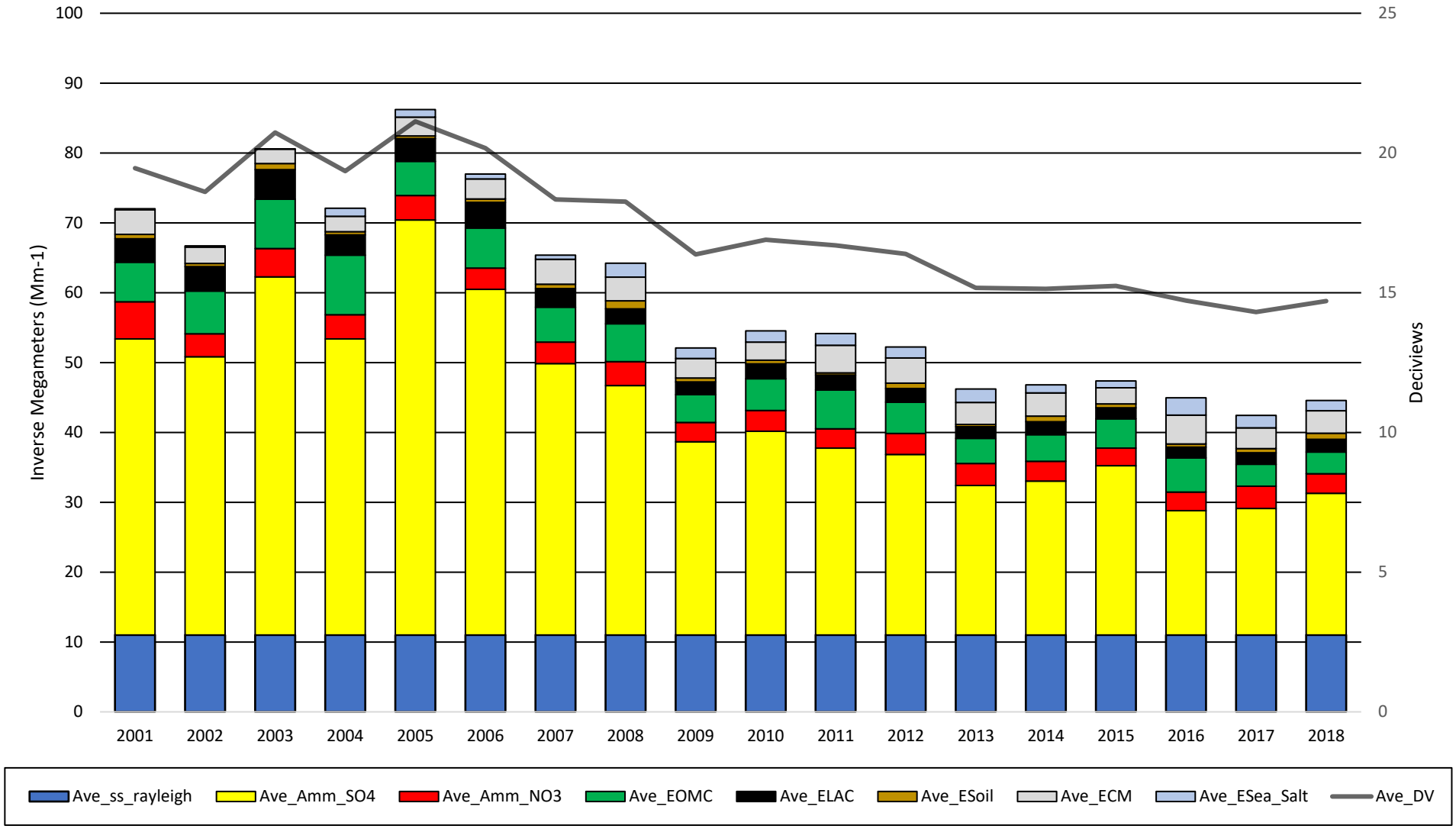
Dolly Sods Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



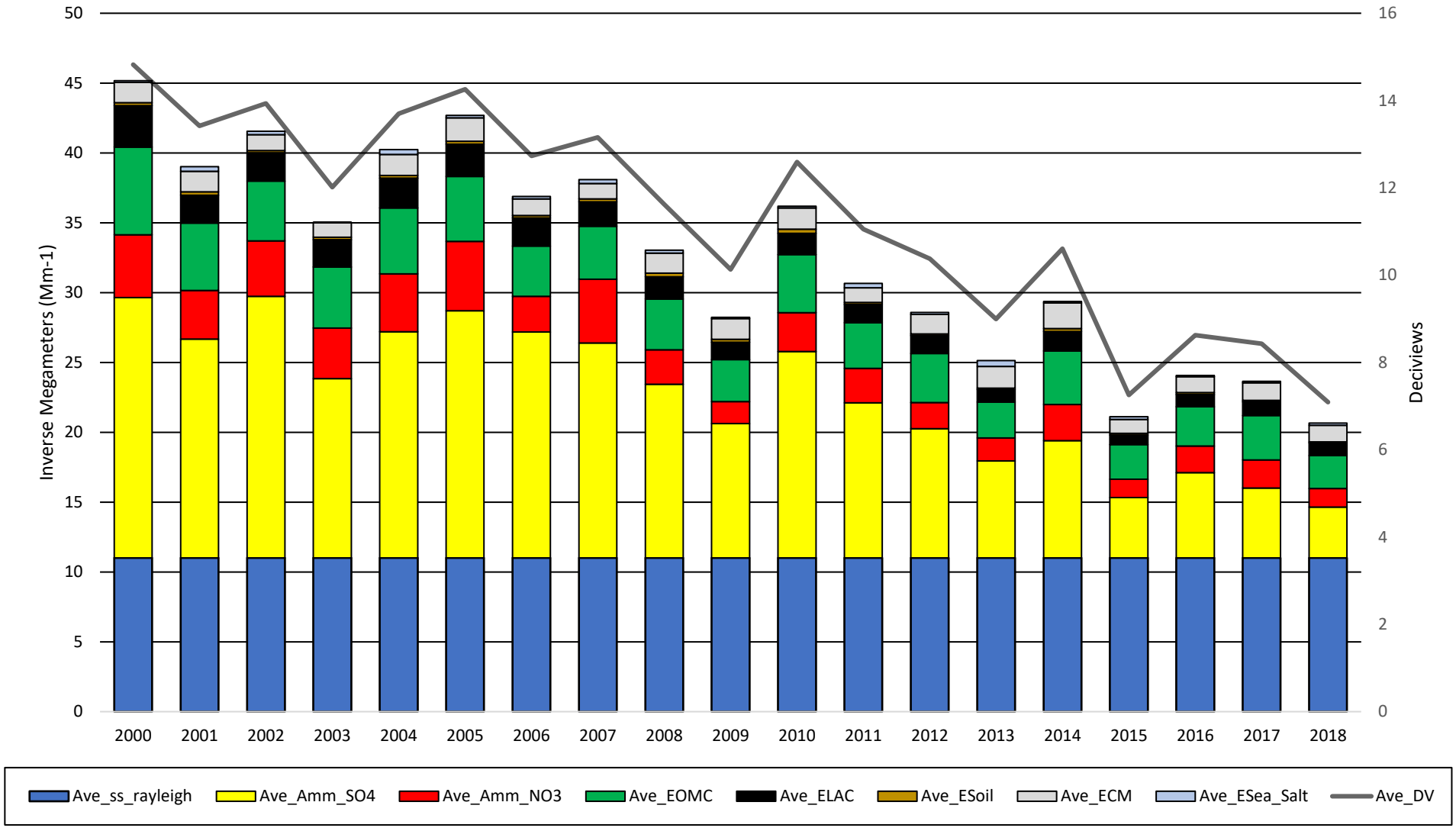
Everglades National Park
Annual Average of 20% Clearest Days, Visibility Impairment by Species



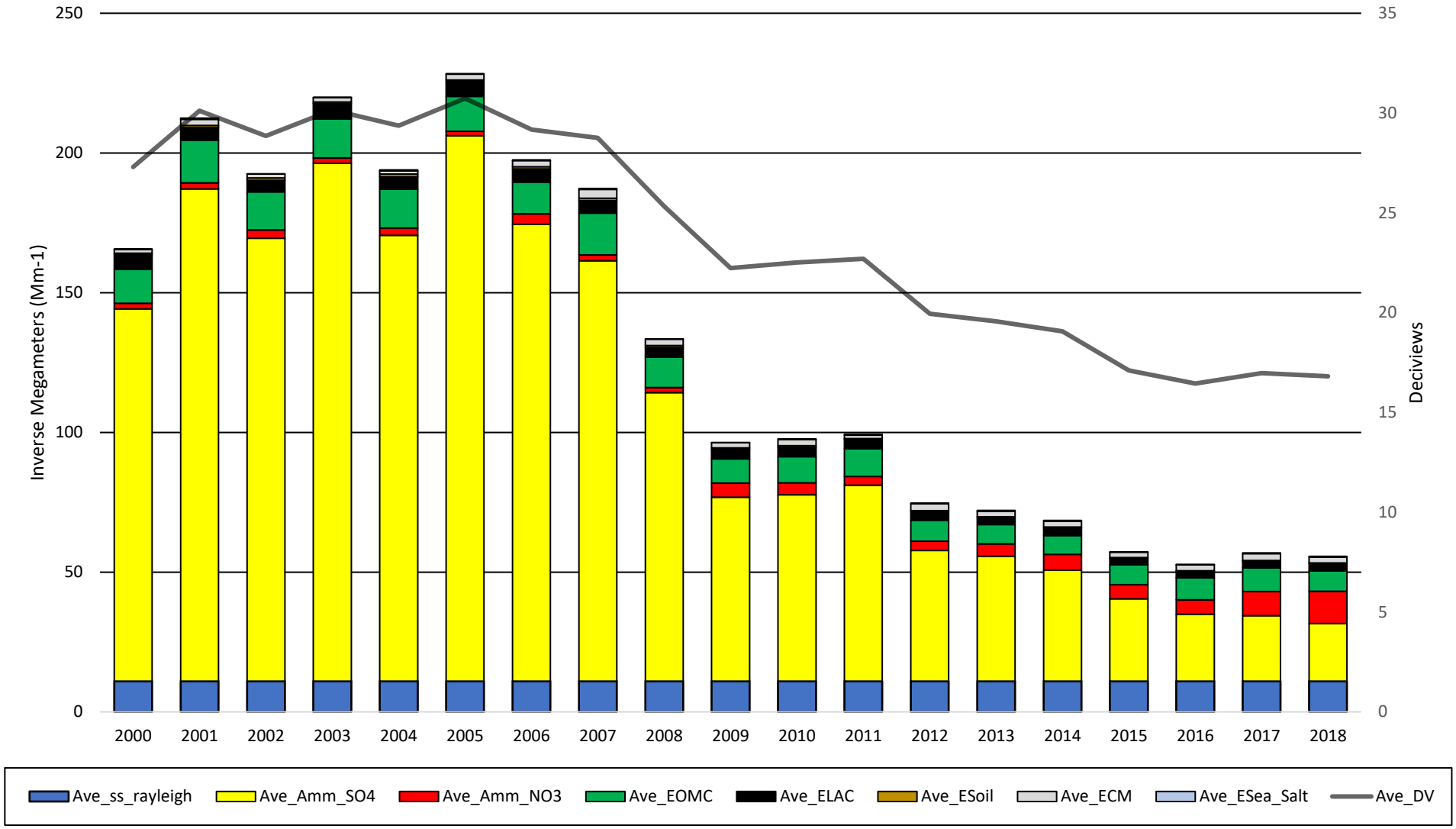
Everglades National Park
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



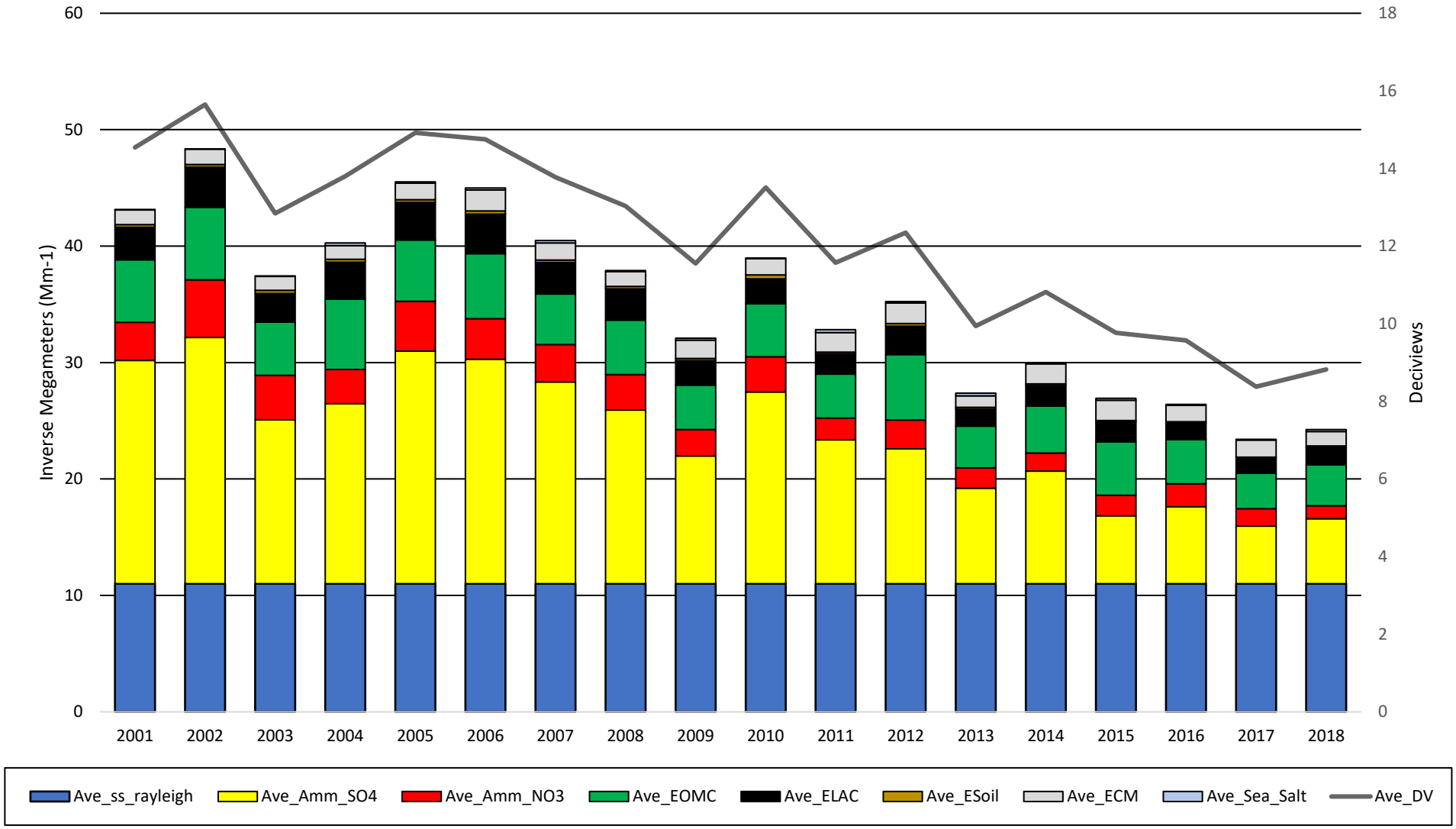
Great Smoky Mountains National Park
Annual Average of 20% Clearest Days, Visibility Impairment by Species



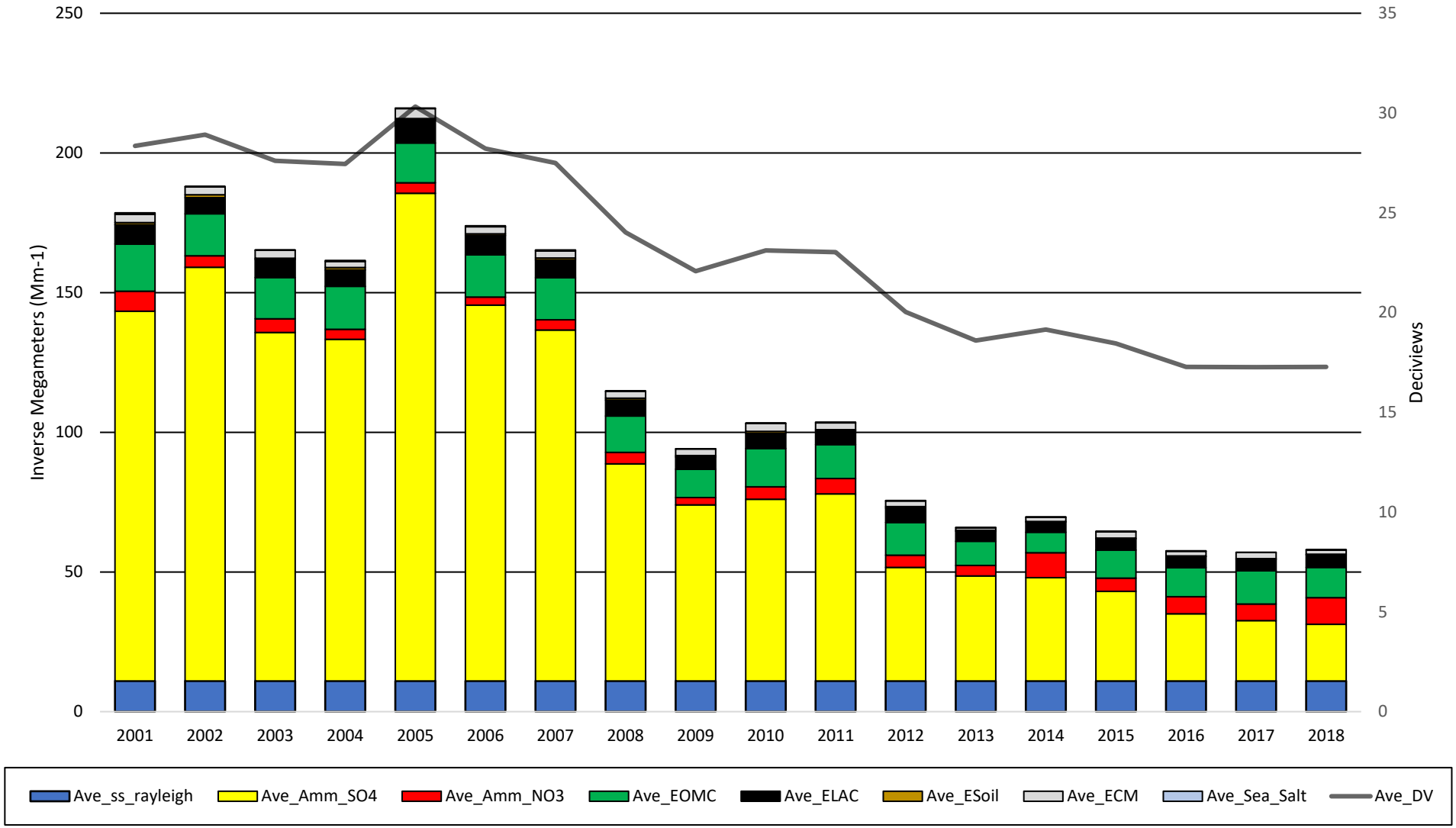
Great Smoky Mountains National Park
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



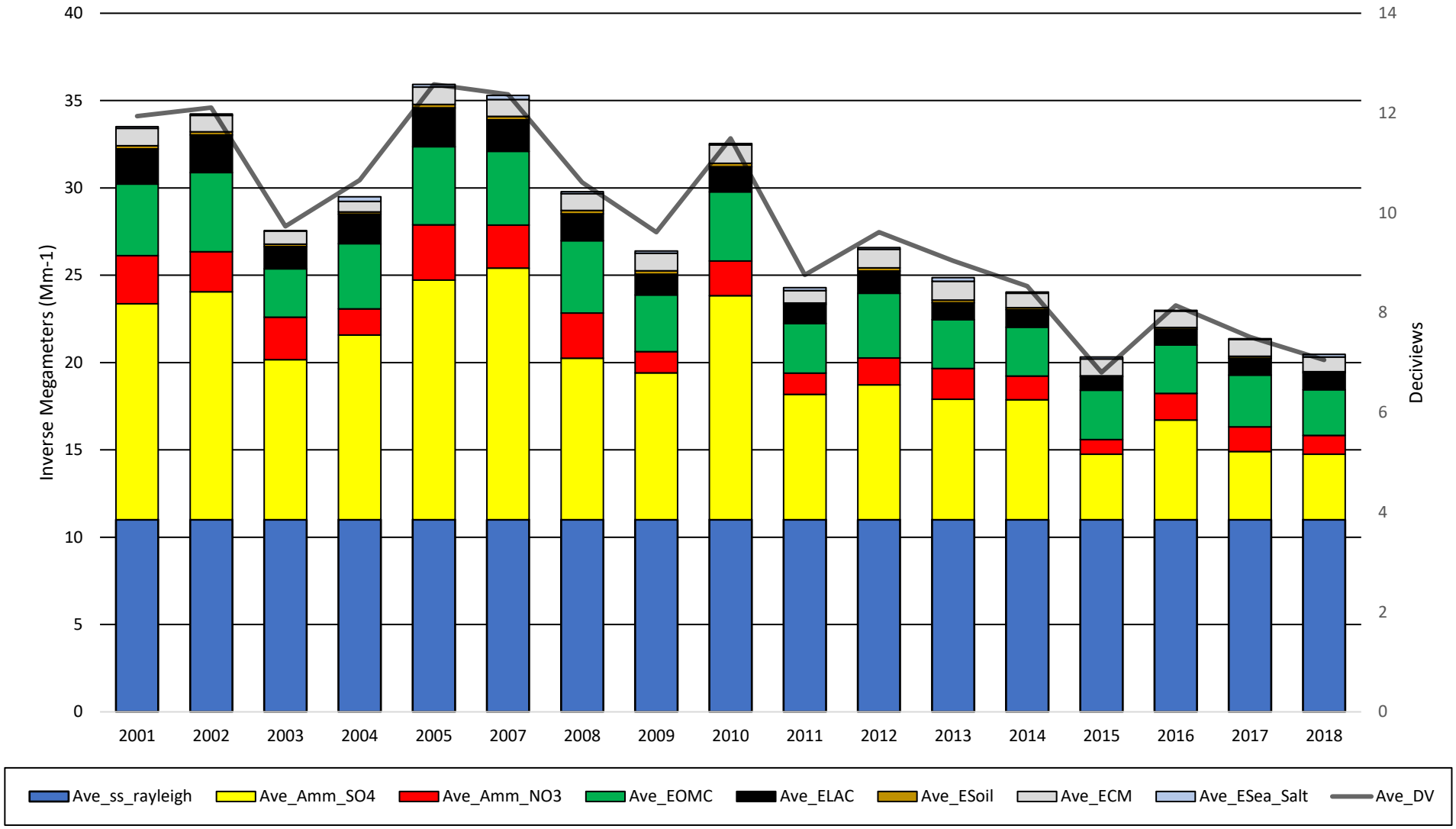
James River Face Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



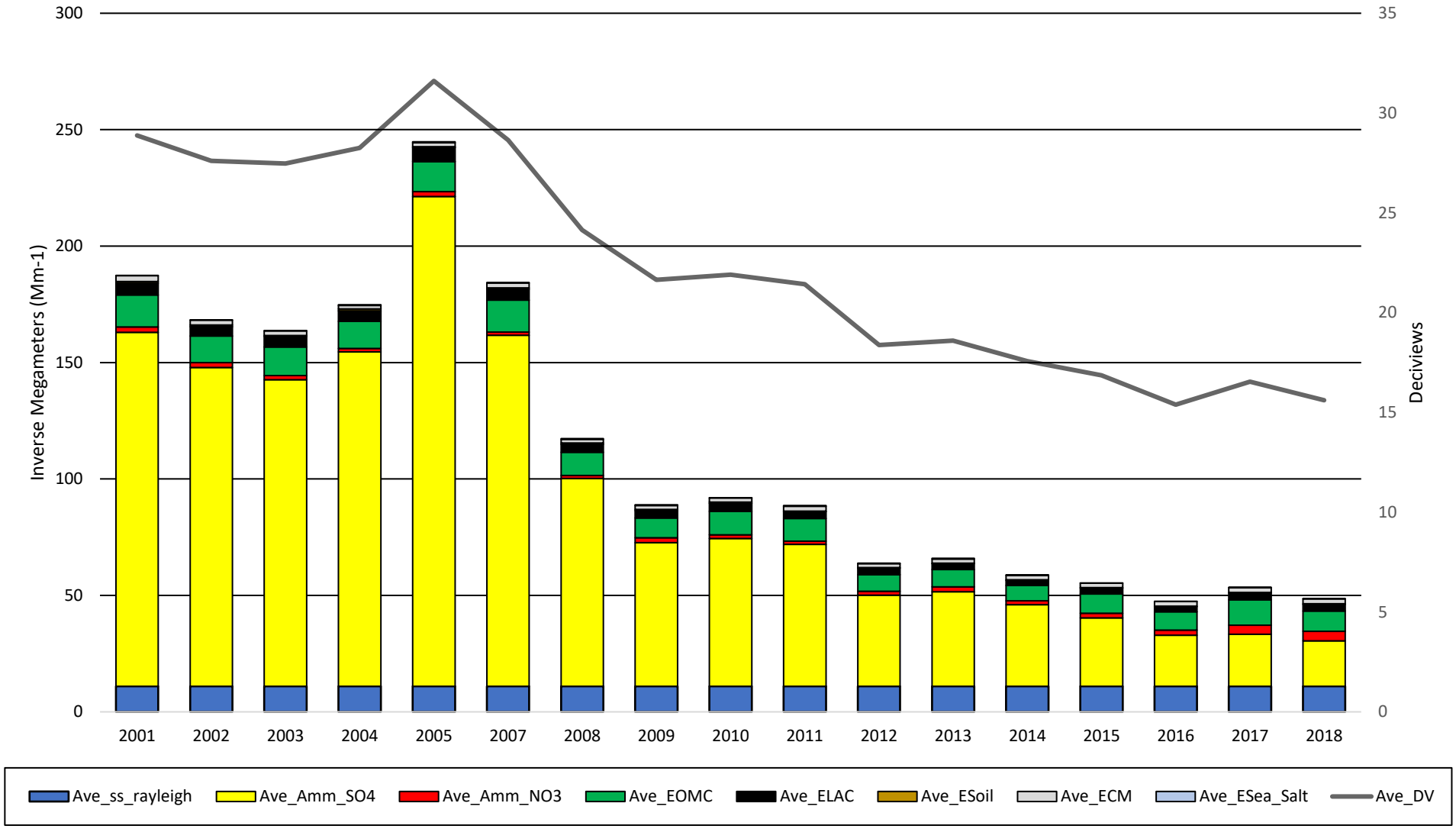
James River Face Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



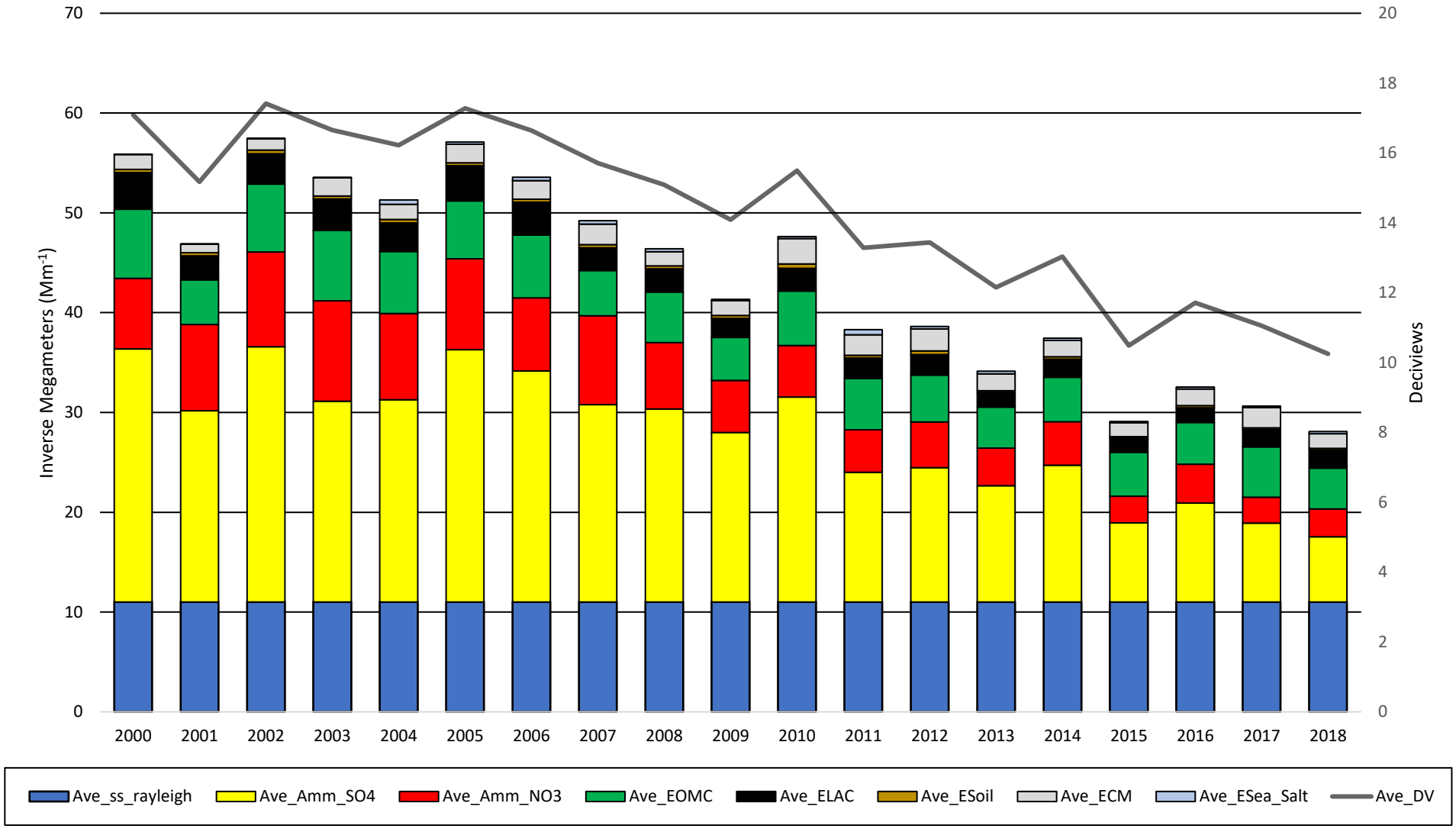
Linville Gorge Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



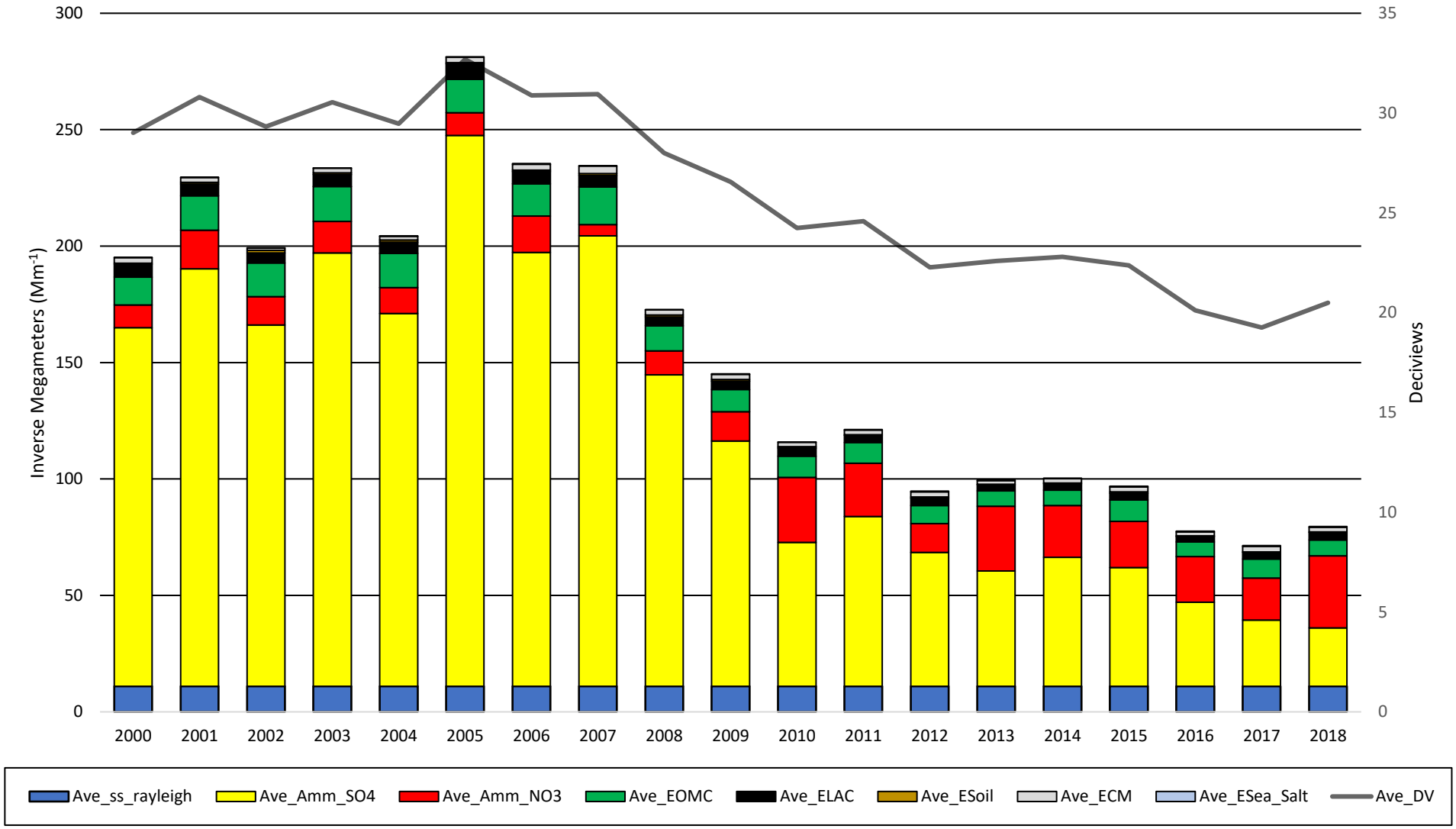
Linville Gorge Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



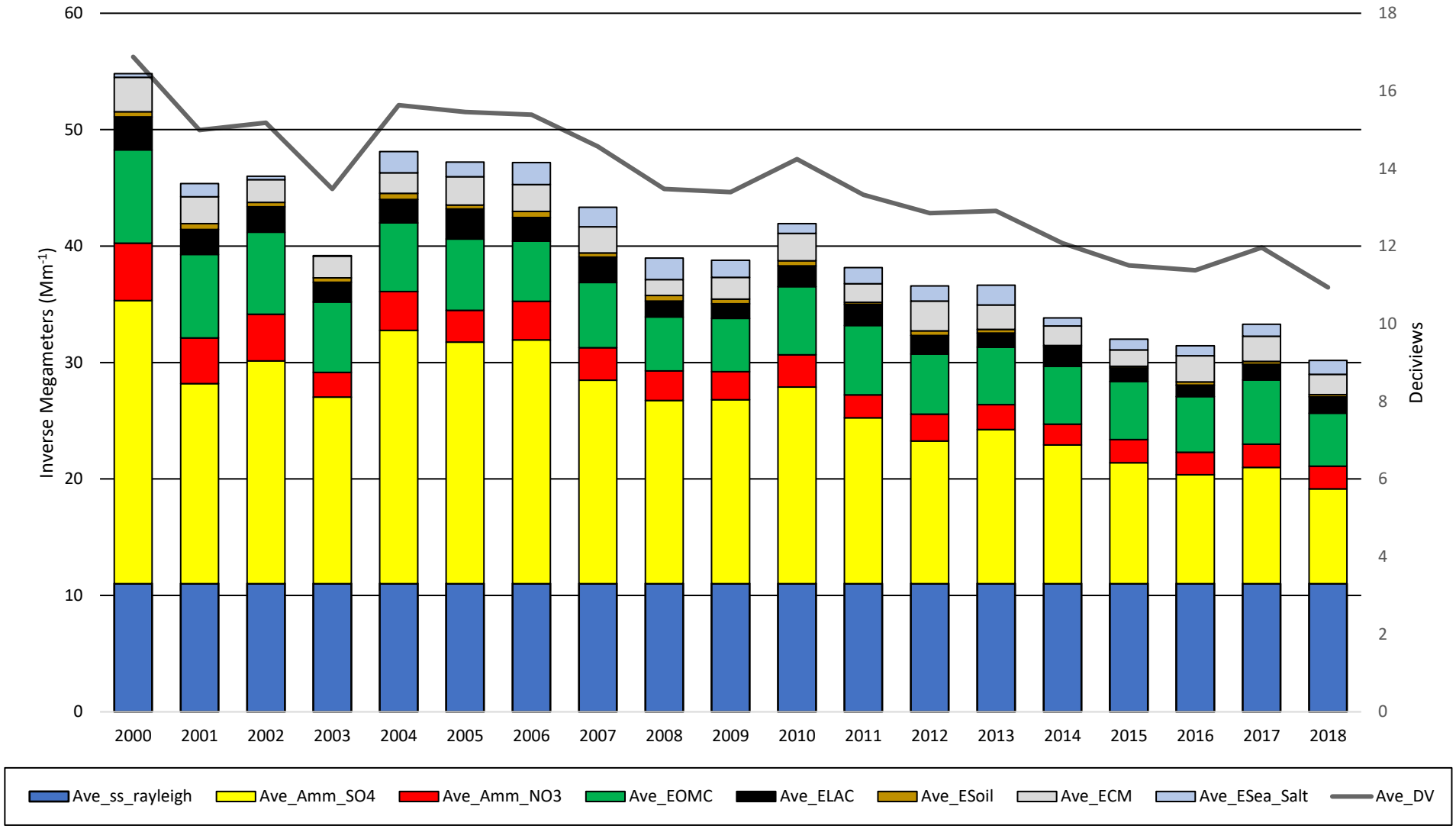
Mammoth Cave National Park
Annual Average of 20% Clearest Days, Visibility Impairment by Species



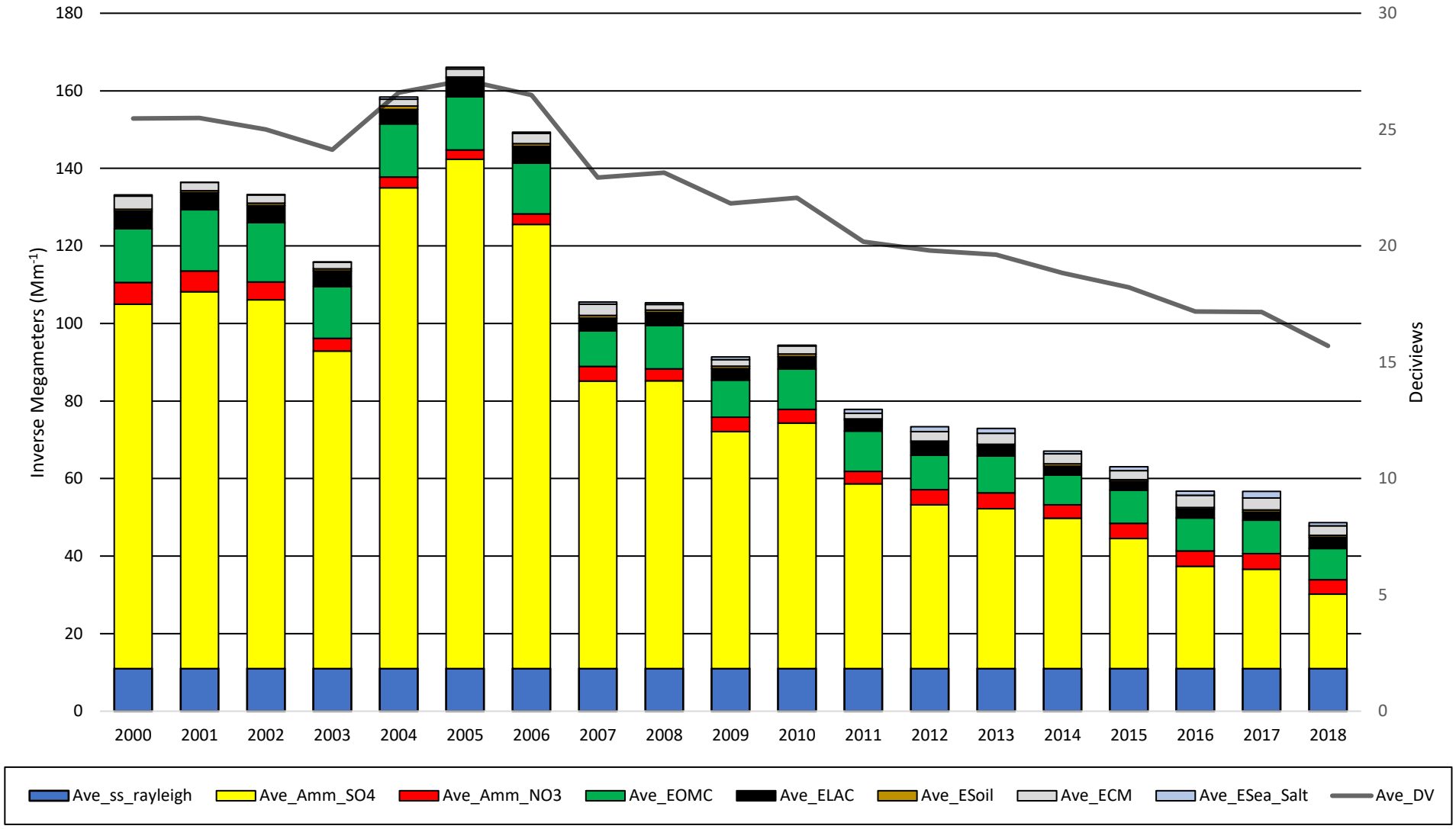
Mammoth Cave National Park
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



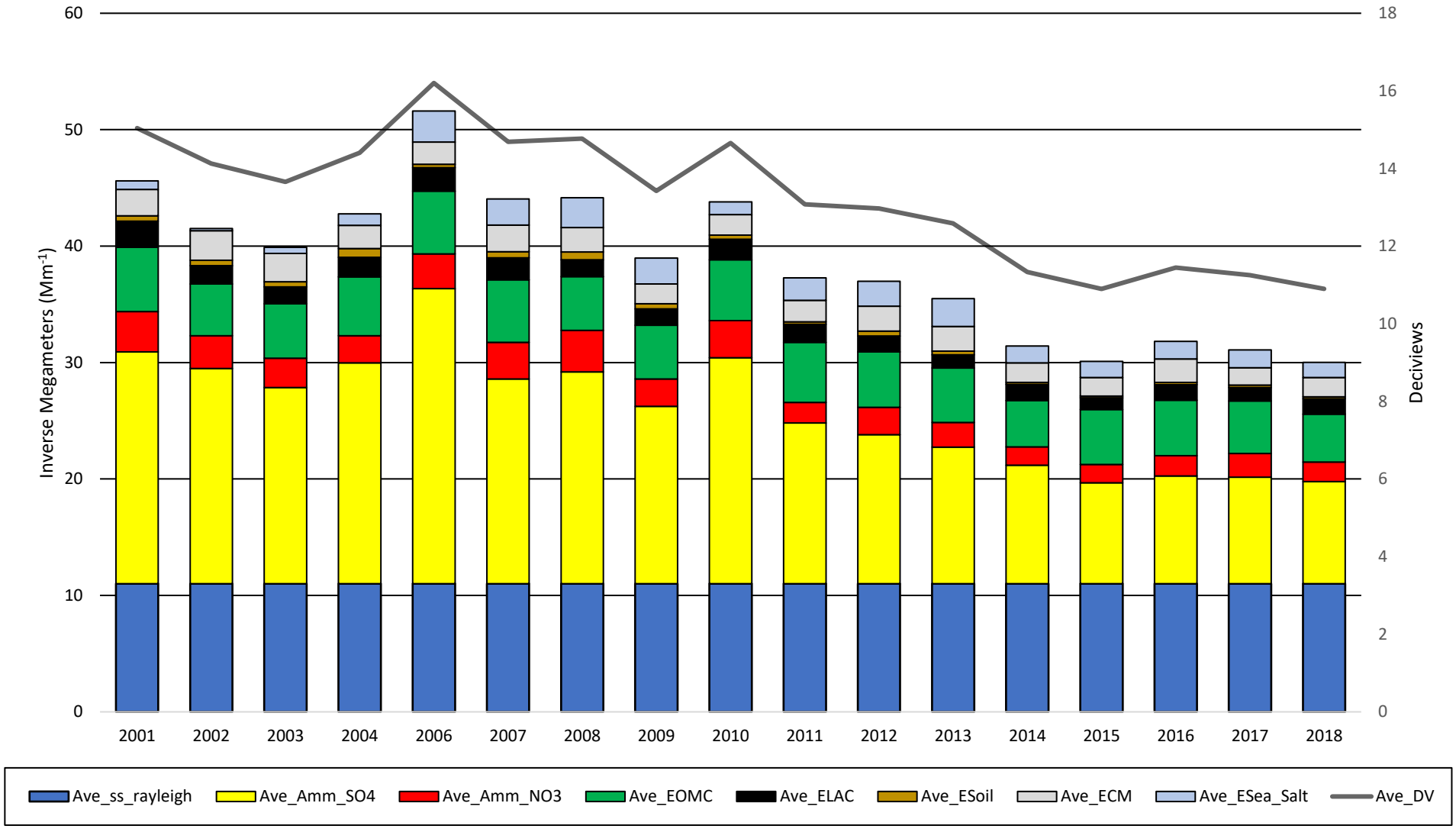
Okefenokee National Wildlife Refuge
Annual Average of 20% Clearest Days, Visibility Impairment by Species



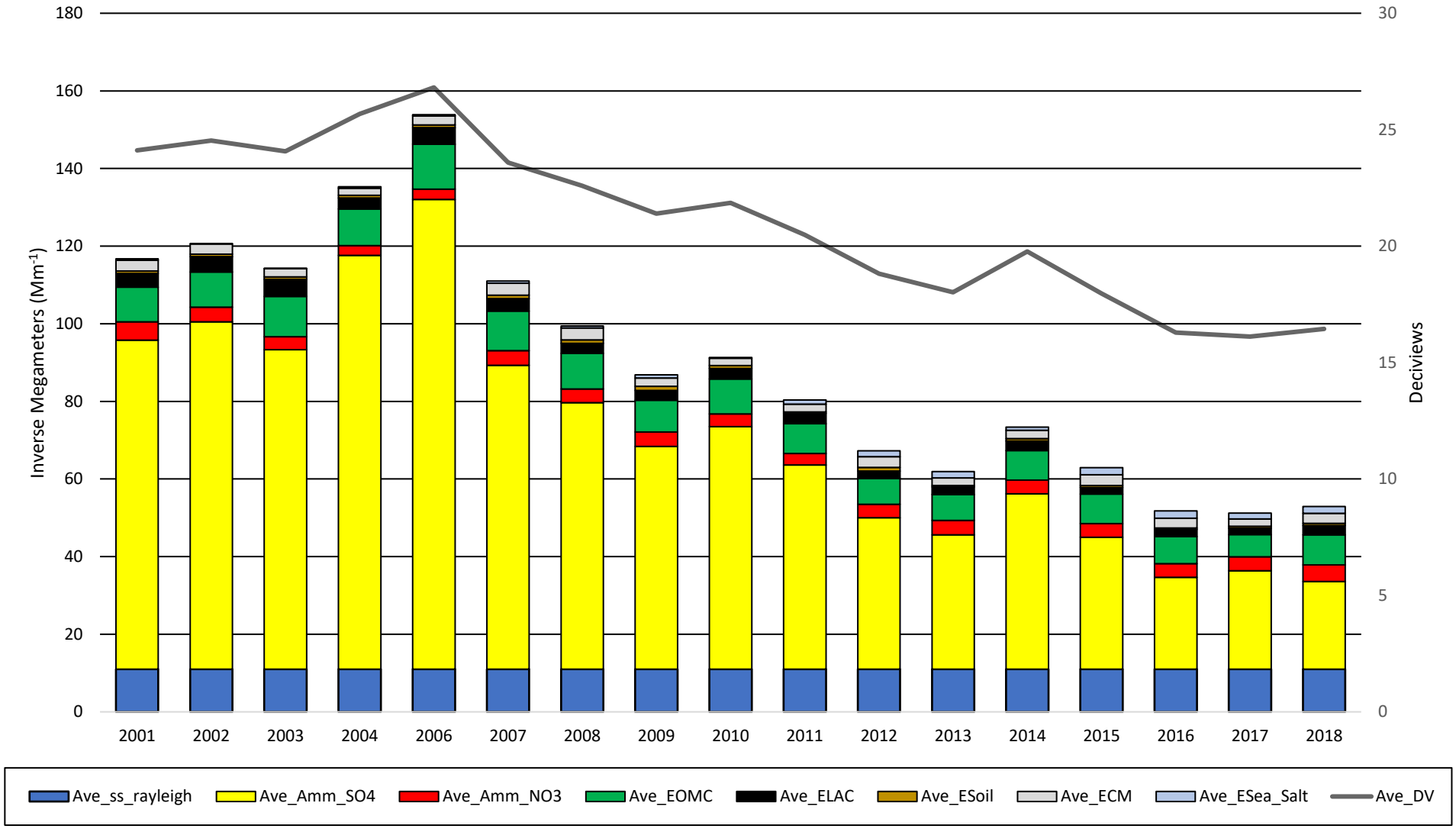
Okefenokee National Wildlife Refuge
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



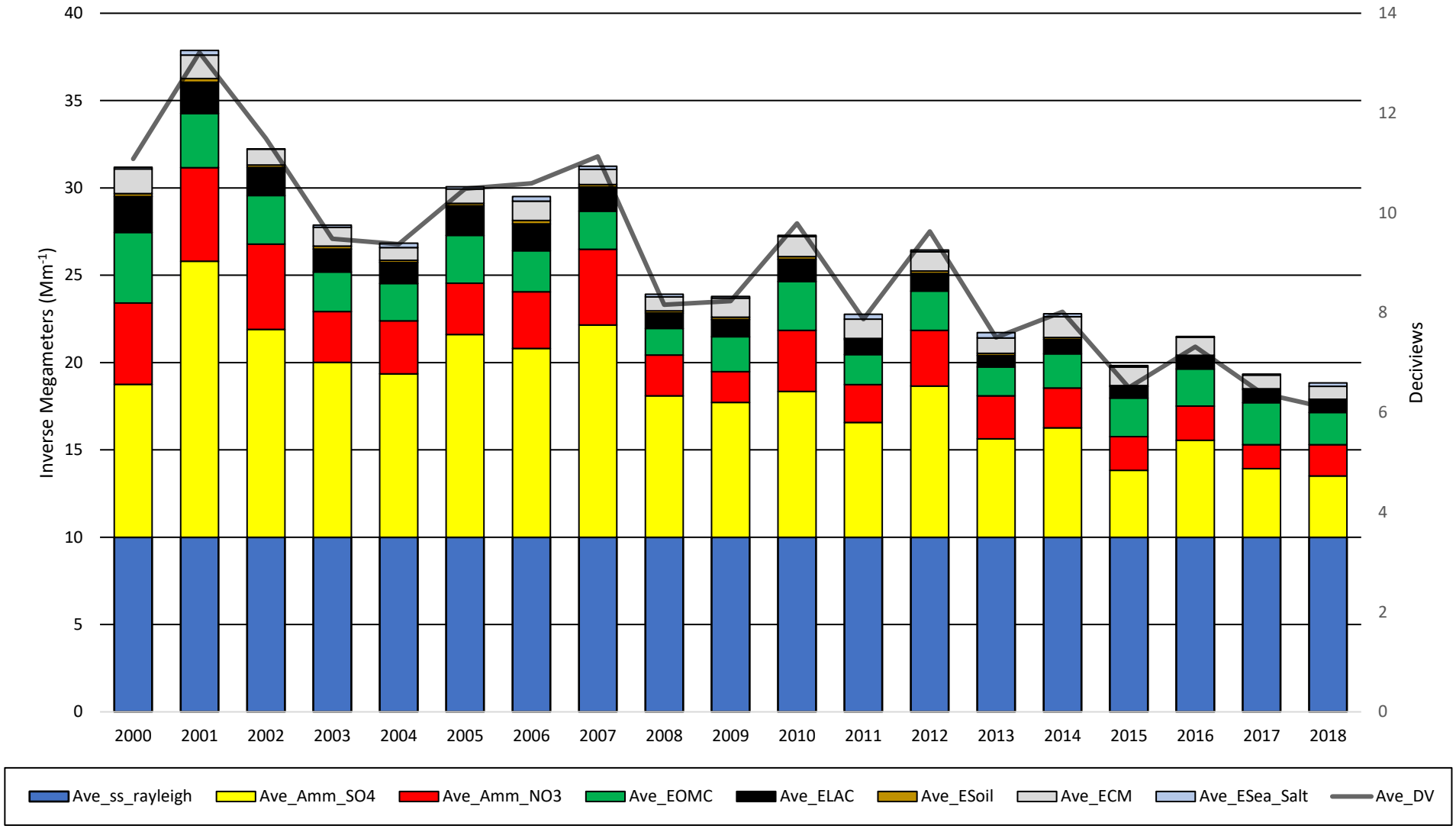
St. Mark's National Wildlife Refuge
Annual Average of 20% Clearest Days, Visibility Impairment by Species



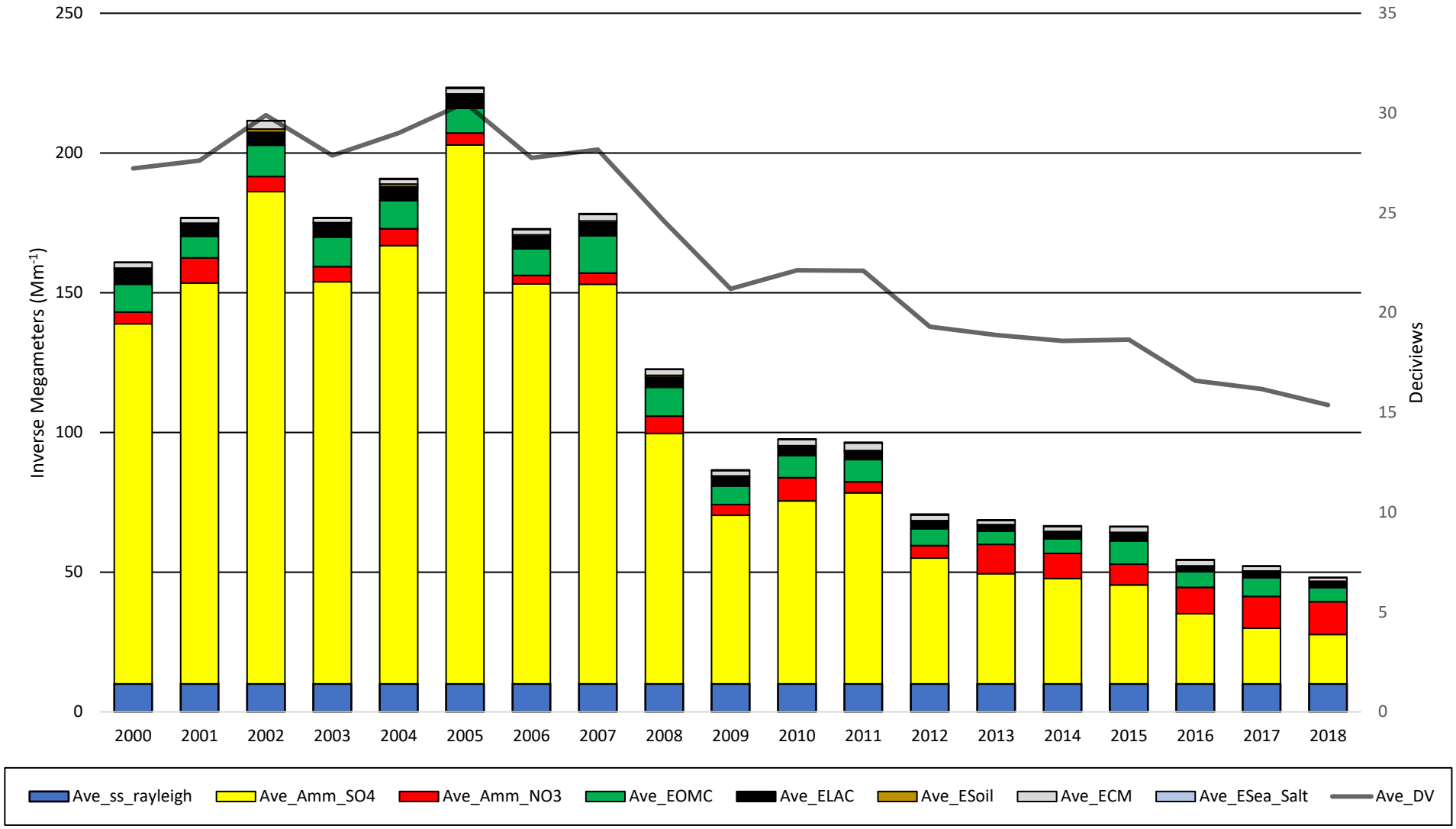
St. Mark's National Wildlife Refuge
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



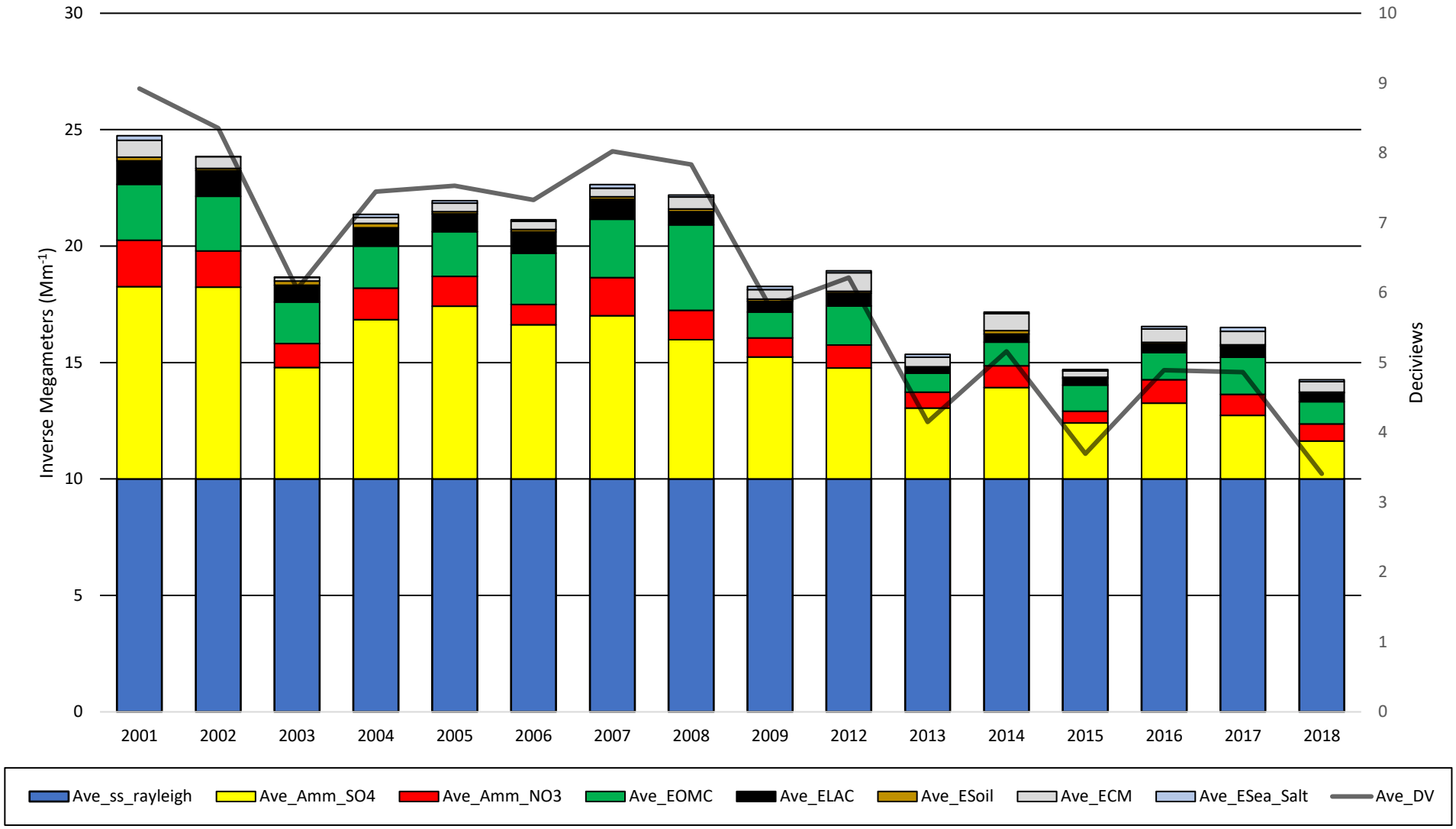
Shenandoah National Park
Annual Average of 20% Clearest Days, Visibility Impairment by Species



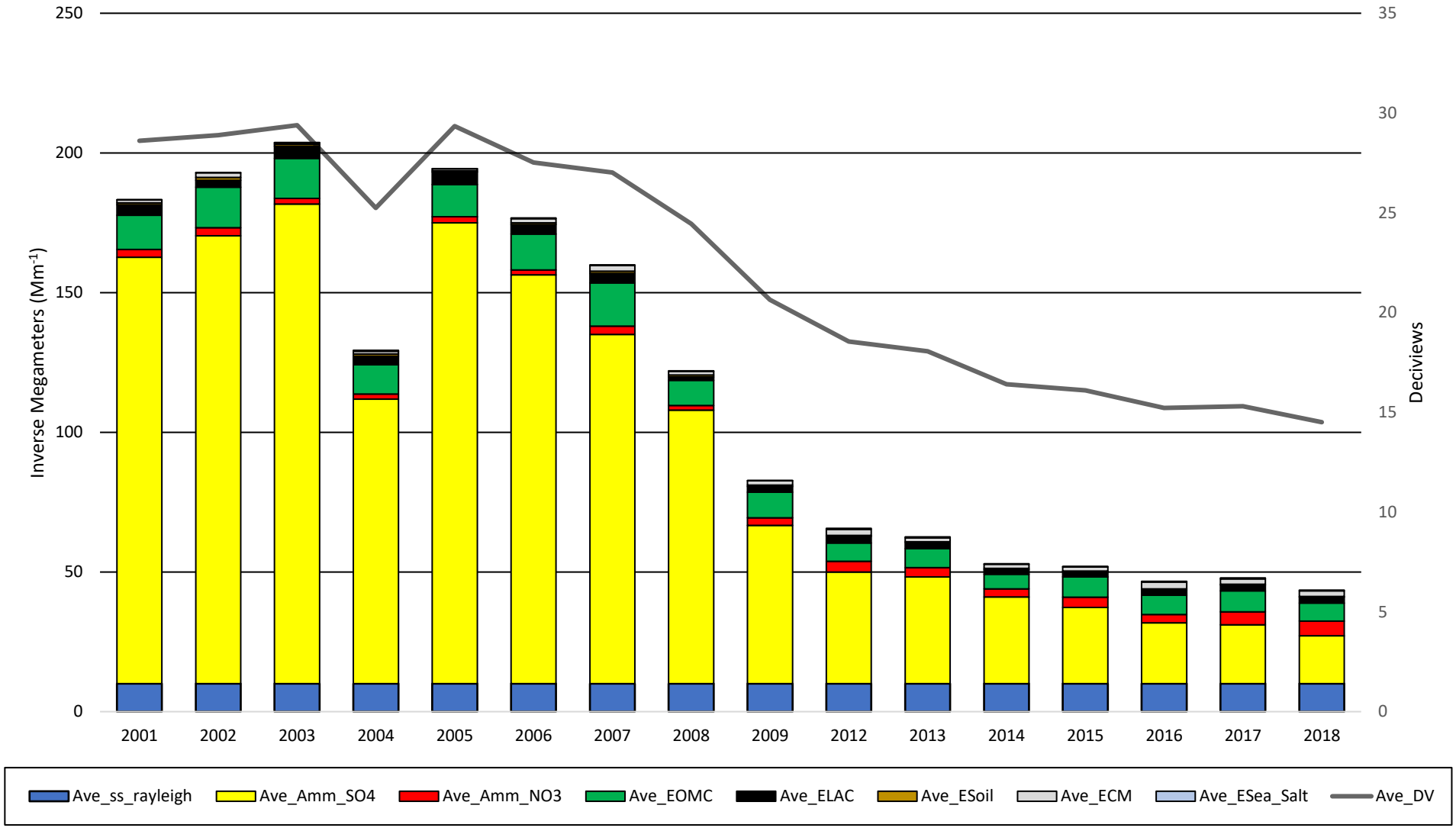
Shenandoah National Park
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



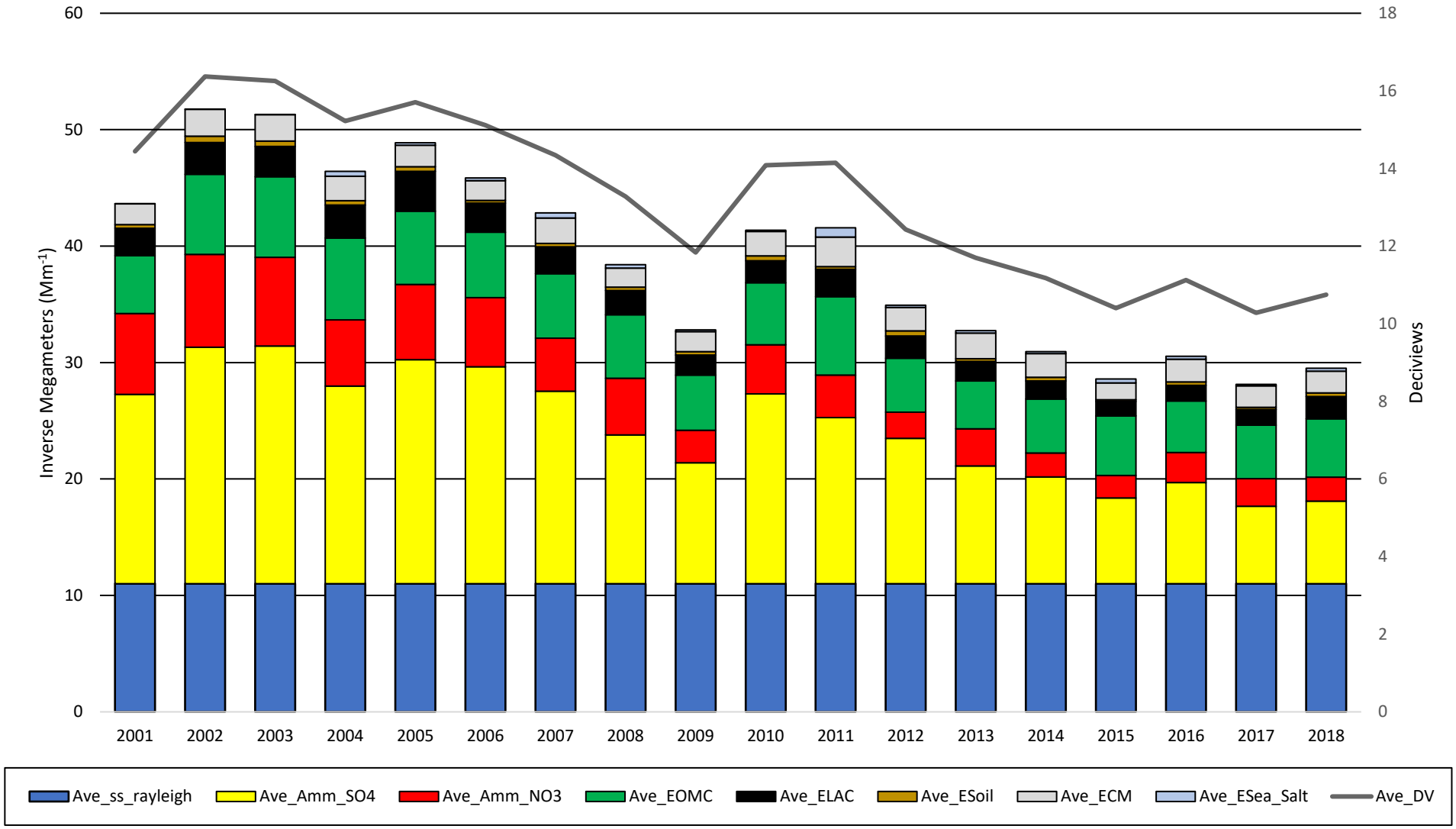
Shining Rock Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



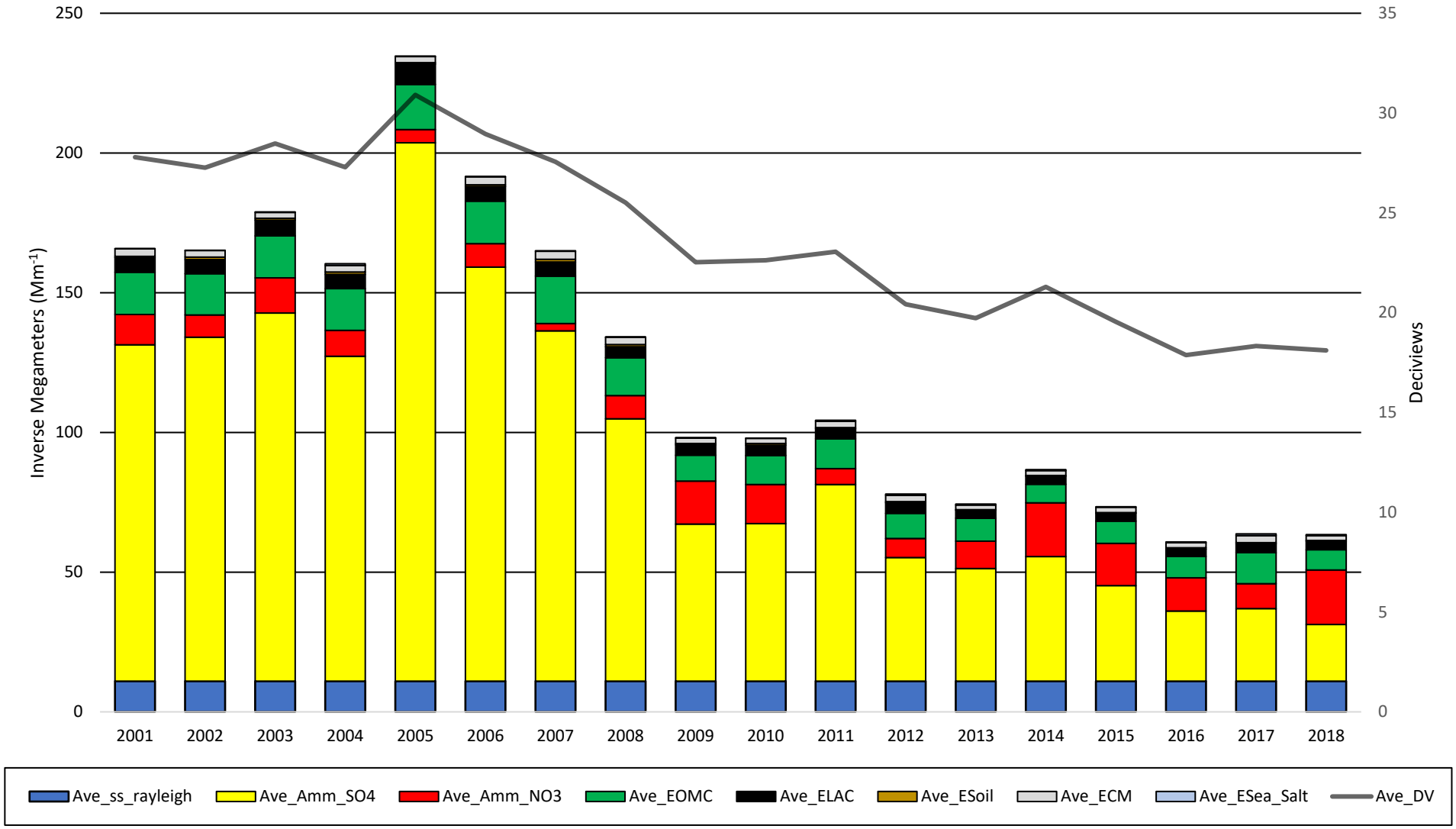
Shining Rock Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



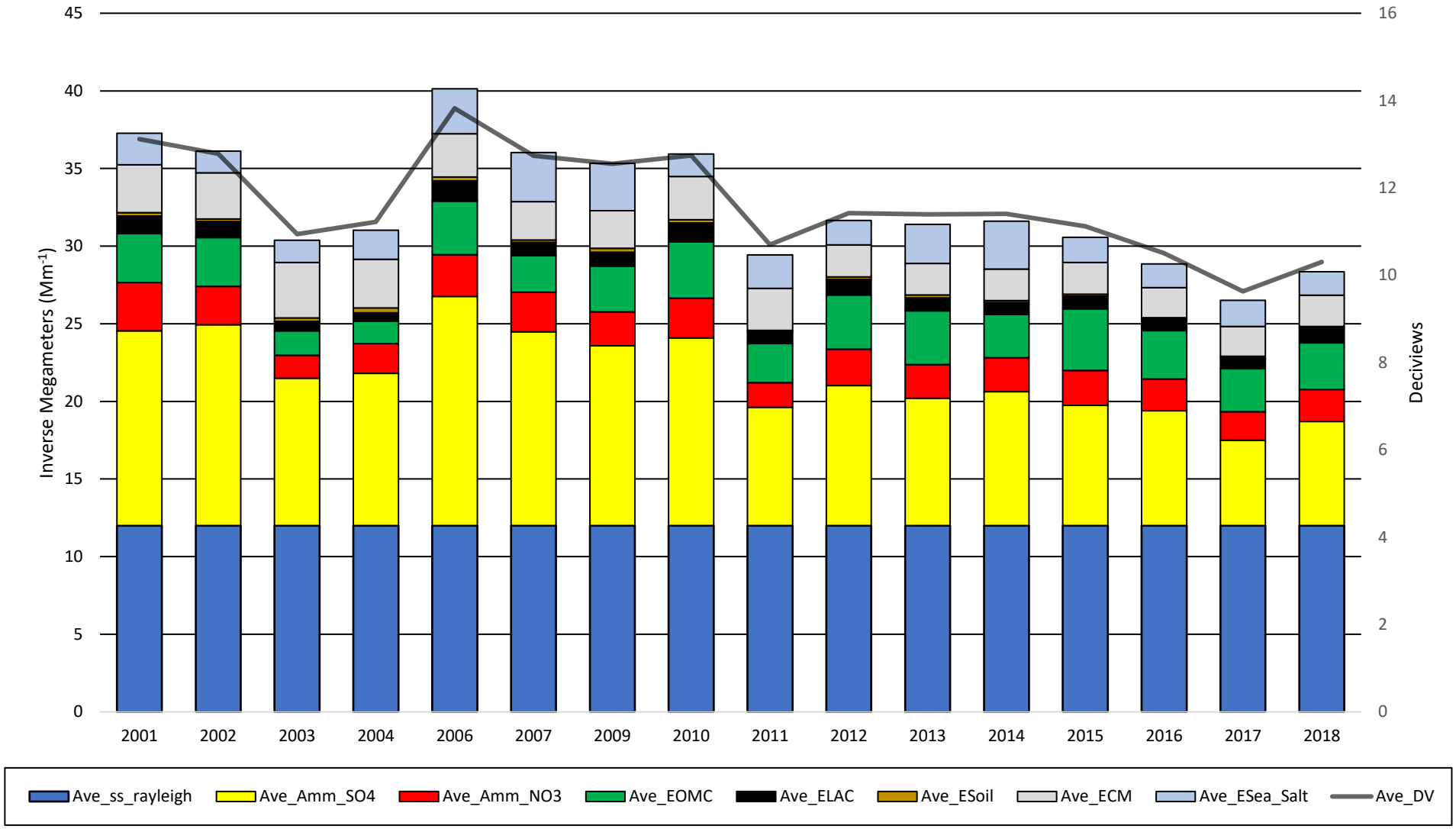
Sipsey Wilderness Area
Annual Average of 20% Clearest Days, Visibility Impairment by Species



Sipsey Wilderness Area
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species



Swanquarter National Wildlife Refuge
Annual Average of 20% Clearest Days, Visibility Impairment by Species



Swanquarter National Wildlife Refuge
Annual Average of 20% Most Impaired Days, Visibility Impairment by Species