Mid-Atlantic/Northeast U.S. Visibility Data

(2nd RH SIP Metrics)

Prepared by
Mid-Atlantic/Northeast Visibility Union (MANEVU)
Technical Support Committee
Visibility Data Workgroup

August 13, 2024
Revised May 19, 2025

Acknowledgments

This document is an update of the following report: *Mid-Atlantic/Northeast U.S. Visibility Data (2nd RH SIP Metrics) – October 17, 2023* (MANEVU 2023).

We could not have completed this work without the IMPROVE (Interagency Monitoring of Protected Visual Environments) program and the long-term commitment of the National Park Service and other state and federal partners to maintain visibility networks and the Federal Land Manager Environmental Database (FED). FED is hosted at the Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA). IMPROVE is a collaborative association of state, Tribal, and federal agencies, and international partners. The U.S. Environmental Protection Agency is the primary funding source, with contracting and research support from the National Park Service. 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.

Special thanks to Scott Copeland, USDA Forest Service Air Data Analyst for all his efforts to complete data analyses used for this report.

TABLE OF CONTENTS

Acknowledgments i
Executive Summary v
1. Introduction 1
2. Visibility Metrics 3
2-1 IMPROVE Equation 5
2-2 Natural Visibility Metrics 6
2-3 Baseline, Current and Reasonable Progress Goal Visibility Metrics 8
2-4 Visibility Metrics Trend Plots 10
3. Visibility Species Light Extinction Trends 19
4. Summary 39
5. References 40

Appendix A: Tracking Progress Data for Class I Areas In and Adjacent to the MANEVU Region

Appendix B: Annual Visibility Species Trends Plots for Current Active IMPROVE Protocol Sites In and Adjacent to the MANE-VU Region

Appendix C: Seasonal Trend Plots of 20 Percent Most Impaired Days for Current Active IMPROVE Protocol Sites In and Adjacent to the MANE-VU Region

Appendix D: Range of Observed Visibility Species for Class I Areas In and Adjacent to the MANEVU Region

FIGURES

Figure 1-1. Class I Areas and IMPROVE Protocol Monitoring Sites In and Adjacent to the MANEVU Region 2
Figure 2-1. Visibility Metrics Levels at Acadia National Park 11
Figure 2-2. Visibility Metrics Levels at Moosehorn Wilderness Area 12
Figure 2-3. Visibility Metrics Levels at Great Gulf Wilderness Area 13
Figure 2-4. Visibility Metrics Levels at Lye Brook Wilderness Area 14
Figure 2-5. Visibility Metrics Levels at Brigantine Wilderness Area 15
Figure 2-6. Visibility Metrics Levels at Dolly Sods Wilderness Area 16
Figure 2-7. Visibility Metrics Levels at Shenandoah National Park 17

Figure 2-8. Visibility Metrics Levels at James River Face Wilderness 18
Figure 3-1. Acadia National Park Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 21
Figure 3-2. Moosehorn Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 22
Figure 3-3. Great Gulf Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 23
Figure 3-4. Lye Brook Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 24
Figure 3-5. Brigantine Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 25
Figure 3-6. Dolly Sods Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 26
Figure 3-7. Shenandoah National Park Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 27
Figure 3-8. James River Face Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels 28
Figure 3-9. Current and Baseline 5-Year Average Light Extinction at Class I Sites on 20 Percent Clearest (left) and 20 Percent Most Impaired Visibility Days (right) 29
Figure 3-10. Individual Species Contribution to Annual Haze Index Levels at Acadia National Park on 20 Percent Clearest and Most Impaired Visibility Days 30
Figure 3-11. Individual Species Contribution to Annual Haze Index Levels at Moosehorn Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days 31
Figure 3-12. Individual Species Contribution to Annual Haze Index Levels at Great Gulf Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days 32
Figure 3-13. Individual Species Contribution to Annual Haze Index Levels at Lye Brook Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days 33
Figure 3-14. Individual Species Contribution to Annual Haze Index Levels at Brigantine Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days 34
Figure 3-15. Individual Species Contribution to Annual Haze Index Levels at Dolly Sods Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days 34

Figure 3-16. Individual Species Contribution to Annual Haze Index Levels at Shenandoah National Park on 20 Percent Clearest and Most Impaired Visibility Days..... 35
Figure 3-17. Individual Species Contribution to Annual Haze Index Levels at James River Face Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days..... 35
Figure 3-18. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for New England Class I Areas..... 36
Figure 3-19. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for New Jersey, West Virginia and Virginia Class I Areas..... 37

TABLES

Table 1-1. Members of the Mid-Atlantic/Northeast Visibility Union (MANEVU)..... 2
Table 2-1. IMPROVE Monitoring Sites..... 4
Table 2-2. 20 Percent Clearest Days Natural Conditions for Class I and IMPROVE Protocol Sites In and Adjacent to the MANEVU Region..... 7
Table 2-3. 20 Percent Most Impaired Days Natural Conditions for Class I and IMPROVE Protocol Sites In and Adjacent to the MANEVU Region..... 8
Table 2-4. Baseline, Current and Reasonable Progress Goal Haze Index Levels for Class I Areas In or Adjacent to the MANEVU Region..... 10

Executive Summary

This technical document fulfills U.S. Environmental Protection Agency's (USEPA's) Regional Haze Rule (RHR) 51.308(f)(1) provision for the second implementation period (2018-28) to determine baseline, current and natural visibility conditions for the 20 percent most impaired days and the 20 percent clearest days for each in-state and out-of-state Class I area for states in the Mid-Atlantic/Northeast Visibility Union (MANEVU) region.

Visibility trends analyses in this document used USEPA recommended metrics in the December 2018 guidance (USEPA 2018) at IMPROVE (Interagency Monitoring of Protected Visual Environments) monitoring sites at federal Class I areas in and adjacent to the MANEVU region that are subject to USEPA's RHR. Visibility trends analyses were also calculated for IMPROVE Protocol monitoring sites in and adjacent to the MANEVU region. For visibility trends at IMPROVE Protocol monitoring sites, October 2023 data downloaded from the FED website were used.

This technical document provides an analysis of visibility data collected at the IMPROVE monitoring sites, starting in the baseline period of 2000-2004 through 2018-2022, the most recent five-year period with available data. The results of this analysis show the following:

- There continue to be definite downward trends in overall haze levels at all Class I areas in and adjacent to the MANEVU region and at IMPROVE Protocol monitoring sites.

- Based on rolling five-year averages demonstrating progress since the 2000-2004 baseline period, all MANEVU and nearby Class I area visibility conditions are currently better than the 2028 uniform rate of progress (URP) visibility condition for the 20 percent most impaired visibility days and below baseline conditions for the 20 percent clearest days.

- Modeled 2028 reasonable progress goals (RPGs) have already been achieved during the 2018-2022 data period at all Class I areas in the MANEVU region except for Acadia National Park. Further progress is needed to achieve modeled 2028 RPGs at Acadia and nearby Class I areas in Virginia and West Virginia.

- Trends are mainly driven by large reductions in sulfate light extinction.

- Levels of organic carbon mass (OCM) and light absorbing carbon (LAC) appear to be approaching natural background levels at most of the MANEVU Class I areas.

- The percent contribution of nitrate light extinction has been significantly increasing at some of the MANEVU Class I areas due to lower sulfate contributions.

- The decrease in sulfate has resulted in more winter days and fewer summer days in the mix of 20 percent most impaired days because the nitrates that have replaced sulfates are more stable in winter.

1. Introduction

Haze, or reduced visibility, occurs when ambient particulate matter and gases scatter or absorb light ("light extinction") that would otherwise reach an observer. Particles responsible for regional haze are produced naturally from windblown dust, forest fires, and aerosolized sea salt; and by human-caused pollution from vehicles, power plants, and other combustion and dust-generating activities. Haze-forming particles can also cause serious health effects in the lungs and cardiopulmonary system, potentially leading to premature death. In addition, some particle species contribute to acidic deposition and other environmental harms.

In 1999, the US Environmental Protection Agency (USEPA) issued a rule under Section 169A of the Clean Air Act (Visibility Protection for the Federal Class I Areas) to address human-caused regional haze: Regional Haze Rule (RHR) [64 FR 35614 (July 1, 1999)]. The RHR is designed to improve visibility at certain national parks and wilderness areas (Class I areas) on the 20 percent haziest ('worst') days while not exacerbating haze on the 20 percent clearest ('best') days. The RHR requires states to submit state implementation plans (SIPs) to USEPA every ten years, setting interim progress goals and strategies consistent with the long-term national visibility goal of achieving natural conditions at Class I areas by 2064. States submitted their first haze SIPs to USEPA beginning in 2008. Additionally, states are required to track their progress against their historic baseline period[1] in achieving reductions in regional haze, submitting reports every five years, and to adjust their emissions management strategies accordingly.

In 2017, USEPA finalized revisions to the 1999 RHR to require states to track visibility progress for the 20 percent 'most impaired' days due to anthropogenic emissions instead of the 20 percent worst visibility days as was done for the first planning period (USEPA 2017). The method for tracking progress for the 20 percent clearest days did not change from the first planning period. USEPA recommended metrics for determining the 20 percent most impaired days in a December 2018 guidance (USEPA 2018), and MANEVU states decided to use those recommended metrics for the second implementation period. All analyses in this document use the most recent recommended metrics (20% most impaired natural conditions were updated in April 2020).

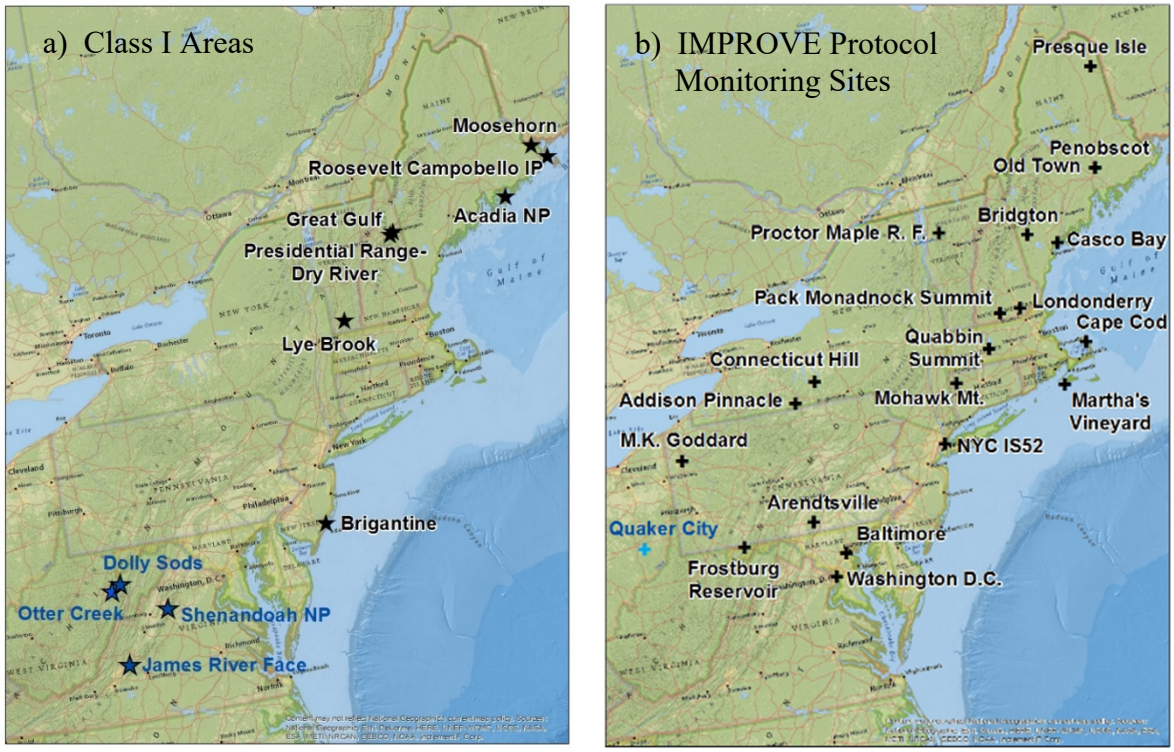
The Mid-Atlantic/Northeast Visibility Union (MANEVU) was formed to support visibility planning efforts in the mid-Atlantic and northeastern portion of the country and includes the members listed in Table 1-1. The seven Class I areas in the MANEVU region (black text) and four Class I areas adjacent to the MANEVU region (blue text) are shown in Figure 1-1(a). This document also includes analyses for IMPROVE Protocol monitoring sites (see Figure 1-1(b)), with twenty monitors in the MANEVU region (black text) and one adjacent to the MANEVU region (blue text)). The purpose of this report is to support MANEVU states in meeting USEPA's RHR 51.308(f)(1) provision for the second implementation period (2018-28) to determine baseline, current and natural visibility conditions for the 20 percent most impaired days and the 20 percent clearest days, for each in-state and out-of-state Class I area for states in the MANEVU region.

[1] This and earlier trends reports use 2004 as the base year because the trend is based on rolling averages of 5-year periods, and 2004 was the end of the initial 5-year period used as the baseline.

Table 1-1. Members of the Mid-Atlantic/Northeast Visibility Union (MANEVU)

Connecticut	Pennsylvania
Delaware	Penobscot Indian Nation
District of Columbia	Rhode Island
Maine	St. Regis Mohawk Tribe
Maryland	Vermont
Massachusetts	National Park Service
New Hampshire	U.S. EPA
New Jersey	U.S. Fish and Wildlife Service
New York	U.S. Forest Service

Figure 1-1. Class I Areas and IMPROVE Protocol Monitoring Sites In and Adjacent to the MANEVU Region



While this report provides readers with a basic background on regional haze, it does not include in-depth discussions of topics covered in previous reports. For a broader understanding of these topics, readers can visit USEPA's regional haze website: https://www.epa.gov/visibility, the IMPROVE technical documentation website: http://vista.cira.colostate.edu/improve/, the MANEVU website: https://otcair.org/manevu, the MARAMA regional haze website: https://marama.org/technical-center/regional-haze/, and the NESCAUM Resource Library: https://www.nescaum.org/resource-library (select the Topic "Regional Haze/Visibility").

2. Visibility Metrics

IMPROVE is a collaborative association of state, Tribal, and federal agencies, and international partners. USEPA is the primary funding source, with contracting and research support from the National Park Service. 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. IMPROVE was initially established as a national visibility network in 1985 consisting of 30 monitoring sites primarily located in national parks, 20 of which began operation in 1987. IMPROVE has operated many sites within the MANEVU and nearby regions, with some sites (Acadia and Shenandoah National Parks) having data available since 1988. For this report, only available data for the period 2000-21 were analyzed. Table 2-1 lists all IMPROVE monitoring sites in the MANEVU and nearby regions used in this report. Other IMPROVE Protocol monitoring sites [BALT (Baltimore, Maryland) and COHI (Connecticut Hills, New York), PITT (Lawrenceville, Pennsylvania) and OLTO (Old Town, Maine)] in the MANEVU region were not included primarily because no impairment statistics were calculated for those sites.

Table 2-1. IMPROVE Monitoring Sites

Site Code	Class I Area or IMPROVE Protocol Site Name	State	Latitude	Longitude	Elevation (m AMSL)	Start Date	End Date
MANEVU Class I Areas							
ACAD	Acadia National Park	ME	44.3771	-68.261	157	3/1988	Active
BRIG	Brigantine Wilderness	NJ	39.465	-74.4492	5	9/1991	Active
GRGU	Great Gulf Wilderness	NH	44.3082	-71.2177	453	6/1995	Active
LYBR	Lye Brook Wilderness	VT	43.1482	-73.1268	1015	9/1991	9/2012
LYEB	Lye Brook Wilderness	VT	42.9561	-72.9098	882	1/2012	Active
MOOS	Moosehorn Wilderness	ME	45.1259	-67.2661	77	12/1994	Active
Nearby Class I Areas							
DOSO	Dolly Sods Wilderness	WV	39.1053	-79.4261	1182	9/1991	Active
SHEN	Shenandoah National Park	VA	38.5229	-78.4348	1079	3/1988	Active
JARI	James River Face Wilderness	VA	37.6266	-79.5125	289	6/2000	Active
MANEVU IMPROVE Protocol Sites							
ADPI	Addison Pinnacle	NY	42.0912	-77.2099	512	4/2001	6/2010
AREN	Arendtsville	PA	39.9232	-77.3079	267	4/2001	12/2010
BRMA	Bridgton	ME	44.1074	-70.7292	233	3/2001	12/2015
CABA	Casco Bay	ME	43.8325	-70.0644	26	3/2001	Active
CACO	Cape Cod	MA	41.9758	-70.0242	49	4/2001	Active
FRRE	Frostburg Reservoir	MD	39.7058	-79.0122	767	4/2004	Active
LOND	Londonderry	NH	42.8624	-71.3801	124	1/2011	Active
MAVI	Martha's Vineyard	MA	41.3309	-70.7846	2	1/2003	Active
MKGO	M.K. Goddard	PA	41.4269	-80.1453	379	4/2001	12/2010
MOMO	Mohawk Mt.	CT	41.8214	-73.2973	521	9/2001	Active
NEYO	New York City – IS52	NY	40.8161	-73.9019	45	8/2004	6/2010
PACK	Pack Monadnock Summit	NH	42.8619	-71.8786	695	10/2007	Active
PENO	Penobscot Nation	ME	44.948	-68.6479	45	1/2006	Active
PMRF	Proctor Maple R. F.	VT	44.5284	-72.8688	401	12/1993	Active
PRIS	Presque Isle	ME	46.6964	-68.0333	165	3/2001	Active
QURE	Quabbin Summit	MA	42.2985	-72.3346	317	3/2001	12/2015
WASH	Washington D.C.	DC	38.8762	-77.0344	15	3/1988	12/2014
Nearby IMPROVE Protocol Site							
QUCI	Quaker City	OH	39.9428	-81.3378	366	5/2001	Active

Figure 1-1(a) shows Class I areas in the MANEVU and nearby regions. Monitoring data for the LYBR (2000-11) and LYEB (2012-21) sites at the Lye Brook Wilderness Class I area were merged with a new LYBR_RHTS site code. The Roosevelt Campobello International Park, Presidential Range-Dry River and Otter Creek Class I areas do not have an IMPROVE monitor. For those Class I sites without an IMPROVE monitor, monitoring data from a nearby representative Class I area was used to track visibility conditions. In addition to sites that are used to represent Class I areas, IMPROVE Protocol sites are in operation to provide expanded spatial coverage for the network. Protocol sites are separately sponsored by state, regional, Tribal, and national organizations and use the same instrumentation, monitoring, and analysis protocols as IMPROVE. Figure 1-1(b) shows the IMPROVE Protocol sites in the MANEVU and nearby regions with at least six years of valid data. Monitoring data and visibility metrics used for both the first and second implementation planning period are available on the Federal Land Manager Environmental Database (FED) website that is hosted at the Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA).

2-1 IMPROVE Equation

MANEVU states have agreed to use the revised IMPROVE equation (Pitchford et al., 2007) to calculate, from monitoring data, light extinction contributions from individual particle components for the first and second implementation period. The equation to estimate light extinction (b_{ext}) from the referenced literature is summarized below.

$$b_{ext} \approx 2.2 \times f_S(RH) \times [\textit{Small Ammonium Sulfate}] + 4.8 \times f_L(RH) \times [\textit{Large Ammonium Sulfate}]$$

$$+ 2.4 \times f_S(RH) \times [\textit{Small Ammonium Nitrate}] + 5.1 \times f_L(RH) \times [\textit{Large Ammonium Nitrate}]$$

$$+ 2.8 \times [\textit{Small Organic Mass}] + 6.1 \times [\textit{Large Organic Mass}]$$

$$+ 10 \times [\textit{Elemental Carbon}]$$

$$+ 1 \times [\textit{Fine Soil}]$$

$$+ 1.7 \times f_{SS}(RH) \times [\textit{Sea Salt}]$$

$$+ 0.6 \times [\textit{Coarse Mass}]$$

$$+ \textit{Rayleigh Scattering (Site Specific)}$$

$$+ 0.33\ (\textit{Mm}^{-1}\textit{/ppb}) \times [\textit{Nitrogen Dioxide (ppb)}]$$

Light extinction and Rayleigh scattering units are inverse megameters (Mm^{-1}), concentrations shown in brackets units are microgram per cubic meter ($\mu g/m^3$), and the water growth terms, f(RH), do not have units. The nitrogen dioxide (NO_2) light absorption term will not be used for MANEVU and nearby region sites due to no NO_2 concentration data being available at those sites. The organic compound mass (OM) to organic carbon mass (OC) ratio is 1.8 (OM=1.8*OC). Sulfate, nitrate and organics are split into small and large modes based on their mass. For masses less than 20 $\mu g/m^3$, the fraction in the large mode is estimated by dividing the total concentration of the component by 20 $\mu g/m^3$ with the remaining in the small mode. If the total concentration of a component exceeds 20 $\mu g/m^3$, all of it is assumed to be in the large mode. The small and large modes of sulfate and nitrate have associated hygroscopicities, f_S(RH) and f_L(RH), respectively, while f_{SS}(RH) is for sea salt.

To convert light extinction to a haze index in deciview (dv) units, the following equation is used:

$$\text{Haze index (dv)} = 10(\ln(b_{ext}/10)$$

Not all visibility metrics used by MANEVU states for the first implementation period can be used for the second implementation period. Recent amendments to the Regional Haze Rule (USEPA 2017) allow states to use the same metrics for the 20 percent clearest days however baseline and current haze metrics for the 20 percent most impaired days must now be calculated for the 20 percent most anthropogenically impaired days. USEPA has recommended metrics for determining 20 percent most impaired days in Chapter 2 of the December 2018 guidance (USEPA 2018). MANEVU states have agreed to use the recommended metrics for the second implementation period.

For all analyses in this report, the latest available (10/2023) data was downloaded from the FED website, including daily calculated light extinction, deciview values (using the revised (new) IMPROVE algorithm including patched data) and other metrics needed in the determination of 20 percent clearest days and 20 percent most impaired days for 2000 through 2022. Natural conditions for 20 percent clearest days (IMPROVE Natural Haze Levels II version 2) and natural conditions for 20 percent most impaired days for Class I areas were downloaded from the IMPROVE website (http://vista.cira.colostate.edu/Improve/rhr-summary-data/).

2-2 Natural Visibility Metrics

Even in the absence of emissions from human activities, some level of light extinction occurs from natural causes. This "natural haze" represents the best expectation for long-term progress at Class I areas and is the goal for these areas by 2064.

For the first SIP planning period ending in 2018, USEPA has guidance (USEPA 2003a) for calculating natural haze levels based on measurements of particulate species at Class I areas during a baseline period. States combine measurements of several parameters to calculate a "Haze Index" in dv units based on estimates of light extinction. A fuller explanation of tracking progress procedures is presented in a 2003 USEPA guidance document (USEPA 2003b). For the current SIP planning period ending in 2028, the December 2018 guidance (USEPA 2018) contains final recommendations on methods for selecting 20 percent most impaired days to track visibility and determining natural visibility conditions.

Natural haze levels are calculated for both 20 percent clearest days and 20 percent most impaired days because changing natural processes lead to variability in natural visibility. For the second planning period, MANEVU states have agreed to use 20 percent clearest days natural levels (IMPROVE Natural Haze Levels II version 2 (4/2020 update)) and derived 20 percent most impaired days natural levels in USEPA's recent guidance (USEPA 2018). Note that for IMPROVE Protocol sites, metrics for 20 percent most impaired days were calculated if at least six years of data is available. Natural visibility levels for the 20 percent clearest days for Class I and IMPROVE Protocol monitoring sites in the MANEVU and adjacent Class I areas are presented in Table 2-2.

Table 2-2. 20 Percent Clearest Days Natural Conditions for Class I and IMPROVE Protocol Sites In and Adjacent to the MANEVU Region

Site Code	Deciview (dv)	Extinction (Mm^{-1})						
		Sulfate	Nitrate	Organic Mass Carbon	Light Absorbing Carbon	Coarse Mass	Sea Salt	Soil
MANEVU Class I Areas								
ACAD	4.66036	0.75945	0.27297	2.00049	0.08352	0.56367	0.18629	0.10431
BRIG	5.51723	0.88119	0.35236	2.54476	0.11958	1.03972	0.22229	0.24231
GRGU	3.73061	0.6705	0.35433	1.61155	0.08198	0.63134	0.10698	0.09615
LYBR_RHTS	2.79447	0.39477	0.25933	1.02682	0.05891	0.3773	0.04617	0.08571
MOOS	5.01796	0.83994	0.32516	2.24568	0.12446	0.75137	0.16123	0.11956
Nearby Class I Areas								
DOSO	3.63715	0.79949	0.38313	2.35139	0.10451	0.57496	0.06985	0.16779
SHEN	3.14633	0.55701	0.5537	1.63632	0.08378	0.71779	0.07105	0.14487
JARI	4.38931	0.81288	0.46888	2.07294	0.09621	0.83206	0.06385	0.19781
MANEVU IMPROVE Protocol Sites								
ADPI	4.1197	0.66484	0.37501	2.05769	0.08995	0.61837	0.19171	0.12611
AREN	4.23823	0.69604	0.28666	2.04036	0.09179	0.82225	0.17024	0.19266
BRMA	4.64585	0.74476	0.30023	1.84437	0.07813	0.65535	0.21168	0.10856
CABA	4.82768	0.72653	0.22981	1.99149	0.07961	0.86898	0.17602	0.16803
CACO	5.95077	0.78033	0.43355	2.55505	0.11739	1.03772	1.1255	0.14441
FRRE	4.48105	0.79186	0.39847	2.14043	0.10559	0.95432	0.11841	0.20139
LOND	4.99519	0.84343	0.24382	2.1785	0.08201	0.8089	0.26277	0.1028
MAVI	6.11041	0.8419	0.3516	2.53561	0.12299	0.9759	1.50675	0.14822
MKGO	4.52286	0.79382	0.4743	2.13868	0.08989	0.87227	0.20685	0.19927
MOMO	3.67408	0.64117	0.28174	1.6037	0.07982	0.55116	0.15415	0.15967
NEYO	5.52124	0.74	0.22607	2.59008	0.11492	0.94187	0.50003	0.28483
PACK	3.17199	0.51903	0.22931	1.36239	0.07343	0.42529	0.09999	0.06772
PENO	4.62004	0.67044	0.2915	1.80158	0.06975	0.73	0.28312	0.1328
PMRF	3.85573	0.57006	0.24555	2.04162	0.08695	0.55555	0.14592	0.08835
PRIS	4.90981	0.71974	0.26817	2.04509	0.11767	0.80764	0.20499	0.20713
QURE	3.92289	0.62331	0.21967	1.8398	0.08	0.72058	0.2309	0.11885
WASH	5.5175	0.86507	0.39121	2.34693	0.12815	1.19015	0.1747	0.28916
Nearby IMPROVE Protocol Site								
QUCI	4.95688	0.76891	0.58488	2.66763	0.11451	0.97224	0.12414	0.22298

Data Source: IMPROVE Natural Conditions (2064) downloaded 2/15/2022 from the FED website.
** Natural haze values are not calculated for areas without 2000-04 baseline monitoring data or nearby representative IMPROVE site values. Visibility for the Presidential Range/Dry River Wilderness Area, Roosevelt Campobello International Park, and Otter Creek Wilderness are represented by the IMPROVE monitors for Great Gulf, Moosehorn and Dolly Sods, respectively.*

Per USEPA guidance (USEPA 2018), other metrics needed to calculate natural (2064) deciview conditions for the 20 percent most impaired days include routine and episodic extinction levels. Table 2-3 shows the derived natural routine and episodic extinction levels and the final derived natural deciview levels for all MANEVU and nearby Class I areas and IMPROVE Protocol sites.

Table 2-3. 20 Percent Most Impaired Days Natural Conditions for Class I and IMPROVE Protocol Sites In and Adjacent to the MANEVU Region

Site Code*	Derived Natural Deciview (dv)	e3 (Mm^{-1})		Natural Extinction# (Mm^{-1})					
		Episodic Carbon	Episodic Dust	Sulfate	Nitrate	Organic Carbon Mass	Light Absorbing Carbon	Soil	Coarse Mass
MANE-VU Class I Areas									
ACAD	10.39	10.43781	3.11129	2.0362	0.9343	5.4325	0.2	0.2471	1.2826
BRIG	10.68	20.14885	9.06602	1.8028	0.8159	6.0084	0.2	0.4716	1.8
GRGU	9.78	12.06917	3.23312	1.8346	0.8185	5.567	0.2	0.2457	1.589
LYBR_RHTS	10.24	11.44467	2.75272	1.7712	0.7974	5.4171	0.2	0.2787	1.0723
MOOS	9.98	11.13297	2.53611	1.9045	0.8729	5.7791	0.2	0.2322	1.5336
Nearby Class I Areas									
DOSO	8.92	13.56802	3.39637	1.8867	0.8222	5.7402	0.2	0.4262	1.3146
SHEN	9.52	15.06487	3.91633	1.8228	0.7919	5.9616	0.2	0.4086	1.7282
JARI	9.47	26.21782	2.94106	1.7784	0.7975	5.7779	0.2	0.481	1.8
MANE-VU IMPROVE Protocol Sites									
ADPI	10.48	14.74291	3.70176	1.8252	0.8309	5.9314	0.2	0.3975	1.549
AREN	10.17	22.12885	5.55573	1.7191	0.7791	5.9075	0.2	0.4788	1.8
BRMA	10.46	12.93536	2.52050	1.7925	0.8171	5.8414	0.2	0.2714	1.2729
CABA	10.93	18.89948	3.77916	1.716	0.7939	6.077	0.2	0.3216	1.7606
CACO	11.00	12.34542	4.92962	1.7068	0.781	6.106	0.2	0.3218	1.8
FRRE	9.61	15.56266	4.50415	1.862	0.8228	5.726	0.2	0.4568	1.8
LOND	10.45	20.85445	4.38664	1.7467	0.7999	5.7653	0.2	0.2256	1.7957
MAVI	11.11	12.19136	6.16371	1.7205	0.7844	5.2647	0.2	0.2763	1.8
MKGO	10.18	29.77069	4.69115	1.9606	0.8908	5.7382	0.2	0.4603	1.8
MOMO	10.90	15.20135	3.02756	1.7634	0.8034	5.9778	0.2	0.3957	1.488
NEYO	10.86	50.20181	11.22020	1.6464	0.755	5.7306	0.2	0.5	1.8
PACK	9.55	12.23893	3.01266	1.7673	0.8032	4.7402	0.2	0.2291	1.3533
PENO	10.34	24.01936	4.65363	1.805	0.8263	5.9382	0.2	0.3332	1.7952
PMRF	10.29	13.69720	2.88460	1.8026	0.7977	5.859	0.2	0.2827	1.2672
PRIS	10.24	16.54543	7.71344	1.8395	0.8386	5.8598	0.2	0.4976	1.8
QURE	10.81	17.02239	3.13621	1.747	0.7909	6.0622	0.2	0.3683	1.612
WASH	9.85	30.73590	6.01375	1.6828	0.7745	5.7776	0.2	0.5	1.8
Nearby IMPROVE Protocol Site									
QUCI	9.77	16.66106	5.52181	1.8759	0.8473	5.716	0.2	0.4862	1.8

Data Sources: 12/19/2020 RH3 (e3) data download from the FED website and Natural Conditions (Extinction)II updated April 2020 file on the IMPROVE website.

***** *Visibility for the Presidential Range/Dry River Wilderness Area, Roosevelt Campobello International Park and Otter Creek Wilderness are represented by the IMPROVE monitors for Great Gulf, Moosehorn and Dolly Sods, respectively.*

[#] *NC-II group 100 (all days)*

2-3 Baseline, Current and Reasonable Progress Goal Visibility Metrics

The RHR requires states to evaluate current regional haze conditions at Class I areas subject to the rule relative to conditions during a historic baseline period. The historic baseline period is the five-year period from 2000 through 2004 and the current five-year period is 2018 through 2022. Reasonable progress goals (RPGs) were established for the first implementation planning period for reduction of regional haze through 2018 for each Class I area and were

established through 2028 in the second implementation planning period. States with Class I areas, in consultation with other states and federal land managers, set 2028 RPGs (MANEVU 2018a) for the 20 percent most impaired days and for the 20 percent clearest days as shown in Figure 2-5. Comparison between the five-year average Haze Index in 2028 (average of the 2024-2028 annual Haze Index values) and the baseline Haze Index will determine if states have met 2028 RPGs. The RPGs are designed to at least ensure no degradation from the baseline period for 20 percent clearest days visibility and achievement of reasonable progress toward natural conditions for 20 percent most impaired days visibility.

Haze indexes for baseline and current 20 percent clearest days are five-year averages of each year's average 20 percent lowest daily haze index values. Results for each Class I area in the MANEVU and nearby regions are in Table 2-4. For all Class I areas, current haze indexes for the 20 percent clearest days are below baseline levels, thus showing no degradation.

Haze indexes for baseline and current 20 percent most impaired days are determined by starting with calculating daily haze index values and calculating anthropogenic impairment levels as specified in Chapter 2 of the guidance (USEPA 2018). The resulting impairment values are then sorted to determine the 20 percent most impaired days for each 'baseline' and 'current' year. The final 'baseline' and 'current' haze index calculation is a five-year average of each year's average 20 percent most impaired days daily haze index values. Results for each Class I area in the MANEVU and nearby regions are in Table 2-4. The uniform rate of progress (URP) levels for 2021 and 2028 plus 2028 RPGs for each Class I area are also included in Table 2-4. Constant annual incremental improvement in the Haze Index (dv) such that natural conditions will be reached by 2064 is termed a "uniform rate of progress (URP)" (also referred to as the glide path). Results show that all Class I areas in the MANEVU and nearby regions are currently between 5 dv and 8 dv below 2022 URP levels and between 4 dv and 7 dv below 2028 URP levels. Results also show that for the 20 percent most impaired days, all MANEVU Class I areas are below the respective modeled 2028 RPGs except for Acadia National Park. Class I areas in Virginia and West Virginia need between 0.02 dv and 0.87 dv improvements to reach the respective modeled 2028 RPGs.

Appendix A contains 20 percent clearest days and 20 percent most impaired days annual and 5-year rolling average haze indexes for all MANEVU and nearby region Class I areas.

Table 2-4. Baseline, Current and Reasonable Progress Goal Haze Index Levels for Class I Areas In or Adjacent to the MANEVU Region

Class I Area	IMPROVE SITE DATA CODE(S)	State	CLEAREST DAYS			MOST IMPAIRED DAYS				
			Baseline (2000-04) (dv)	Current (2018-22) (dv)	RPG^ (2028) (dv)	Baseline (2000-04) (dv)	Current (2018-22) (dv)	URP* 2022 (dv)	URP* 2028 (dv)	RPG^ (2028) (dv)
Acadia National Park	ACAD	ME	8.78	6.20	6.33	22.01	13.84	18.53	17.36	13.35
Moosehorn Wilderness Area	MOOS	ME NB	9.16	6.10	6.45	20.65	12.86	17.45	16.38	13.12
Roosevelt Campobello International Park										
Great Gulf Wilderness Area	GRGU	NH	7.65	4.53	5.06	21.88	11.82	18.25	17.04	12.00
Presidential Range/Dry River Wilderness Area										
Lye Brook Wilderness Area	LYBR_RHTS	VT	6.37	4.41	3.86	23.57	13.34	19.57	18.24	13.68
Brigantine Wilderness Area	BRIG	NJ	14.33	9.97	10.47	27.43	16.91	22.41	20.73	17.97
Dolly Sods Wilderness Area†	DOSO	WV	12.28	6.15	7.27	28.29	15.37	22.48	20.54	15.09
Otter Creek Wilderness Area†										
James River Face Area†	JARI	VA	14.21	8.50	9.36	28.08	16.18	22.50	20.64	15.31
Shenandoah National Park†	SHEN	VA	10.96	6.42	6.83	28.32	14.27	22.68	20.80	14.25

† *Class I area adjacent to the MANEVU region;*
** Uniform Rate of Progress;*
^ *Modeled Reasonable Progress Goal (MANEVU 2018a)*

2-4 Visibility Metrics Trend Plots

Figures 2-1 through Figure 2-8 present annual and 5-year average haze indexes on the 20 percent clearest days and 20 percent most impaired days at MANEVU and adjacent Class I areas between 2000 and 2022 in the context of long-term visibility goals. Table A-1 through Table A-5 in Appendix A present haze index trends numerically. URPs and RPGs shown in the figures are the long-term visibility goals for each Class I area.

These figures show that haze levels on the 20 percent clearest and 20 percent most impaired days from 2000 through 2022 have dropped across the entire region (although in very recent years, a leveling off, or even increase, is evident at some sites). The grey region in the figures denotes the range of 20 percent clearest to 20 percent most impaired haze levels expected to occur under natural conditions. Thus, the URP line intersects with the highest portion of the grey area in 2064 for most sites. For the Brigantine, Dolly Sods, Shenandoah and James River Face Wilderness Areas, whose haze levels on the 20 percent clearest days during the 2000 to 2004 baseline period were higher than estimated natural conditions on the 20 percent most impaired days, the no degradation line (representing the long-term clearest-day goal) is higher than the URP at dates approaching 2064. This nonsensical situation by 2064 is an artifact of technical guidance and only represents stated haze level goals, not anticipated results.

Figure 2-1. Visibility Metrics Levels at Acadia National Park

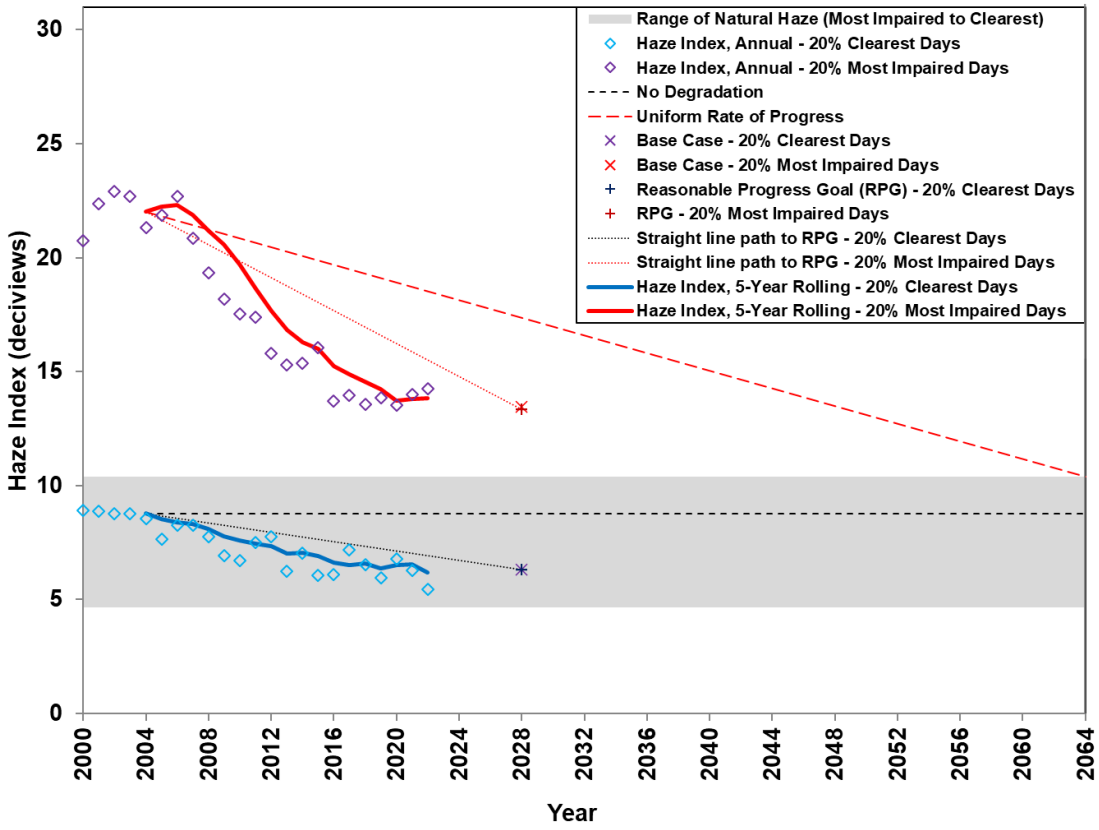


Figure 2-2. Visibility Metrics Levels at Moosehorn Wilderness Area

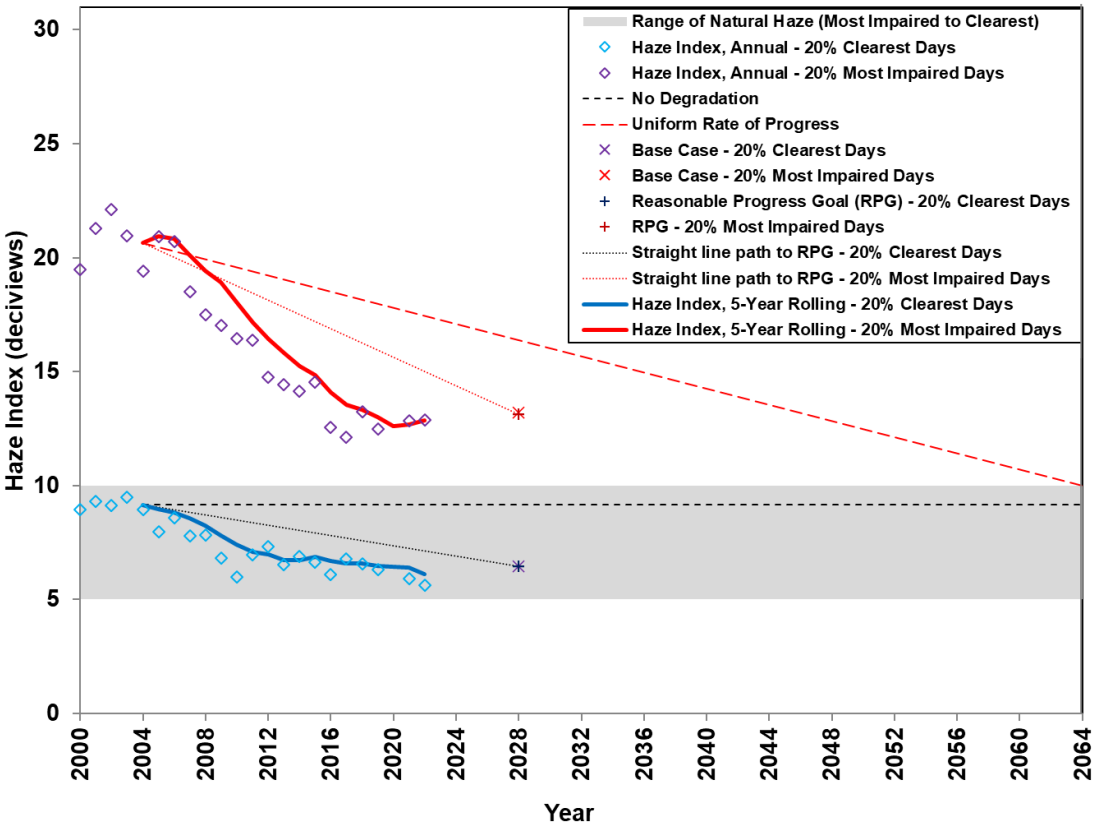


Figure 2-3. Visibility Metrics Levels at Great Gulf Wilderness Area

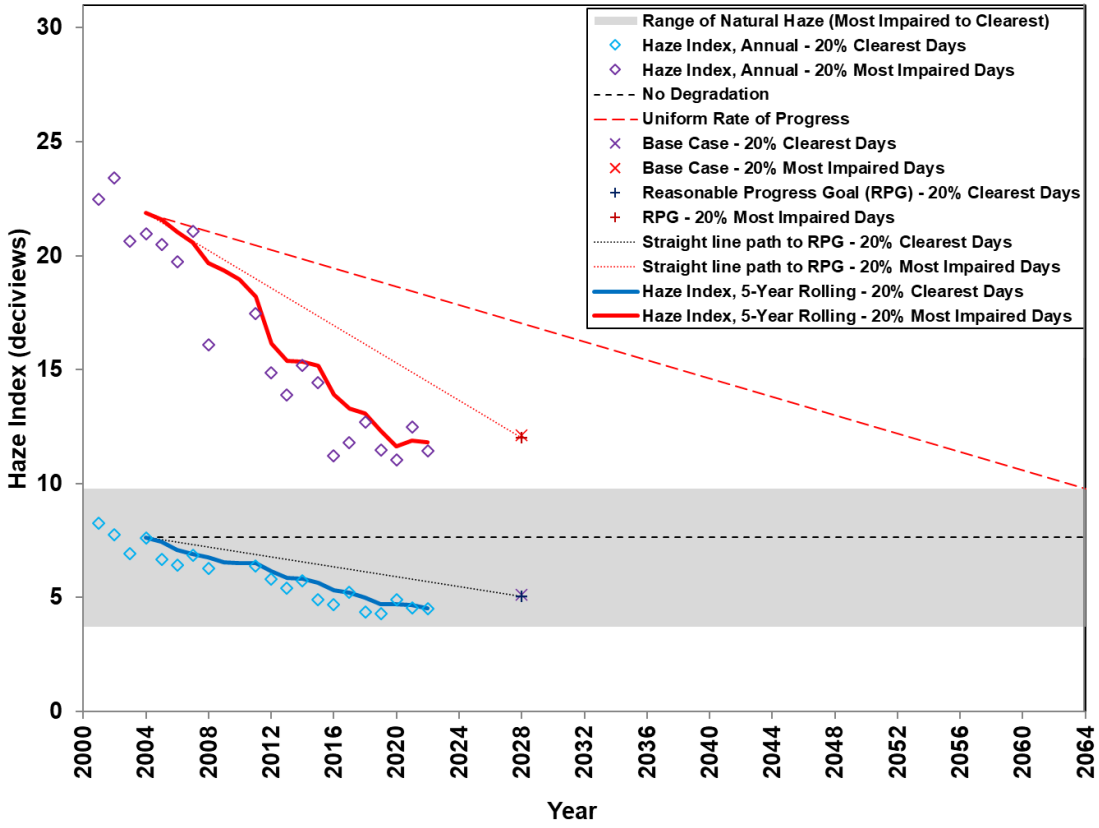


Figure 2-4. Visibility Metrics Levels at Lye Brook Wilderness Area

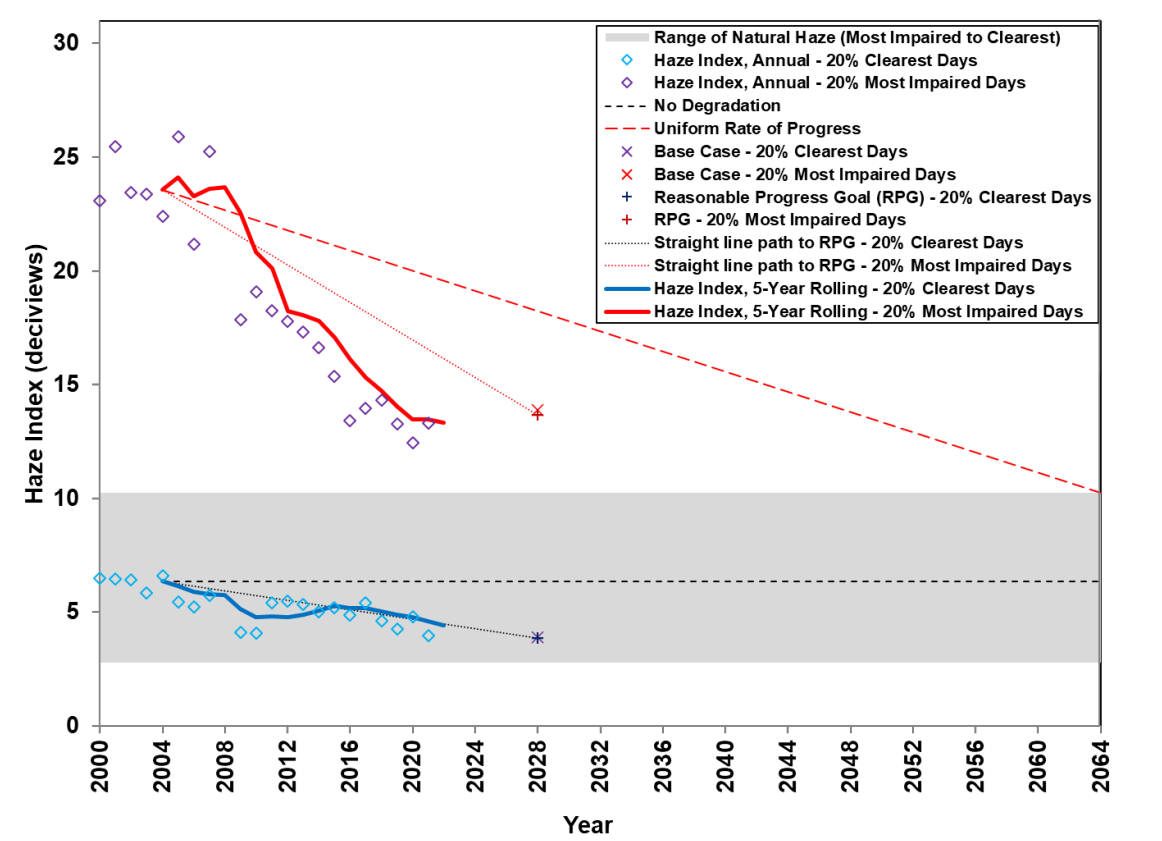


Figure 2-5. Visibility Metrics Levels at Brigantine Wilderness Area

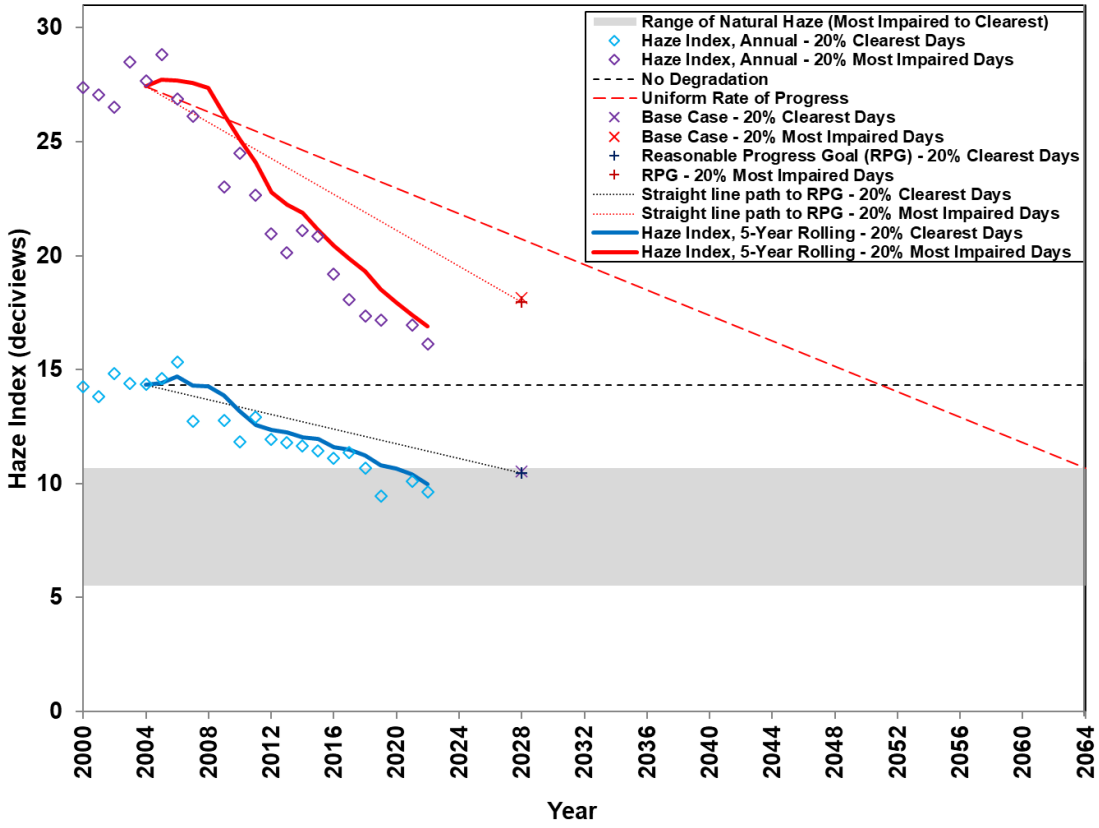


Figure 2-6. Visibility Metrics Levels at Dolly Sods Wilderness Area

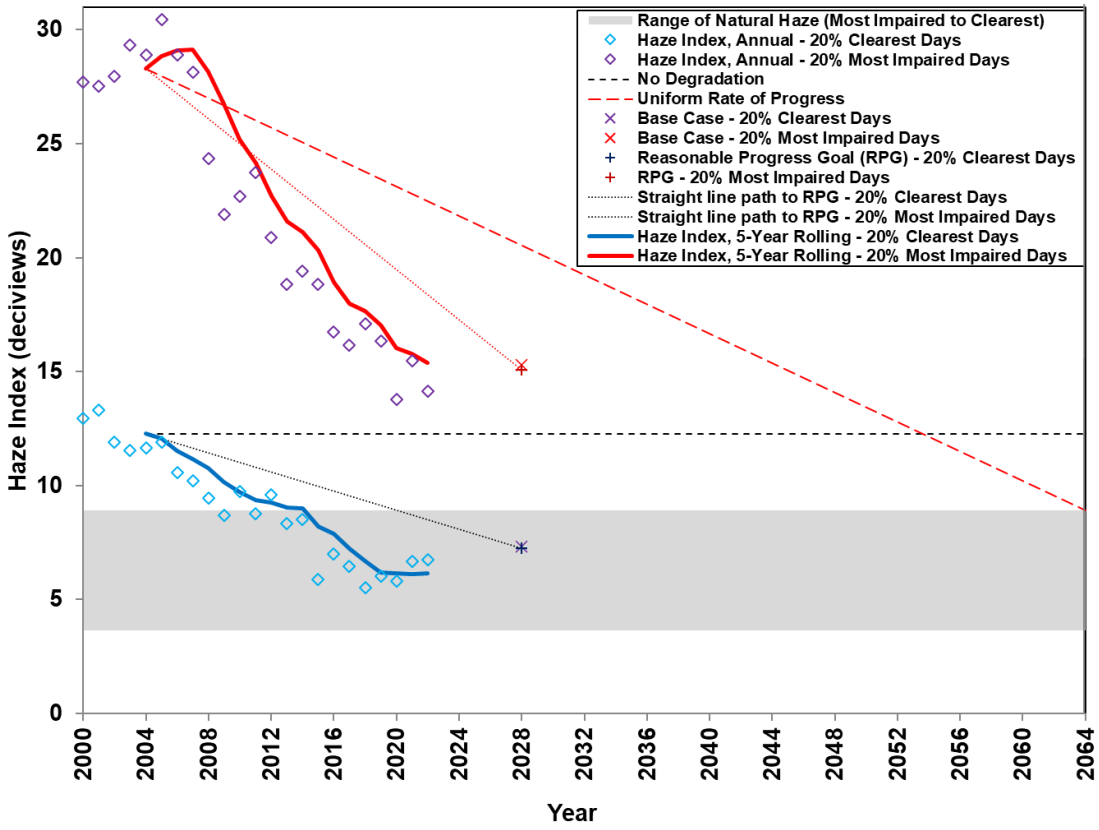


Figure 2-7. Visibility Metrics Levels at Shenandoah National Park

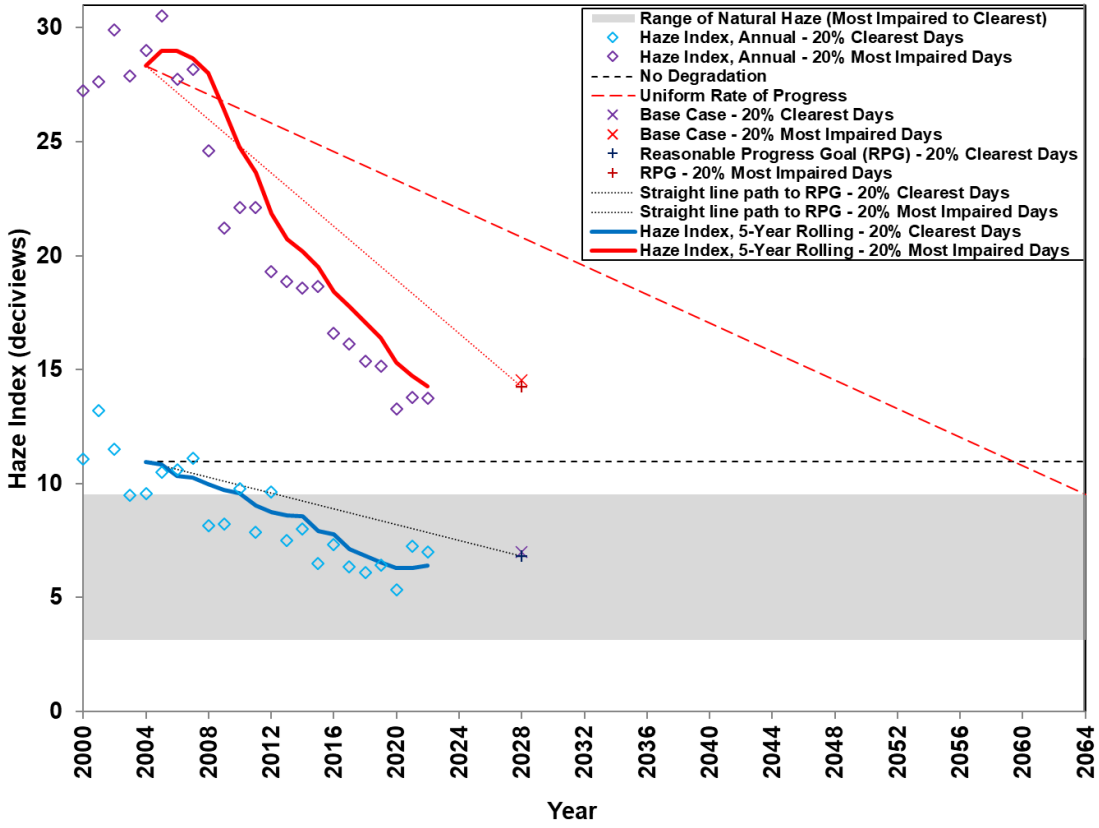
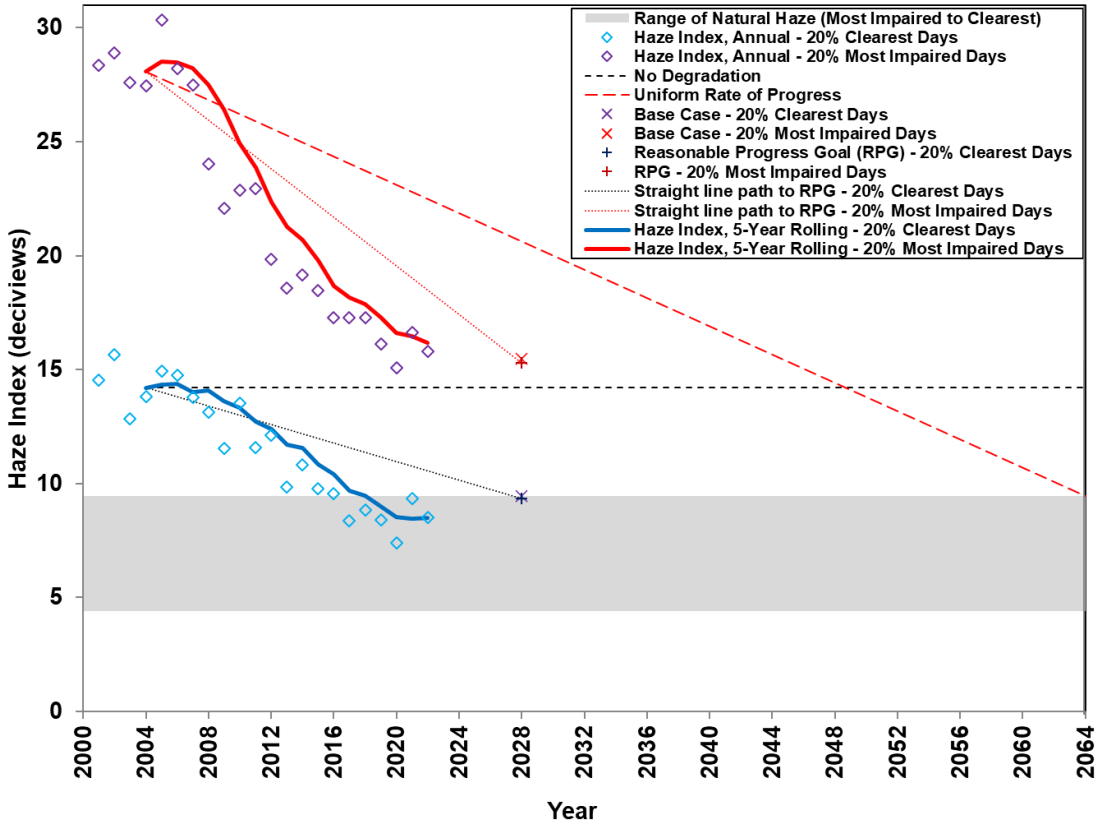


Figure 2-8. Visibility Metrics Levels at James River Face Wilderness



3. Visibility Species Light Extinction Trends

In addition to analyzing trends in overall visibility changes at IMPROVE monitoring locations in the region, data for changes in individual PM species (constituents) contributions to visibility impairment were also examined. Both natural and anthropogenic species contributions were included in the analyses. Rayleigh, sea salt, and soil species are natural components of visibility. Sulfate, nitrate, organic carbon mass, light absorbing carbon (elemental carbon), and coarse mass species in the analyses are both natural and anthropogenic components of visibility.

Analyses of visibility by species help policy decision makers determine what control strategies to consider for the second regional haze implementation planning period. The first set of analysis plots in Figure 3-1 through Figure 3-8 show 5-year baseline period vs. 5-year current period species average percent contributions for both 20 percent clearest and 20 percent most impaired days. Results clearly show a significant reduction in contributions at all Class I areas from sulfates for the 20 percent most impaired days with varying levels of increases for other species.

Current and baseline 5-year average light extinction levels for the 20 percent clearest (see Figure 3-9(a)) and 20 percent most impaired (see Figure 3-9(b)) visibility days for all Class I IMPROVE sites are shown side by side. This is just another way to show decreases in the region and shows that decreases were primarily due to sulfate reductions with nitrate and OCM reductions more evident during the 20 percent clearest days. Because there are more winter days in the current 20 percent most impaired days mix, the relative contribution of nitrates increased from the baseline especially at the Brigantine Wilderness Class I area.

The next set of analysis plots in Figure 3-10 to Figure 3-17 show individual species relative contributions [haze index∗(species light extinction/total light extinction) (units = deciview (dv))] as stacked bar charts for sulfate, nitrate, organic carbon mass (OCM), light absorbing carbon (EC or LAC), soil, coarse mass, sea salt, and Rayleigh extinction levels on 20 percent clearest days (“a” plot) and 20 percent most impaired days (“b” plot). The total of the stacked bars represents annual Haze Index values and are marked by circles connected by a thin black line. The thick black line represents five-year back annual averages from 2004 to 2022. Two dashed lines descend from the 2004 five-year back average (i.e., the baseline value): the red dashed line represents the URP glide path to the 2064 natural visibility goal and the black dashed line represents the glide path to the modeled 2028 RPG. These figures confirm that large reductions in overall Haze Index values on the 20 percent most impaired days are primarily due to decreases in sulfate visibility impacts at MANEVU and other nearby Class I areas. Significant decreases in sulfate contributions started in 2007 at Maine’s Class I areas and in 2008 at all other Class I areas analyzed. As the sulfate contributions declined, relative nitrate contributions have started to increase at many sites, especially at the Brigantine Wilderness monitoring site. This increase is primarily due to having more winter days in the 20 percent most impaired days mix during recent years. During the winter, relative nitrate contributions are much higher than during the summer (more discussion of winter nitrates is found at the end of this section). Steady decreases in sulfate contributions have reduced overall haze levels on the 20 percent clearest days. These decreases on the 20 percent clearest days started to occur after 2004 at most of the Class I areas.

Sulfate remains the most significant contributor to light extinction at all Class I areas on the most impaired days in and adjacent to the MANEVU region, followed by nitrate and OCM. For the Brigantine and Lye Brook Class I sites, nitrate contributions are nearing the level of sulfate contributions. For the most part, light extinction from soil and sea salt, which help indicate the extent to which natural haze processes contribute to overall haze levels, are insignificant when compared to extinction from sulfate and nitrate. Similar plots for the 20 most impaired days at the IMPROVE Protocol sites are in Appendix B.

The third set of analysis plots in Figure 3-18 for New England Class I areas and Figure 3-19 for other Class I areas show the mix of 20 percent most impaired days by season. Results clearly show that summer days no longer dominate the mix at all Class I areas. For many of the Class I areas there are now more winter days in the mix than in any other season. That trend is more evident at New Jersey, Virginia, and West Virginia Class I areas. The increase in nitrate extinction percent contributions is consistent with the greater stability of nitrates during the winter months and the lower amount of sulfate to compete with nitrate formation. Similar plots for IMPROVE Protocol sites are in Appendix E.

BASELINE AND CURRENT VISIBILITY SPECIES TRENDS PLOTS

Figure 3-1. Acadia National Park Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels

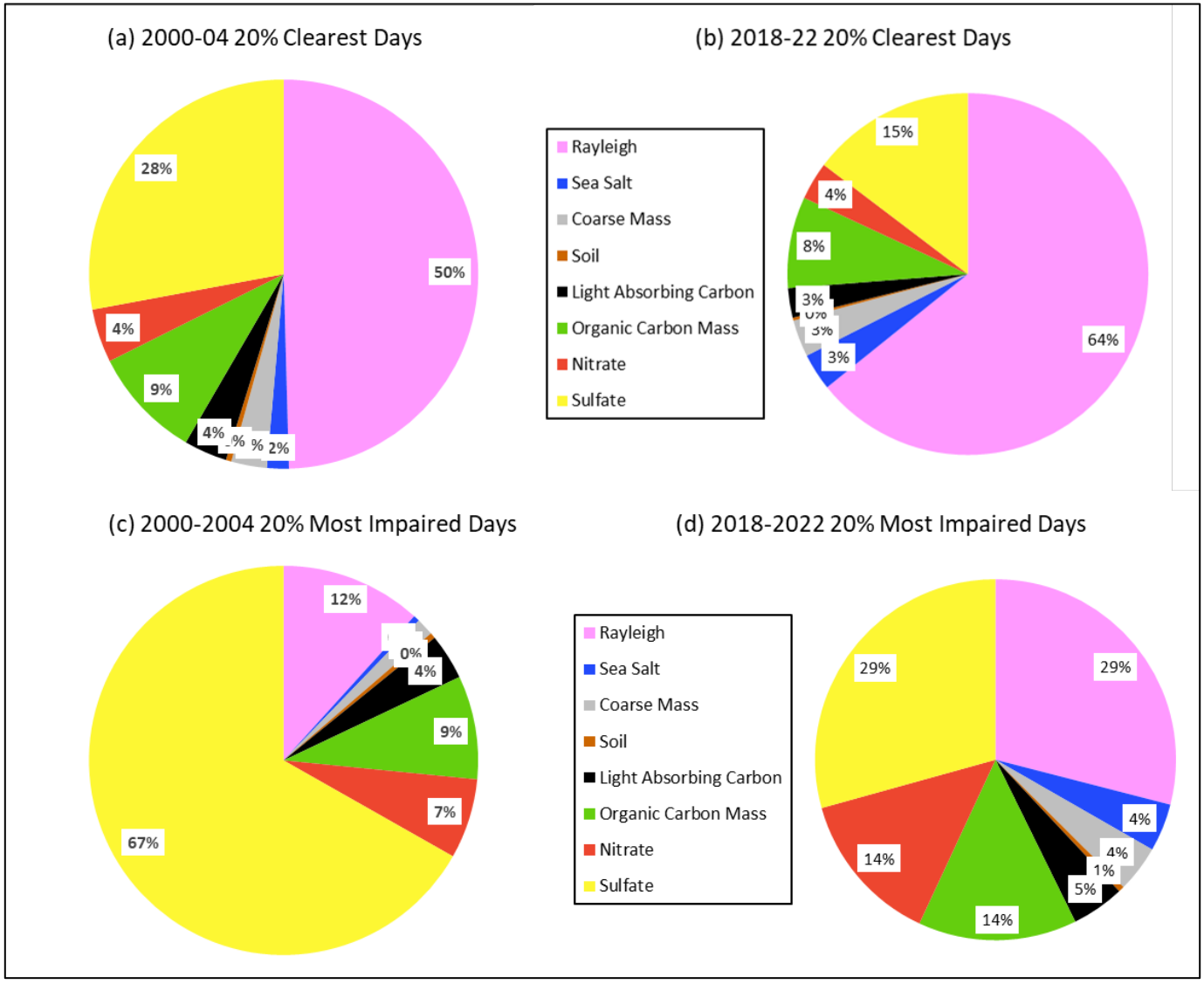
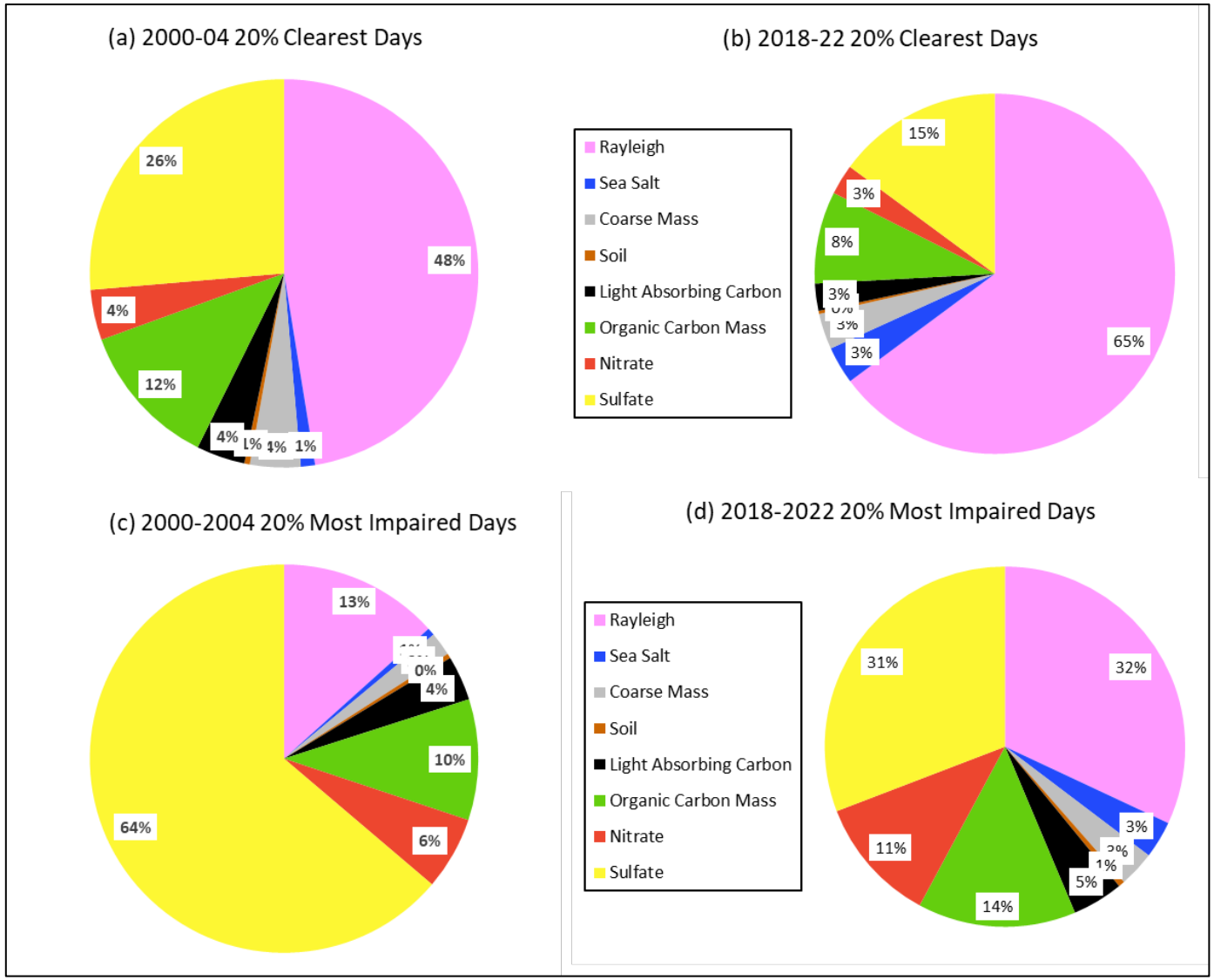
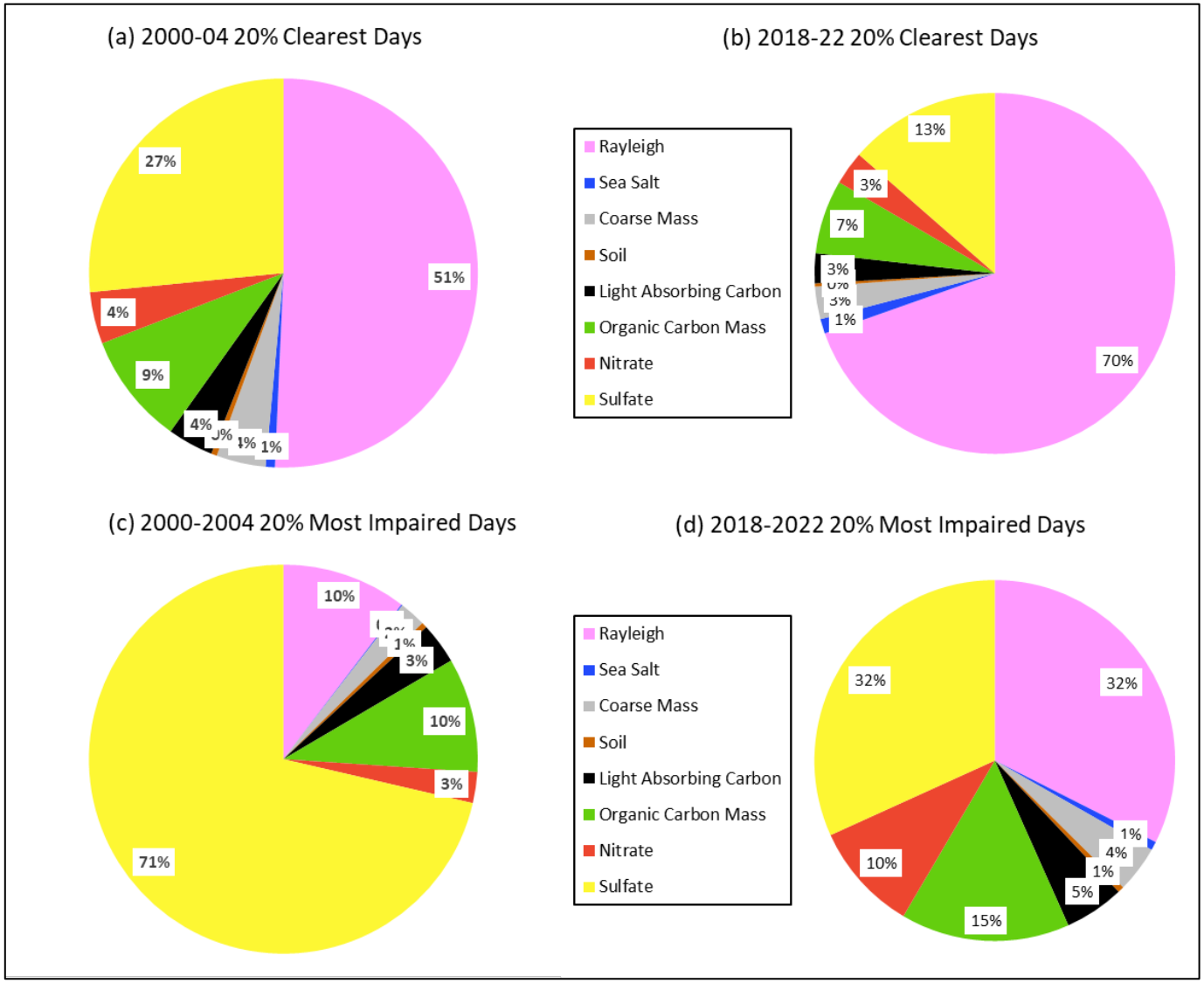


Figure 3-2. Moosehorn Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels



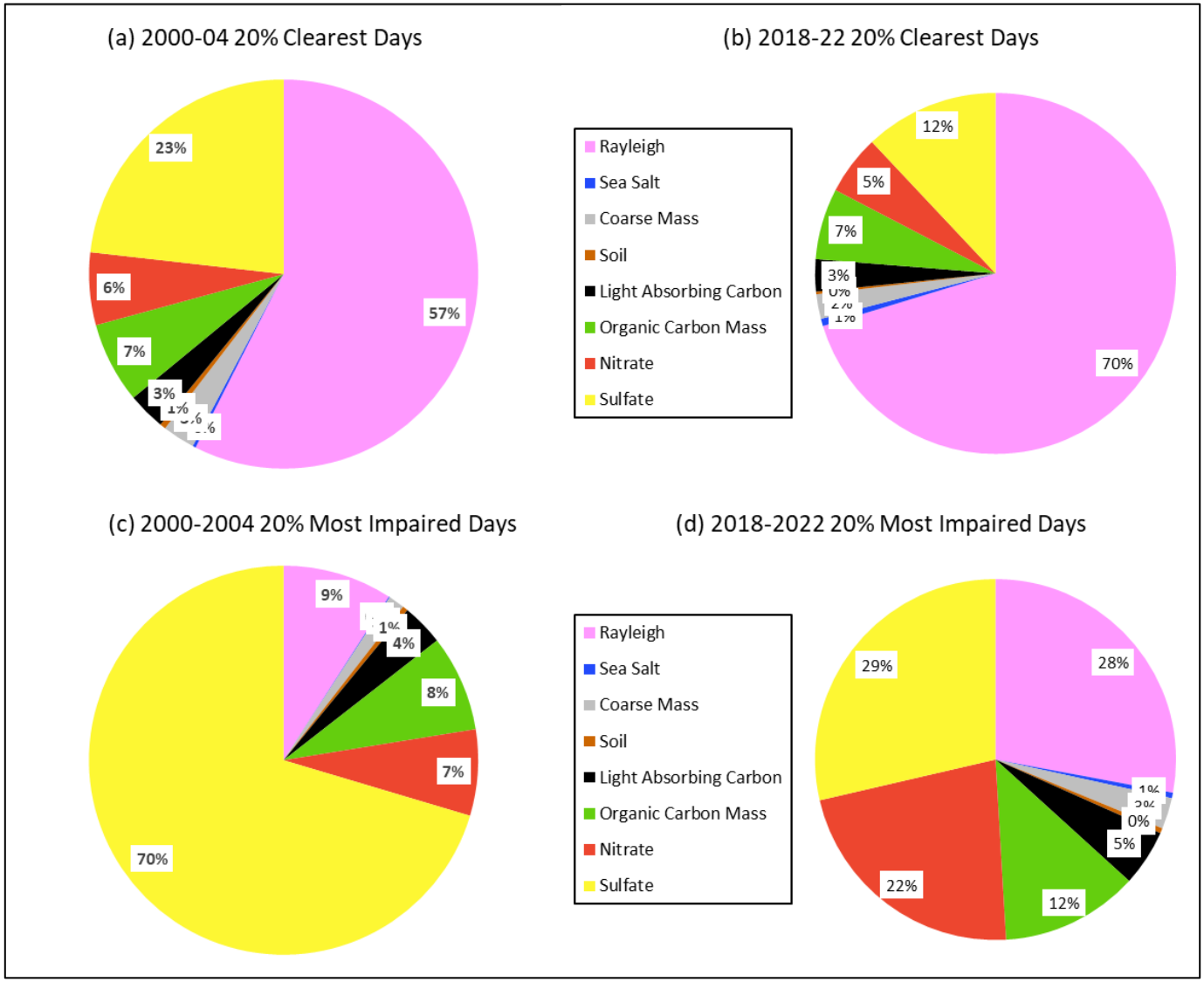
Note: Moosehorn did not have data for 2020.

Figure 3-3. Great Gulf Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels



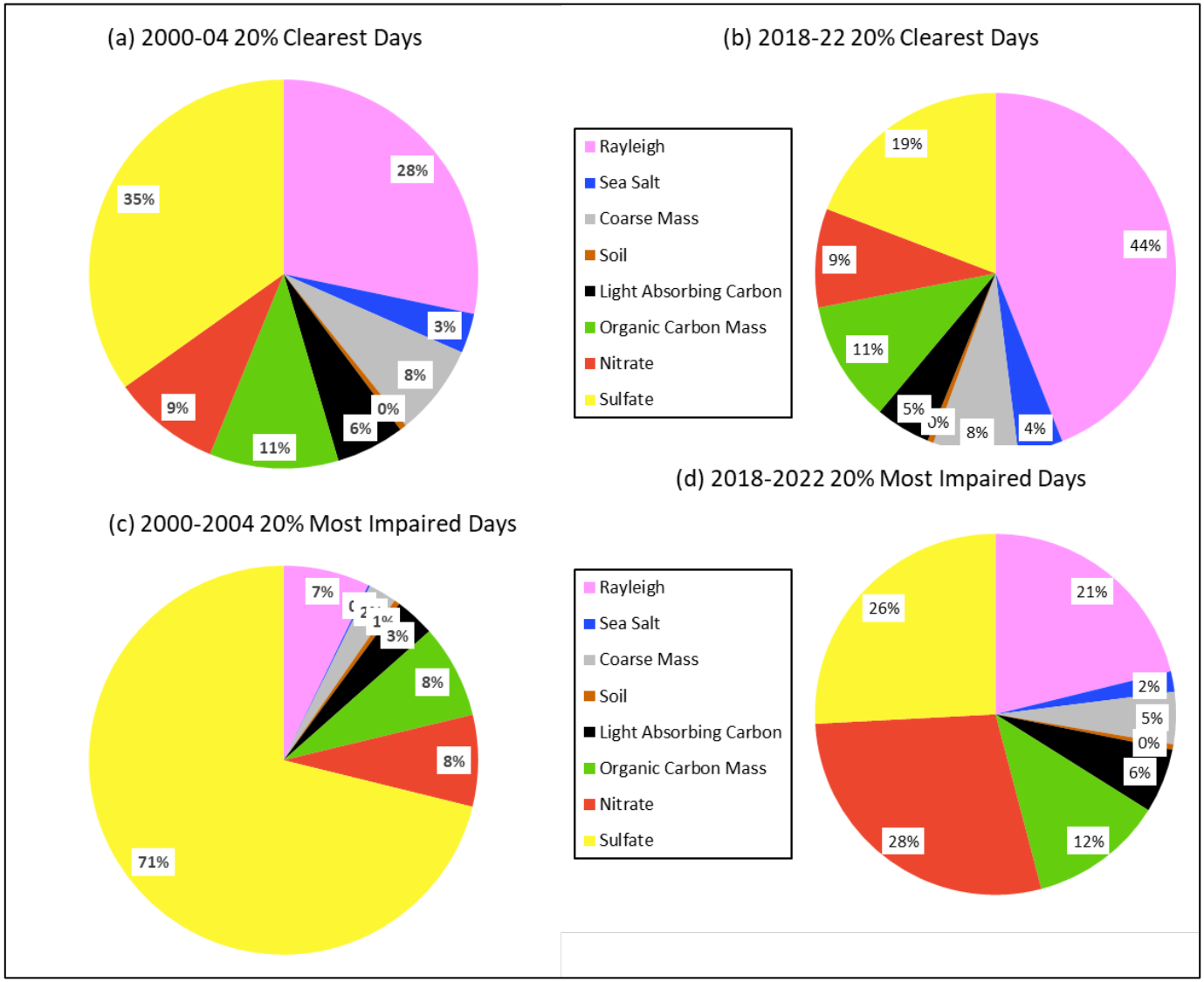
Note: Great Gulf did not have data for 2000.

Figure 3-4. Lye Brook Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels



Note: Lye Brook did not have data for 2022.

Figure 3-5. Brigantine Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels



Note: Brigantine did not have data for 2020.

Figure 3-6. Dolly Sods Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels

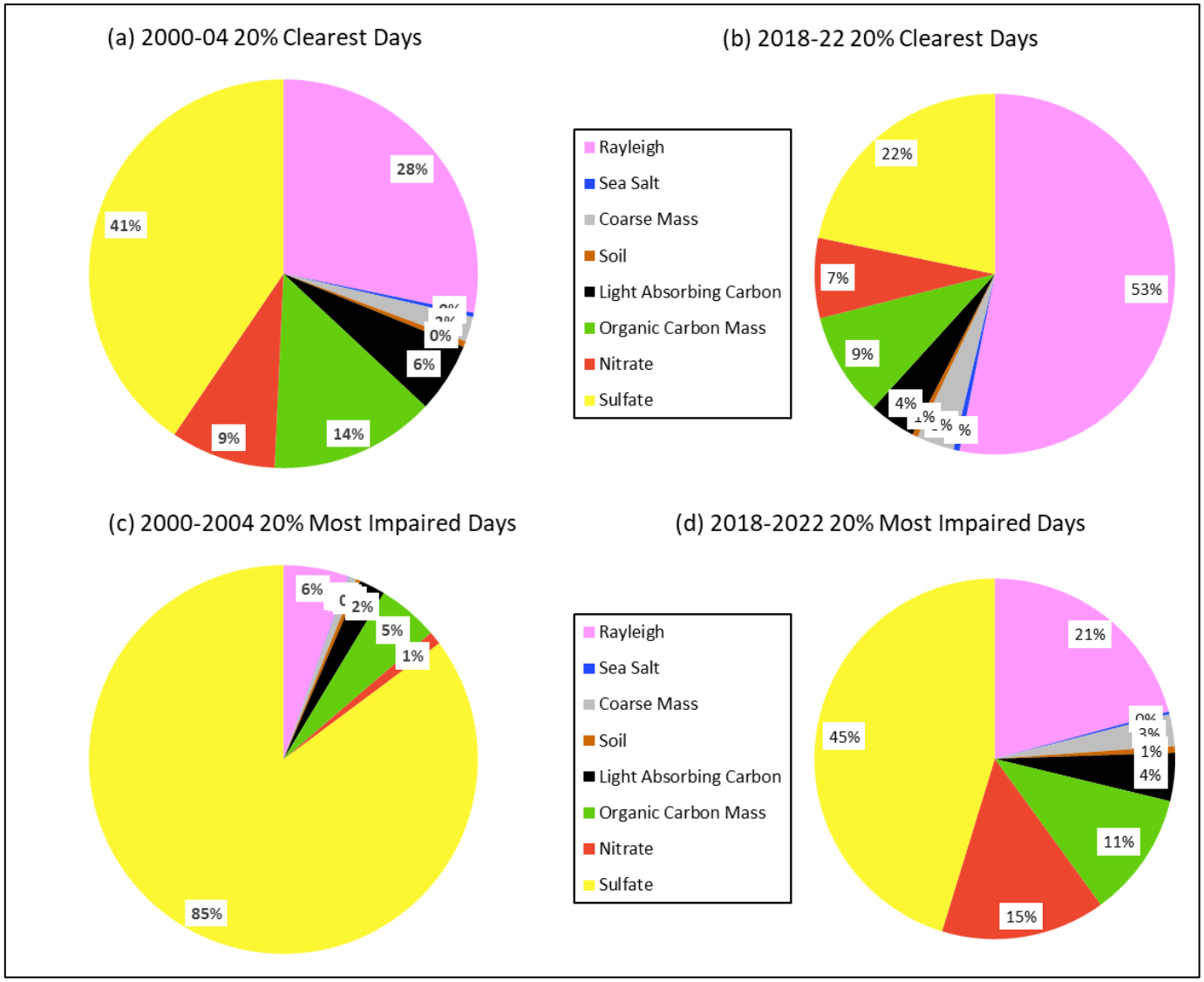


Figure 3-7. Shenandoah National Park Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels

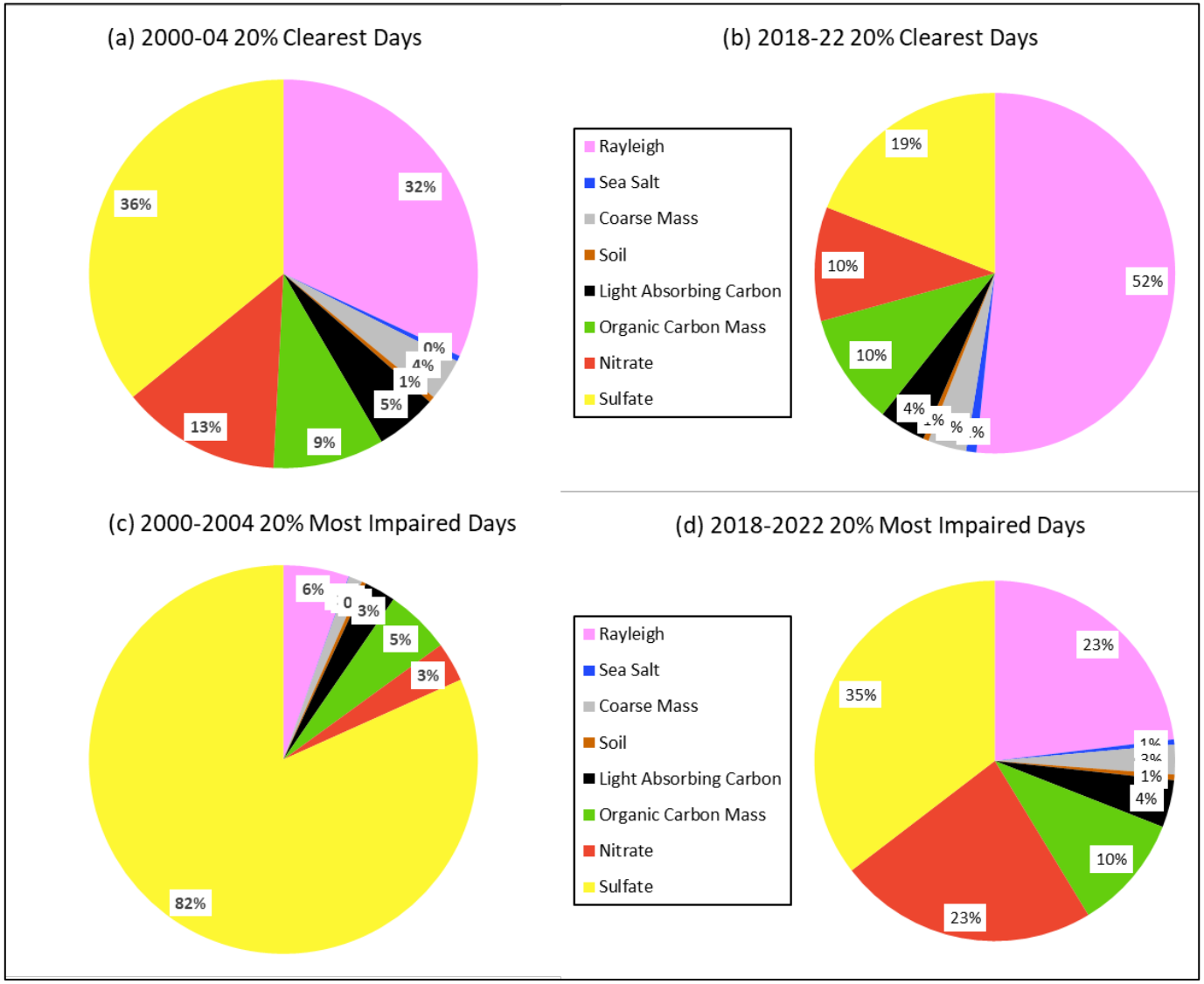
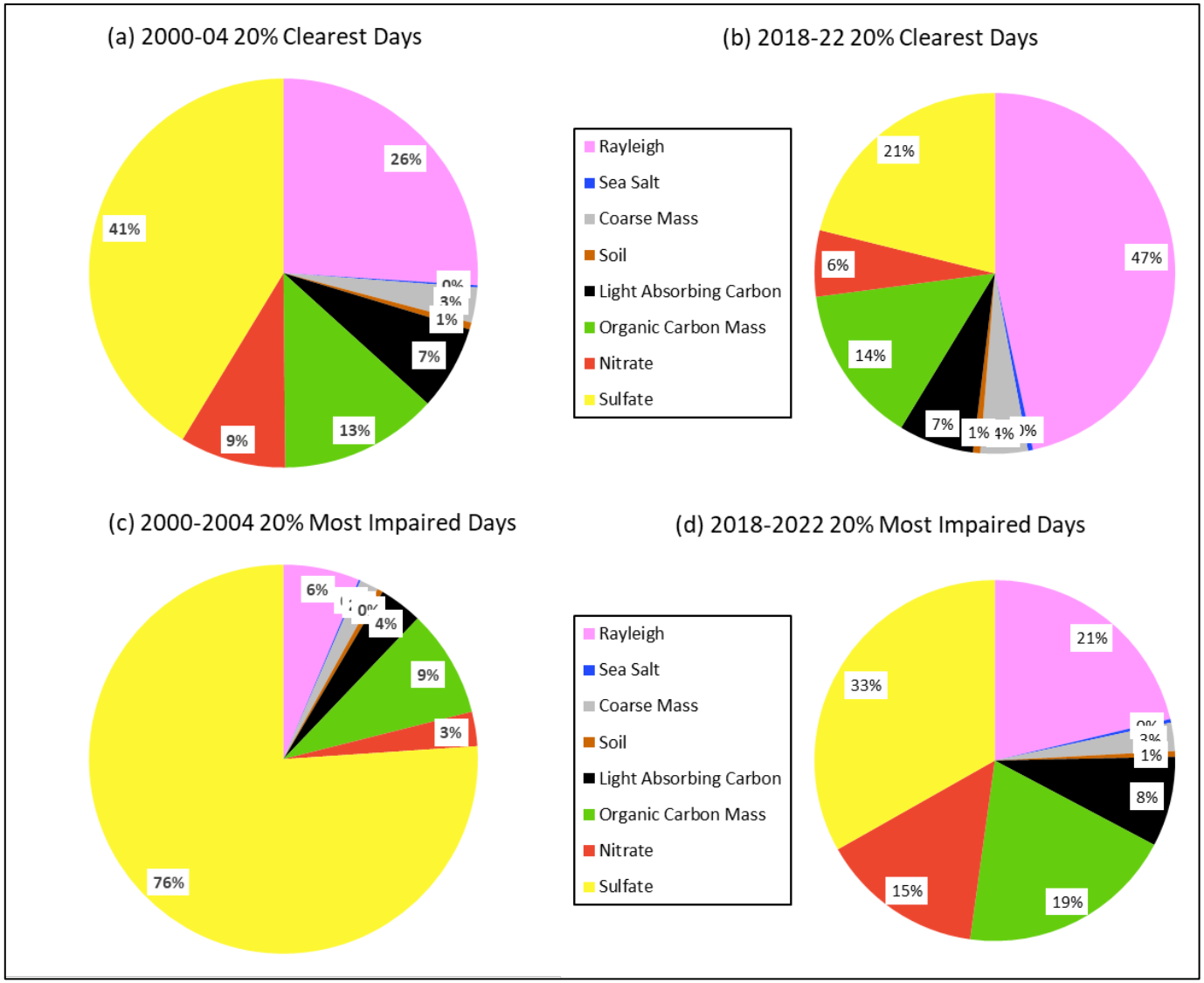
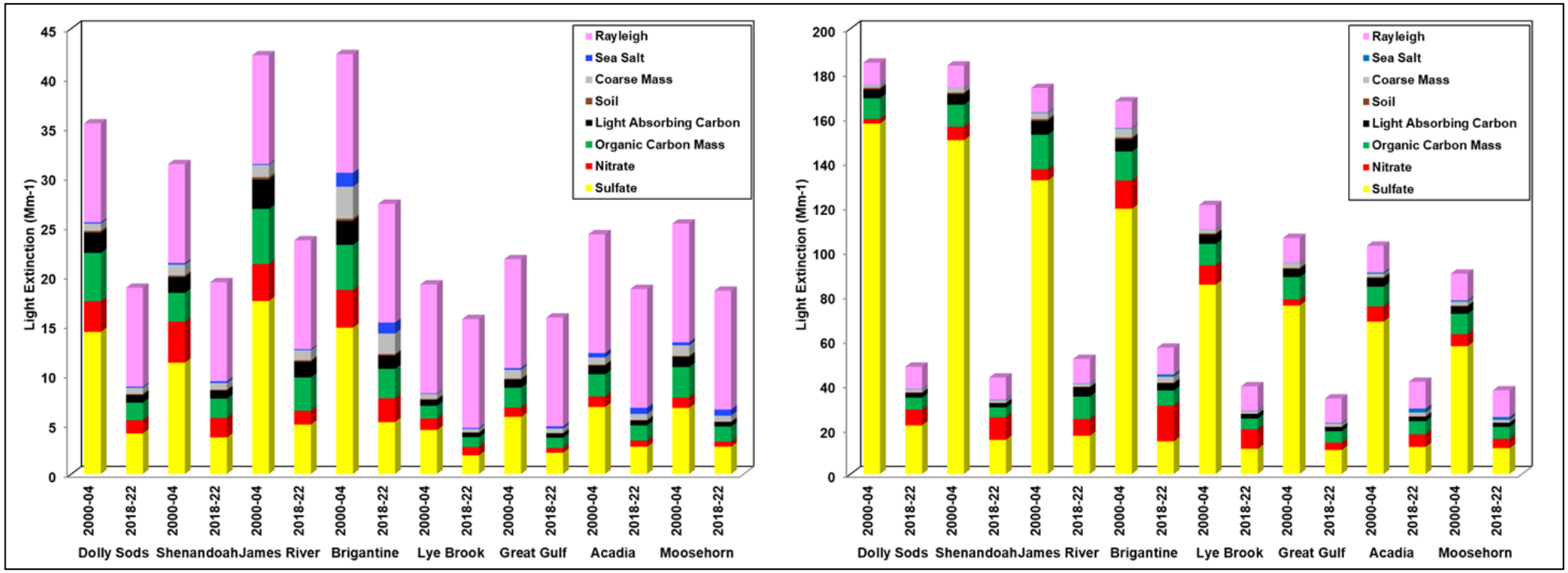


Figure 3-8. James River Face Wilderness Area Species Percent Contribution to Baseline (2000-04) and Current (2018-22) Haze Index Levels



Note: James River Face did not have data for 2000.

Figure 3-9. Current and Baseline 5-Year Average Light Extinction at Class I Sites on 20 Percent Clearest (left) and 20 Percent Most Impaired Visibility Days (right)



Note the different Y-axis scales for the 20 percent clearest (left) and 20 percent most impaired (right) charts.

ANNUAL VISIBILITY SPECIES TRENDS PLOTS

Figure 3-10. Individual Species Contribution to Annual Haze Index Levels at Acadia National Park on 20 Percent Clearest and Most Impaired Visibility Days

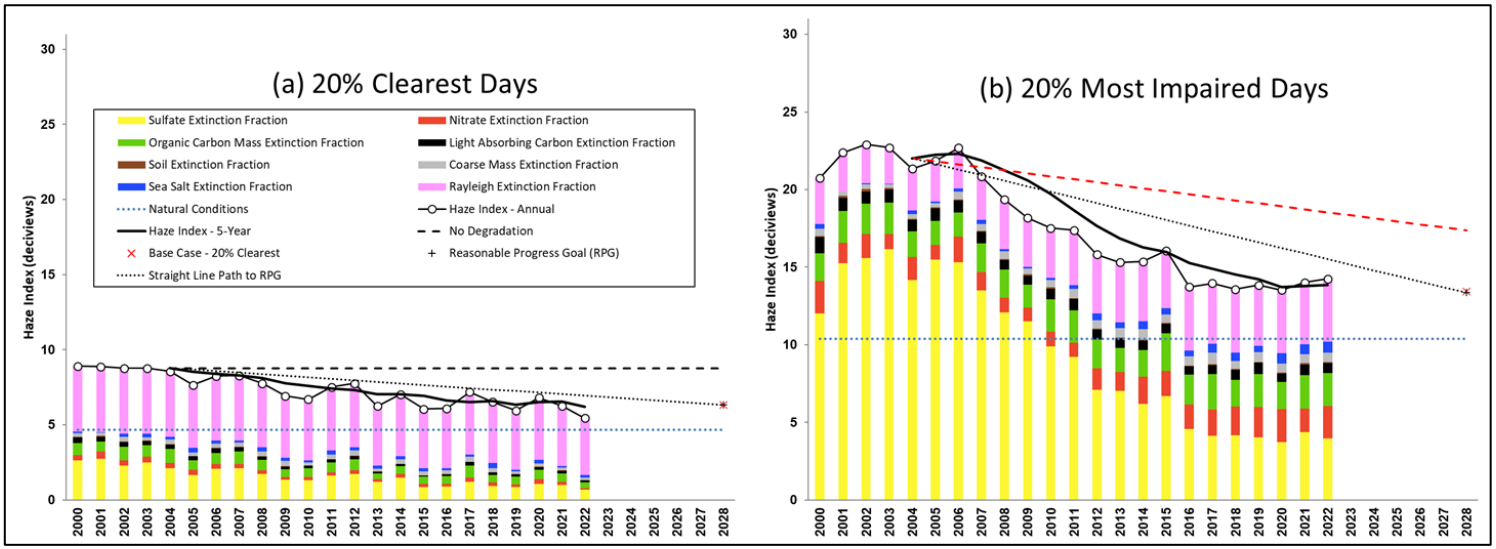


Figure 3-11. Individual Species Contribution to Annual Haze Index Levels at Moosehorn Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days

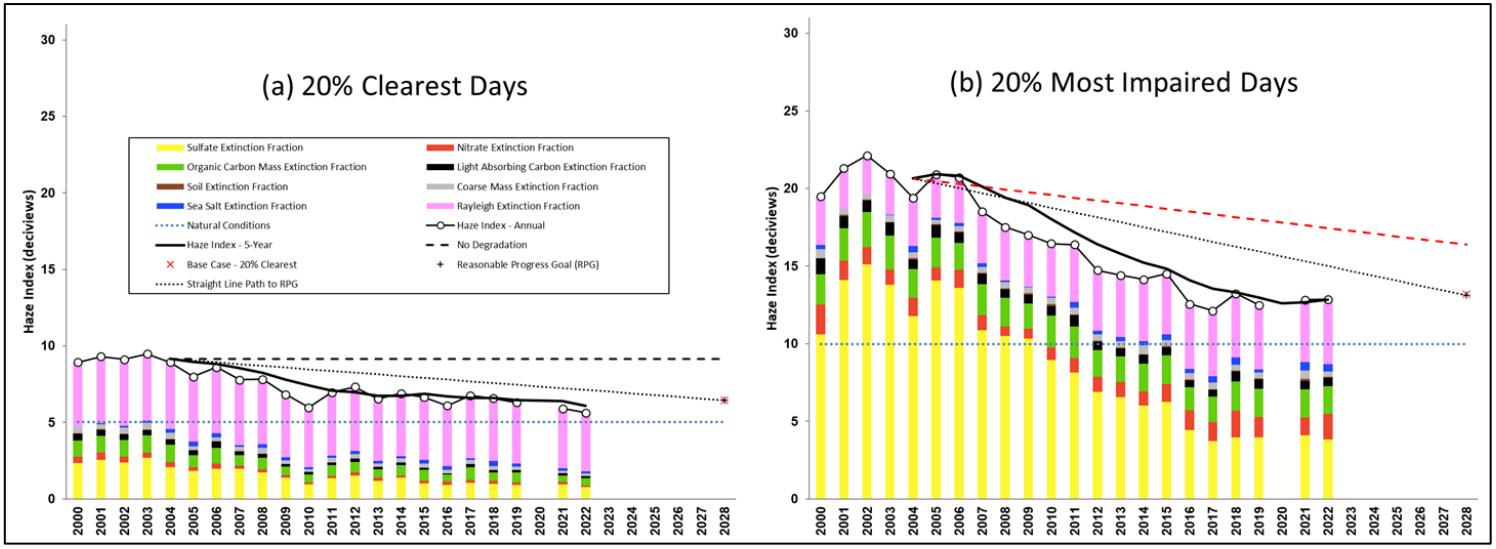


Figure 3-12. Individual Species Contribution to Annual Haze Index Levels at Great Gulf Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days

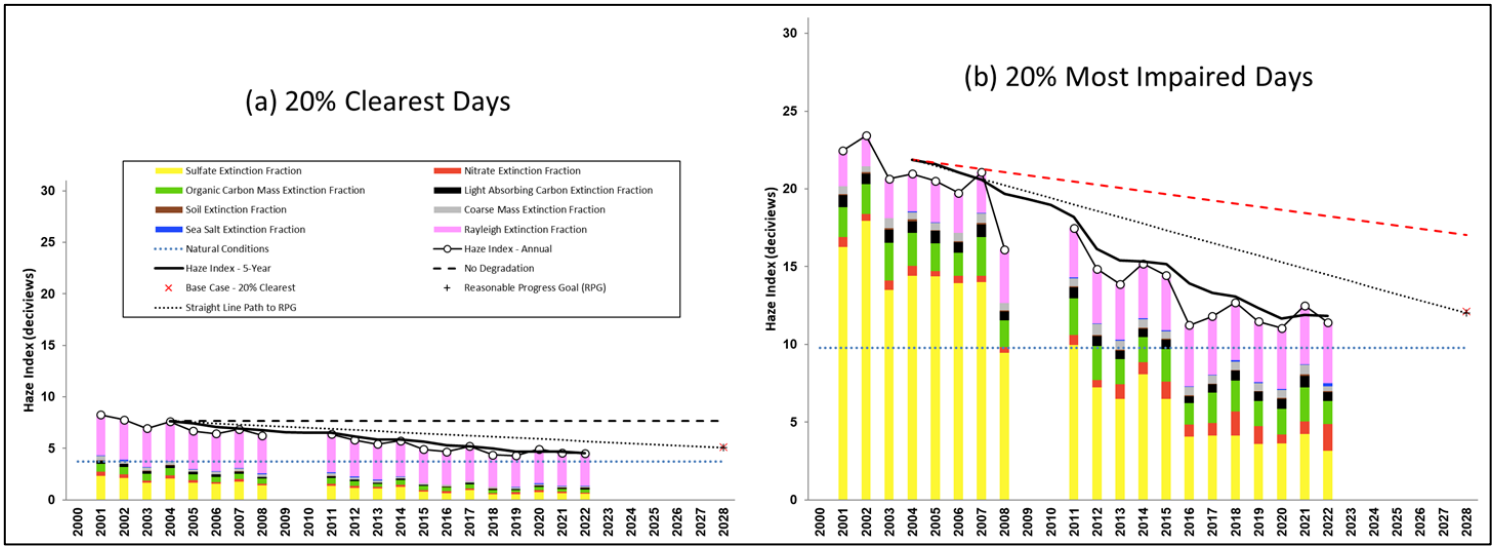
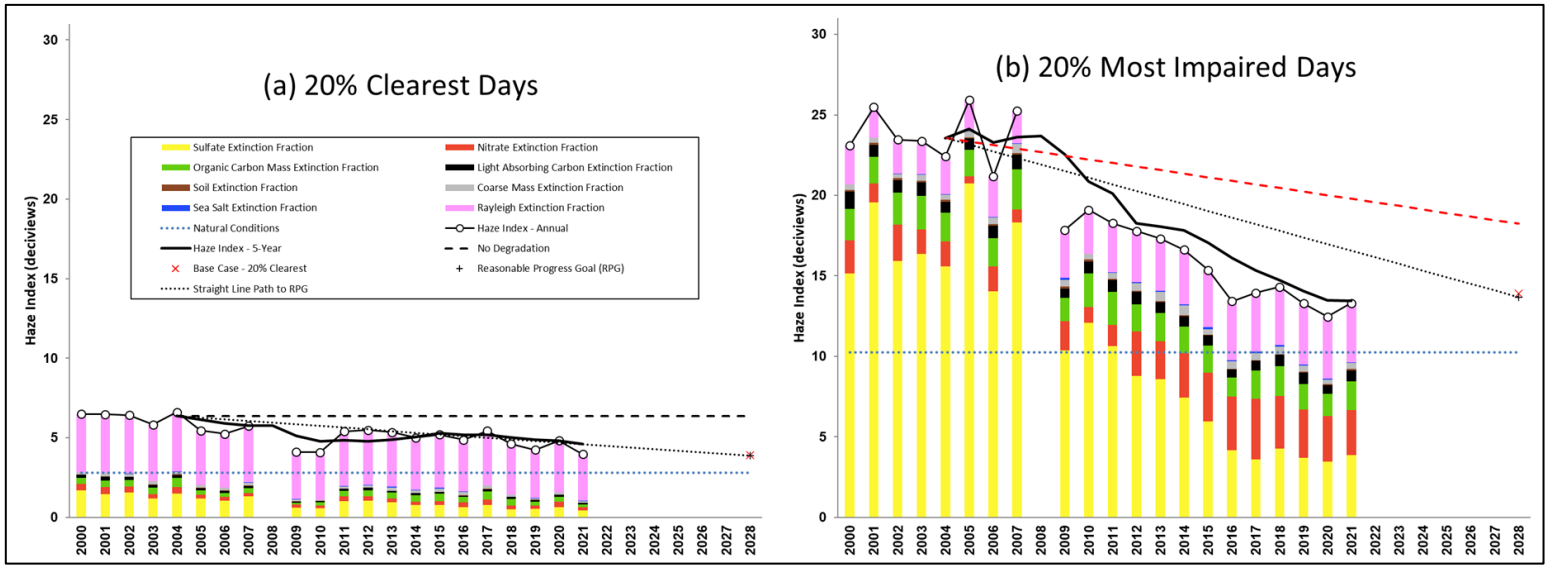


Figure 3-13. Individual Species Contribution to Annual Haze Index Levels at Lye Brook Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days



Note: Lye Brook did not have data for 2022.

Figure 3-14. Individual Species Contribution to Annual Haze Index Levels at Brigantine Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days

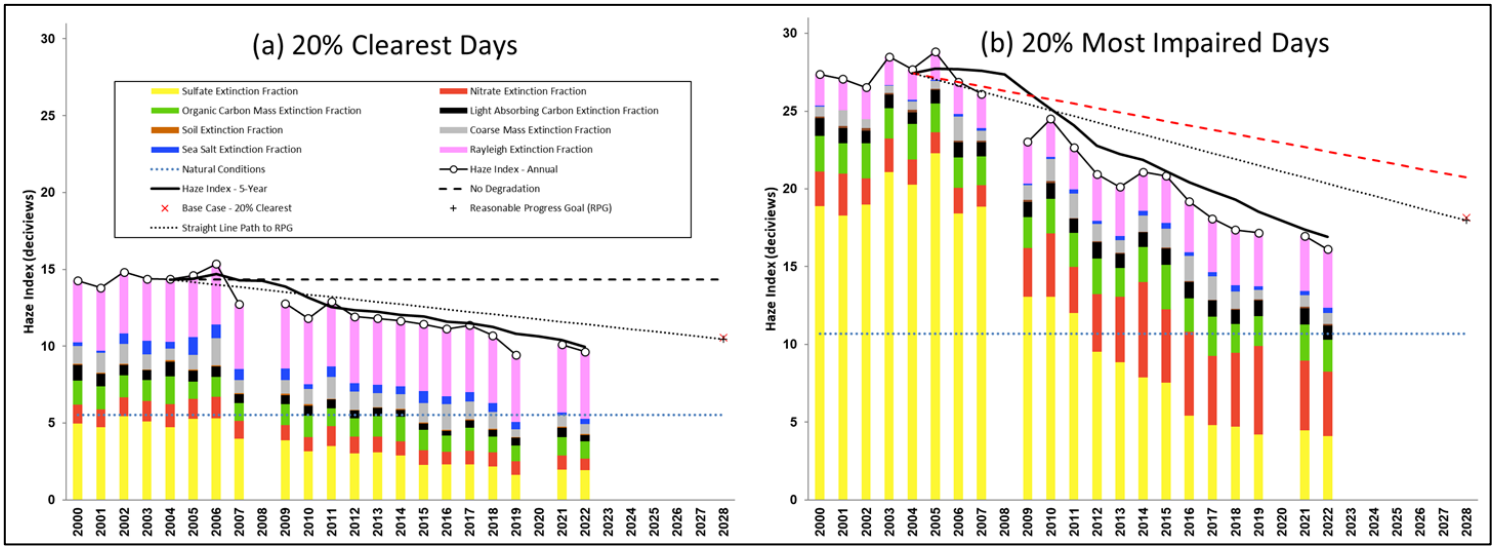


Figure 3-15. Individual Species Contribution to Annual Haze Index Levels at Dolly Sods Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days

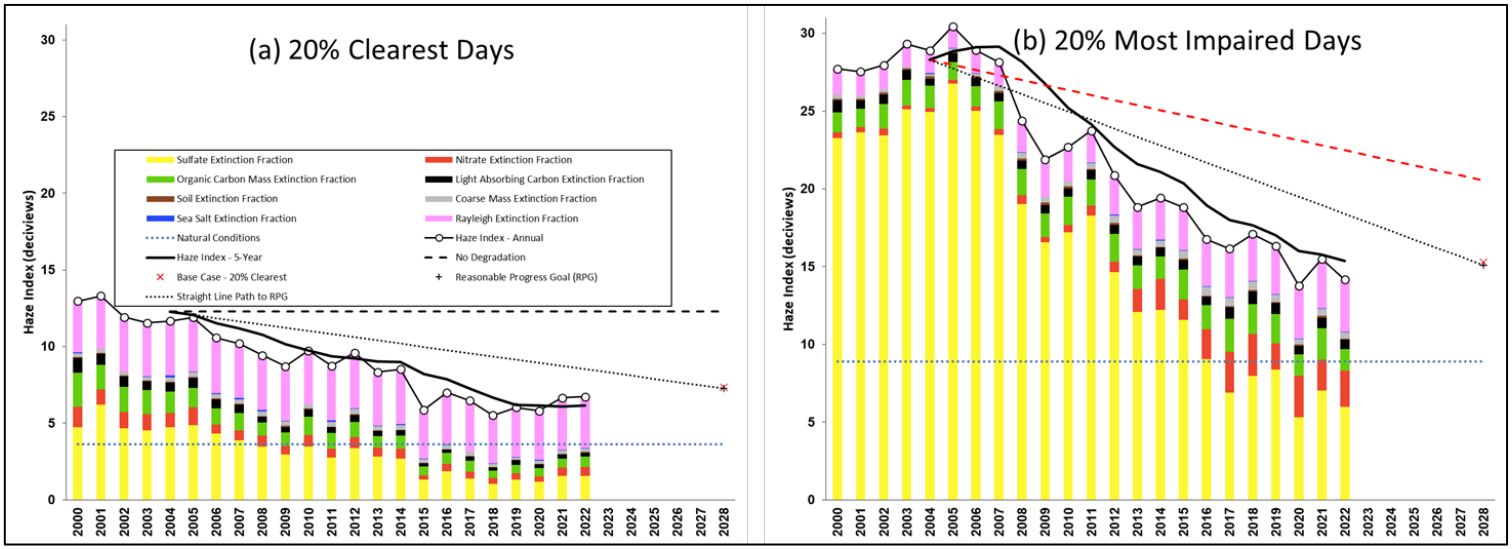


Figure 3-16. Individual Species Contribution to Annual Haze Index Levels at Shenandoah National Park on 20 Percent Clearest and Most Impaired Visibility Days

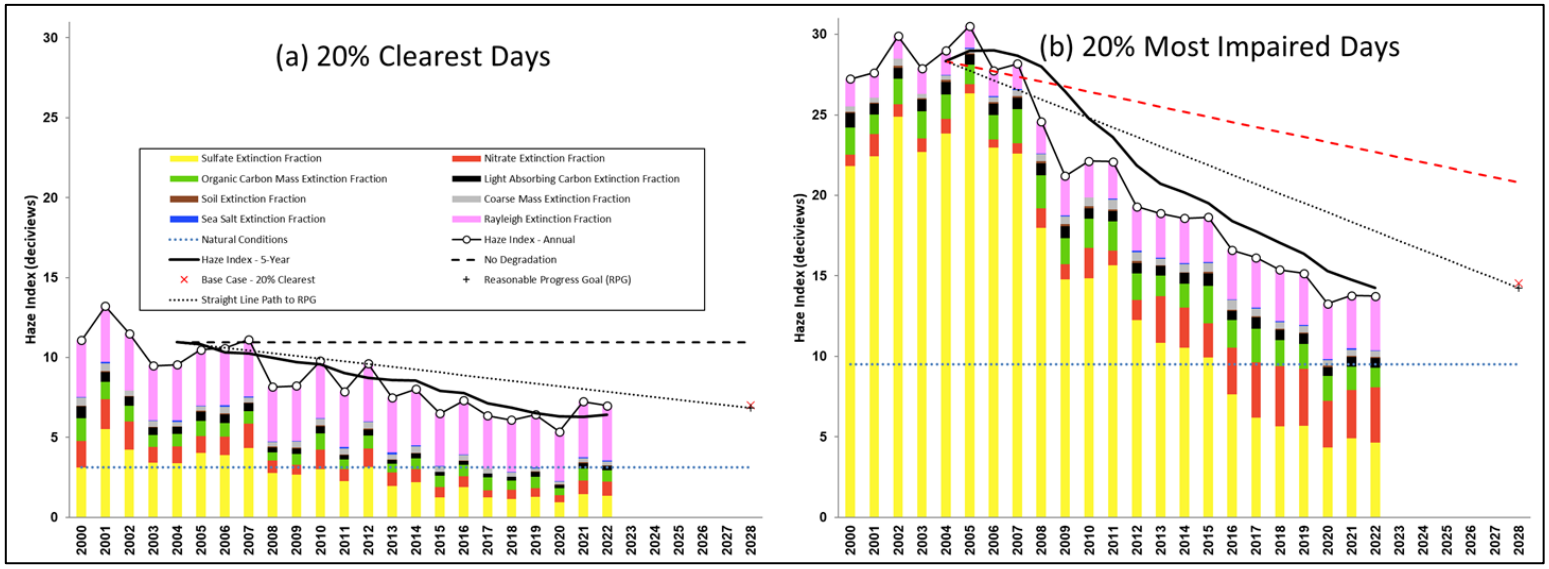
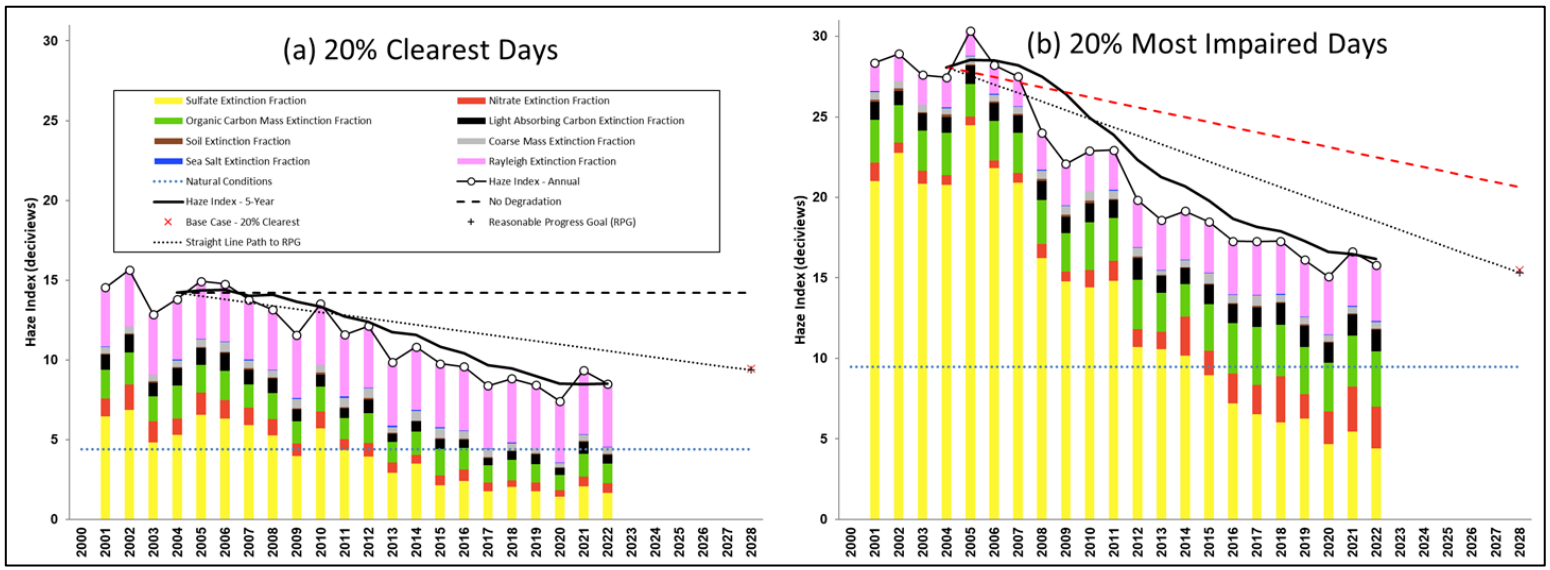
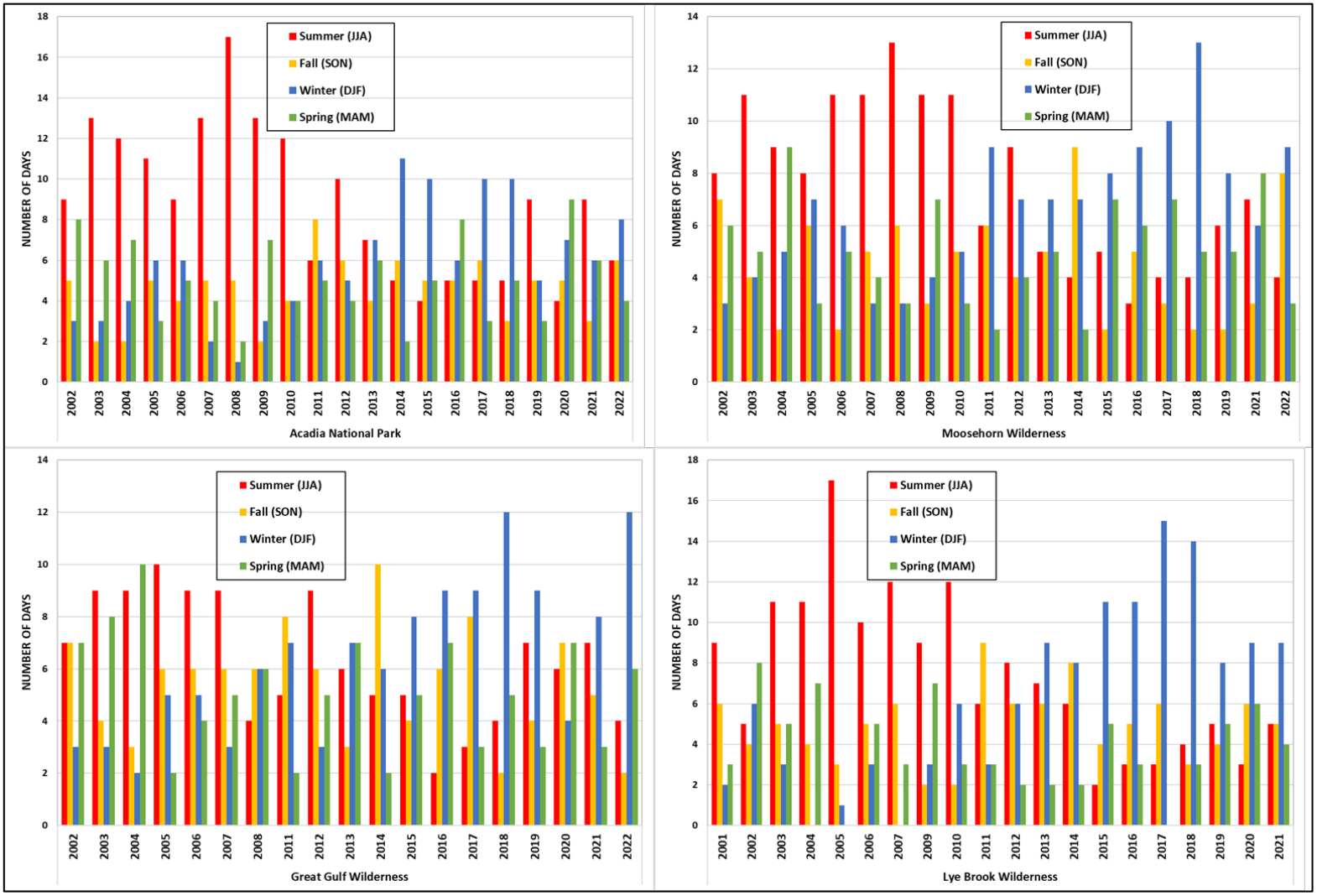


Figure 3-17. Individual Species Contribution to Annual Haze Index Levels at James River Face Wilderness Area on 20 Percent Clearest and Most Impaired Visibility Days



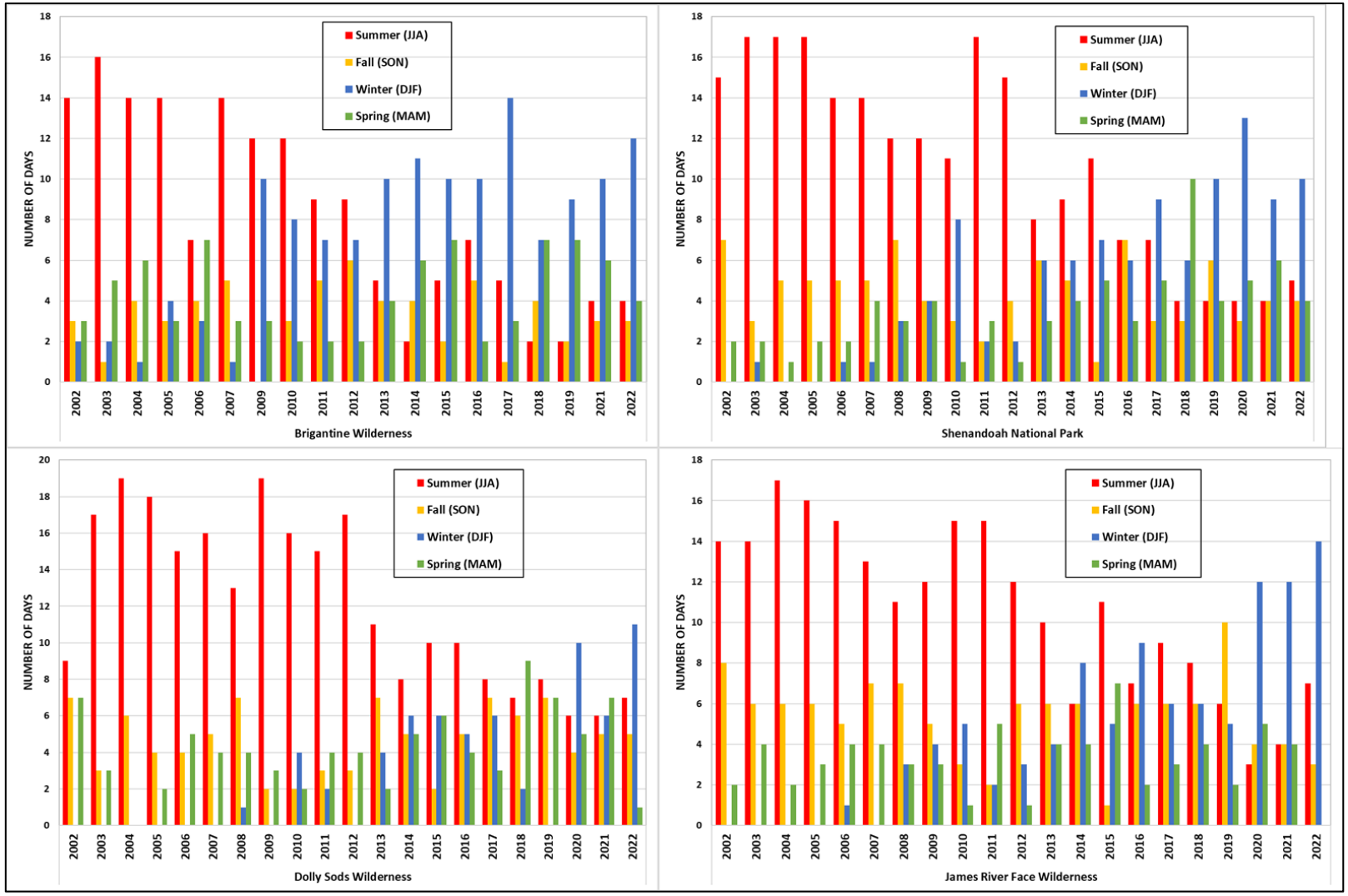
SEASONAL TRENDS OF 20 PERCENT MOST IMPAIRED DAYS

Figure 3-18. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for New England Class I Areas



Note: Lye Brook did not have data for 2022.

Figure 3-19. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for New Jersey, West Virginia and Virginia Class I Areas



4. Summary

Reductions in air pollution continue to bring down levels of fine particulate matter in the eastern United States, which in turn are leading to improved visibility at federally protected Class I areas in and adjacent to the MANEVU region. The MANEVU Class I sites are experiencing significant improvements in visibility largely as the result of reductions in sulfate levels. Based on rolling five-year averages demonstrating progress since the 2000-2004 baseline period, MANEVU Class I areas are currently below the 2021 URP and baseline period levels for the 20 percent clearest visibility days. The trends are mainly driven by large reductions in sulfate light extinction. Levels of nitrate extinction are approaching natural conditions for the 20 percent clearest days; however, its relative percent contribution levels are increasing for the 20 percent most impaired days in recent years as more winter days are in the 20 percent most impaired days mix, especially for the Brigantine and Lye Brook Class I areas. Though states are on track to be below 2028 URPs, current (2018-22) visibility levels are greater than modeled 2028 RPGs for Acadia and the Virginia and West Virginia Class I areas; the 2028 RPG is the metric states need to achieve for the second planning period. Therefore, more work is needed to ensure that reasonable progress towards the goal of natural conditions by 2064 continues. Continued sulfate and nitrate reductions are primary drivers in continuing to improve visibility.

Large emission reductions of NO_x and sulfur dioxide (SO_2) across the region in response to regional emission reduction requirements for power plants (i.e., NO_x SIP Call, NO_x Reasonably Available Control Technology (RACT), Cross State Air Pollution Rule (CSAPR), 2010 SO_2 National Ambient Air Quality Standard (NAAQS), etc.) are likely principal drivers for these visibility improvements. Reductions have occurred recently as the power sector continued to control or phase out coal plants across the eastern United States in response to competitive pressures from natural gas generation, overall reduced electricity demand, and more stringent requirements to reduce emissions of air toxics (i.e., 2011 Mercury and Air Toxics (MATS) rule).

In addition to addressing emissions from power plants, states across the MANEVU region have enacted low sulfur content requirements for fuel oils, which cover home heating oil (distillate) and residual oils (#4 and #6). At the federal level, USEPA finalized the Tier 3 motor vehicle program in 2014 that includes lowering sulfur content in gasoline. While gasoline combustion is a minor source of SO_2 emissions, the Tier 3 fuel requirements significantly reduced NO_x emissions from the existing fleet of on-road gasoline vehicles by reducing sulfur poisoning of the catalyst in catalytic converters, thus improving control technology performance. This helped lead to lower nitrate levels, most notably during colder weather months when nitrates are more thermally stable. In warmer weather months, NO_x promotes ground-level ozone formation, which in turn can enhance formation of visibility-limiting secondary organic aerosols (Carleton *et al.* 2010). Therefore, lower levels of NO_x because of Tier 3 also likely improved visibility by reducing ozone formation that leads to carbonaceous PM. MANEVU anticipates further improvements from more recent light-, medium, and heavy-duty vehicle national emission standards finalized by USEPA in 2024 (USEPA 2024a, 2024b).

In summary, the visibility data examined using the 20 percent most impaired and 20 percent clearest days metrics in this report demonstrate that broad, regional efforts to reduce emissions of

visibility-impairing pollutants have had a beneficial effect at the region's Class I areas. IMPROVE data trends indicate that states continue to be on track keeping visibility levels significantly below the uniform rate of progress levels and some Class I areas have already achieved levels below the respective RPGs. However, further progress is needed at some Class I areas to achieve 2028 reasonable progress goals that have been established for the second regional haze implementation planning period. Further work is also needed to ensure that downward trends continue towards the RHR goal of natural visibility conditions by 2064.

5. References

Carleton, A.G., R.W. Pinder, P.V. Bhave, and G.A. Pouliot. 2010. To What Extent Can Biogenic SOA be Controlled? 44 *Environ. Sci. Technol.* 3376-3380, doi:10.1021/es903506b.

Copeland, S.A., Pitchford, M, and Ames, R. 2008. Regional Haze Rule Natural Level Estimates Using the Revised IMPROVE Aerosol Reconstructed Light Extinction Algorithm. Final Paper #48. Available at http://vista.cira.colostate.edu/improve/Publications/GrayLit/032_NaturalCondIIpaper/Copeland_etal_NaturalConditionsII_Description.pdf.

Federal Land Manager Environmental Database (FED). 2018. IMPROVE and RHR Summary Data. Available at: http://views.cira.colostate.edu/fed/DataWizard/.

MANEVU. 2018a. Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union 2011 Based Modeling Platform Support Document - October 2018 Update. Available at https://otcair.org/manevu/document.asp?fview=Reports.

MANEVU. 2021. Mid-Atlantic/Northeast U.S. Visibility Data 2004-2019 (2nd RH SIP Metrics) – January 21, 2021 Update. Available at https://otcair.org/manevu/document.asp?fview=Reports.

NESCAUM. 2010. Tracking Visibility Progress, 2004-2008 (2010). MANEVU Technical Memorandum, May 12, 2010. Available at http://www.nescaum.org/topics/regional-haze/regional-haze-documents.

NESCAUM. 2013. Tracking Visibility Progress, 2004-2011 (2013). MANEVU Technical Memorandum, May 24, 2013. Available at http://www.nescaum.org/topics/regional-haze/regional-haze-documents.

Pitchford, Mark, William Malm, Bret Schichtel, Naresh Kumar, Douglas Lowenthal & Jenny Hand (2007) Revised Algorithm for Estimating Light Extinction from IMPROVE Particle Speciation Data, Journal of the Air & Waste Management Association, 57:11, 1326-1336, DOI: 10.3155/1047-3289.57.11.1326.

US Environmental Protection Agency (USEPA). 2003a. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule. Research Triangle Park: Office of Air Quality Planning and Standards, September 2003. EPA-454/B-03-005.

US Environmental Protection Agency (USEPA). 2003b. Guidance for Tracking Progress Under the Regional Haze Rule. Research Triangle Park: Office of Air Quality Planning and Standards, September 2003. EPA-454/B-03-004.

US Environmental Protection Agency (USEPA). 2017. Protection of Visibility: Amendments to Requirements for State Plans. Final Rule. 82 FR 3078, January 10, 2017, https://www.gpo.gov/fdsys/pkg/FR-2017-01-10/pdf/2017-00268.pdf.

US Environmental Protection Agency (USEPA). 2018. Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program. Research Triangle Park: Office of Air Quality Planning and Standards, December 2018. EPA-454/R-18-010.

US Environmental Protection Agency (USEPA). 2024a. Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. 89 FR 27842, April 18, 2024, https://www.govinfo.gov/content/pkg/FR-2024-04-18/pdf/2024-06214.pdf.

US Environmental Protection Agency (USEPA). 2024b. Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3. 89 FR 29440, April 22, 2024, https://www.govinfo.gov/content/pkg/FR-2024-04-22/pdf/2024-06809.pdf.

Appendix A: Tracking Progress Data for Class I Areas In and Adjacent to the MANEVU Region

Table A-1. Tracking Progress Data for Acadia National Park (ME) and Brigantine Wilderness (NJ) Class I Areas in the MANEVU Region (dv)

		20 Percent Clearest Days		20 Percent Most Impaired Days	
Class I Area	Year	Haze Index, Annual	Haze Index, 5-Year Rolling	Haze Index, Annual	Haze Index, 5-Year Rolling
Acadia National Park (ACAD)	2000	8.90	-	20.75	-
	2001	8.87	-	22.37	-
	2002	8.77	-	22.91	-
	2003	8.77	-	22.70	-
	2004	8.56	8.78	21.34	22.01
	2005	7.66	8.53	21.85	22.23
	2006	8.25	8.40	22.69	22.30
	2007	8.28	8.30	20.84	21.88
	2008	7.76	8.10	19.35	21.21
	2009	6.92	7.77	18.17	20.58
	2010	6.71	7.58	17.52	19.71
	2011	7.51	7.44	17.39	18.65
	2012	7.75	7.33	15.81	17.65
	2013	6.25	7.03	15.31	16.84
	2014	7.03	7.05	15.36	16.28
	2015	6.05	6.92	16.07	15.99
	2016	6.08	6.63	13.72	15.26
	2018	7.18	6.52	13.97	14.89
	2018	6.53	6.58	13.58	14.54
	2019	5.95	6.36	13.85	14.24
	2020	6.80	6.51	13.52	13.73
	2021	6.26	6.54	14.01	13.78
	2022	5.45	6.20	14.24	13.84
	2028 RPG		**6.33 RPG**		**13.35 RPG**
	2064 NAT		**4.66 NAT**		**10.39 ER NAT**
Brigantine Wilderness (BRIG)	2000	14.26	-	27.37	-
	2001	13.80	-	27.07	-
	2002	14.83	-	26.53	-
	2003	14.39	-	28.49	-
	2004	14.36	14.33	27.69	27.43
	2005	14.61	14.40	28.81	27.72
	2006	15.35	14.71	26.88	27.68
	2007	12.74	14.29	26.10	27.60
	2008	*	14.26	*	27.37
	2009	12.78	13.87	23.03	26.21
	2010	11.82	13.17	24.51	25.13
	2011	12.92	12.56	22.66	24.08
	2012	11.93	12.36	20.95	22.79
	2013	11.80	12.25	20.12	22.25
	2014	11.66	12.03	21.09	21.87
	2015	11.44	11.95	20.84	21.13
	2016	11.12	11.59	19.18	20.44
	2017	11.36	11.48	18.09	19.86
	2018	10.70	11.26	17.37	19.31
	2019	9.44	10.81	17.19	18.53
	2020	*	10.66	*	17.96
	2021	10.11	10.40	16.97	17.40
	2022	9.64	9.97	16.12	16.91
	2028 RPG		**10.47 RPG**		**17.97 RPG**
	2064 NAT		**5.52 NAT**		**10.68 ER NAT**

"-" = not applicable; "*" = no data available; "RPG" = Reasonable Progress Goal; "NAT" = Natural Conditions; "ER" = episodic routine

Table A-2. Tracking Progress Data for Great Gulf Wilderness (NH) and Lye Brook Wilderness (VT) Class I Areas in the MANEVU Region (dv)

		20 Percent Clearest Days		20 Percent Most Impaired Days	
Class I Area	Year	Haze Index, Annual	Haze Index, 5-Year Rolling	Haze Index, Annual	Haze Index, 5-Year Rolling
Great Gulf Wilderness Area (GRGU)	2000	*	-	*	-
	2001	8.26	-	22.47	-
	2002	7.77	-	23.43	-
	2003	6.94	-	20.65	-
	2004	7.61	7.65	20.97	21.88
	2005	6.69	7.46	20.51	21.61
	2006	6.43	7.09	19.74	21.06
	2007	6.86	6.91	21.06	20.59
	2008	6.26	6.77	16.10	19.67
	2009	*	6.56	*	19.35
	2010	*	6.52	*	18.96
	2011	6.39	6.50	17.48	18.21
	2012	5.81	6.16	14.86	16.14
	2013	5.41	5.87	13.87	15.40
	2014	5.75	5.84	15.19	15.35
	2015	4.92	5.66	14.44	15.17
	2016	4.69	5.32	11.23	13.92
	2017	5.22	5.20	11.81	13.31
	2018	4.37	4.99	12.70	13.07
	2019	4.30	4.70	11.47	12.33
	2020	4.92	4.70	11.04	11.65
	2021	4.54	4.67	12.49	11.90
	2022	4.53	4.53	11.42	11.82
	2028 RPG		**5.06 RPG**		**12.00 RPG**
	2064 NAT		**3.73 NAT**		**9.78 ER NAT**
Lye Brook Wilderness Area (LYBR 2000-2011) (LYEB 2012-current)	2000	6.49	-	23.10	-
	2001	6.47	-	25.48	-
	2002	6.43	-	23.46	-
	2003	5.83	-	23.37	-
	2004	6.61	6.37	22.41	23.57
	2005	5.45	6.16	25.92	24.13
	2006	5.24	5.91	21.19	23.27
	2007	5.74	5.78	25.26	23.63
	2008	*	5.76	*	23.69
	2009	4.11	5.14	17.85	22.55
	2010	4.08	4.80	19.09	20.85
	2011	5.40	4.83	18.27	20.12
	2012	5.49	4.77	17.78	18.25
	2013	5.35	4.89	17.32	18.06
	2014	5.00	5.07	16.61	17.81
	2015	5.20	5.29	15.36	17.07
	2016	4.88	5.19	13.42	16.10
	2017	5.43	5.17	13.95	15.33
	2018	4.62	5.03	14.31	14.73
	2019	4.25	4.88	13.28	14.06
	2020	4.82	4.80	12.46	13.48
	2021	3.97	4.62	13.30	13.46
	2022	*	4.41	*	13.34
	2028 RPG		**3.86 RPG**		**13.68 RPG**
	2064 NAT		**2.79 NAT**		**10.24 ER NAT**

"-" = not applicable; "*" = no data available; "RPG" = Reasonable Progress Goal; "NAT" = Natural Conditions; "ER" = episodic routine

Table A-3. Tracking Progress Data for the Moosehorn Wilderness (ME) Class I Area in the MANEVU Region (dv)

		20 Percent Clearest Days		20 Percent Most Impaired Days	
Class I Area	Year	Haze Index, Annual	Haze Index, 5-Year Rolling	Haze Index, Annual	Haze Index, 5-Year Rolling
Moosehorn Wilderness Area (MOOS)	2000	8.94	-	19.48	-
	2001	9.31	-	21.30	-
	2002	9.12	-	22.12	-
	2003	9.48	-	20.96	-
	2004	8.93	9.16	19.40	20.65
	2005	7.99	8.97	20.92	20.94
	2006	8.60	8.82	20.72	20.82
	2007	7.79	8.56	18.50	20.10
	2008	7.82	8.23	17.51	19.41
	2009	6.83	7.81	17.01	18.93
	2010	5.98	7.41	16.45	18.04
	2011	6.97	7.08	16.38	17.17
	2012	7.32	6.99	14.74	16.42
	2013	6.55	6.73	14.42	15.80
	2014	6.90	6.74	14.15	15.23
	2015	6.64	6.88	14.53	14.85
	2016	6.09	6.70	12.56	14.08
	2017	6.77	6.59	12.13	13.56
	2018	6.57	6.59	13.23	13.32
	2019	6.31	6.48	12.49	12.99
	2020	*	6.43	*	12.60
	2021	5.90	6.39	12.83	12.67
	2022	5.63	6.10	12.87	12.86
	2028 RPG		**6.45 RPG**		**13.12 RPG**
	2064 NAT		**5.02 NAT**		**9.98 ER NAT**

"-" = not applicable; "*" = no data available; "RPG" = Reasonable Progress Goal; "NAT" = Natural Conditions; "ER" = episodic routine

Table A-4. Tracking Progress Data for the Dolly Sods Wilderness (WV) Class I Area Adjacent to the MANEVU Region (dv)

		20 Percent Clearest Days		20 Percent Most Impaired Days	
Class I Area	Year	Haze Index, Annual	Haze Index, 5-Year Rolling	Haze Index, Annual	Haze Index, 5-Year Rolling
Dolly Sods Wilderness (DOSO)	2000	12.96	-	27.72	-
	2001	13.30	-	27.53	-
	2002	11.91	-	27.96	-
	2003	11.54	-	29.33	-
	2004	11.67	12.28	28.91	28.29
	2005	11.91	12.07	30.45	28.84
	2006	10.57	11.52	28.91	29.11
	2007	10.20	11.18	28.15	29.15
	2008	9.44	10.76	24.37	28.16
	2009	8.70	10.16	21.89	26.75
	2010	9.74	9.73	22.68	25.20
	2011	8.75	9.37	23.75	24.17
	2012	9.59	9.25	20.88	22.71
	2013	8.34	9.03	18.83	21.61
	2014	8.52	8.99	19.41	21.11
	2015	5.88	8.22	18.82	20.34
	2016	7.00	7.87	16.76	18.94
	2017	6.47	7.24	16.15	17.99
	2018	5.52	6.68	17.10	17.65
	2019	6.04	6.18	16.34	17.03
	2020	5.82	6.17	13.77	16.02
	2021	6.67	6.10	15.49	15.77
	2022	6.73	6.15	14.16	15.37
	2028 RPG		**7.27 RPG**		**15.09 RPG**
	2064 NAT		**3.64 NAT**		**8.92 ER NAT**

"-" = not applicable; "*" = no data available; "RPG" = Reasonable Progress Goal; "NAT" = Natural Conditions; "ER" = episodic routine

Table A-5. Tracking Progress Data for James River Face Wilderness and Shenandoah National Park (VA) Class I Areas Adjacent to the MANEVU Region (dv)

		20 Percent Clearest Days		20 Percent Most Impaired Days	
Class I Area	Year	Haze Index, Annual	Haze Index, 5-Year Rolling	Haze Index, Annual	Haze Index, 5-Year Rolling
James River Face (JARI)	2000	*	-	*	-
	2001	14.54	-	28.36	-
	2002	15.65	-	28.91	-
	2003	12.85	-	27.61	-
	2004	13.80	14.21	27.45	28.08
	2005	14.92	14.35	30.32	28.53
	2006	14.75	14.39	28.21	28.50
	2007	13.78	14.02	27.49	28.22
	2008	13.15	14.08	24.01	27.50
	2009	11.55	13.63	22.07	26.42
	2010	13.51	13.35	22.88	24.94
	2011	11.57	12.71	22.93	23.88
	2012	12.12	12.38	19.84	22.35
	2013	9.86	11.72	18.59	21.27
	2014	10.81	11.58	19.14	20.68
	2015	9.76	10.83	18.47	19.80
	2016	9.57	10.42	17.28	18.67
	2017	8.38	9.68	17.26	18.15
	2018	8.82	9.47	17.28	17.89
	2019	8.41	8.99	16.11	17.28
	2020	7.41	8.52	15.08	16.60
	2021	9.34	8.47	16.63	16.47
	2022	8.50	8.50	15.81	16.18
	2028 RPG		**9.36 RPG**		**15.31 RPG**
	2064 NAT		**4.39 NAT**		**9.47 ER NAT**
Shenandoah National Park (SHEN)	2000	11.08	-	27.23	-
	2001	13.21	-	27.62	-
	2002	11.49	-	29.89	-
	2003	9.48	-	27.87	-
	2004	9.55	10.96	29.00	28.32
	2005	10.48	10.84	30.51	28.98
	2006	10.59	10.32	27.75	29.01
	2007	11.13	10.25	28.17	28.66
	2008	8.16	9.98	24.59	28.00
	2009	8.23	9.72	21.20	26.44
	2010	9.79	9.58	22.12	24.77
	2011	7.87	9.04	22.10	23.64
	2012	9.63	8.73	19.30	21.86
	2013	7.50	8.60	18.88	20.72
	2014	8.02	8.56	18.58	20.20
	2015	6.50	7.90	18.65	19.50
	2016	7.32	7.79	16.59	18.40
	2017	6.35	7.14	16.14	17.77
	2018	6.09	6.85	15.37	17.07
	2019	6.44	6.54	15.16	16.38
	2020	5.35	6.31	13.27	15.31
	2021	7.24	6.30	13.78	14.74
	2022	6.98	6.42	13.75	14.27
	2028 RPG		**6.83 RPG**		**14.25 RPG**
	2064 NAT		**3.15 NAT**		**9.52 ER NAT**

"-" = not applicable; "*" = no data available; "RPG" = Reasonable Progress Goal; "NAT" = Natural Conditions; "ER" = episodic routine

Appendix B: Annual Visibility Species Trends Plots for Current Active IMPROVE Protocol Sites In and Adjacent to the MANEVU Region

Figure B-1. Presque Isle, ME Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

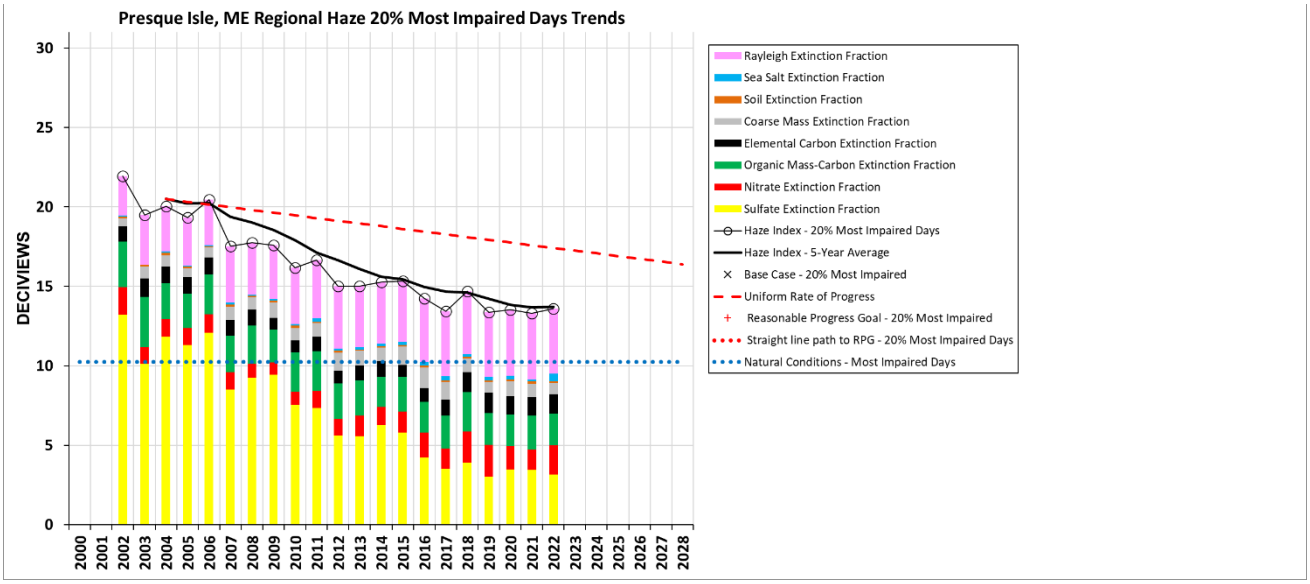


Figure B-2. Penobscot Nation, ME Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

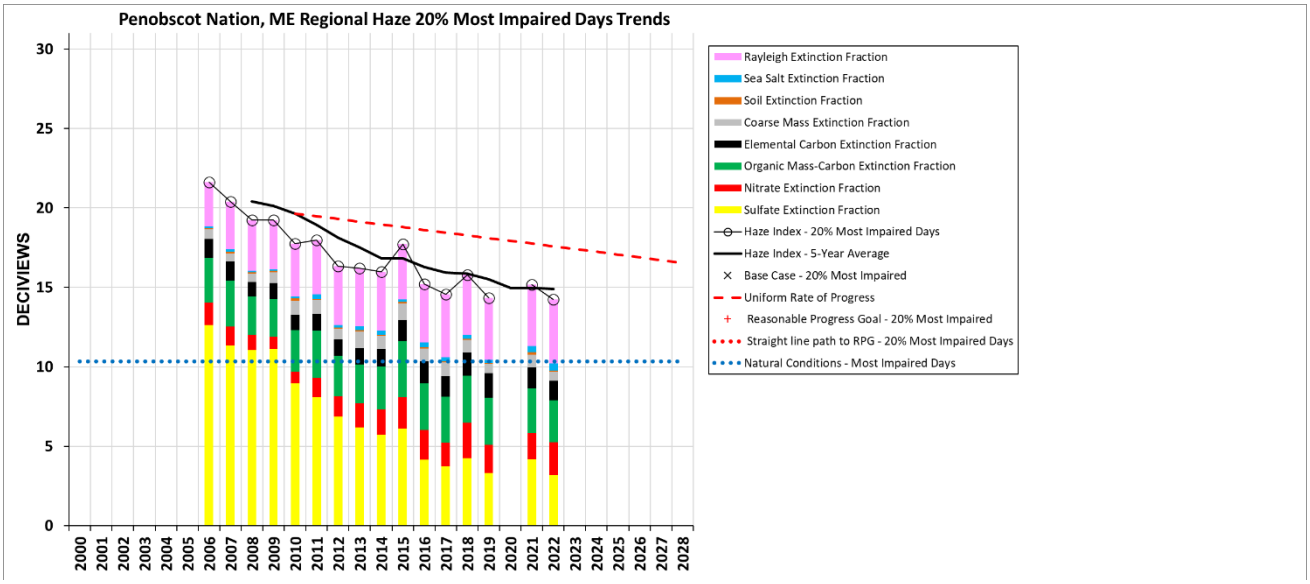


Figure B-3. Casco Bay, ME Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

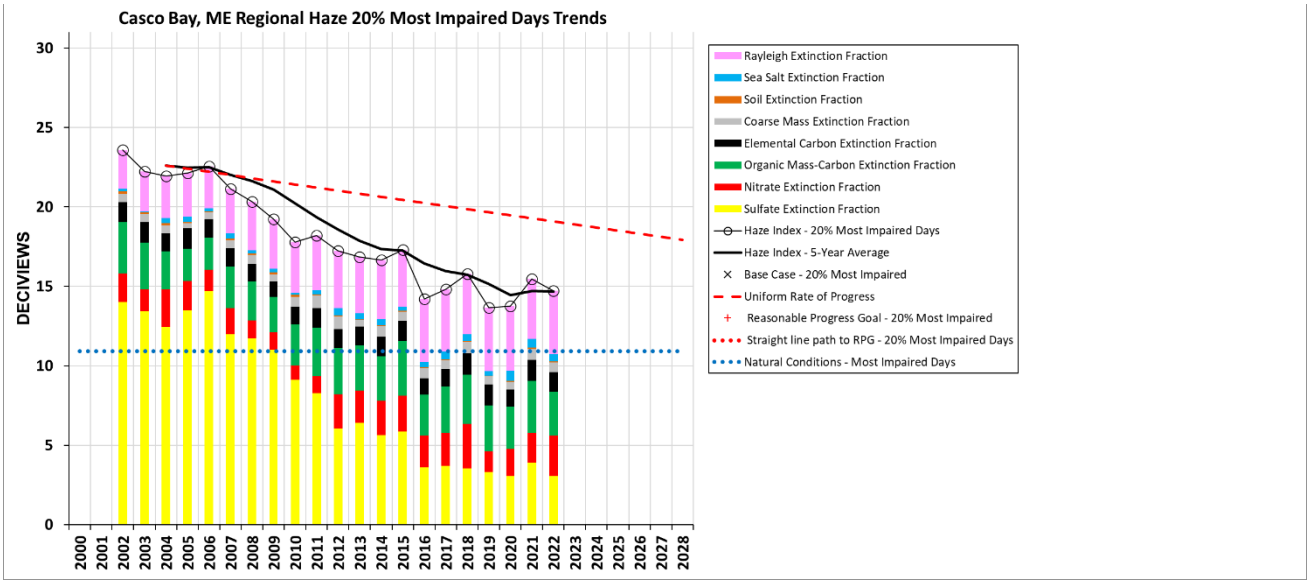


Figure B-4. Proctor Maple R.F., VT Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

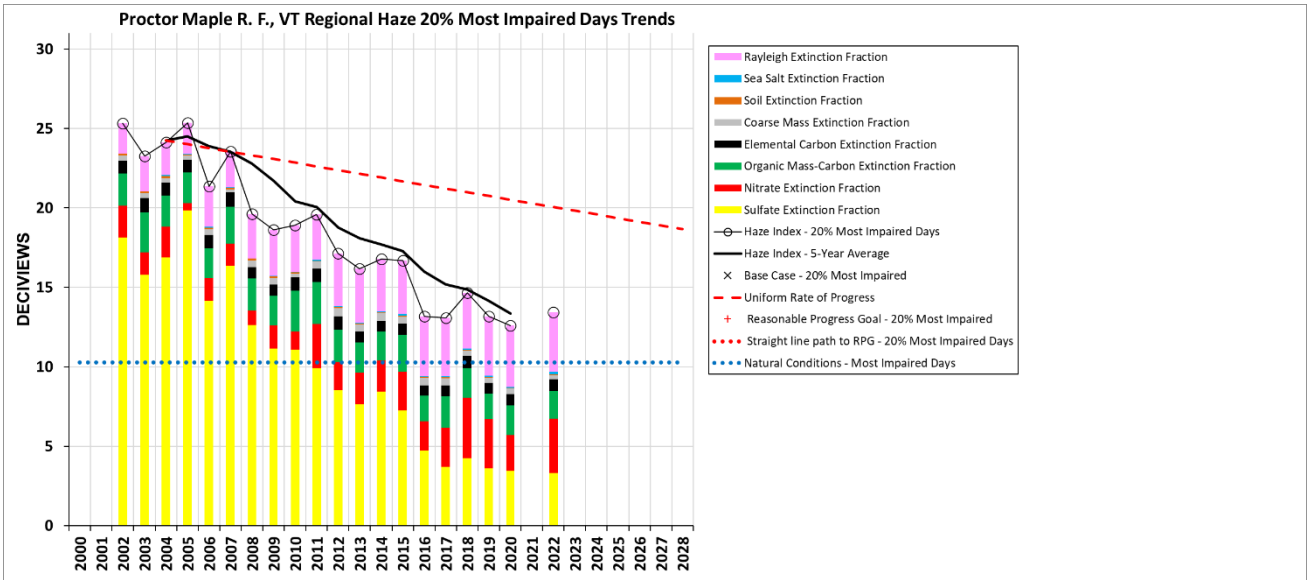


Figure B-5. Londonderry, NH Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

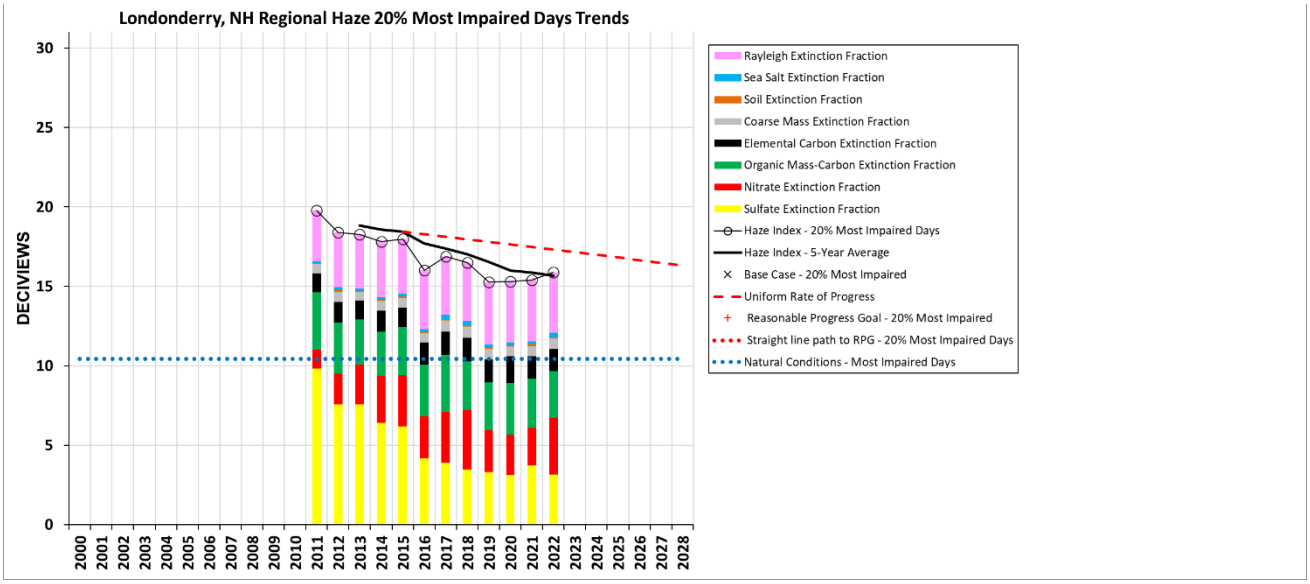


Figure B-6. Pack Monadnock Summit, NH Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

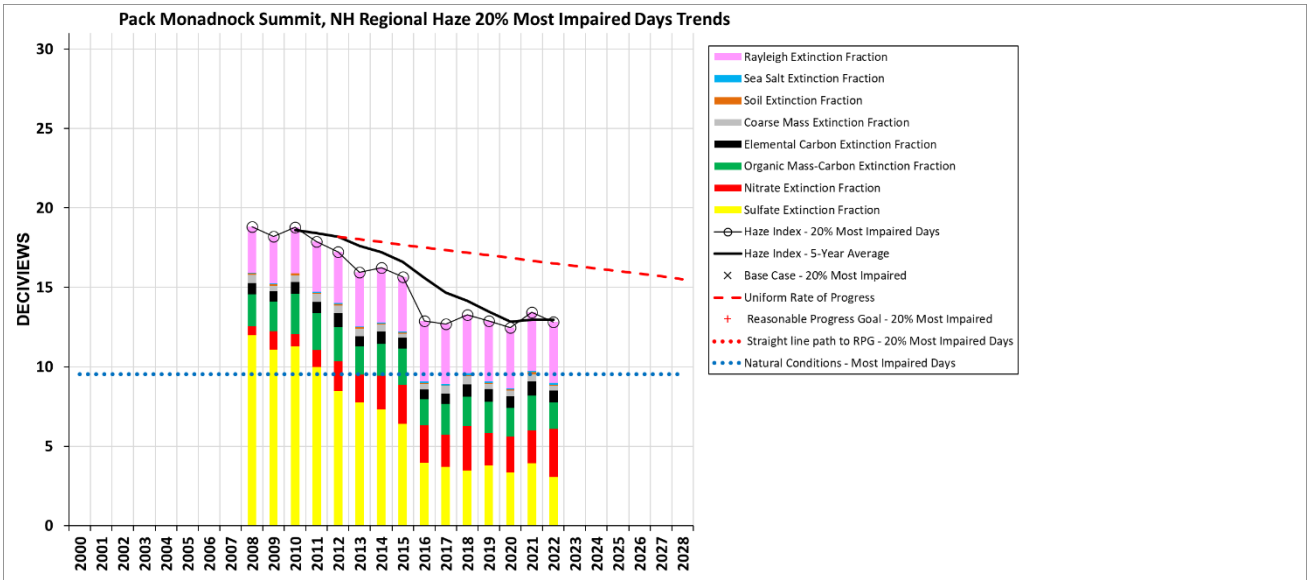


Figure B-7. Mohawk Mt., CT Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

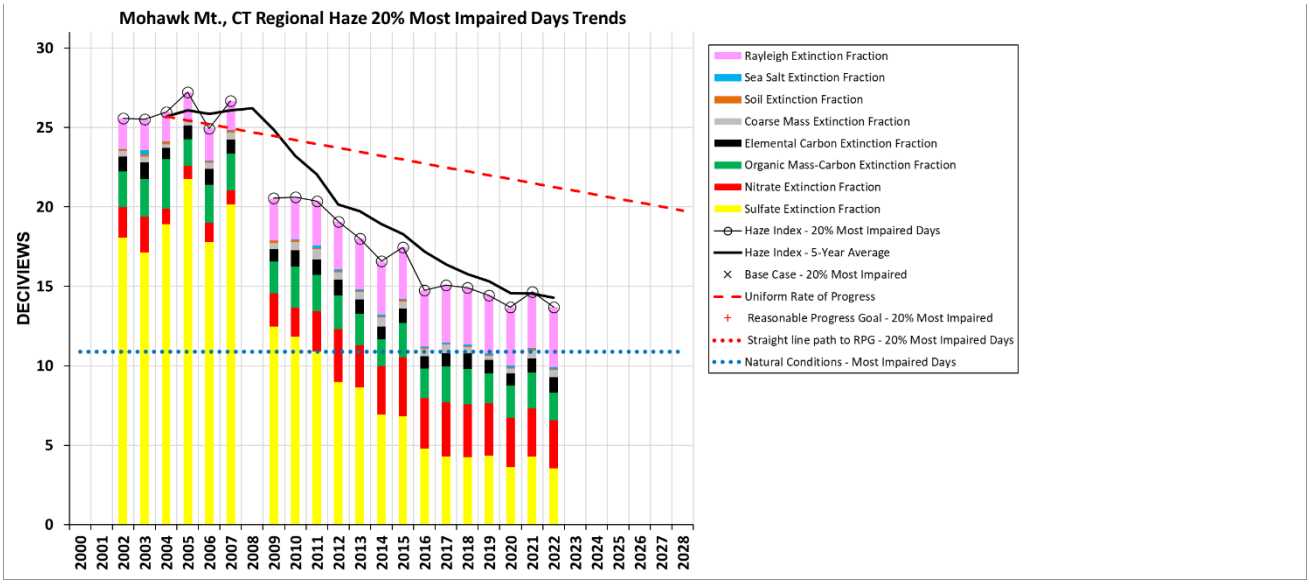


Figure B-8. Cape Cod, MA Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

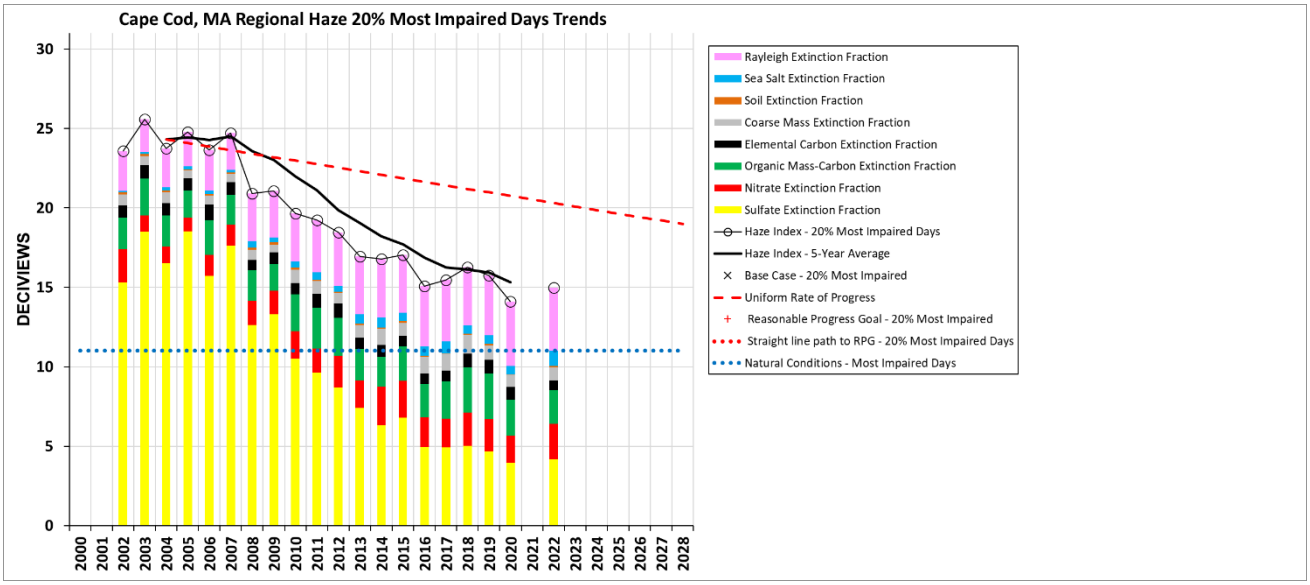


Figure B-9. Martha's Vineyard, MA Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

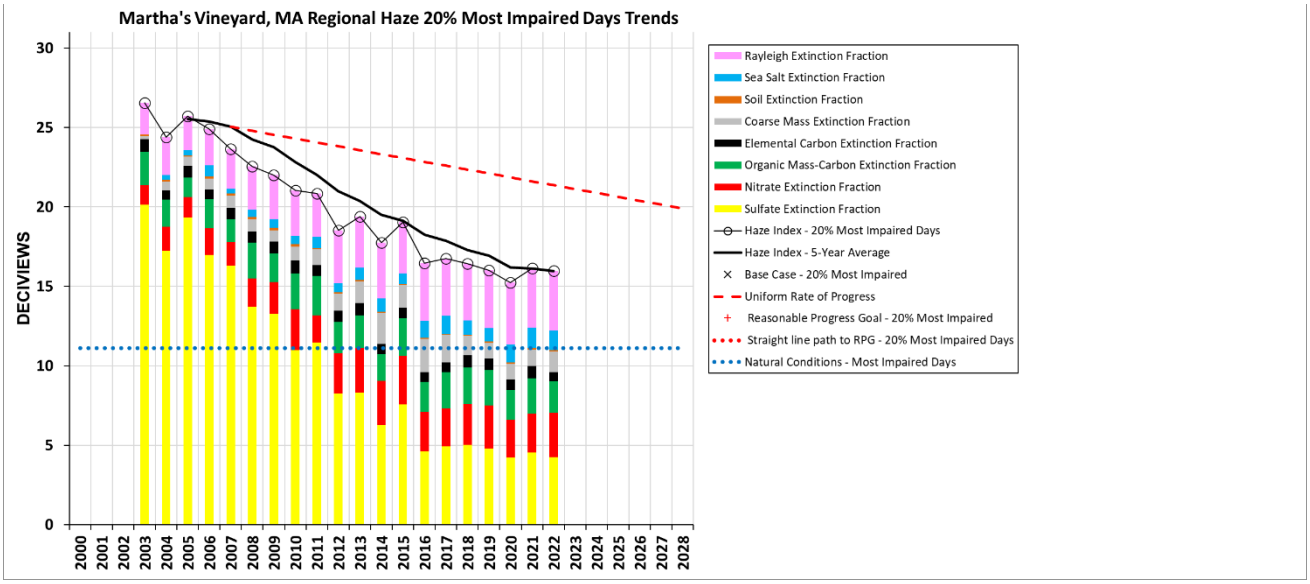


Figure B-10. Frostburg Reservoir, MD Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days

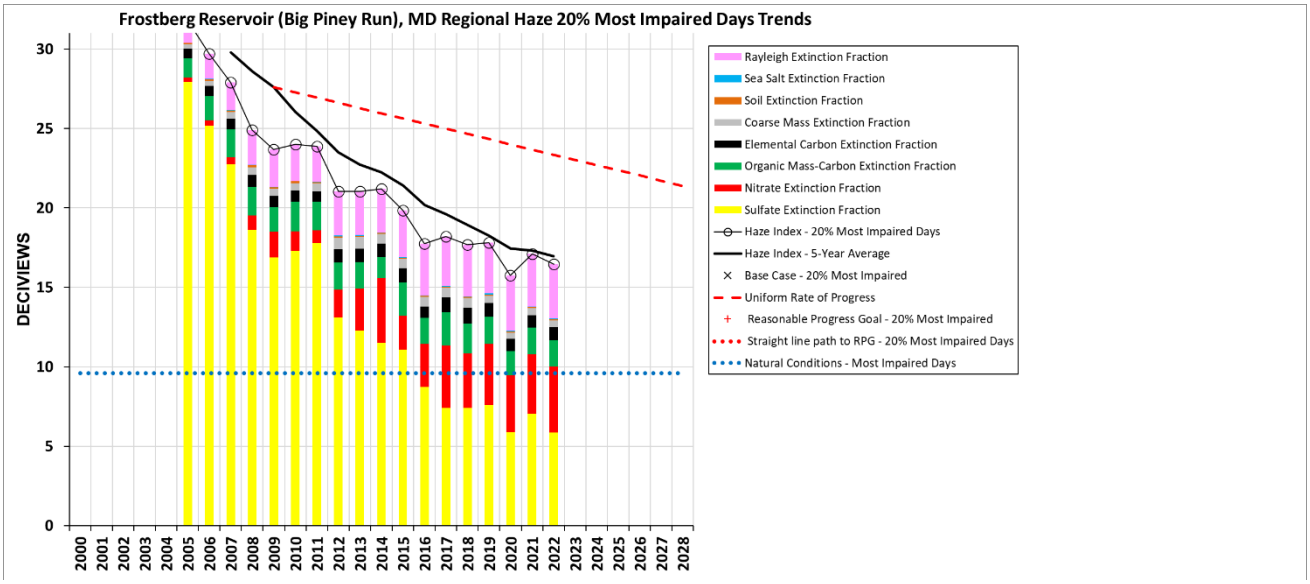
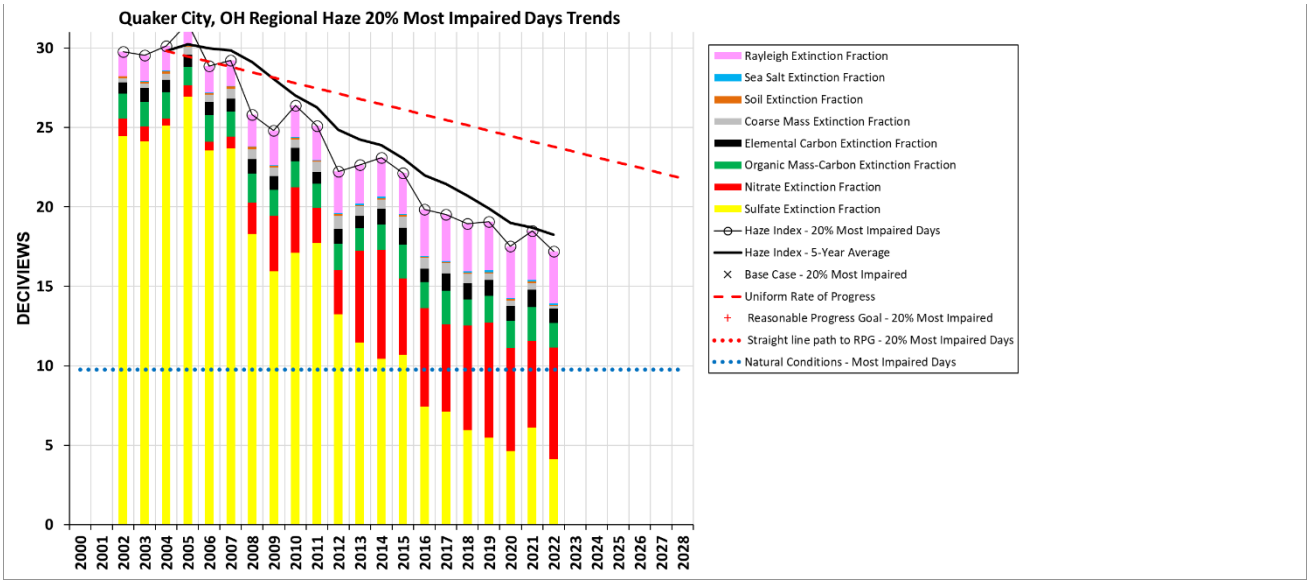


Figure B-11. Quaker City, OH Individual Species Contribution to Annual Haze Index Levels on 20 Percent Most Impaired Visibility Days



Appendix C: Seasonal Trend Plots of 20 Percent Most Impaired Days for Current Active IMPROVE Protocol Sites In and Adjacent to the MANEVU Region

Figure C-1. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for Maine and Vermont IMPROVE Protocol Sites

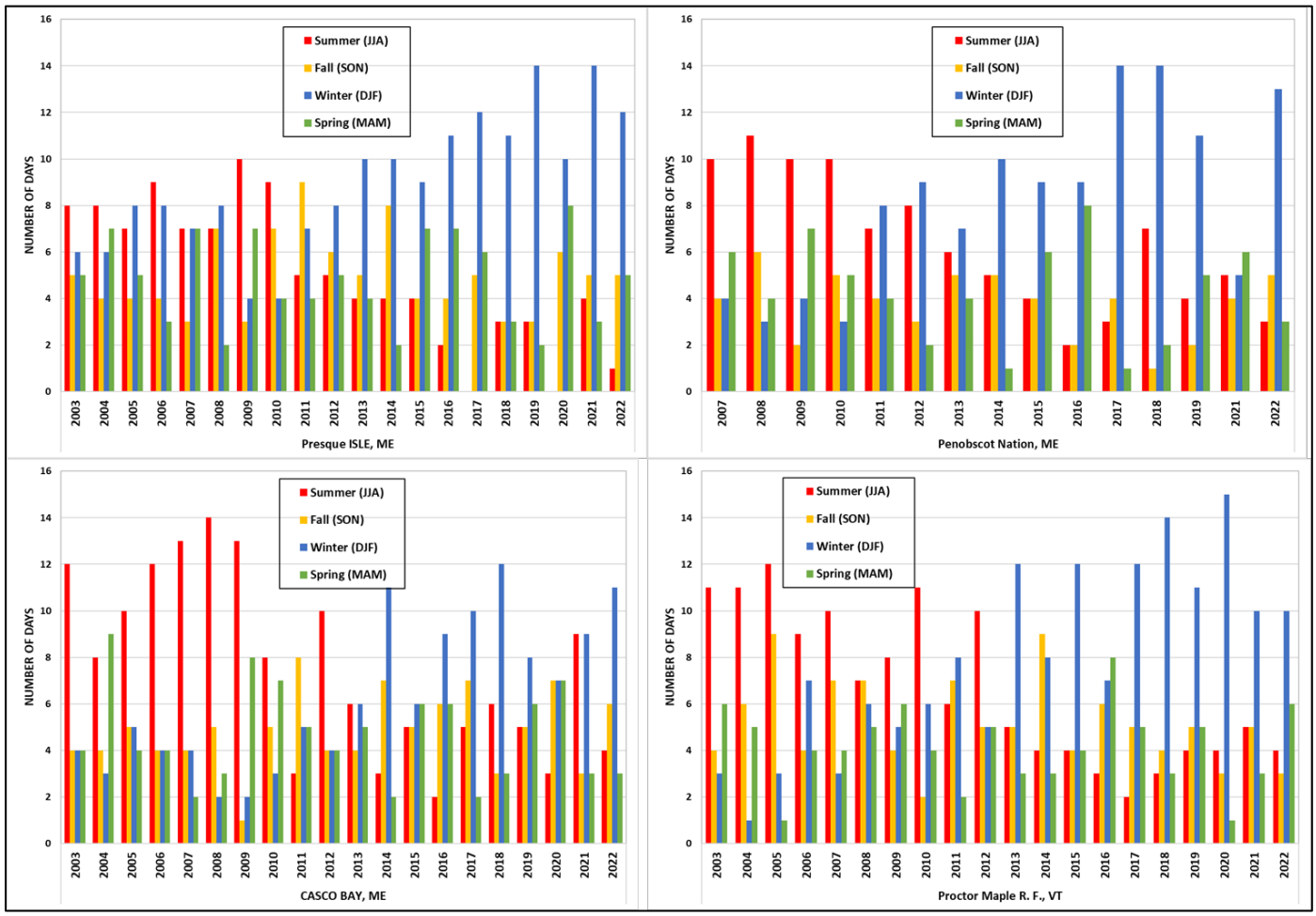


Figure C-2. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for New Hampshire, Connecticut and Cape Cod, MA IMPROVE Protocol Sites

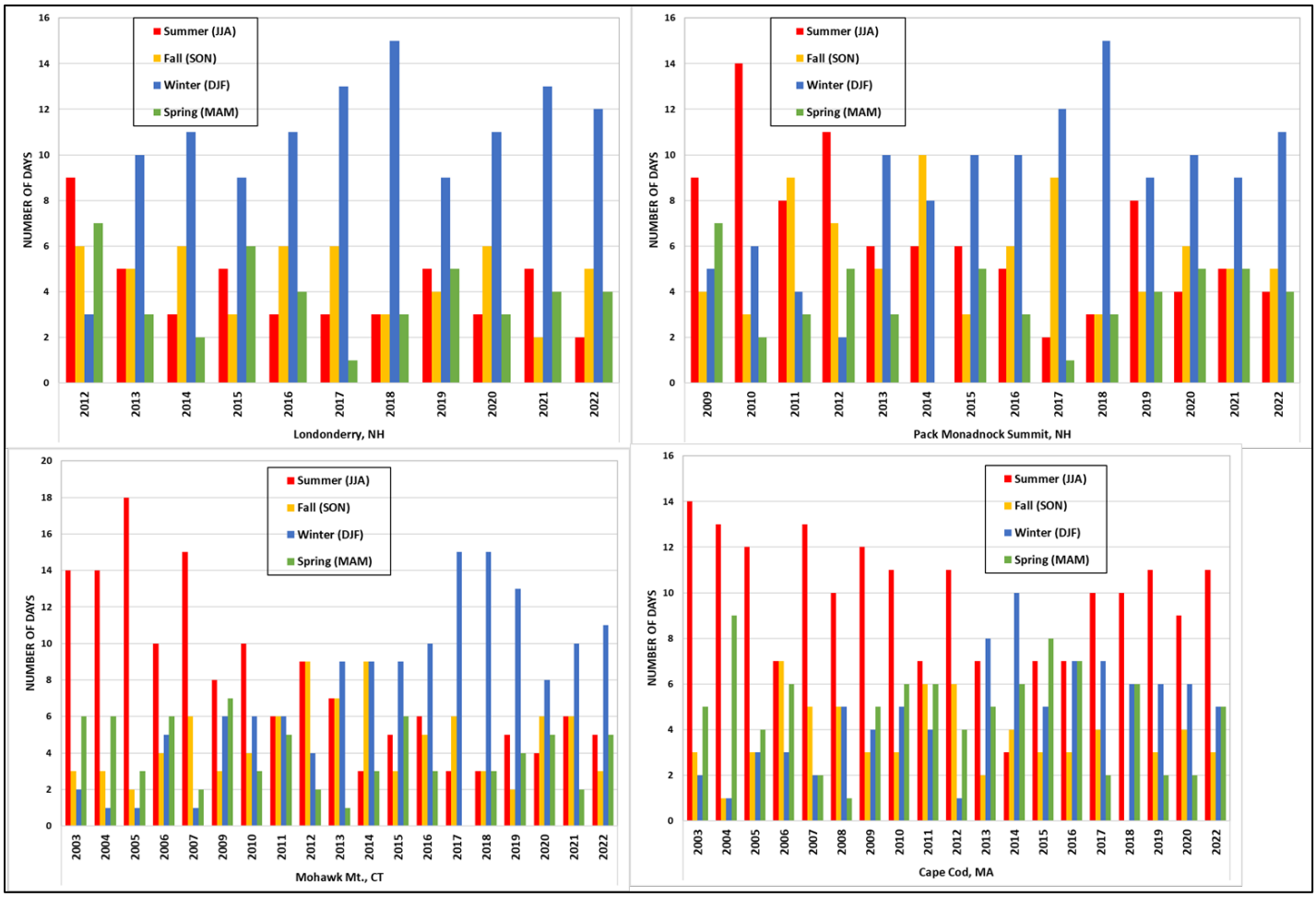
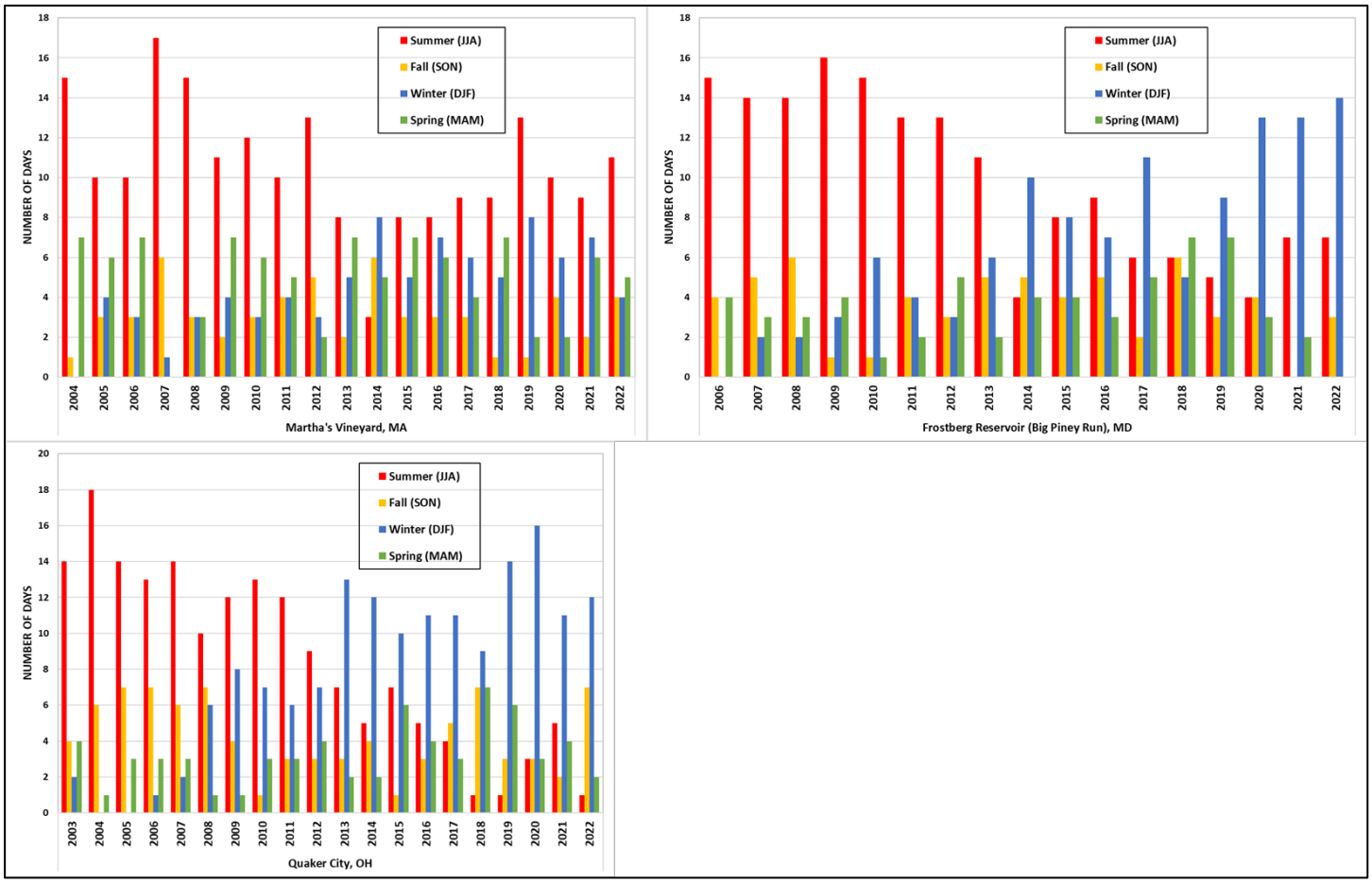


Figure C-3. Seasonal Breakdown of 20 Percent Most Impaired Visibility Days for Martha's Vineyard, MA, Maryland, and Ohio IMPROVE Protocol Sites



Appendix D: Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Current Active IMPROVE Monitoring Sites In and Adjacent to the MANEVU Region

Figure D-1. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Acadia National Park on 20 Percent Clearest and Most Impaired Visibility Days

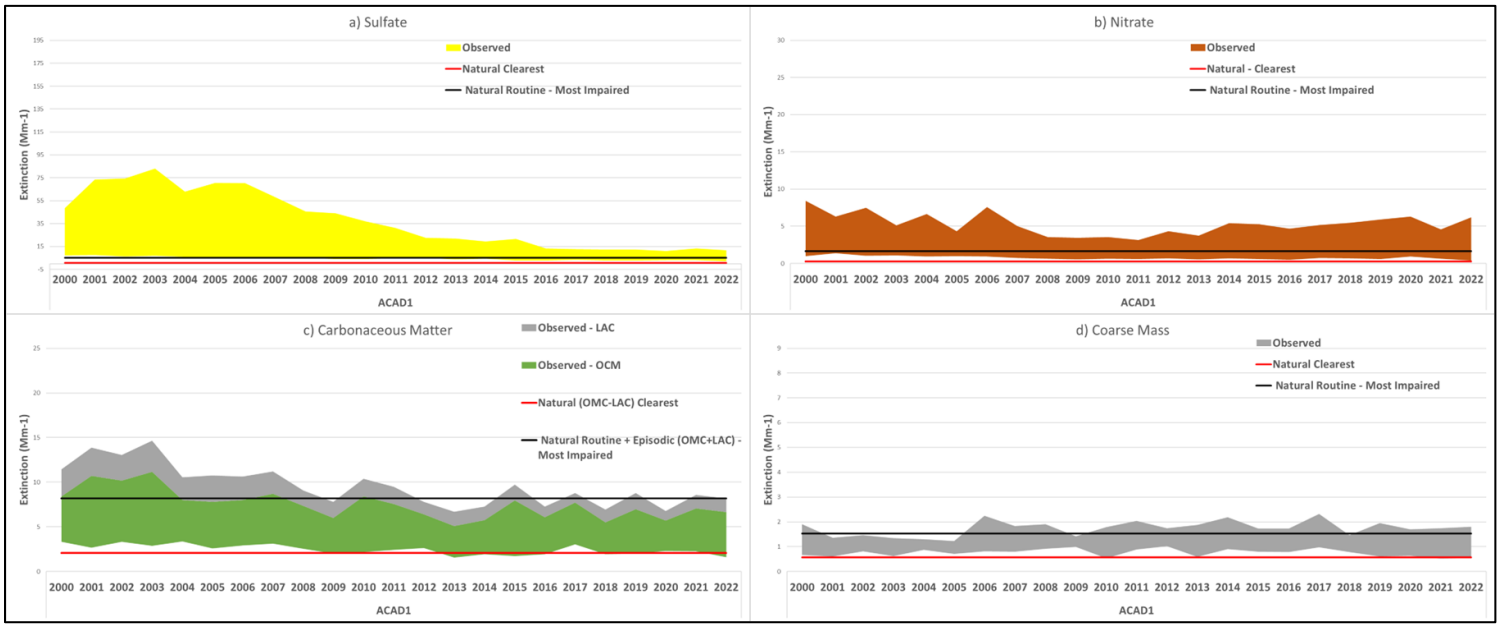


Figure D-2. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Moosehorn on 20 Percent Clearest and Most Impaired Visibility Days

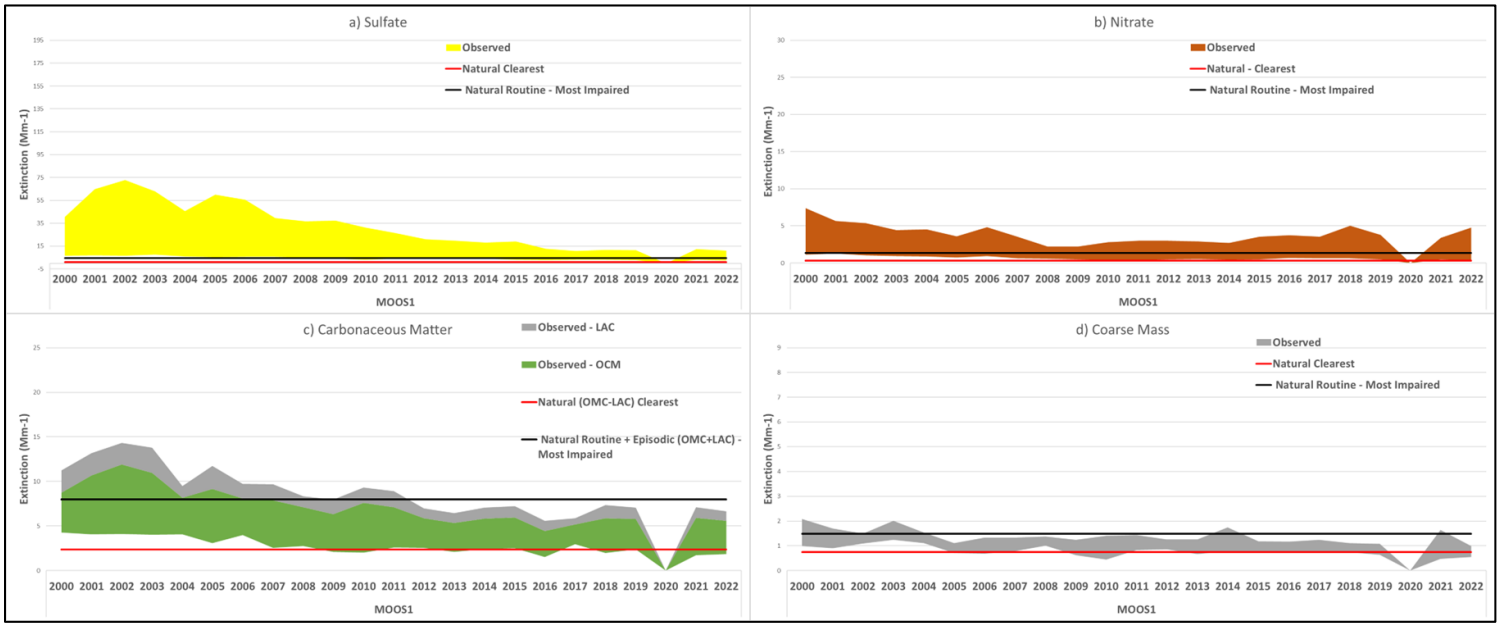


Figure D-3. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Great Gulf on 20 Percent Clearest and Most Impaired Visibility Days

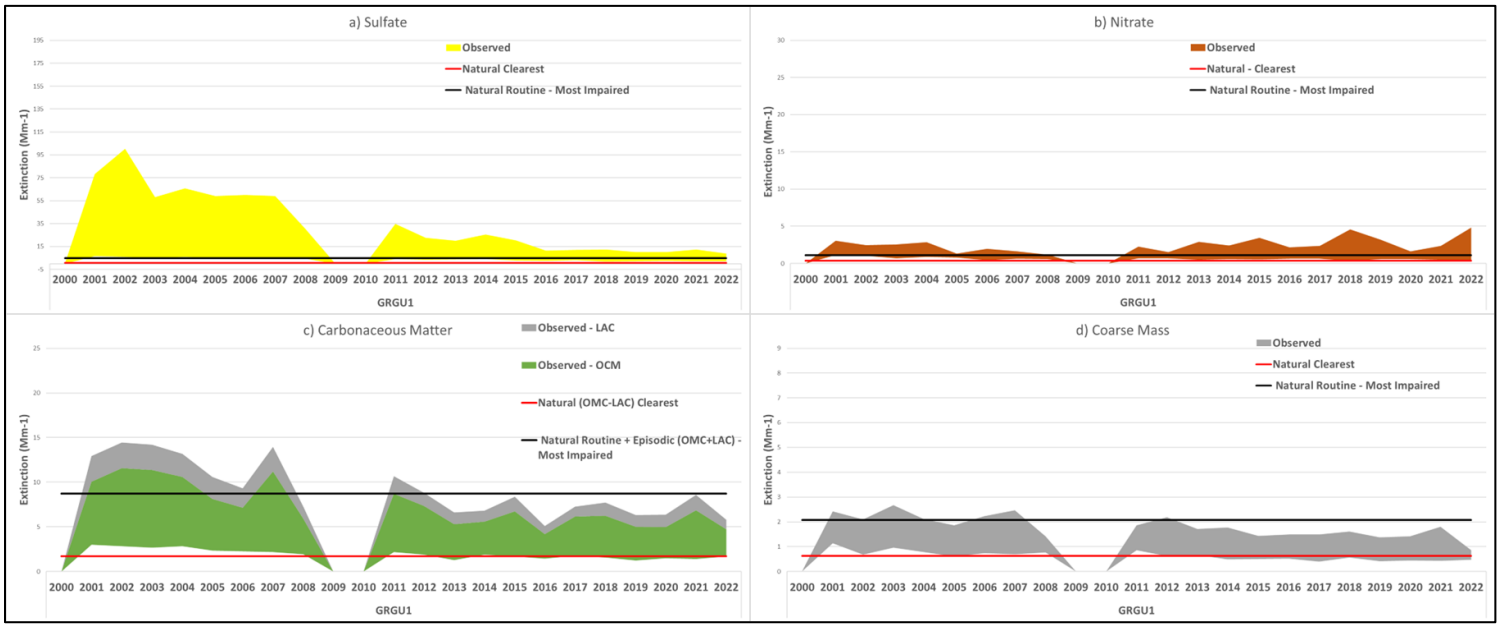
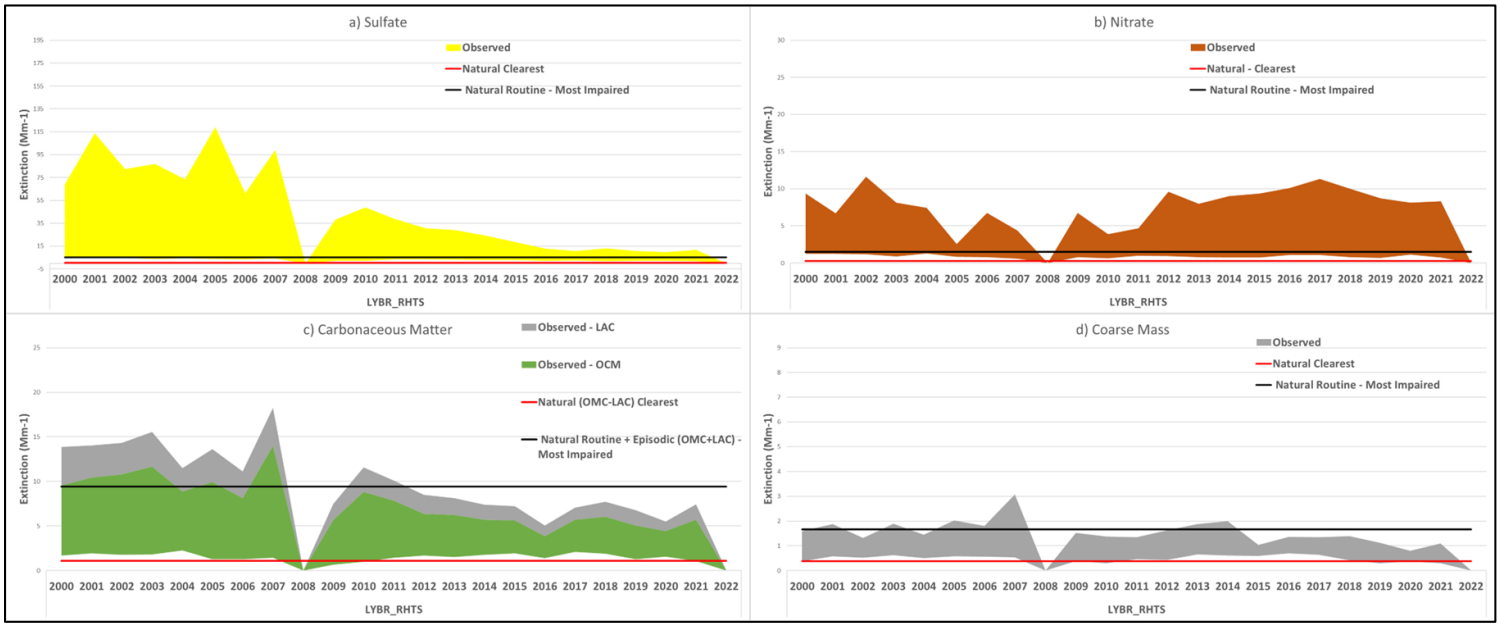


Figure D-4. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Lye Brook on 20 Percent Clearest and Most Impaired Visibility Days



Note: Lye Brook did not have data for 2022.

Figure D-5. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Brigantine on 20 Percent Clearest and Most Impaired Visibility Days

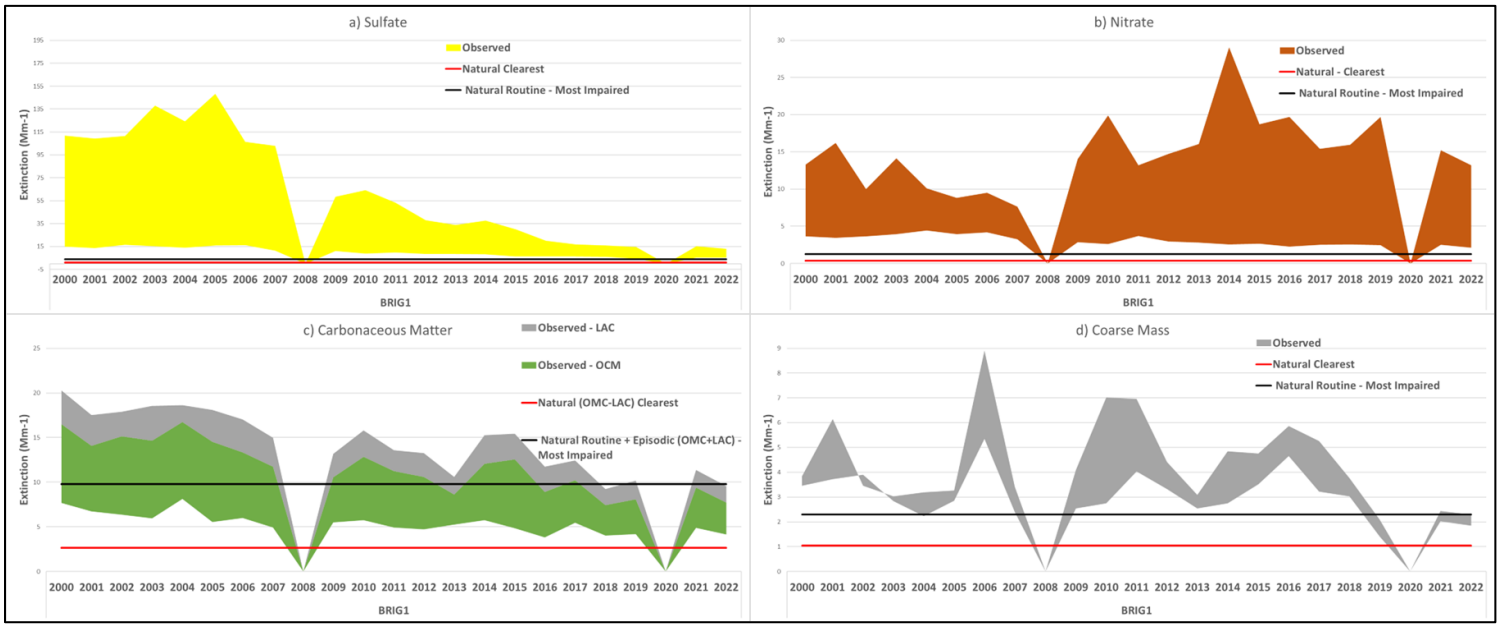


Figure D-6. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at Shenandoah on 20 Percent Clearest and Most Impaired Visibility Days

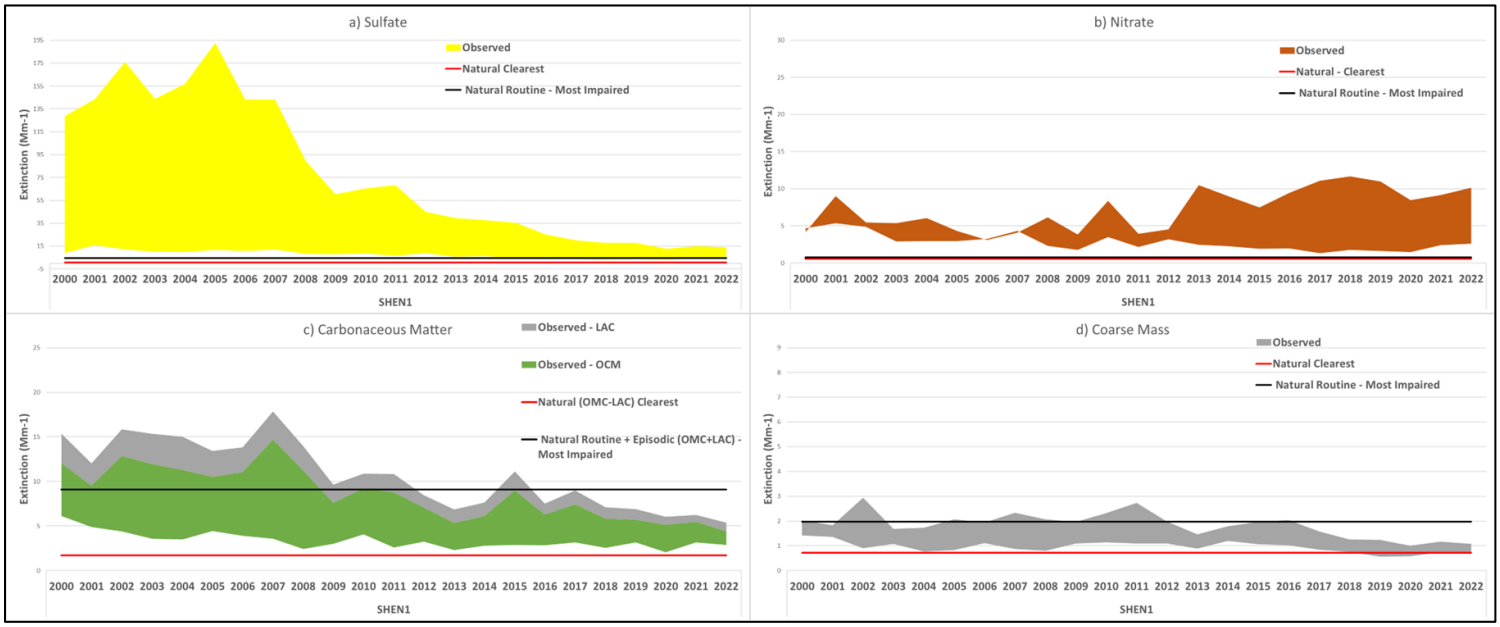


Figure D-7. Range of Observed and Estimated Natural Light Extinction for Select Individual Species at James River Face on 20 Percent Clearest and Most Impaired Visibility Days