# Tracking Visibility Progress
# 2004-2011

**Prepared by**
**NESCAUM**
for the
Mid-Atlantic/Northeast Visibility Union (MANE-VU)

**April 30, 2013**
Revised May 24, 2013

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# TRACKING VISIBILITY PROGRESS 2004-2011

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# Executive Summary

In this report, we present visibility trends at federal “Class I areas” in the Mid-Atlantic/Northeast Visibility Union (MANE-VU) region that are subject to the US Environmental Protection Agency’s (USEPA’s) Regional Haze Rule (RHR). This analysis was performed to determine the extent of progress in meeting short-term and long-term visibility goals under the RHR.

This technical document provides an analysis of visibility data collected at the Class I areas, starting in the historic baseline period of 2000-2004 through 2007-2011, the most recent five-year period with available data.

The results of this analysis show the following:

- There are definite downward trends in overall haze levels at the Class I areas in and adjacent to the MANE-VU region.
- Based on rolling-five year averages demonstrating progress since the 2000-2004 baseline period, the MANE-VU Class I areas appear to be on track to meet their 2018 Reasonable Progress Goals (RPGs) for both best and worst visibility days.
- The trends are mainly driven by large reductions in sulfate light extinction, and to a lesser extent, nitrate light extinction.
- Levels of organic carbon mass (OCM) and light absorbing carbon (LAC) appear to be approaching natural background levels at most of the MANE-VU Class I areas.
- In some cases, the levels set by 2018 RPGs have already been met, and progress beyond those goals appears achievable.
- Though the Brigantine Wilderness Area is on track to meet its 2018 RPGs, challenges remain. Sulfate light extinction levels are higher at this site than at others across the region. Additional sulfate reductions would be a significant driver in reducing overall haze levels at Brigantine.

# 1. INTRODUCTION

## 1.1. Background

Haze, or reduced visibility, occurs when ambient particulate matter and gases scatter or absorb light ("light extinction") that would otherwise reach an observer. The 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. Some particle constituents 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: the 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 haziest days while not exacerbating haze on the clearest 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. States are additionally 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.

The Mid-Atlantic/Northeast Visibility Union (MANE-VU) 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 MANE-VU region are shown in Figure 1-1. This document also includes information for two Class I areas that are adjacent to the MANE-VU region: the Dolly Sods Wilderness Area in West Virginia and Shenandoah National Park in Virginia. The purpose of this report is to

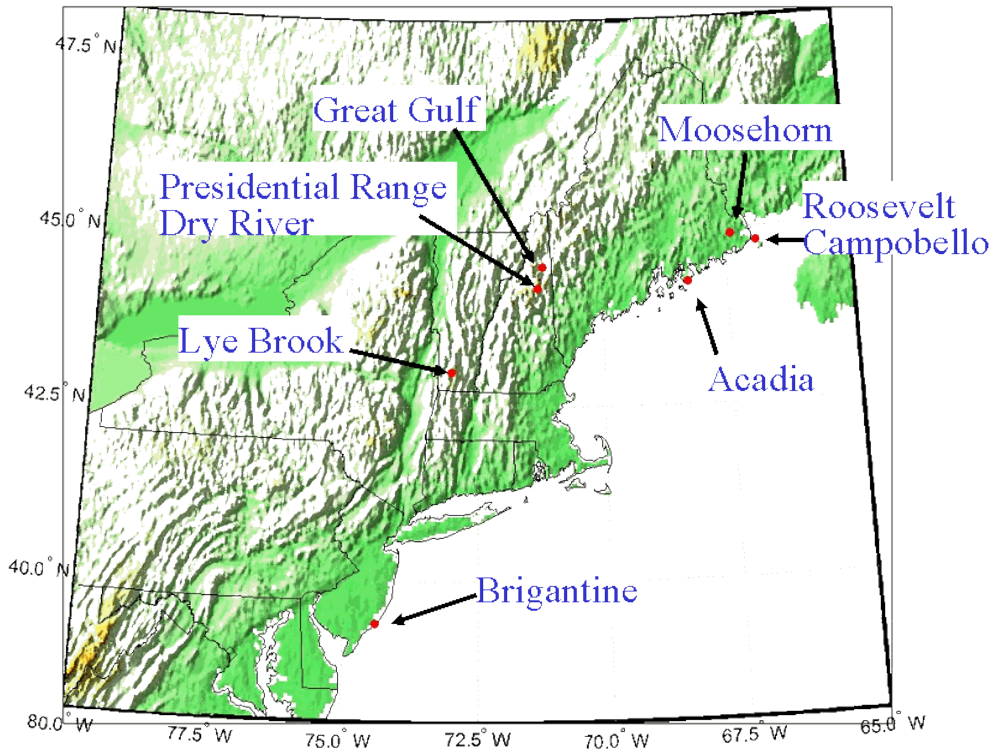
**Table 1-1. Members of the Mid-Atlantic/Northeast Visibility Union (MANE-VU)**

| | |
|---|---|
| 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 |

*Source: MANE-VU Board Members, http://www.otcair.org/manevu/members.asp.*

[1] The title of 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.

**Figure 1-1. Class I Areas of the MANE-VU Region**




support MANE-VU states in meeting the tracking progress requirement of the RHR.

While this report provides readers with a basic background on regional haze, it does not include in-depth discussion of topics covered in previous reports. For a broader understanding of these topics, readers should visit the NESCAUM regional haze documents archive, located at the following web address:

http://www.nescaum.org/topics/regional-haze.

In the documents archive, readers may find the following of particular interest in understanding regional haze in the MANE-VU region:

- Regional Haze and Visibility in the Northeast and Mid-Atlantic States (2001)
- 2002: A Year in Review (2004)
- Contributions to Regional Haze in the Northeast and Mid-Atlantic United States (2006)
- Public Health Benefits of Reducing Ground-level Ozone and Fine Particulate Matter in the Northeast U.S. (2008)
- MANE-VU Modeling for Reasonable Progress Goals (2008)
- 2018 Visibility Projections (2008)
- Tracking Visibility Progress, 2004-2008 (2010)
- Contribution of Non-Sulfate Aerosols to MANE-VU Regional Haze (2012)

- The Nature of the Fine Particle and Regional Haze Air Quality Problems in the MANE-VU Region: A Conceptual Description (Updated July 31, 2012)

# 2. PROCESS FOR TRACKING PROGRESS

## 2.1. Long Term Goals and Natural Visibility

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.

The USEPA (2003a) has guidance for calculating natural haze levels based on measurements of particulate constituents at Class I areas during a baseline period. States combine measurements of several parameters to calculate a "Haze Index" in deciview (dv) units based on estimates of light extinction. A fuller explanation of tracking progress procedures is presented in a 2003 USEPA guidance document for tracking progress (USEPA 2003b; hereafter, "the Guidance"), though readers should note that the calculation for estimating total light extinction has since been updated. Details on the revised IMPROVE algorithm used to estimate light extinction are presented elsewhere (e.g., NESCAUM 2010).

Natural haze levels are calculated for both the least impaired (i.e., clearest or "best") days and the most impaired (i.e., haziest or "worst") days, because changing natural processes lead to variability in natural visibility. Natural visibility levels on least and most impaired (i.e., best and worst) days for the MANE-VU and adjacent Class I

**Table 2-1. Natural Visibility Conditions for Class I Areas in and Adjacent to the MANE-VU Region**

| Class I Area | State Abbr. | Best Days (dv) | Worst Days (dv) |
|---|---|---|---|
| Acadia National Park | ME | 4.66 | 12.43 |
| Moosehorn Wilderness Area | ME | 5.01 | 12.01 |
| Roosevelt Campobello International Park* | ME | - | - |
| Great Gulf Wilderness Area | NH | 3.73 | 11.99 |
| Presidential Range/Dry River Wilderness Area* | NH | - | - |
| Lye Brook Wilderness Area | VT | 2.79 | 11.73 |
| Brigantine Wilderness Area | NJ | 5.51 | 12.24 |
| Dolly Sods Wilderness Area† | WV | 3.63 | 10.39 |
| Shenandoah National Park† | VA | 3.14 | 11.35 |

*Note: The Class I areas are arranged with the areas located in the MANE-VU region presented first, followed by those adjacent to MANE-VU.*
** Natural haze values are not calculated for areas without baseline monitoring data. Visibility for the Presidential Range/Dry River Wilderness Area and Roosevelt Campobello International Park are represented by the IMPROVE monitors for Great Gulf and Moosehorn, respectively.*
*Source: IMPROVE 2011 (IMPROVE Natural Haze Levels II version 2 workbook).*
*† Class I area adjacent to the MANE-VU region.*

areas are presented in Table 2-1. Achievement of these goals through constant annual incremental improvement in the Haze Index (in dv) such that natural conditions will be reached by 2064 is termed a "uniform rate of progress." Natural background haze levels are not available for some Class I areas without monitoring data, i.e., Presidential Range/Dry River Wilderness Area and Roosevelt Campobello International Park.

## 2.2. Reasonable Progress Goals

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 baseline period is the five-year period from 2000 through 2004. The state haze SIPs established reasonable progress goals (RPGs) for reduction of regional haze through 2018. Comparison between the five-year average Haze Index in 2018 (a back average of the previous five years' annual Haze Index values) and the baseline Haze Index will determine whether a state has met its 2018 RPG.

A state sets RPGs for the 20 percent most impaired (i.e., the haziest or "worst") days and for the 20 percent least impaired (i.e., clearest or "best") days. The RPGs are designed to at least ensure no degradation for best-day visibility and achievement of uniform rate of progress for worst-day visibility. In most cases, states in the MANE-VU region have adopted RPGs that achieve lower Haze Index values by 2018 than would be achieved using either the "no degradation" and "uniform rate of progress" rates for best and worst days, respectively. Table 2-2 presents the best- and worst-day RPGs adopted

**Table 2-2. 2018 Goals for Class I Areas in or Adjacent to the MANE-VU Region**

| | | Best Days | | Worst Days | |
|---|---|---|---|---|---|
| Class I Area | State Abbr. | No Degradation (dv) | Reasonable Progress Goal (dv) | Uniform Rate of Progress (dv) | Reasonable Progress Goal (dv) |
| Acadia National Park | ME | 8.8 | 8.3 | 20.4 | 19.4 |
| Moosehorn Wilderness Area | ME | 9.2 | 8.6 | 19.4 | 19.0 |
| Roosevelt Campobello International Park | ME | 9.2 | 8.6 | 19.4 | 19.0 |
| Great Gulf Wilderness Area | NH | 7.7 | 7.2 | 20.3 | 19.1 |
| Presidential Range/Dry River Wilderness Area | NH | 7.7 | 7.2 | 20.3 | 19.1 |
| Lye Brook Wilderness Area | VT | 6.4 | 5.5 | 21.5 | 20.9 |
| Brigantine Wilderness Area | NJ | 14.3 | 14.3 | 25.1 | 25.1 |
| Dolly Sods Wilderness Area† | WV | 12.3 | 11.1 | 24.7 | 21.7 |
| Shenandoah National Park† | VA | 10.9 | 8.7 | 25.1 | 21.9 |

*Note: The Class I areas are arranged with the areas located in the MANE-VU region presented first, followed by those adjacent to MANE-VU.*
*† Class I area adjacent to the MANE-VU region.*
*Sources: Maine: 76 FR 73956-73982; New Hampshire: 77 FR 11809-11826; New Jersey: 76 FR 49711-49724; Vermont: 77 FR 11914-11928; Virginia: 77 FR 3691-3711; West Virginia: 76 FR 41158-41177.*

by states for each Class I area in or adjacent to the MANE-VU region per state haze SIPs.

## 2.3. Measurement and Data Support

The Haze Index is calculated using light extinction estimates based on measured concentrations of particulate matter (PM) species. Measurements are taken at a network of sites in the Interagency Monitoring of Protected Visual Environments (IMPROVE) program at or near Class I areas. IMPROVE is the result of coordination between the National Park Service, the Fish and Wildlife Service, the Bureau of Land Management, the Forest Service, and USEPA. IMPROVE has operated 17 sites within the MANE-VU region since 2002.

The Visibility Information Exchange Web System (VIEWS) team develops and maintains the IMPROVE website in addition to its other activities related to maintenance of air quality monitoring databases. Using the data from IMPROVE, the VIEWS team calculates and regularly posts updated metrics for tracking visibility across the country at the national parks and wilderness areas subject to the RHR. VIEWS is hosted at the Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA).

Another resource, the Federal Land Manager Database (FED), is an extensive database of environmental data and an integrated suite of online tools and resources to help Federal Land Managers assess and analyze the air quality and visibility in federally protected lands such as National Parks, National Forests, and Wilderness Areas.

For this analysis, we used data from IMPROVE (2011) downloaded through VIEWS for both the natural haze levels (calculated using the revised IMPROVE algorithm) and daily values, including patched values,[2] for 2000 through 2010. For 2011, we used unpatched data obtained from FED. We analyzed the individual missing constituent data for 2011 using the patching methodology described in the Guidance and determined that patching was unnecessary for all sites in and adjacent to the MANE-VU region for this analysis.

[2] "Patching" is a procedure for replacing missing values for individual or multiple measured PM constituents with appropriate values, per the Guidance.

# 3. RESULTS

We analyzed total Haze Index and individual constituent light extinction annual results for each site in or adjacent to the MANE-VU region for years between 2000 and 2011. The following sections describe the results of this analysis. Section 3.1 provides results for the total Haze Index for each site and discusses trends and progress toward short-term goals. Section 3.2 provides individual constituent analysis and trends for each site over the time period in the context of regional emissions reduction efforts and continued regional and federal policy directions. Finally, Section 3.3 summarizes conclusions based on these results. Results indicate consistent improvement in regional haze on the best and worst visibility days across the region.

## 3.1. Haze Index Trends

Figure 3-1 (page 3-2) through Figure 3-7 (page 3-8) present the annual Haze Index on the 20 percent most and least impaired days at MANE-VU and adjacent Class I areas between 2000 and 2011 in the context of short- and long-term visibility goals. The figures are arranged with the areas located in the MANE-VU region presented first, followed by those adjacent to MANE-VU. Table A-1 in Appendix A presents these data numerically.

Annual average best and worst visibility day Haze Index values are represented by blue and purple diamonds, respectively. Five-year back annual averages are represented by solid red (worst) and blue (best) lines. Red (worst) and black (best) plus signs represent the 2018 RPGs described in the state haze SIP. The red (worst) and black (best) dotted lines represent the glidepaths to meet 2018 RPGs. Red (worst) and black (best) dashed lines represent the glidepaths to meet long-term natural visibility goals; the worst-day glidepath is also called the "uniform rate of progress" line, and the best-day glidepath is also called the "no degradation" line.[3] The grey region denotes the range of 20-percent best to worst haze levels expected to occur under natural conditions. Thus, the uniform rate of progress line intersects with highest portion of the grey area in 2064.

These figures indicate that haze levels on the best and worst days from 2000 through 2011 have dropped across the entire region. Trends evident in our last report (NESCAUM 2010) for annual average haze levels on best and worst days through 2008 have largely continued through 2010. In 2011, most of the areas experienced around the same or slightly higher levels of haze on both best and worst days as compared to 2010. The steep drop in Haze Index values for the 20 percent worst days, therefore, appears to have occurred primarily during the period between 2007 and 2010 for these areas.

[3] For the Brigantine and Dolly Sods Wilderness Areas, whose haze levels on the 20 percent best days during the 2000 to 2004 baseline period were higher than estimated natural conditions on the 20 percent worst days, the no degradation line (representing the long-term best-day goal) is higher than the uniform rate of progress line (representing the long-term worst-day goal) 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 3-1. Annual Haze Index Levels at Acadia National Park**

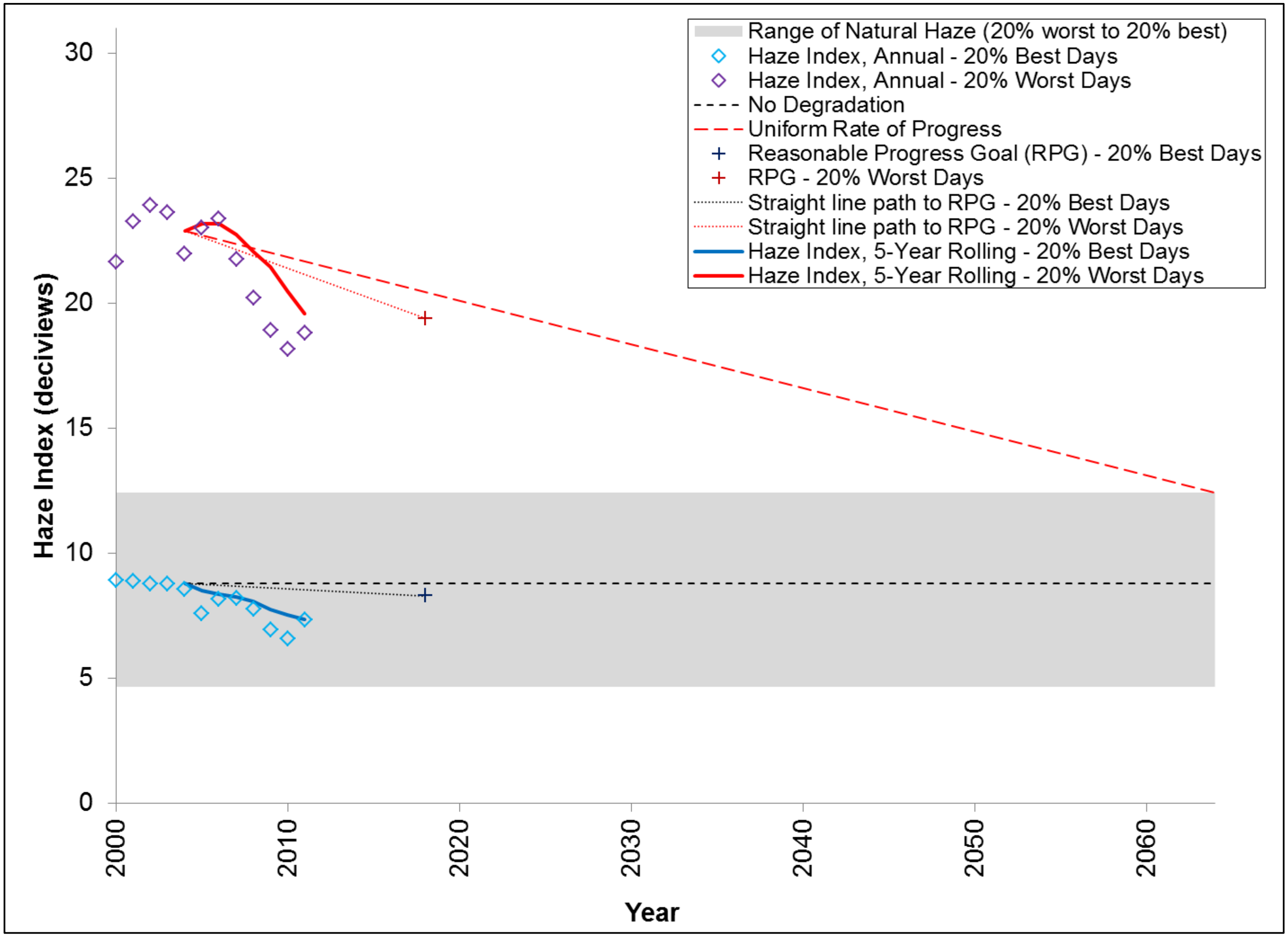


**Figure 3-2. Annual Haze Index Levels at Moosehorn Wilderness Area**

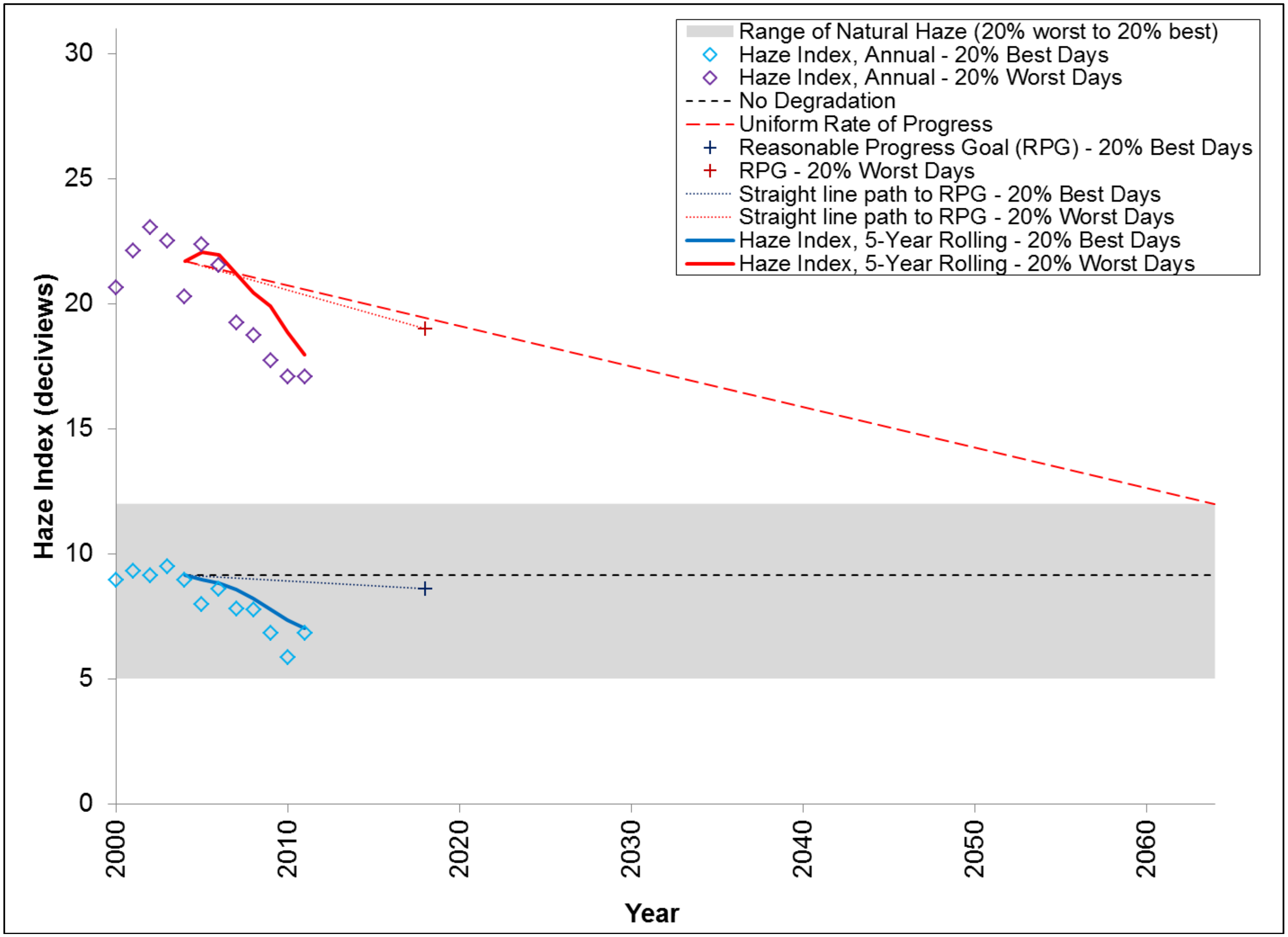


**Figure 3-3. Annual Haze Index Levels at Great Gulf Wilderness Area**

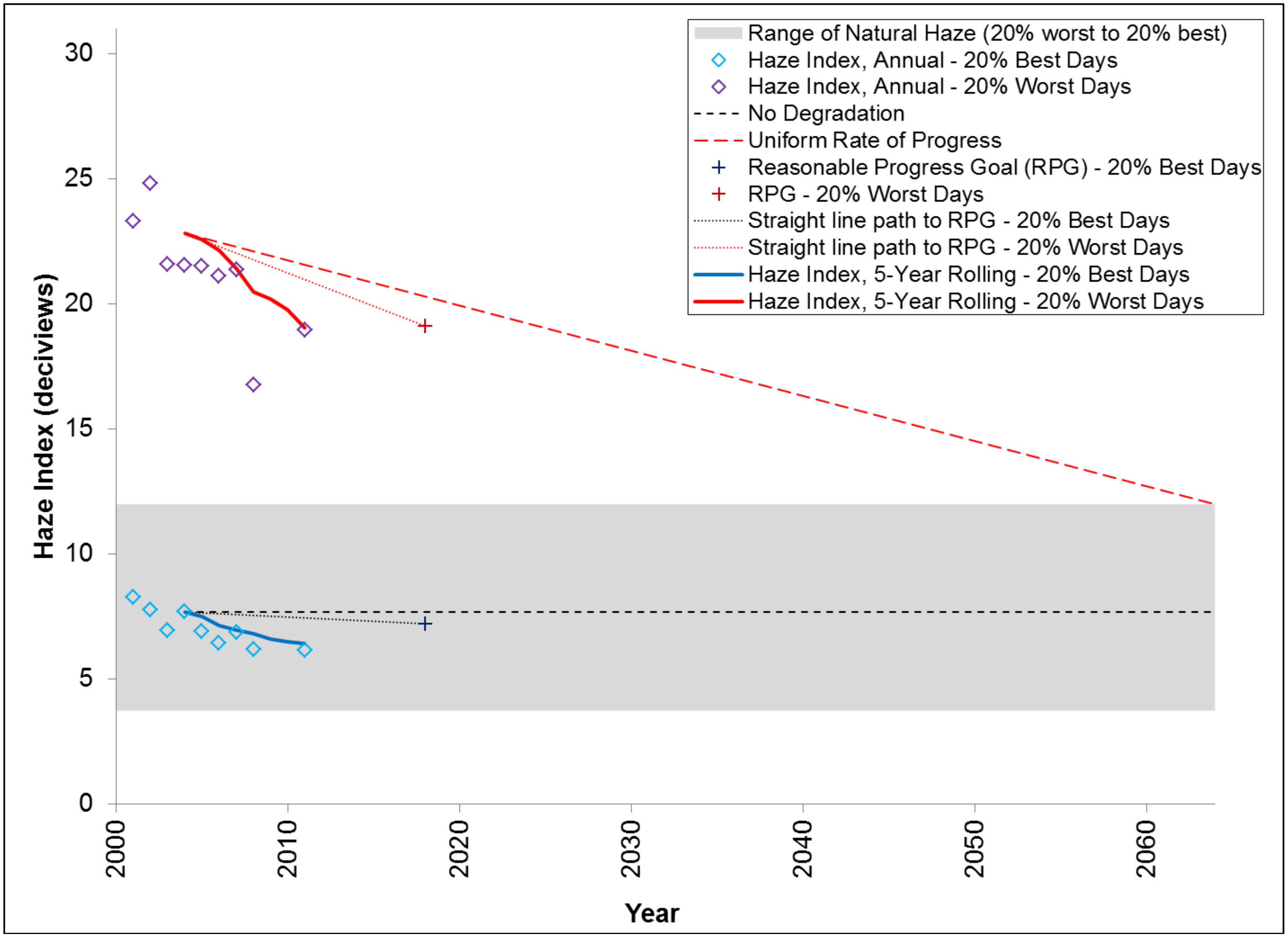


**Figure 3-4. Annual Haze Index Levels at Lye Brook Wilderness Area**

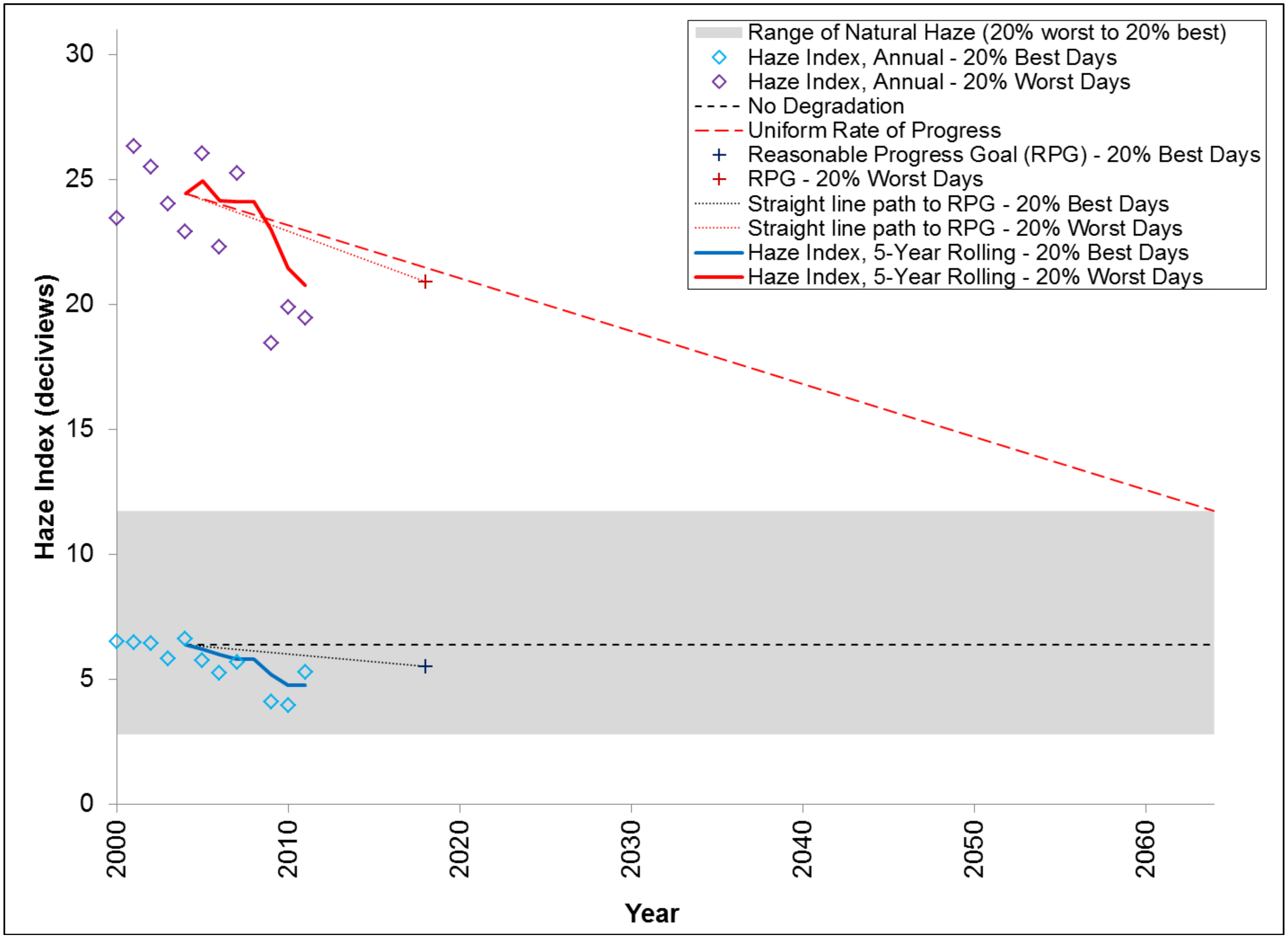


**Figure 3-5. Annual Haze Index Levels at Brigantine Wilderness Area**

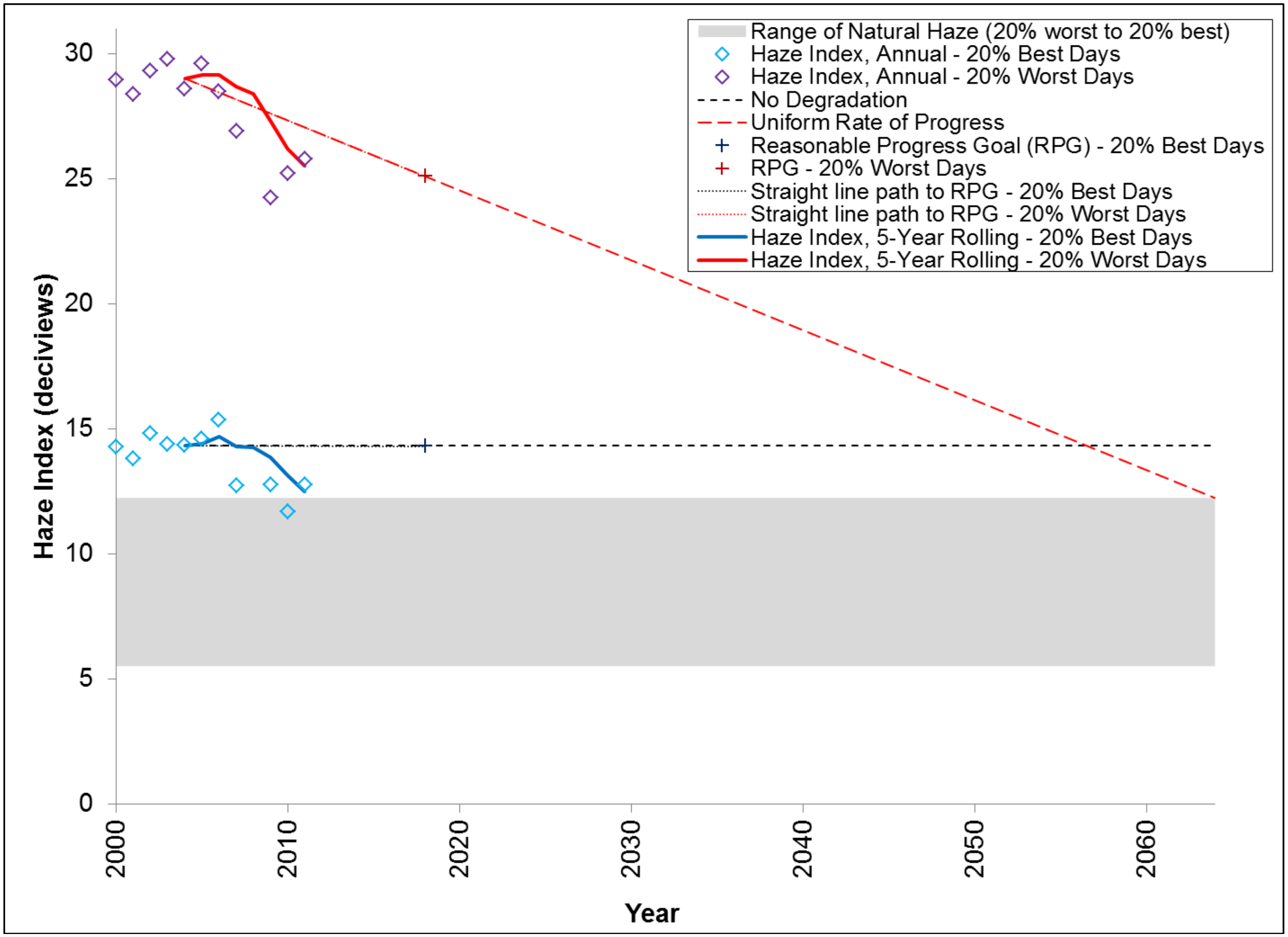


**Figure 3-6. Annual Haze Index Levels at Dolly Sods Wilderness Area**

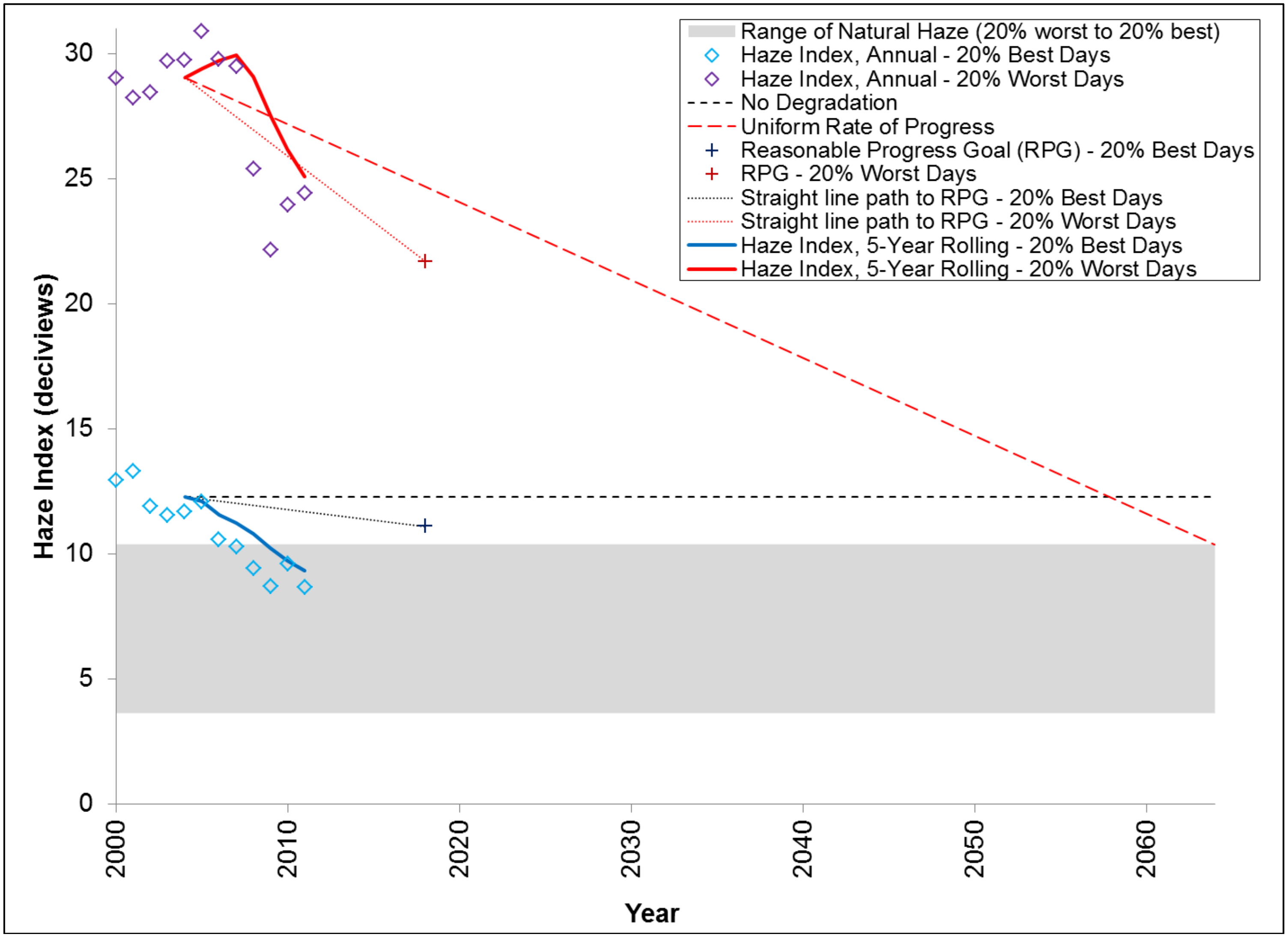
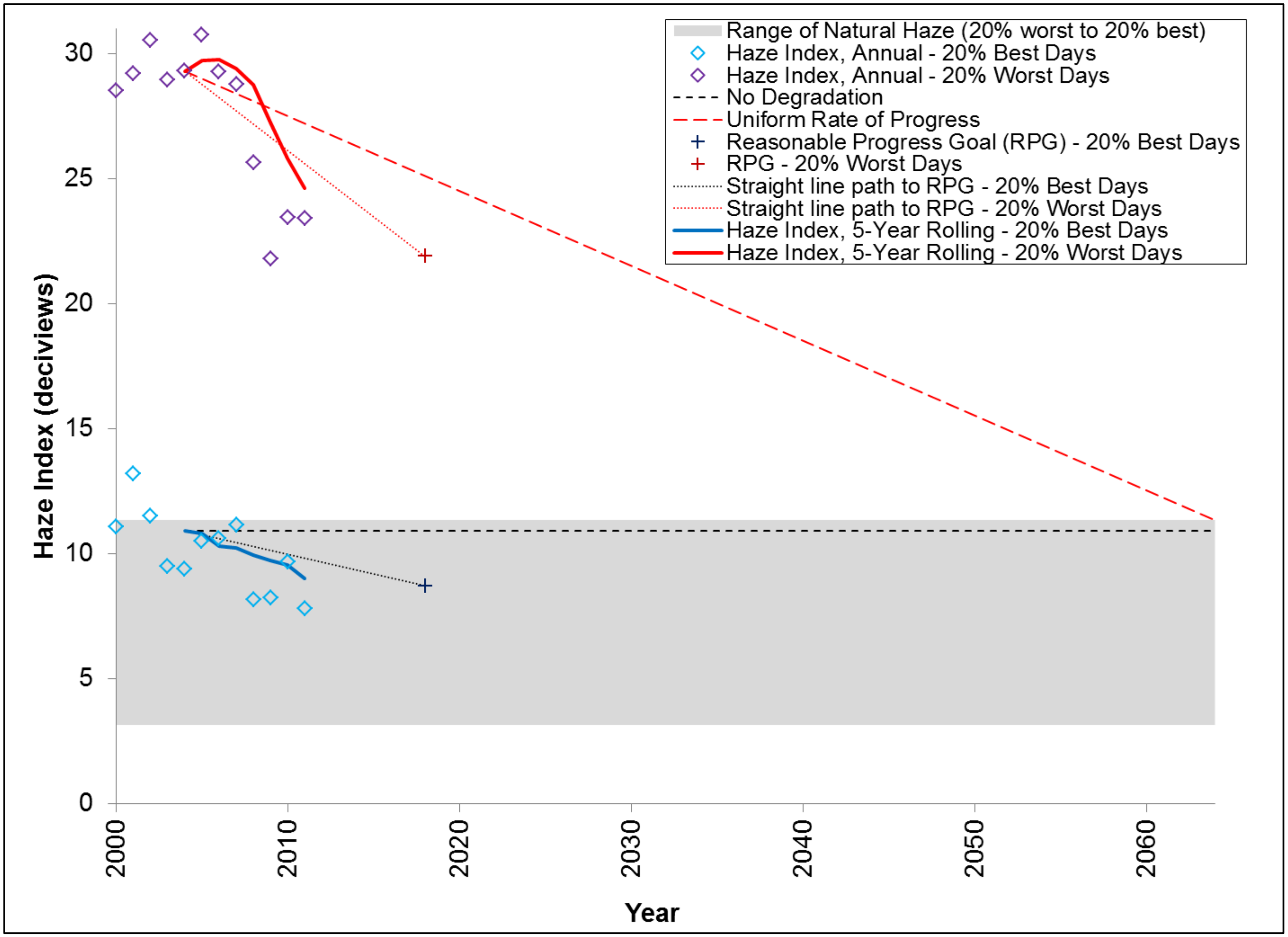


**Figure 3-7. Annual Haze Index Levels at Shenandoah National Park**



Comparison of the five-year annual average haze index to the glidepaths for the 2018 SIP commitments show that all areas in and adjacent to the MANE-VU region are on pace to meet those commitments. In fact, the 2018 RPGs will be met if 5-year average levels for best and worst days are maintained at Acadia National Park and at the Great Gulf, Lye Brook, and Moosehorn Wilderness Areas. However, the small uptick in annual average haze levels in 2011 for most areas in the MANE-VU region demonstrates that efforts are still needed to ensure that 2018 RPGs will be met and to prevent backsliding. The small relative increase for 2011 over the previous several years is almost certainly due, at least in part, to special and converging circumstances: the economic downturn followed by slow recovery, unusual meteorology, and the rapid shift toward natural gas.

At Brigantine Wilderness Area and both Class I areas adjacent to the MANE-VU region, best-day visibility levels are already below 2018 RPGs, but worst-day visibility levels require additional progress to meet the short-term goals.

## 3.2. Constituent Light Extinction Trends

In addition to analyzing trends in overall visibility changes at the sites, we also examined the data for changes in individual PM constituent contributions to visibility impairment. Figure 3-8 through Figure 3-14 present the annual Haze Index by constituent on the 20 percent least and most impaired days at MANE-VU and adjacent Class I areas between 2000 and 2011 in the context of RPGs. The figures are arranged with the areas located in the MANE-VU region presented first, followed by those adjacent to MANE-VU.

These figures show individual constituent values as stacked bar charts for sulfate, nitrate, organic carbon mass (OCM), light absorbing carbon (LAC), soil, coarse mass, sea salt, and Rayleigh extinction levels on best (left, “a”) and worst (right, “b”) days. The total of the stacked bars represent 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 2011. The 2018 RPG from the state haze SIP is marked with a black plus sign. Two red lines descend from the 2004 five-year back average (i.e., the baseline value): the red dotted line represents the glidepath to the 2018 RPG; and the red dashed line represents the glidepath to the 2064 natural visibility goal, or the “uniform rate of progress” line.

These figures confirm that large reductions in overall Haze Index values on the 20 percent worst days are primarily due to decreases in sulfate visibility impacts at MANE-VU Class I areas. Steady decreases in sulfate and nitrate contributions have also reduced overall haze levels on the least impaired days. These decreases occurred mainly from 2005 through 2011 at most of the studied areas, though in some locations (e.g., Dolly Sods Wilderness Area, Shenandoah National Park), the contribution from sulfate stopped its decline in 2009 and held steady or increased on the worst days through 2011.

Despite the reduced contribution from sulfate on the worst days at most of the MANE-VU Class I areas, the overall level of haze has remained largely unchanged since about 2009 on the worst days due to increases in contributions from sea salt and organic carbon mass, depending on the site. At Brigantine, the contribution from coarse mass in 2011 was unusually high, indicating a possible anomaly for that year (Pietarinen 2013).

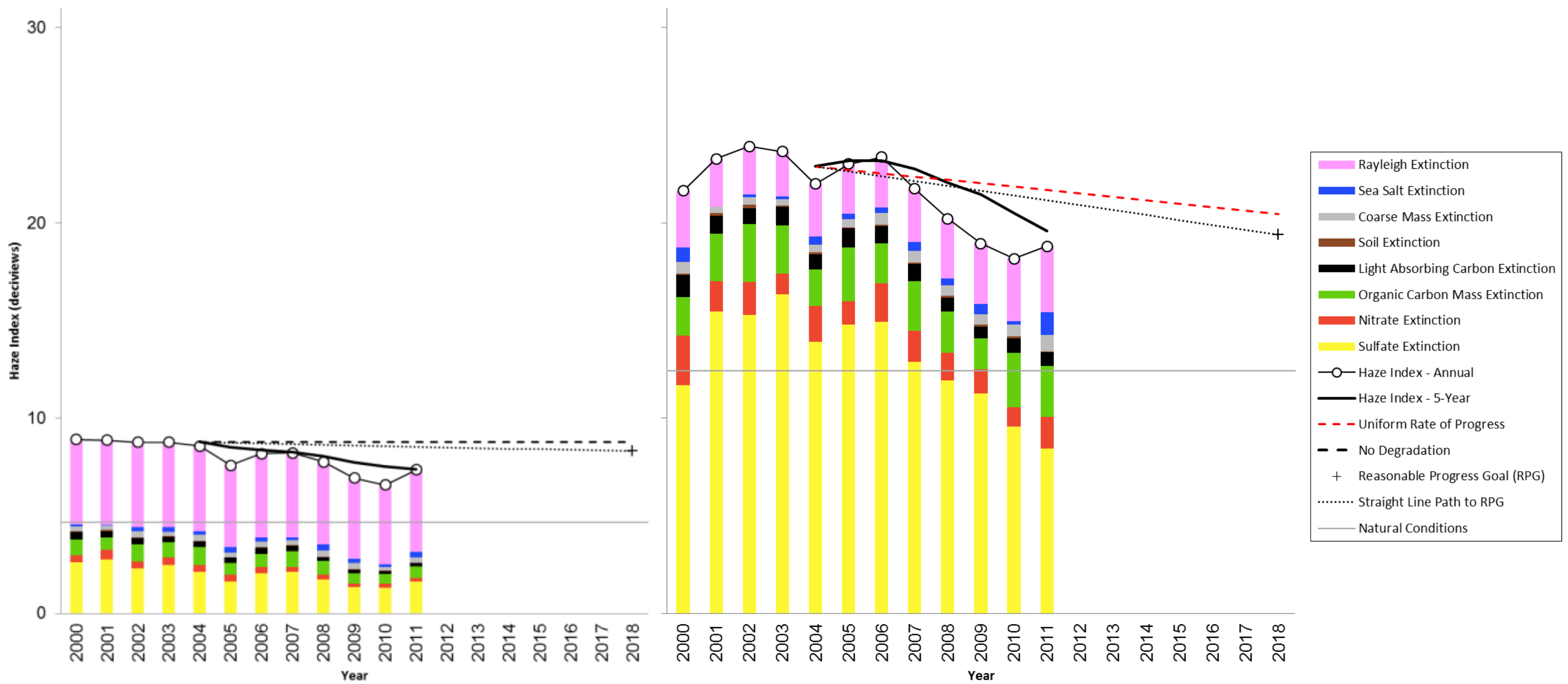
This increase in coarse mass contribution offset reductions in both nitrate and sulfate levels from the preceding years. Contribution from OCM appears to be highly variable from year to year at most sites. For instance, high OCM extinction levels at Brigantine and Lye Brook Wilderness Areas in 2002, and at Great Gulf Wilderness Area in 2011 on the worst days, undercut declines in contributions from sulfate to raise overall haze levels for those years.

Sulfate remains the most significant contributor to light extinction at all Class I areas on the most impaired days in and adjacent to the MANE-VU region, followed by OCM and nitrate. 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. Based on these figures, continued progress in sulfate and nitrate levels appears to be driving the trend in overall improvement in worst- and best-day haze level reductions.

To examine the individual constituent trends more closely, we plotted the range of individual light extinction on best and worst days from 2000 through 2011 at the Class I areas against the estimated light extinction under natural conditions. Figure 3-15 through Figure 3-19 show the range of light extinction levels at the MANE-VU Class I areas (areas adjacent to the MANE-VU region are excluded from this analysis for simplicity) as compared to natural light extinction for selected constituents. Estimated natural light extinction is represented in each chart by the lighter grey band, and observed extinction by the other band. For the case of the carbonaceous species, OCM and LAC, the green band is observed OCM and the dark grey band is observed LAC. Note that the observations do not represent the range of the highest and lowest 20 percent light extinction levels for those constituents; rather, they represent the range of constituent light extinction levels on the 20 percent least and most impaired visibility days. For Great Gulf Wilderness Area, where observations were missing in 2009 and 2010, 2011 observations are presented as a broad range rather than a single data point for ease of visualization, but note that this is a visual distortion.

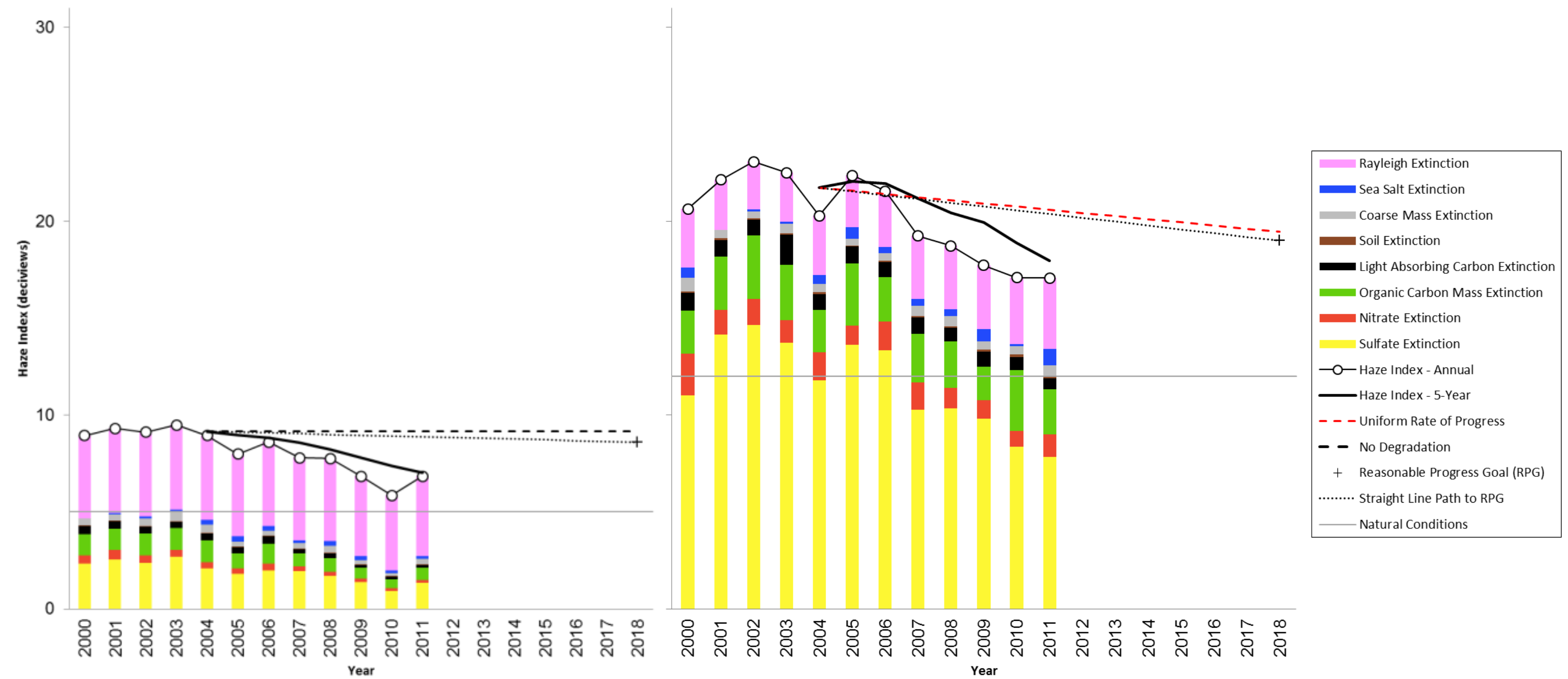
It is clear from these charts that levels of extinction from sulfate have dropped significantly since 2002 at all the MANE-VU Class I areas, although still remaining at levels much higher than the estimated natural range at all sites. Extinction due to nitrate has also dropped steadily, and at several sites is approaching natural levels on the best days. At Brigantine Wilderness Area, extinction due to nitrate remains considerably higher than the natural baseline. At Acadia National Park, levels of extinction due to carbonaceous constituents and coarse mass appear to be approximately at natural levels. At Great Gulf, Lye Brook, and Moosehorn Wilderness Areas, coarse mass extinction is approximately at natural levels, and carbonaceous matter has dropped from levels slightly above natural into the natural range. Prior peaks in carbonaceous matter extinction at these sites were driven by OCM levels. At Brigantine Wilderness Area, carbonaceous matter has been holding steadily above natural levels with little observable trend downward, and coarse mass light extinction levels also remain above natural levels, though the 2011 peak in coarse mass light extinction may be a result of construction activity near the monitor location (Pietarinen 2013).

**Figure 3-8. Individual Constituent Contribution to Annual Haze Index Levels at Acadia National Park on 20 Percent Best and Worst Visibility Days**



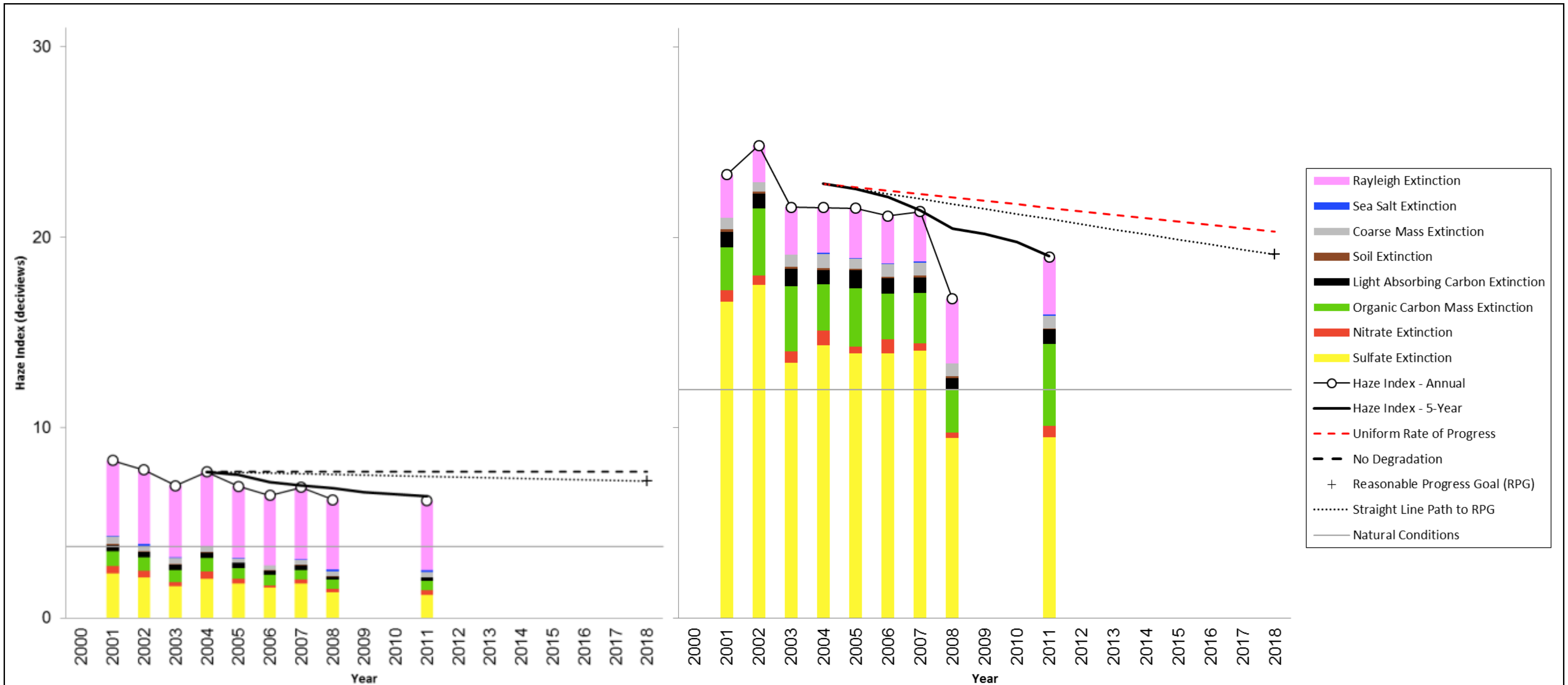

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-9. Individual Constituent Contribution to Annual Haze Index Levels at Moosehorn Wilderness Area on 20 Percent Best and Worst Visibility Days**



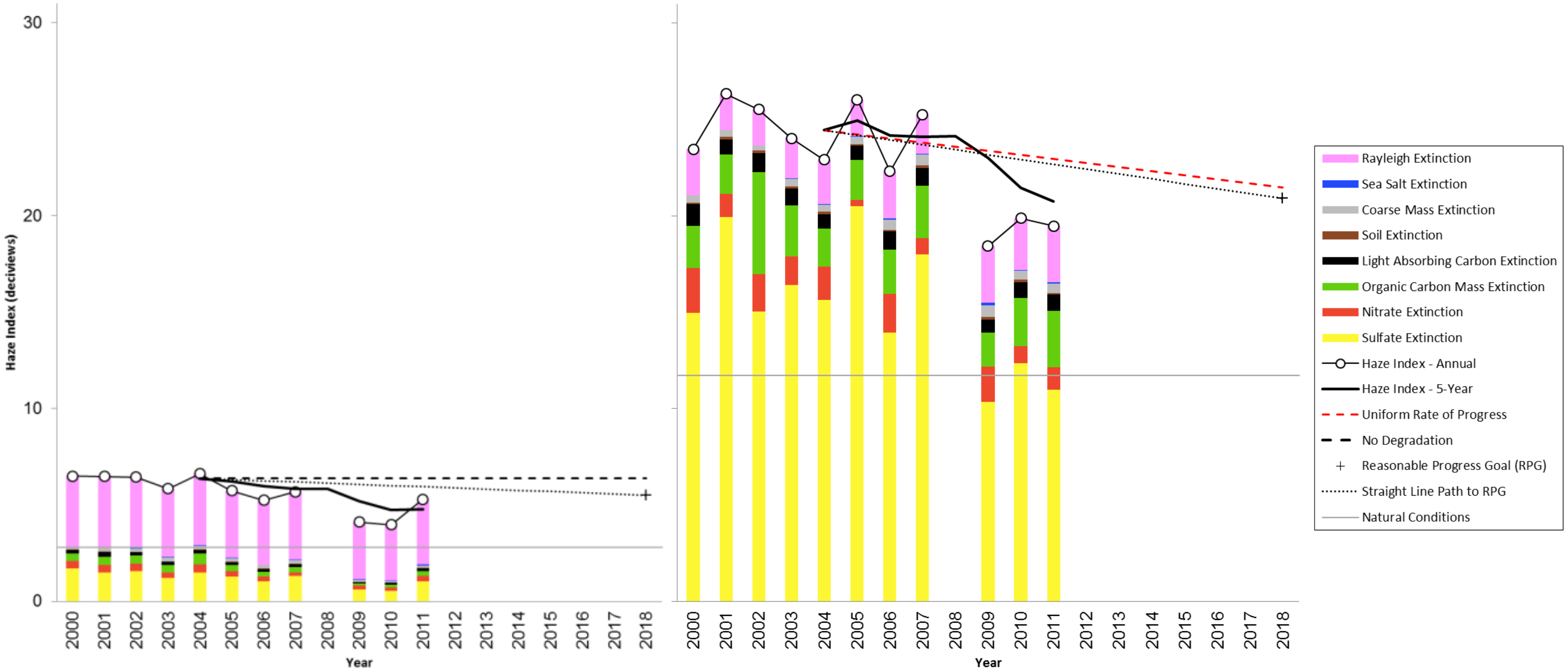

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-10. Individual Constituent Contribution to Annual Haze Index Levels at Great Gulf Wilderness Area on 20 Percent Best and Worst Visibility Days**



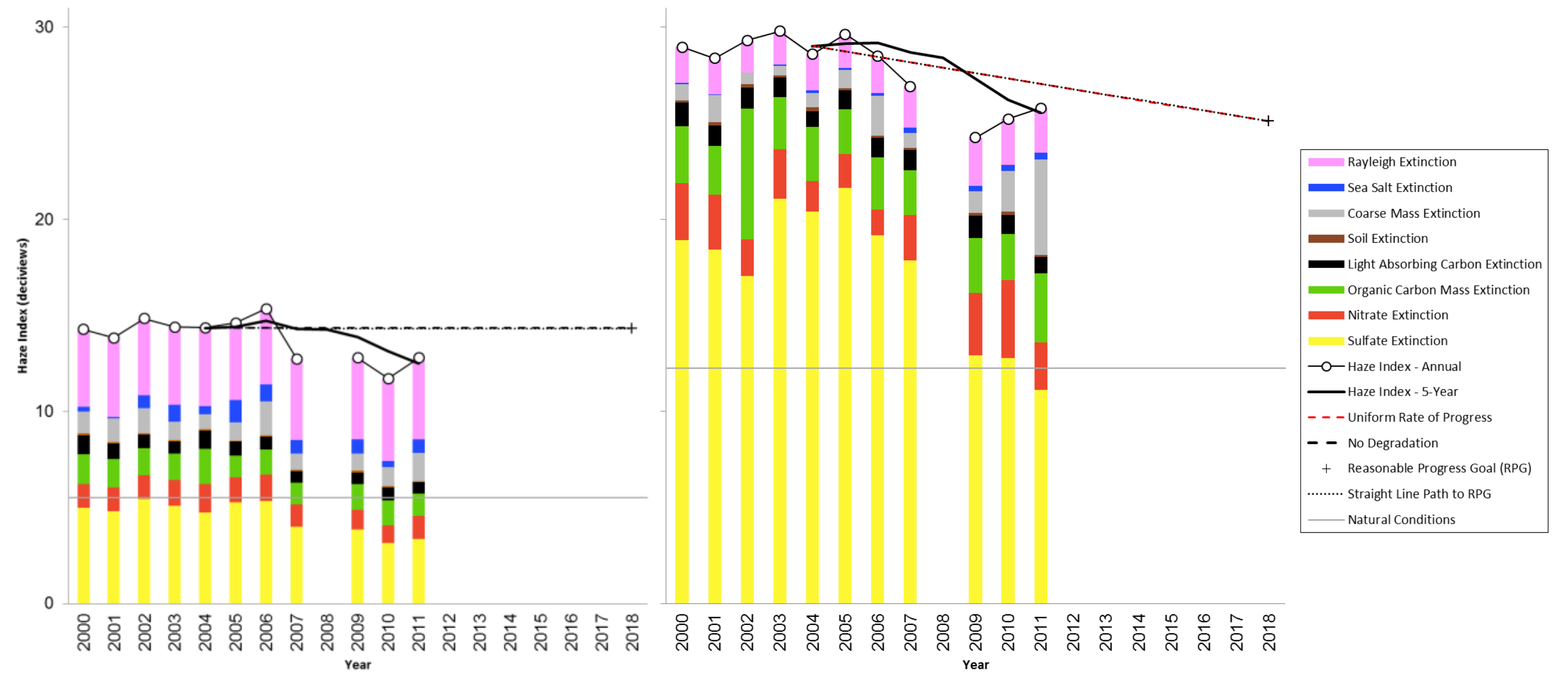
(a) 20% Best Days (b) 20% Worst Days

**Figure 3-11. Individual Constituent Contribution to Annual Haze Index Levels at Lye Brook Wilderness Area on 20 Percent Best and Worst Visibility Days**



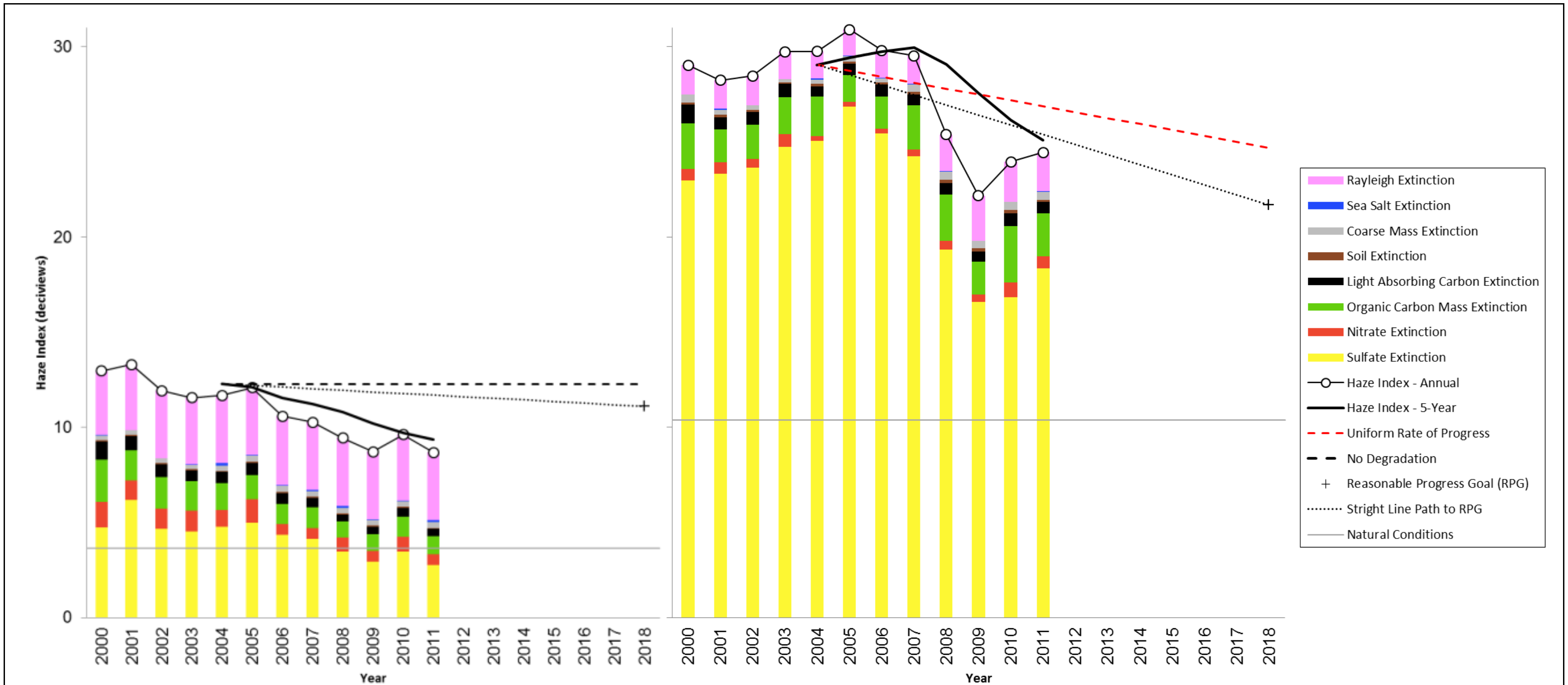

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-12. Individual Constituent Contribution to Annual Haze Index Levels at Brigantine Wilderness Area on 20 Percent Best and Worst Visibility Days**



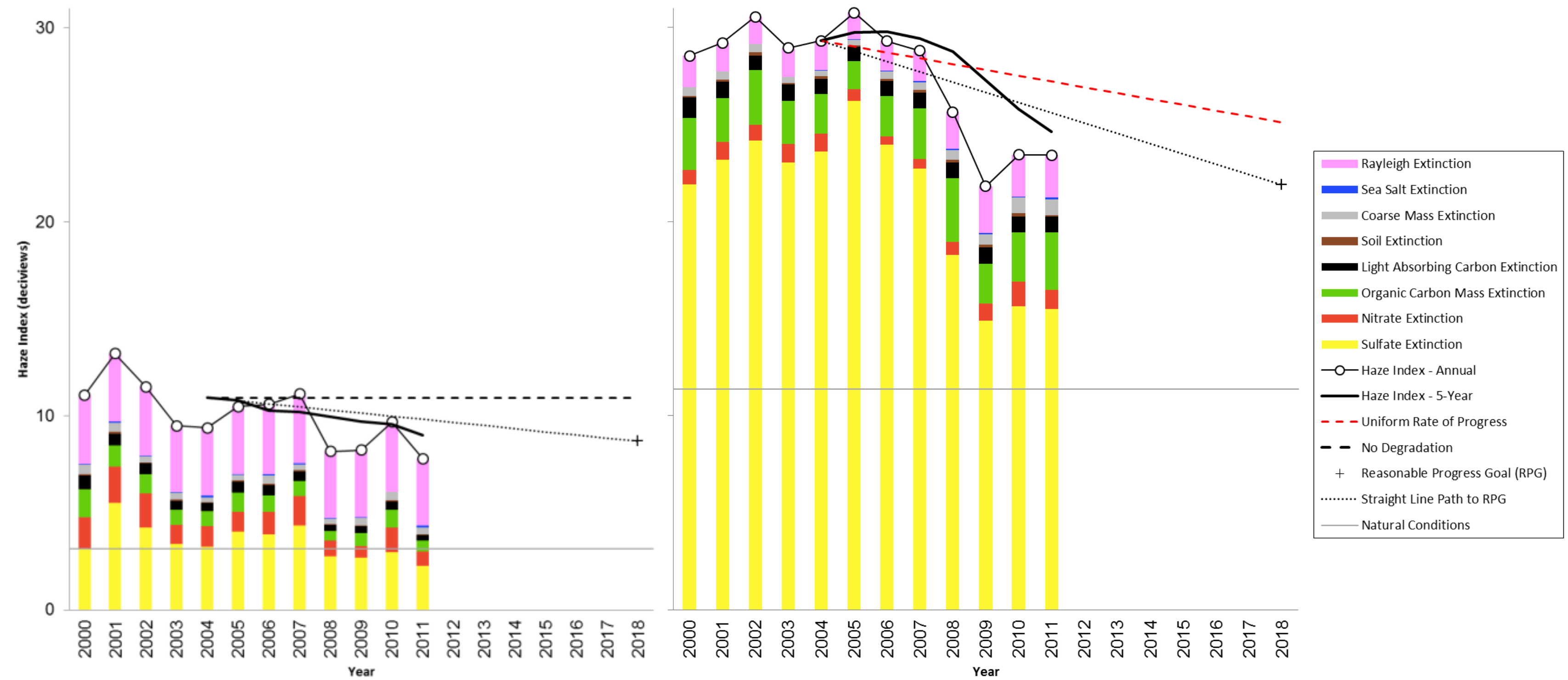

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-13. Individual Constituent Contribution to Annual Haze Index Levels at Dolly Sods Wilderness Area on 20 Percent Best and Worst Visibility Days**



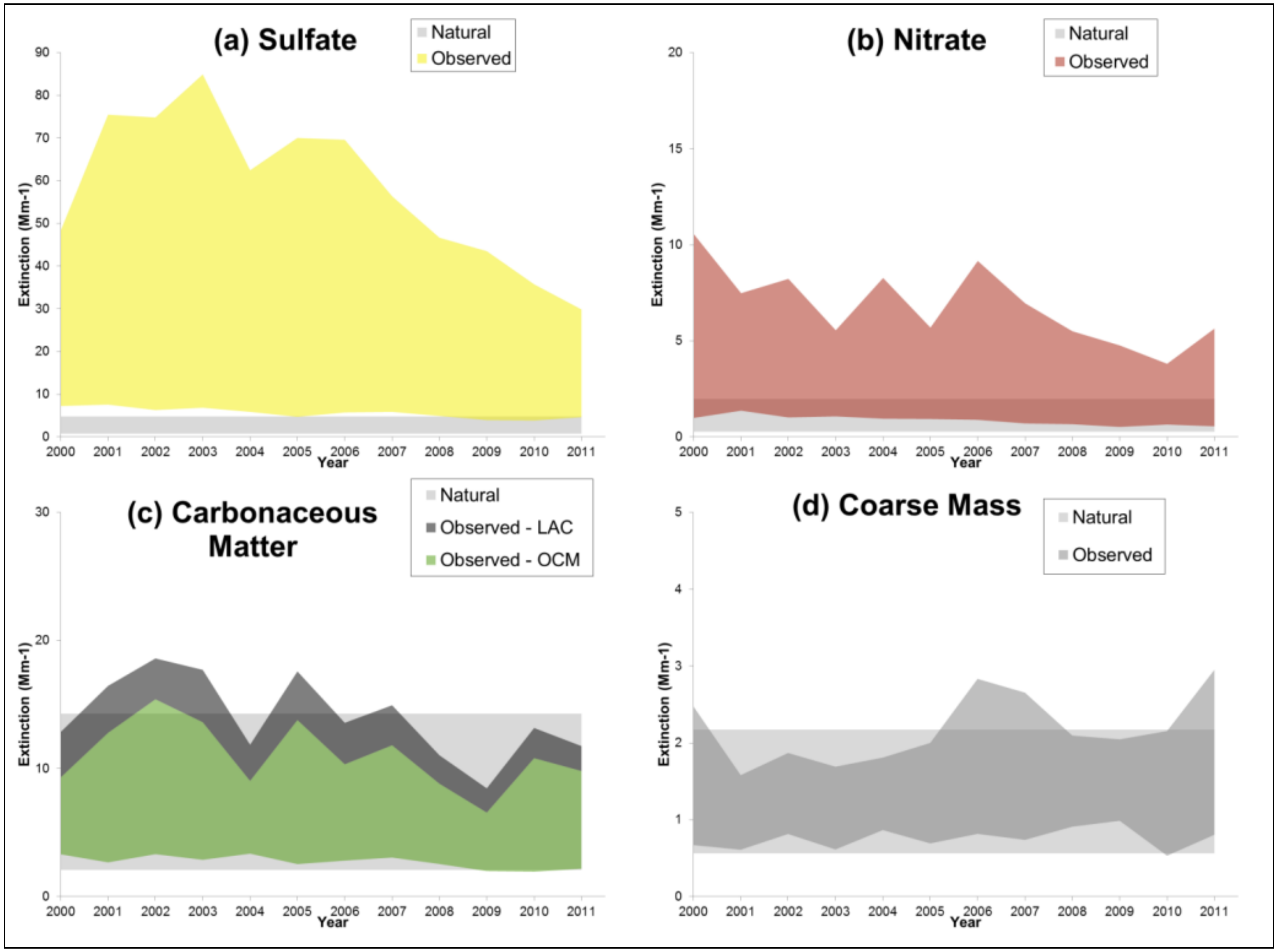

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-14. Individual Constituent Contribution to Annual Haze Index Levels at Shenandoah National Park on 20 Percent Best and Worst Visibility Days**



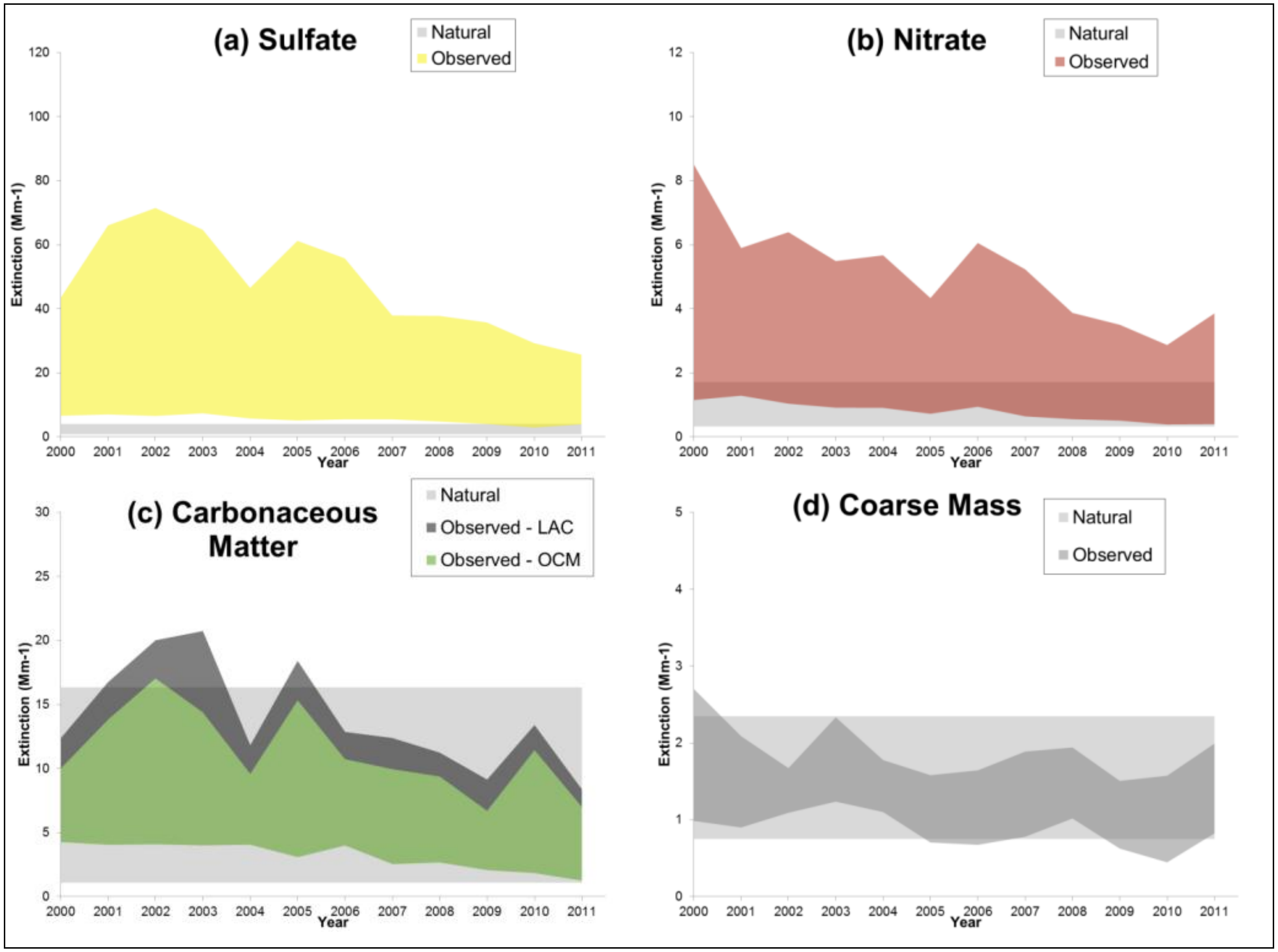

(a) 20% Best Days (b) 20% Worst Days

**Figure 3-15. Range of Observed and Estimated Natural Light Extinction for Select Individual Constituents at Acadia National Park on 20 Percent Best and Worst Visibility Days**



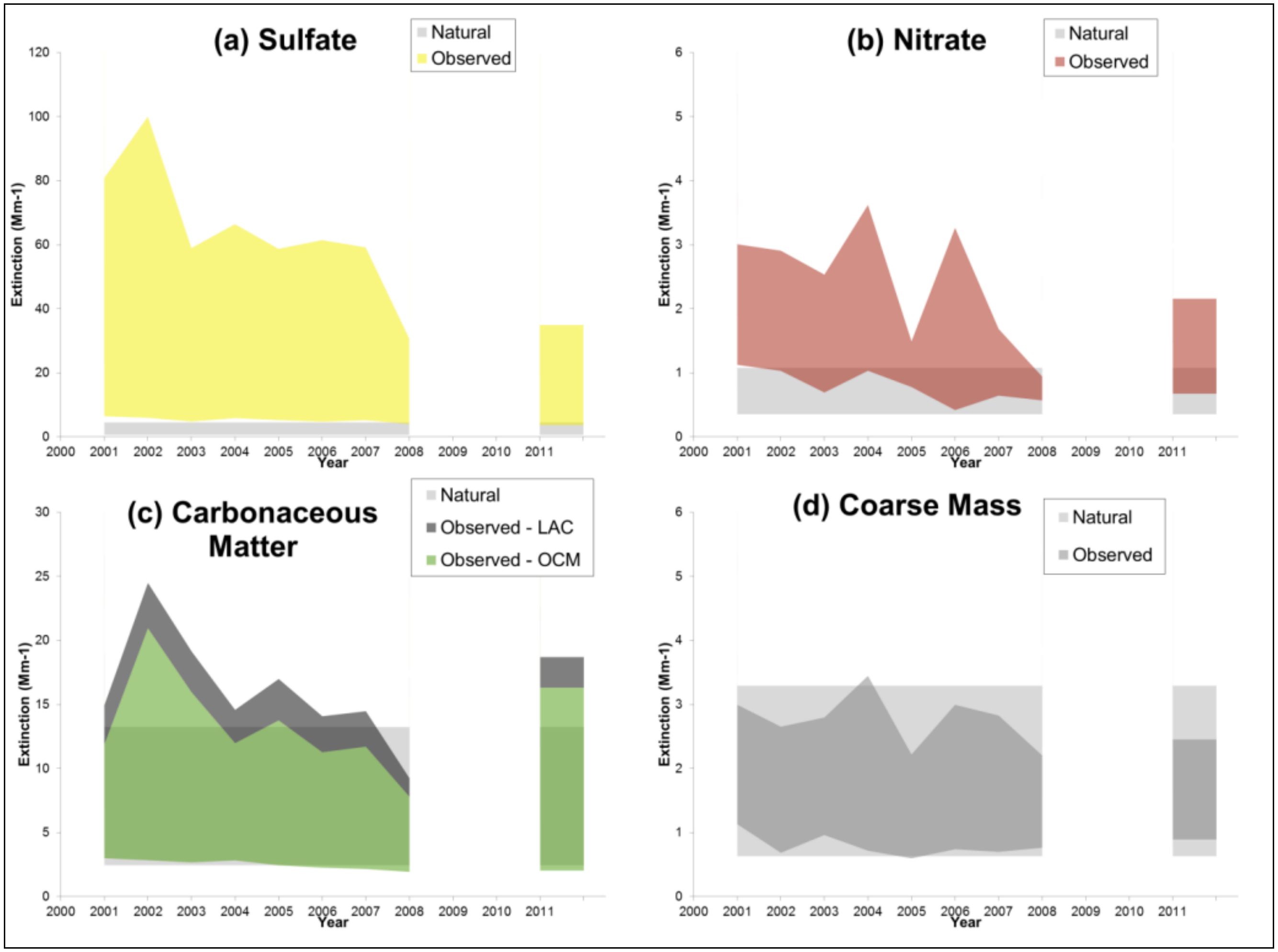

Notes: Light extinction from (a) sulfate, (b) nitrate, (c) carbonaceous matter (i.e., organic carbon mass or OCM and light absorbing carbon or LAC), and (d) coarse mass, alongside estimated natural light extinction from those constituents.

**Figure 3-16. Range of Observed and Estimated Natural Light Extinction for Select Individual Constituents at Moosehorn Wilderness Area on 20 Percent Best and Worst Visibility Days**



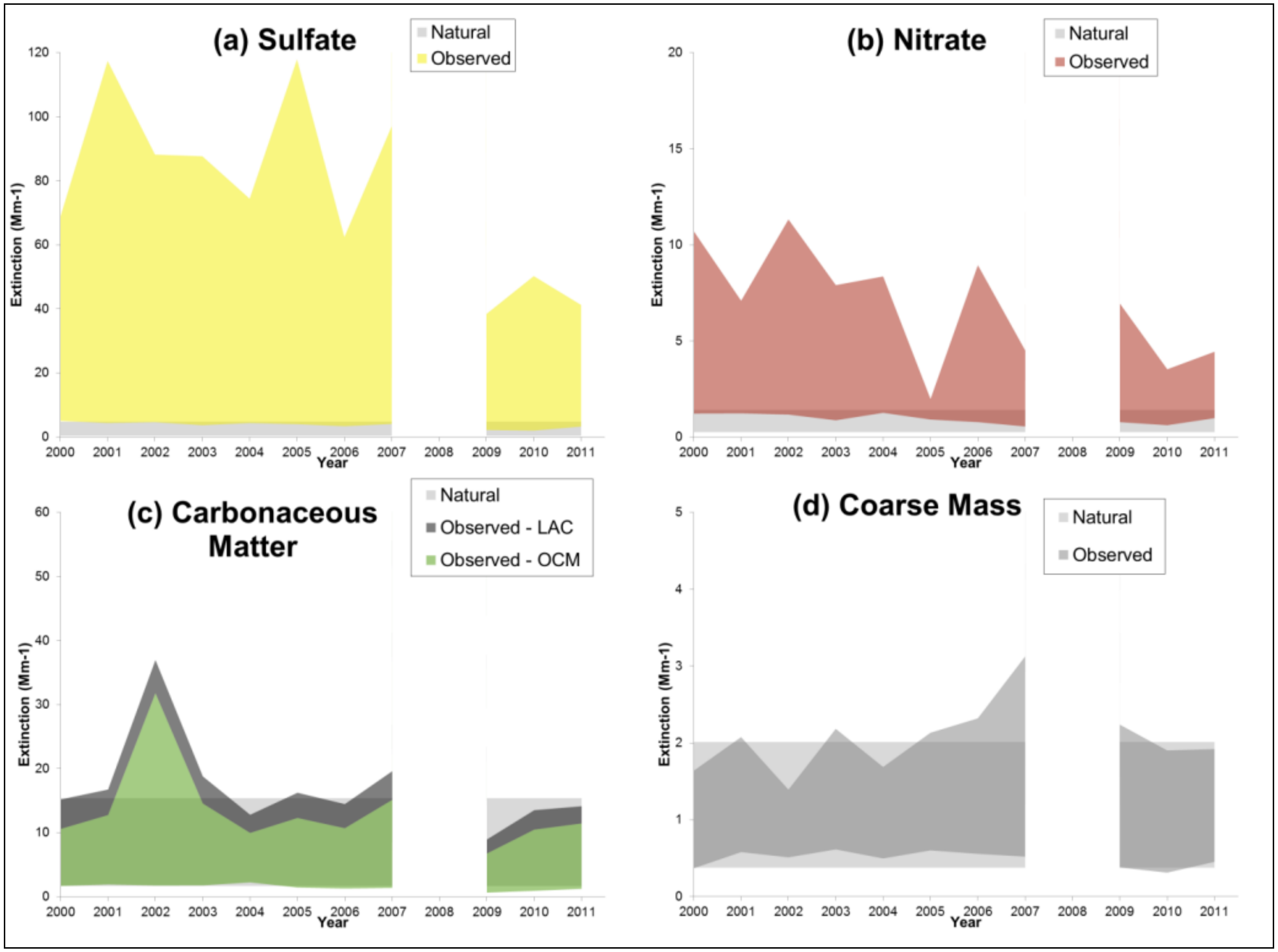

Notes: Light extinction from (a) sulfate, (b) nitrate, (c) carbonaceous matter (i.e., organic carbon mass or OCM and light absorbing carbon or LAC), and (d) coarse mass, alongside estimated natural light extinction from those constituents.

**Figure 3-17. Range of Observed and Estimated Natural Light Extinction for Select Individual Constituents at Great Gulf Wilderness Area on 20 Percent Best and Worst Visibility Days**



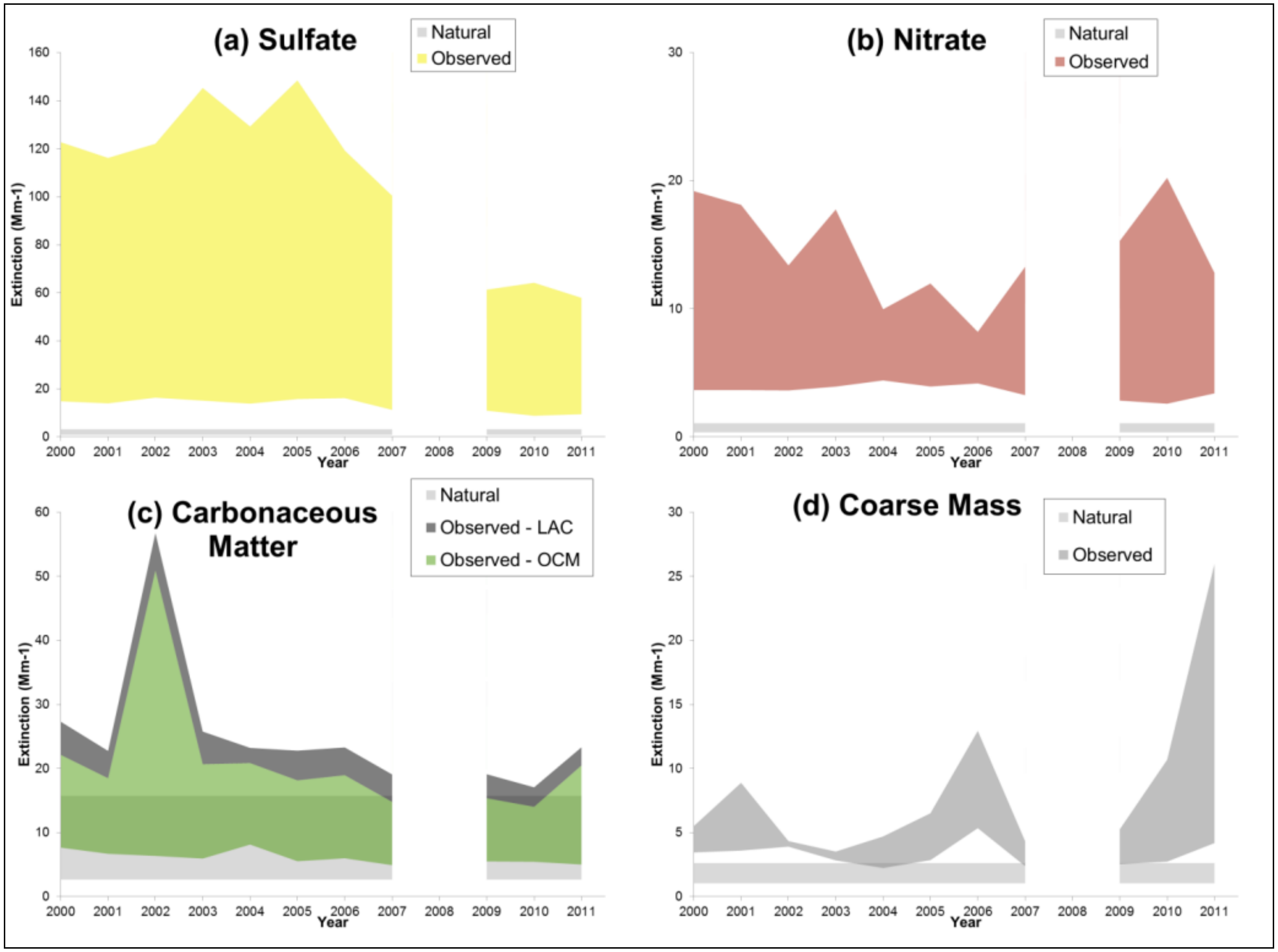

Notes: Light extinction from (a) sulfate, (b) nitrate, (c) carbonaceous matter (i.e., organic carbon mass or OCM and light absorbing carbon or LAC), and (d) coarse mass, alongside estimated natural light extinction from those constituents.

**Figure 3-18. Range of Observed and Estimated Natural Light Extinction for Select Individual Constituents at Lye Brook Wilderness Area on 20 Percent Best and Worst Visibility Days**




Notes: Light extinction from (a) sulfate, (b) nitrate, (c) carbonaceous matter (i.e., organic carbon mass or OCM and light absorbing carbon or LAC), and (d) coarse mass, alongside estimated natural light extinction from those constituents.

**Figure 3-19. Range of Observed and Estimated Natural Light Extinction for Select Individual Constituents at Brigantine Wilderness Area on 20 Percent Best and Worst Visibility Days**




Notes: Light extinction from (a) sulfate, (b) nitrate, (c) carbonaceous matter (i.e., organic carbon mass or OCM and light absorbing carbon or LAC), and (d) coarse mass, alongside estimated natural light extinction from those constituents.

## 3.3. Conclusions on Visibility Progress

Despite variability in the year-to-year data, there are definite downward trends in overall haze levels at the Class I areas in and adjacent to the MANE-VU region. Based on rolling five-year averages demonstrating progress since the 2000-2004 baseline period, the MANE-VU Class I areas appear to be on track to meet their 2018 RPGs for both best and worst visibility days. The trends are mainly driven by large reductions in sulfate light extinction, and to a lesser extent, nitrate light extinction. Levels of carbonaceous matter (OCM and LAC) appear to be approaching natural levels at most of the MANE-VU Class I areas. In some cases, the levels set by these goals have already been met, and progress beyond the 2018 RPGs appears achievable. Though it is on track to meet its 2018 RPGs, challenges remain for the Brigantine Wilderness Area. Sulfate light extinction levels are higher at this site than at others across the region, and continued sulfate reductions would be a significant driver in continuing to improve visibility at this site.

# 4. DISCUSSION

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 within and adjacent to the MANE-VU region. Since our last report (NESCAUM 2010), significant improvements in visibility at the MANE-VU Class I sites have been observed, and these changes have been largely driven by reductions in sulfate levels. Levels of nitrates and carbonaceous PM are also decreasing.

Large emission reductions of nitrogen oxides (NOx) and sulfur dioxide ($SO_2$) across the region in response to regional emission reduction requirements for power plants is likely a principal driver for these visibility improvements. Further reductions over the next several years should occur if the power sector continues 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 (e.g., acid gases, toxic metals).

In addition to addressing emissions from power plants, states across the Northeast have enacted or are in process of enacting low sulfur content requirements for fuel oils, which cover home heating oil (distillate) and residual oils (#4 and #6). At the federal level, USEPA has proposed the Tier 3 motor vehicle program that includes lowering sulfur content in gasoline. While gasoline combustion is a minor source of $SO_2$ emissions, the Tier 3 fuel requirements would significantly reduce NOx 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 would lead to lower nitrate levels, most notably during colder weather months when nitrates are more thermally stable. In warmer weather months, NOx 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 NOx as a result of Tier 3 can also improve visibility by reducing ozone formation that leads to carbonaceous PM.

In summary, the visibility data examined in this report demonstrate that broad, regional efforts to reduce emissions of visibility-impairing pollutants are having a beneficial effect at the region's Class I areas. The most recent IMPROVE data indicate that the states continue to be on track to meet their 2018 reasonable progress goals for improved visibility. Further progress may occur through additional pollution reductions achievable under recently adopted or proposed regulatory programs.

# 5. REFERENCES

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IMPROVE. 2011. IMPROVE and RHR Summary Data. Available at: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

NESCAUM. 2010. Tracking Visibility Progress, 2004-2008 (2010). MANE-VU Technical Memorandum, May 12, 2010. Available at http://www.nescaum.org/documents/tracking-progress-final-05-12-10.pdf

Pietarinen, C. 2013. Conversation with Charles Pietarinen, Chief of the Bureau of Air Monitoring at the New Jersey Department of Environmental Protection on March 11, 2013. Mr. Pietarinen indicated that construction activity at the Brigantine Visitor's Center, which is very close to the monitor, may have affected the monitoring site in recent years. Prescribed burns may also be having an influence at the site.

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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.

# Appendix A: Tracking Progress Data for Class I Areas in and Adjacent to the MANE-VU Region

# Appendix A: Tracking Progress Data for Class I Areas in and Adjacent to the MANE-VU Region

Tracking progress data for sites in the MANE-VU region are presented in Table A-1, and for sites adjacent to it in Table A-2.

**Table A-1. Tracking Progress Data for Class I Areas in and Adjacent to the MANE-VU Region (dv)**

| Class I Area | Year | Best Days: Haze Index, Annual | Best Days: Haze Index, 5-Year Rolling | Worst Days: Haze Index, Annual | Worst Days: Haze Index, 5-Year Rolling |
|---|---|---|---|---|---|
| Acadia National Park | 2000 | 8.90 | - | 21.64 | - |
| | 2001 | 8.87 | - | 23.28 | - |
| | 2002 | 8.77 | - | 23.91 | - |
| | 2003 | 8.77 | - | 23.65 | - |
| | 2004 | 8.56 | 8.78 | 21.98 | 22.89 |
| | 2005 | 7.58 | 8.51 | 23.01 | 23.17 |
| | 2006 | 8.17 | 8.37 | 23.37 | 23.19 |
| | 2007 | 8.21 | 8.26 | 21.74 | 22.75 |
| | 2008 | 7.76 | 8.06 | 20.21 | 22.06 |
| | 2009 | 6.92 | 7.73 | 18.93 | 21.45 |
| | 2010 | 6.57 | 7.53 | 18.16 | 20.48 |
| | 2011 | 7.35 | 7.36 | 18.80 | 19.57 |
| Moosehorn Wilderness Area | 2000 | 8.94 | - | 20.63 | - |
| | 2001 | 9.31 | - | 22.14 | - |
| | 2002 | 9.12 | - | 23.07 | - |
| | 2003 | 9.48 | - | 22.50 | - |
| | 2004 | 8.93 | 9.16 | 20.28 | 21.72 |
| | 2005 | 7.99 | 8.97 | 22.36 | 22.07 |
| | 2006 | 8.60 | 8.82 | 21.55 | 21.95 |
| | 2007 | 7.79 | 8.56 | 19.24 | 21.19 |
| | 2008 | 7.75 | 8.21 | 18.73 | 20.43 |
| | 2009 | 6.83 | 7.79 | 17.71 | 19.92 |
| | 2010 | 5.85 | 7.37 | 17.09 | 18.87 |
| | 2011 | 6.84 | 7.01 | 17.07 | 17.97 |
| Great Gulf Wilderness Area | 2000 | | - | | - |
| | 2001 | 8.26 | - | 23.29 | - |
| | 2002 | 7.77 | - | 24.84 | - |
| | 2003 | 6.94 | - | 21.59 | - |
| | 2004 | 7.68 | 7.66 | 21.56 | 22.82 |
| | 2005 | 6.90 | 7.51 | 21.53 | 22.56 |
| | 2006 | 6.43 | 7.14 | 21.12 | 22.13 |
| | 2007 | 6.86 | 6.96 | 21.35 | 21.43 |
| | 2008 | 6.20 | 6.81 | 16.78 | 20.47 |
| | 2009 | * | 6.60 | * | 20.19 |
| | 2010 | * | 6.50 | * | 19.75 |
| | 2011 | 6.15 | 6.40 | 18.96 | 19.03 |

Symbols: "-" = not applicable; "*" = missing data; "†" = Class I Area adjacent to the MANE-VU region

*Table continued on next page.*

**Table A-1. Tracking Progress Data for Class I Areas in and Adjacent to the MANE-VU Region (dv), continued**

| Class I Area | Year | Best Days | | Worst Days | |
|---|---|---|---|---|---|
| | | Haze Index, Annual | Haze Index, 5-Year Rolling | Haze Index, Annual | Haze Index, 5-Year Rolling |
| Lye Brook Wilderness Area | 2000 | 6.49 | - | 23.45 | - |
| | 2001 | 6.47 | - | 26.33 | - |
| | 2002 | 6.43 | - | 25.52 | - |
| | 2003 | 5.83 | - | 24.02 | - |
| | 2004 | 6.61 | 6.37 | 22.91 | 24.45 |
| | 2005 | 5.74 | 6.22 | 26.04 | 24.96 |
| | 2006 | 5.24 | 5.97 | 22.31 | 24.16 |
| | 2007 | 5.68 | 5.82 | 25.25 | 24.11 |
| | 2008 | * | 5.82 | * | 24.13 |
| | 2009 | 4.11 | 5.19 | 18.44 | 23.01 |
| | 2010 | 3.96 | 4.75 | 19.88 | 21.47 |
| | 2011 | 5.28 | 4.76 | 19.47 | 20.76 |
| Brigantine Wilderness Area | 2000 | 14.26 | - | 28.95 | - |
| | 2001 | 13.83 | - | 28.38 | - |
| | 2002 | 14.83 | - | 29.31 | - |
| | 2003 | 14.39 | - | 29.79 | - |
| | 2004 | 14.36 | 14.33 | 28.59 | 29.01 |
| | 2005 | 14.61 | 14.40 | 29.62 | 29.14 |
| | 2006 | 15.35 | 14.71 | 28.50 | 29.16 |
| | 2007 | 12.74 | 14.29 | 26.91 | 28.68 |
| | 2008 | * | 14.26 | * | 28.41 |
| | 2009 | 12.78 | 13.87 | 24.25 | 27.32 |
| | 2010 | 11.70 | 13.14 | 25.22 | 26.22 |
| | 2011 | 12.78 | 12.50 | 25.78 | 25.54 |
| Dolly Sods Wilderness Area† | 2000 | 12.96 | - | 29.03 | - |
| | 2001 | 13.30 | - | 28.24 | - |
| | 2002 | 11.91 | - | 28.47 | - |
| | 2003 | 11.54 | - | 29.73 | - |
| | 2004 | 11.67 | 12.28 | 29.76 | 29.05 |
| | 2005 | 12.09 | 12.10 | 30.89 | 29.42 |
| | 2006 | 10.57 | 11.56 | 29.80 | 29.73 |
| | 2007 | 10.27 | 11.23 | 29.52 | 29.94 |
| | 2008 | 9.44 | 10.81 | 25.39 | 29.07 |
| | 2009 | 8.70 | 10.21 | 22.17 | 27.55 |
| | 2010 | 9.62 | 9.72 | 23.94 | 26.16 |
| | 2011 | 8.67 | 9.34 | 24.44 | 25.09 |
| Shenandoah National Park† | 2000 | 11.08 | - | 28.53 | - |
| | 2001 | 13.21 | - | 29.21 | - |
| | 2002 | 11.49 | - | 30.54 | - |
| | 2003 | 9.48 | - | 28.94 | - |
| | 2004 | 9.37 | 10.93 | 29.32 | 29.31 |
| | 2005 | 10.48 | 10.81 | 30.75 | 29.75 |
| | 2006 | 10.59 | 10.28 | 29.30 | 29.77 |
| | 2007 | 11.13 | 10.21 | 28.79 | 29.42 |
| | 2008 | 8.16 | 9.95 | 25.65 | 28.76 |
| | 2009 | 8.23 | 9.72 | 21.81 | 27.26 |
| | 2010 | 9.67 | 9.56 | 23.44 | 25.80 |
| | 2011 | 7.80 | 9.00 | 23.42 | 24.62 |

Symbols: “-” = not applicable; “*” = missing data; “†” = Class I Area adjacent to the MANE-VU region