**Appendix B**

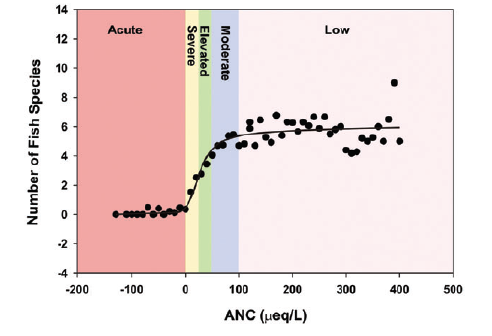


Figure B-3. Number of fish species per lake verses acidity status, expressed as acid neutralizing capacity, for Adirondack lakes. The data are presented as the mean (filled circles) of species richness within 10 μeq/L ANC categories, based on data collected by the Adirondacks Lakes Survey Corporation. Source: Modified from Sullivan et al. (2006).

Table B-1. Aquatic Status Categories

|  |  |  |
| --- | --- | --- |
| **Table B-1. Aquatic status categories** | | |
| Acute | <0μeq/L  (pH< 5) | Acute impacts on all life forms are expected. Planktonic and macroinvertebrates communities have extremely low diversity and are dominated by acidophilic forms and their population numbers are sharply reduced. Mayflies are eliminated. A near complete loss of fish populations is expected, including non-acid sensitive species such as brook trout, northern pike, and others. Aquatic diversity is at its lowest level. |
| Severe | 0-20 μeq/L  (pH 5.2-5.5) | All biota exhibit some level of negative effects. Plankton and macroinvertebrates populations decline sharply to levels where acid-tolerant species outnumber non-acid sensitive species. Sensitive species are absent (e.g. brown trout, common shiner, etc.) while non-sensitive fish species populations decline. Waterbodies are highly sensitive to episodic acidification (e.g <0μeq/L and pH< 5), causing acute impacts to biota. During episodes, brook trout and other fish species may experience lethal effects. Aquatic diversity is depressed. |
| Elevated | 20–50 μeq/L  (pH 5.5-6) | This ANC range is associated with species death or loss of fitness, and reproduction of biota that are sensitive to acidification for plankton to fish populations. Macroinvertebrate assemblages are moderately impacted. Fish species richness is greatly reduced (i.e., more than half of expected  species can be missing) with sensitive species such as Atlantic salmon smolts, blacknose shiner, etc.) still expected to be absence. Brook trout are comparatively acid tolerant when conditions are such ANC >20 μeq/L, pH>6, and Ali<0.1 mg/L can have healthy brook trout populations. However, episodic acidification during events may reduce pH and ANC to levels lethal to brook trout and other fish and biota or sublethal, causing, loss of health, reduced reproduction, and reduced fitness of biota. Aquatic diversity is declining. |
| Moderate | 50–80 μeq/L  (pH 6-6.2) | The fitness and population size of sensitive species of plankton, macroinvertebrate and fish (e.g. Atlantic salmon smolts, blacknose shiner) begins to decline. Fish species richness begins to decline (i.e., sensitive species are lost first). ANC above 50 μeq/L is considered suitable for brook trout and most fish species because buffering capacity is sufficient to prevent the likelihood of lethal episodic acidification events. Aquatic diversity typically declines as sensitive species are impacted as ANC levels decline. |
| Low | >80 μeq/L  (pH >6.2) | Plankton, macroinvertebrate, and fish assemblages are likely to be unimpacted above 80 μeq/L. Fish populations are expected where habitat is suitable. Biota exhibit expected diversity and distribution. |

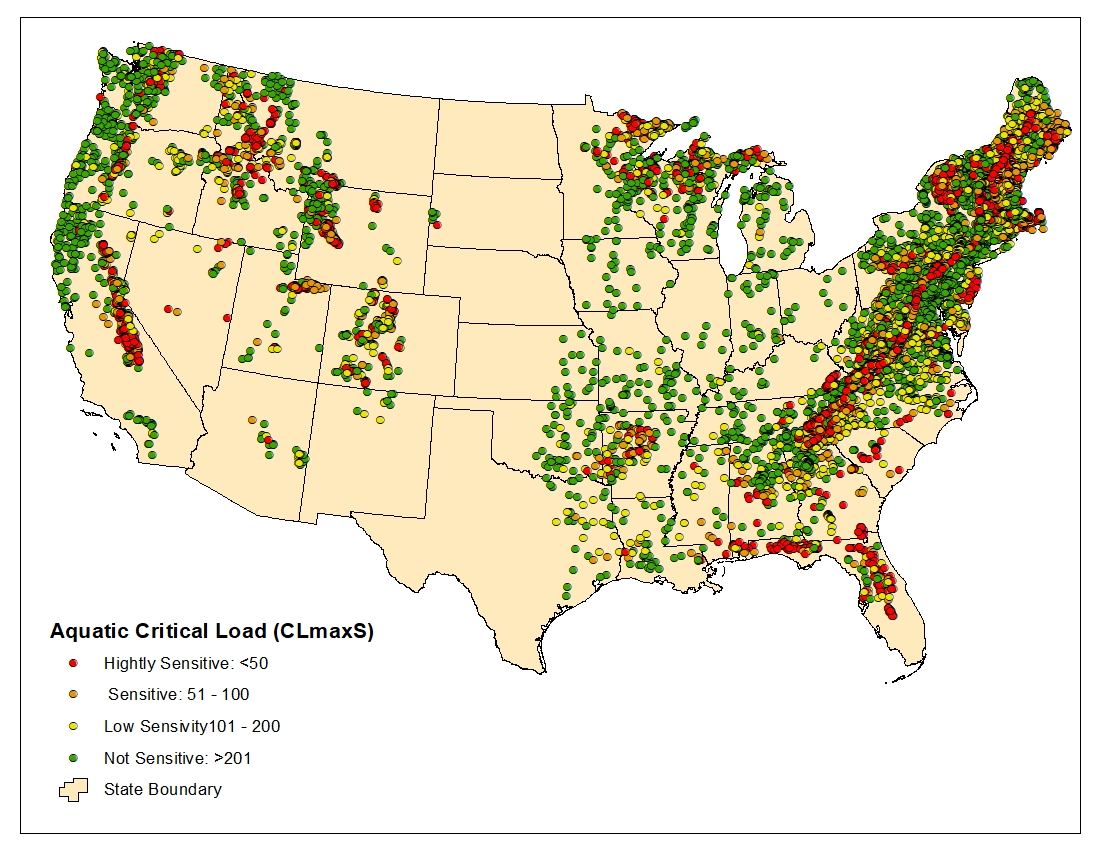


Figure B-7. Critical loads of acidifying deposition that each surface waterbody in the National Case Study Area can receive while maintaining or exceeding an acid neutralizing capacity concentration of 50 μeq/L based. Watersheds with critical load values less than 100 meq/m2-yr (red and orange circles) are most sensitive to surface water acidification, whereas watersheds with values greater than 100 meq/m2-yr (yellow and green circles) are the least sensitive sites.

Table. B-5. National aquatic CL exceedances by ANC threshold. The number and percent of modeled waterbodies where deposition from 2014-16 is above the CL.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ANC | Sulfur Only | | Sulfur and Nitrogen\* | | Sulfur and Nitrogen\*\* | |
| Threshold | No. | Percent | No. | Percent | No. | Percent |
| 20 | 382 | 3% | 402 | 4% | 2540 | 22% |
| 30 | 564 | 5% | 597 | 5% | 2847 | 25% |
| 50 | 1118 | 9% | 1193 | 10% | 3831 | 34% |
| 80 | 1708 | 15% | 1794 | 16% | 4349 | 38% |

\*Determine using method A, where nitrogen impact is determined by leaching of nitrate.

\*\*Determine using method B, where nitrogen loss is a function of biogeochemical model.

**Appendix C**

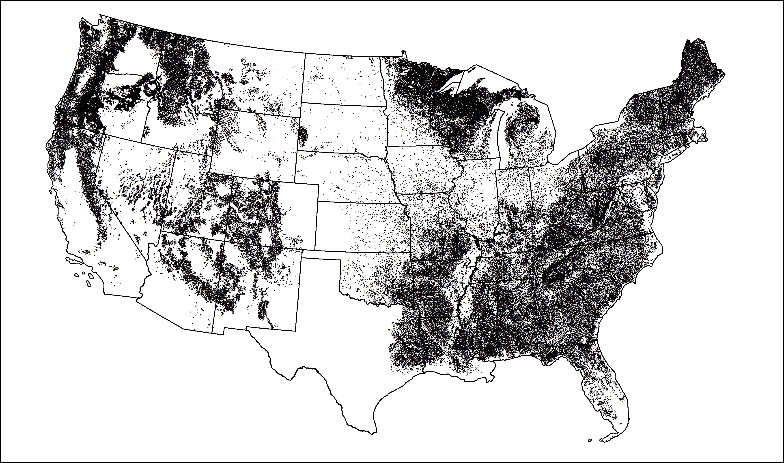


Figure C3. FIA plots used for application of the Horn curves

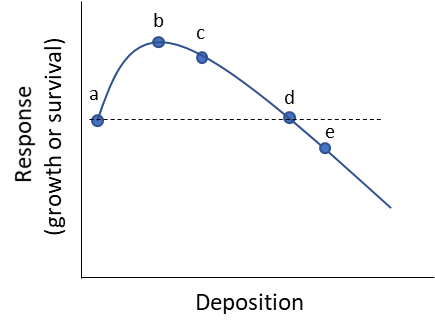


Figure C6. Canonical example of a unimodal relationship with N (common for growth). At low rates, N deposition often increases growth up to point b, decreasing growth above point b. The net effect of N deposition (including increases from a to b, and decreases from b to d) is positive between a and d, and negative above point d.

|  |  |
| --- | --- |
| Survival | Growth |
| Mean |  |
| Median  a | b |
| Min  c | d |
| Max  e | f |

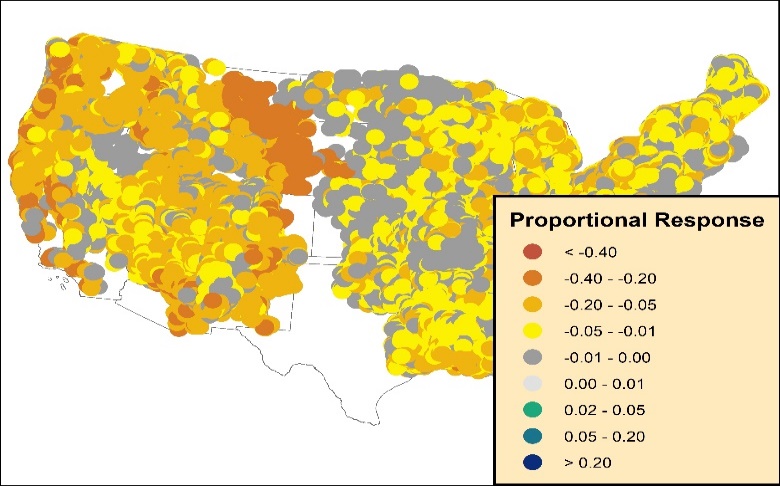


Figure C8. Survival (left column) and growth (right) responses to current N deposition across the U.S. Shown are the average (a, b), median (c, d), minimum (e, f), and maximum (g, h) for multiple trees within each of the plots.

|  |  |
| --- | --- |
| Survival | Growth |
| Mean |  |
| Median  a | b |
| Min  c | d |
| Max  e | f |

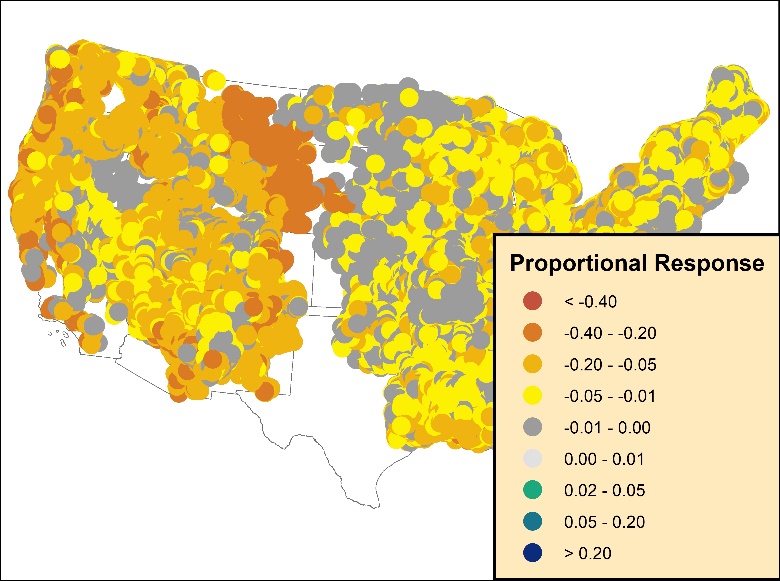
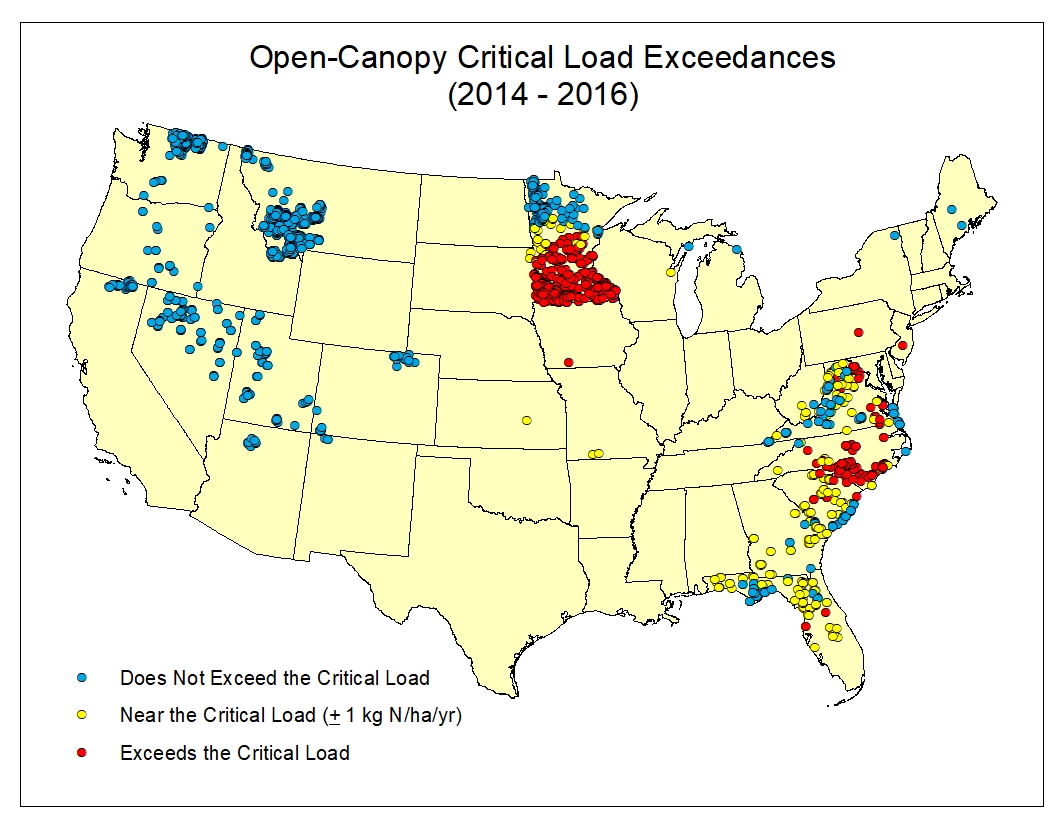


Figure C9. Survival (left column) and growth (right) responses to current S deposition across the U.S. Shown are the average (a, b), median (c, d), minimum (e, f), and maximum (g, h) for multiple trees within each of the plots.

**Appendix D**

**A**.

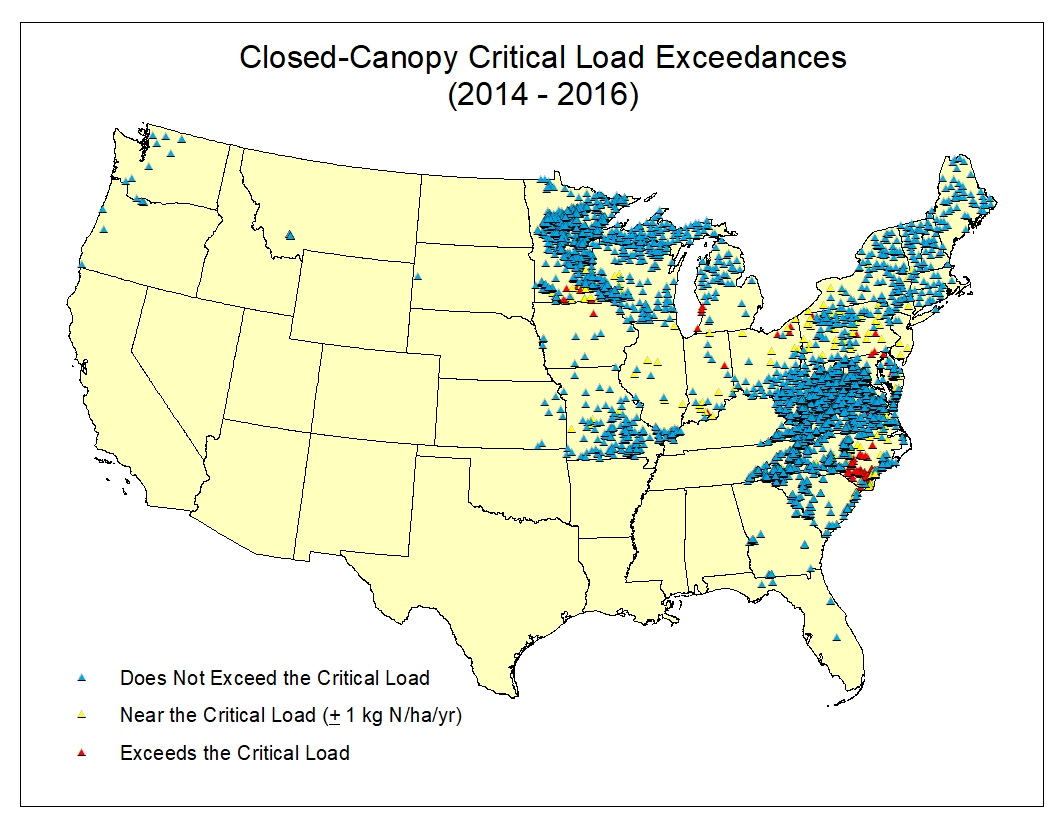
**B**.

Figure D-3: Critical load exceedances. Critical load exceedances for (A) open-canopy and (B) closed-canopy sites. CL exceedances were calculated following the methods described in section D.2. Exceedances are expressed in terms of N deposition (kg N/ha/yr). A positive number indicates that deposition is exceeding the CL.

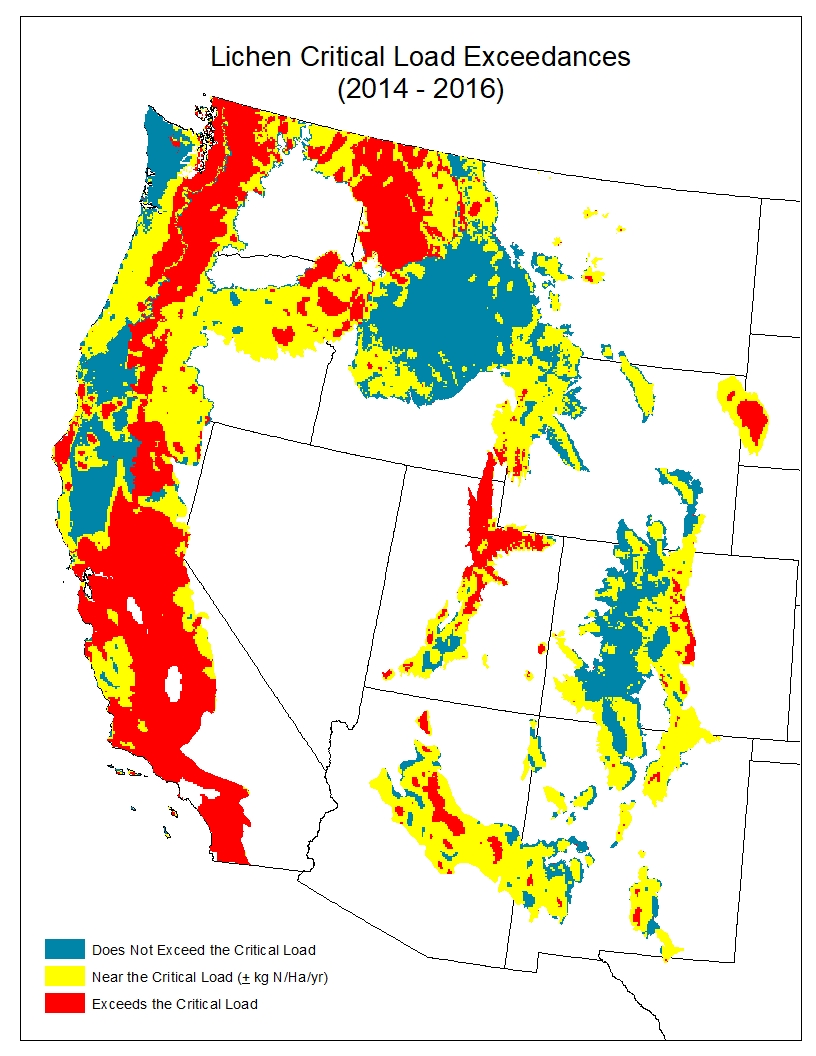
****

Figure D-7: Lichen community composition CL exceedances. CL exceedances were calculated following the methods described in Section D.2. An exceedance of + 1 kg N/ha/yr was considered “Near the Critical Load”.

**Appendix E**

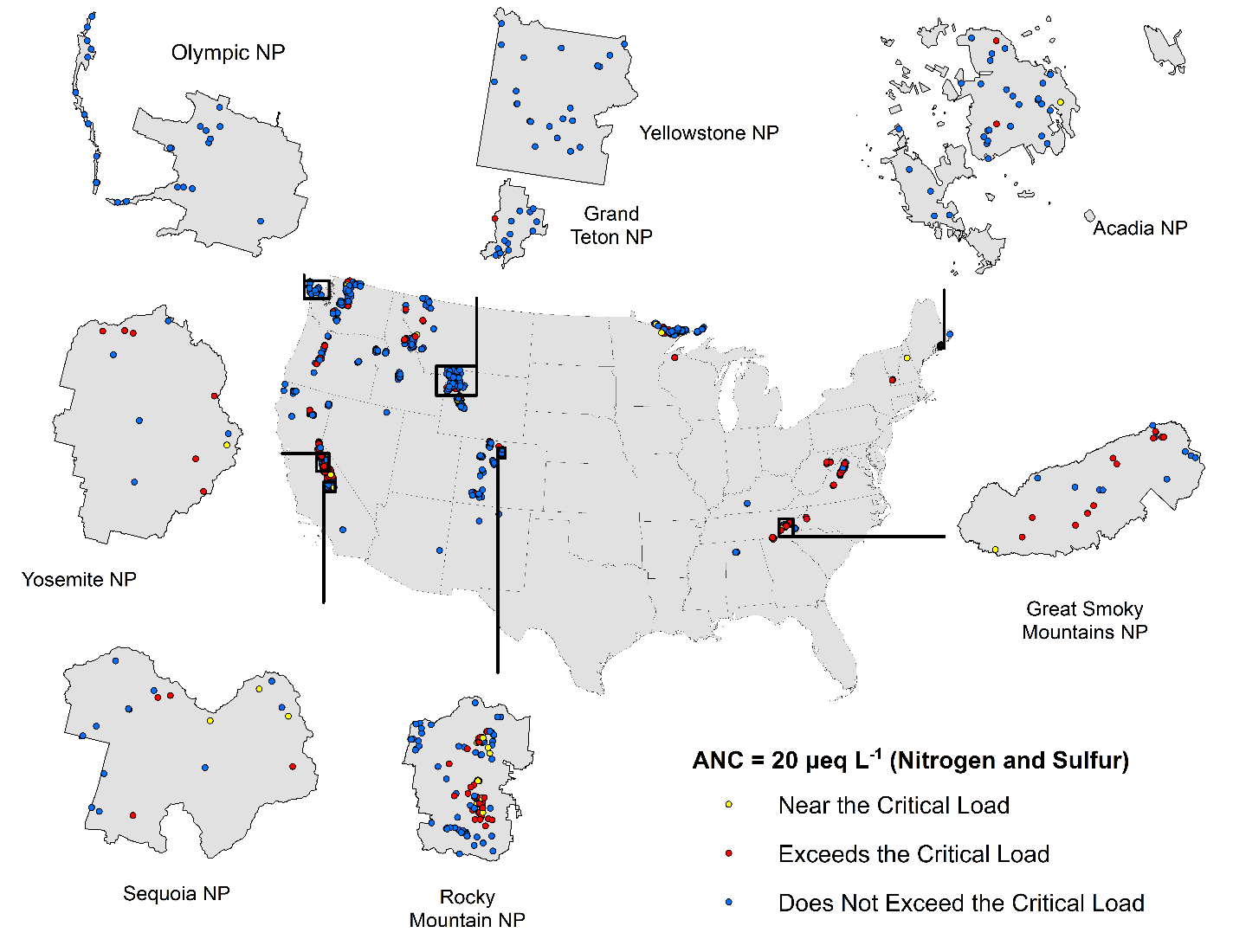


Figure 2.2‑4 Map of water body exceedances (ANC = 20 µeq L-1 – nitrogen and sulfur model) within Class I areas across the contiguous US. Eight frequently visited national parks in the US are shown as inset maps with water body critical load exceedance results..

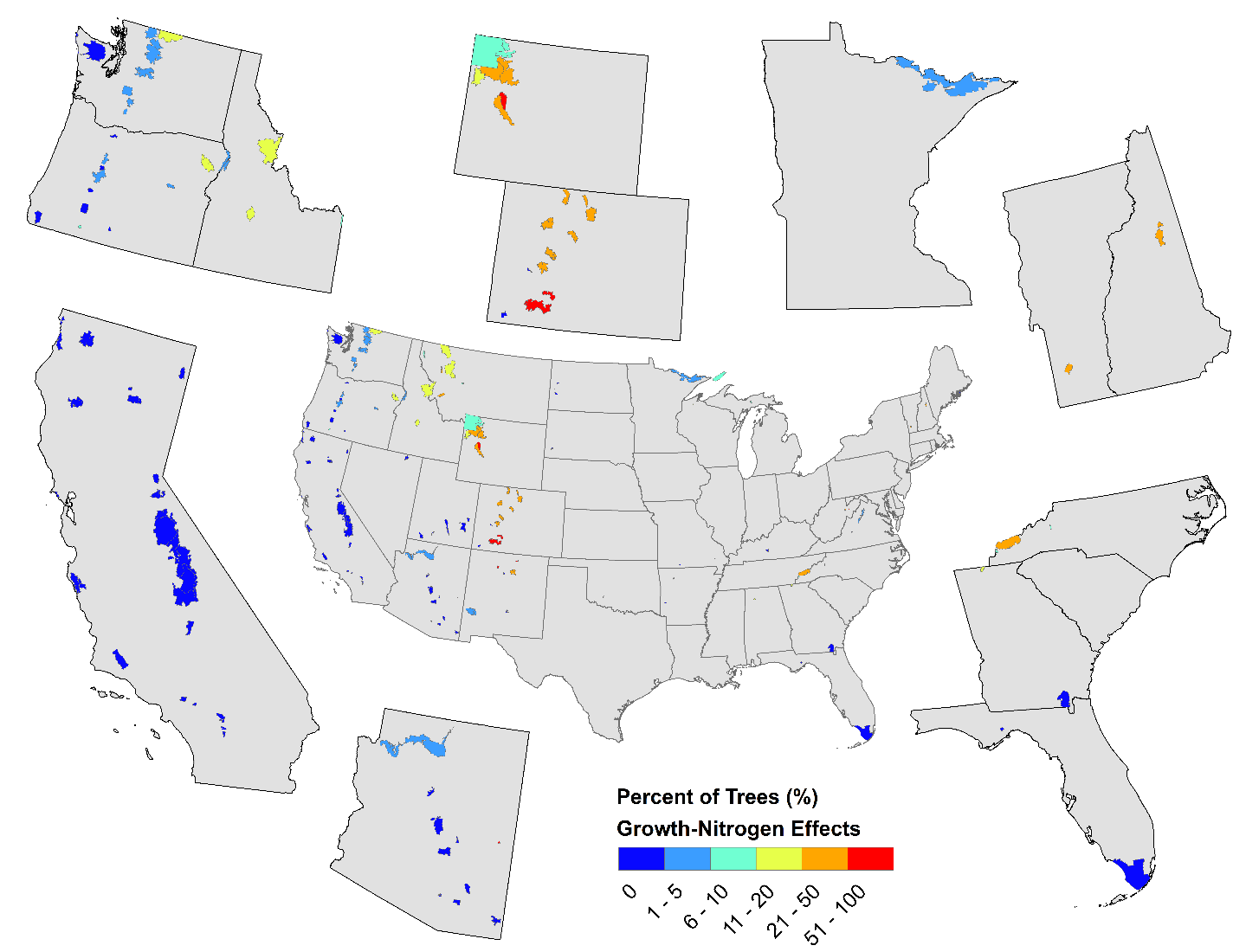


Figure 2.3‑2 Map of Federal Class I areas across the US. Percentages of total trees within the areas that are experiencing > 5% reduction in nitrogen-growth rates are differentiated by color bins. Inset maps of different regions within the US are shown to observe smaller scale variations in the Class I area responses.

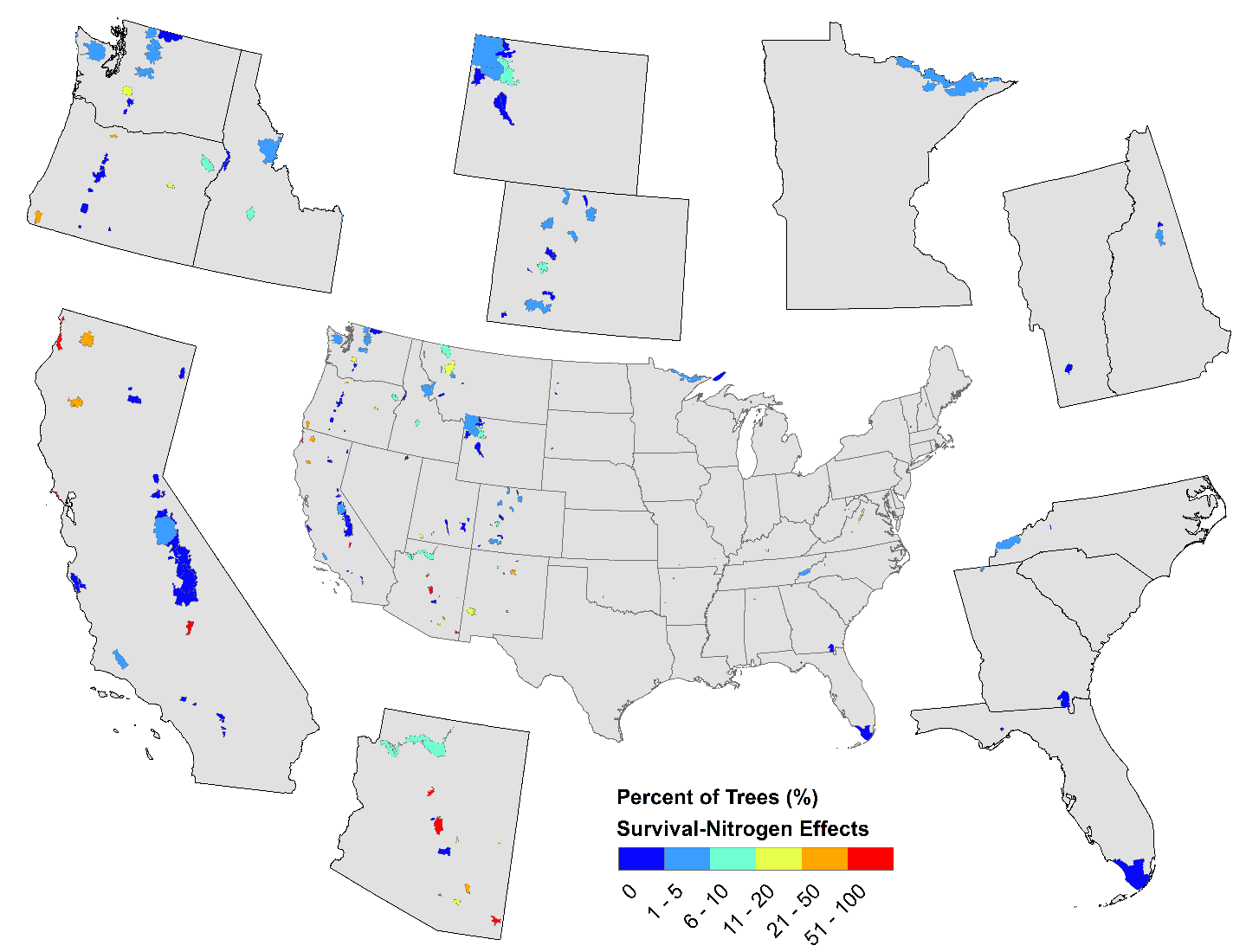


Figure 2.3‑6 Map of Federal Class I areas across the US. Percentages of total trees within the areas that are experiencing > 1% reduction in survival rates due to nitrogen are shown by the color bins. Inset maps of different regions within the US are shown to observe smaller scale variations in the Class I area responses.

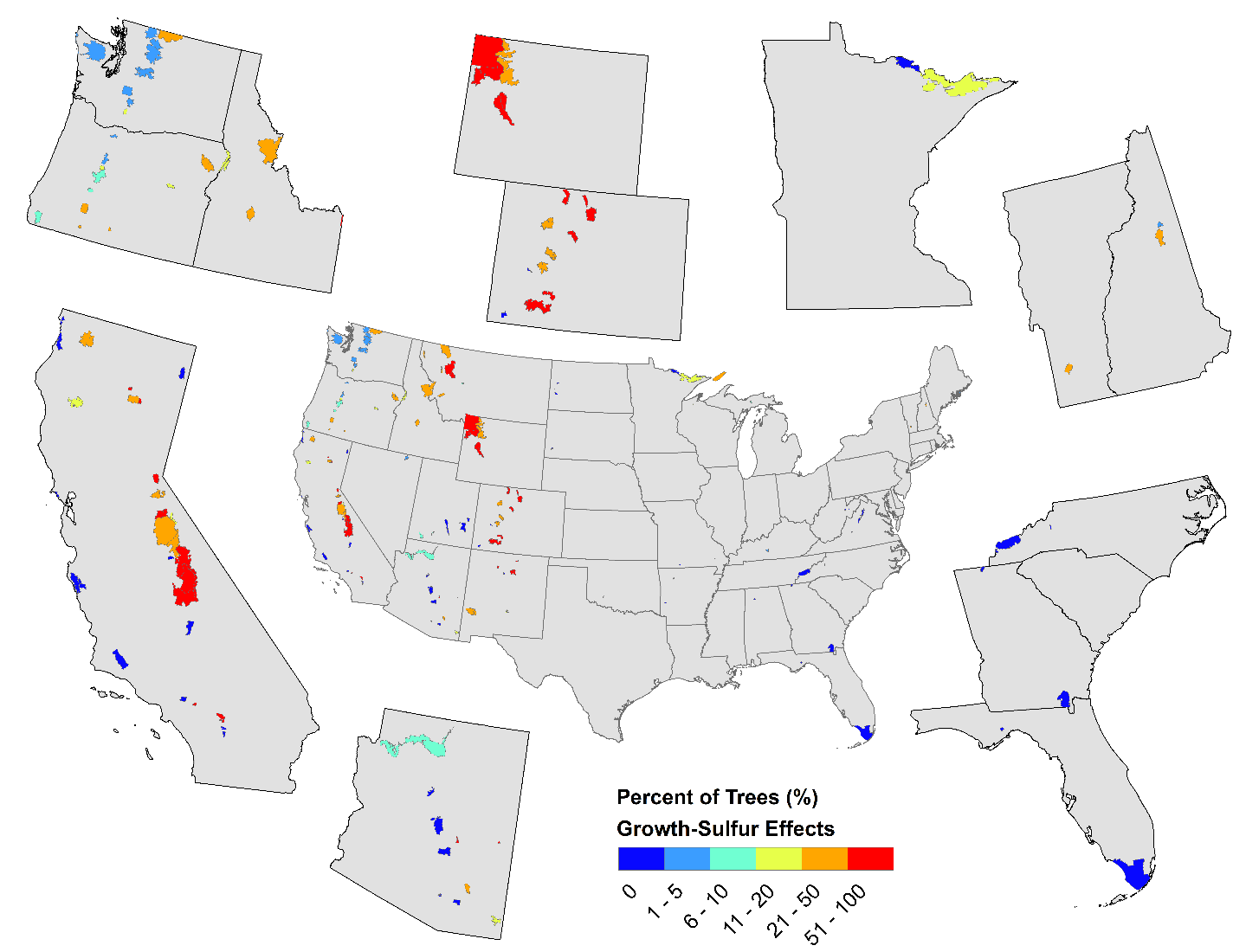


Figure 2.3‑10 Map of Federal Class I areas across the US. Percentages of total trees within the areas that are experiencing > 5% reduction in growth rates due to sulfur are shown by the color bins. Inset maps of different regions within the US are shown to observe smaller scale variations in the Class I area responses.

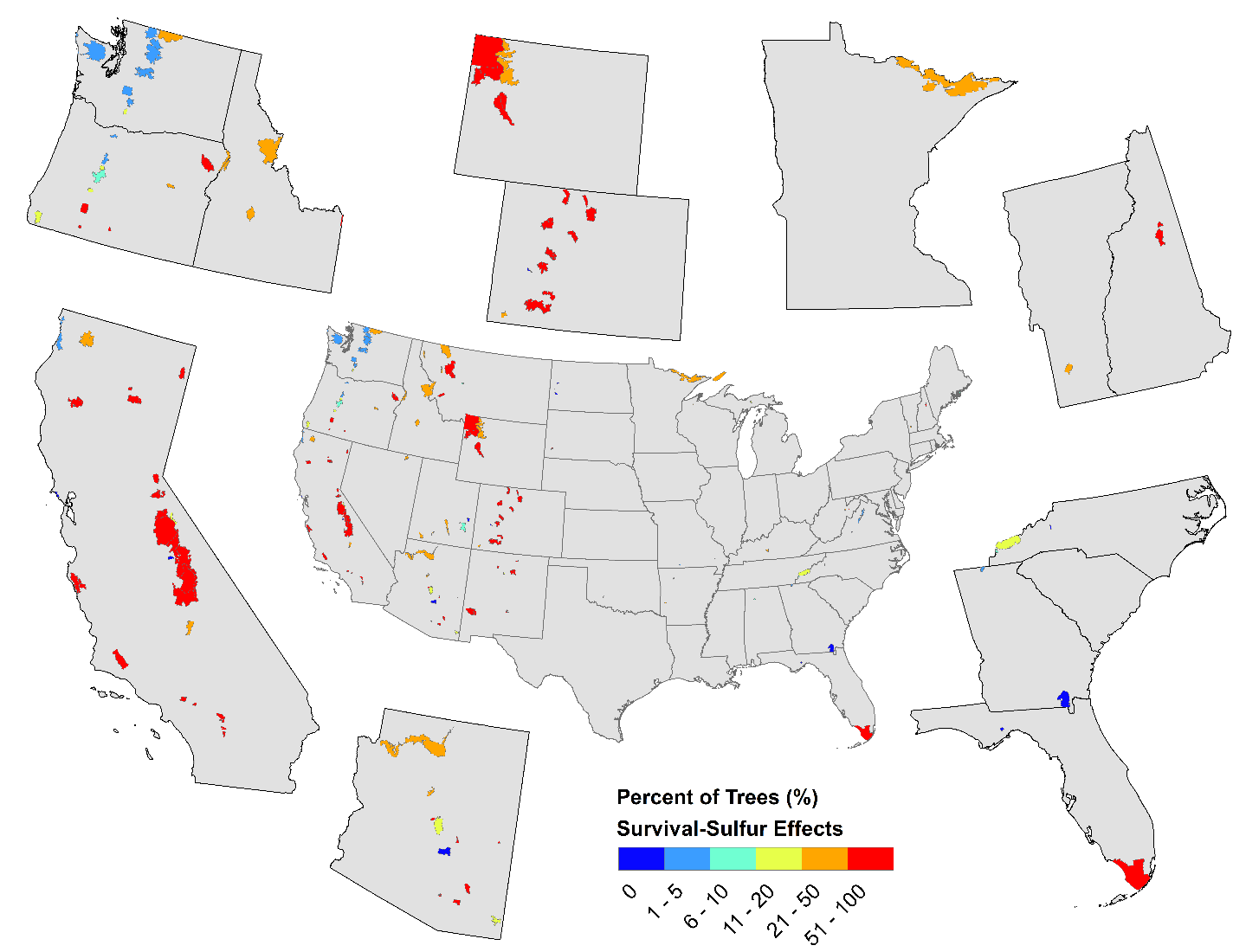


Figure 2.3‑14 Map of Federal Class I areas across the US. Percentages of total trees within the areas that are experiencing > 1% reduction in survival rates due to sulfur are shown by the color bins. Inset maps of different regions within the US are shown to observe smaller scale variations in the Class I area responses.

**Table F-8**: Applying the procedure described in above, this table lists the three-year historical periods identified where conditions at each case study area were just meeting the PM2.5 concentration threshold. For the Sierra Nevada case study, since concentrations are above the existing threshold, the multipliers are shown that are used to proportionally scale the current deposition levels to each of the three PM2.5 concentration scenarios. For some locations, it was not possible to select a three-year historical period as PM2.5 concentrations, from the time period 2000 -- 2018, have not been as high as the threshold for that scenario.

|  |  |  |  |
| --- | --- | --- | --- |
| Case Study Area | years for 15 µg m-3 | years for 12 µg m-3 | years for 10 µg m-3 |
| Coastal South Carolina | 2004-2006 | 2007-2009 | 2011-2013 |
| Gila National Forest | PM2.5 concentrations have not been this high | 2002-2004 | 2005-2007 |
| Northern Minnesota | PM2.5 concentrations have not been this high | 2000—2002 | 2007-2009 |
| Rocky Mountain National Park | PM2.5 concentrations have not been this high | PM2.5 concentrations have not been this high | 2000-2002 |
| Shenandoah Valley | 2005—2007 | 2009—2011 | 2014-2016 |
| Sierra Nevada | S deposition: 0.70  N deposition: 0.72 | S deposition: 0.56  N deposition: 0.57 | S deposition: 0.46  N deposition: 0.48 |
| White Mountain National Forest | 2000—2002 | 2005-2007 | 2009-2011 |

**Table F-14:** CL exceedances by case study, deposition, and ANC threshold. The CL exceedance (number and percent of modeled waterbodies) for each air quality (10, 12, and 15 µg/m3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Areas | Air Quality  Scenario | ANC  (µeq/L) | Sulfur Only | | Sulfur and Nitrogen  (Method A) | | Sulfur and Nitrogen  (Method B) | |
|  | µg/m3 | Threshold | No. | Percent | No. | Percent | No. | Percent |
| ROMO | 10 | 20 | 3 | 2% | 6 | 5% | 62 | 51% |
| SINE | 10 | 20 | 1 | 1% | 1 | 1% | 12 | 9% |
| NOMN | 10 | 20 | 2 | 1% | 2 | 1% | 84 | 46% |
| WHMT | 10 | 20 | 3 | 4% | 5 | 7% | 25 | 34% |
| SHVA | 10 | 20 | 9 | 2% |  |  | 228 | 49% |
| ROMO | 12 | 20 |  |  |  |  |  |  |
| SINE | 12 | 20 | 1 | 1% | 1 | 1% | 23 | 17% |
| NOMN | 12 | 20 | 2 | 1% | 6 | 3% | 95 | 52% |
| WHMT | 12 | 20 | 21 | 28% | 30 | 41% | 49 | 66% |
| SHVA | 12 | 20 | 16 | 3% |  |  | 321 | 69% |
| ROMO | 15 | 20 |  |  |  |  |  |  |
| SINE | 15 | 20 | 2 | 1% | 2 | 1% | 39 | 28% |
| NOMN | 15 | 20 |  |  |  |  |  |  |
| WHMT | 15 | 20 | 23 | 31% | 35 | 47% | 52 | 70% |
| SHVA | 15 | 20 | 156 | 34% |  |  | 443 | 95% |
| ROMO | 10 | 30 | 6 | 5% | 16 | 13% | 72 | 60% |
| SINE | 10 | 30 | 3 | 2% | 3 | 2% | 30 | 22% |
| NOMN | 10 | 30 | 2 | 1% | 2 | 1% | 90 | 49% |
| WHMT | 10 | 30 | 9 | 12% | 10 | 14% | 31 | 42% |
| SHVA | 10 | 30 | 11 | 2% |  |  | 264 | 57% |
| ROMO | 12 | 30 |  |  |  |  |  |  |
| SINE | 12 | 30 | 9 | 6% | 9 | 6% | 38 | 27% |
| NOMN | 12 | 30 | 2 | 1% | 11 | 6% | 99 | 54% |
| WHMT | 12 | 30 | 25 | 33% | 36 | 49% | 53 | 72% |
| SHVA | 12 | 30 | 19 | 4% |  |  | 349 | 75% |
| ROMO | 15 | 30 |  |  |  |  |  |  |
| SINE | 15 | 30 | 11 | 8% | 11 | 8% | 50 | 36% |
| NOMN | 15 | 30 |  |  |  |  |  |  |
| WHMT | 15 | 30 | 27 | 36% | 41 | 55% | 55 | 74% |
| SHVA | 15 | 30 | 202 | 44% |  |  | 446 | 96% |
| ROMO | 10 | 50 | 25 | 21% | 37 | 31% | 90 | 74% |
| SINE | 10 | 50 | 13 | 9% | 13 | 9% | 52 | 37% |
| NOMN | 10 | 50 | 3 | 2% | 4 | 2% | 98 | 54% |
| WHMT | 10 | 50 | 18 | 24% | 19 | 26% | 44 | 59% |
| SHVA | 10 | 50 | 20 | 4% |  |  | 322 | 69 |
| ROMO | 12 | 50 |  |  |  |  |  |  |
| SINE | 12 | 50 | 34 | 24% | 34 | 24% | 55 | 40% |
| NOMN | 12 | 50 | 6 | 3% | 21 | 11% | 105 | 55% |
| WHMT | 12 | 50 | 37 | 50% | 48 | 65% | 61 | 82% |
| SHVA | 12 | 50 | 68 | 15% |  |  | 399 | 86% |
| ROMO | 15 | 50 |  |  |  |  |  |  |
| SINE | 15 | 50 | 38 | 27% | 38 | 27% | 66 | 47% |
| NOMN | 15 | 50 |  |  |  |  |  |  |
| WHMT | 15 | 50 | 38 | 51% | 49 | 66% | 64 | 86% |
| SHVA | 15 | 50 | 279 | 60% |  |  | 451 | 97% |
| ROMO | 10 | 80 | 60 | 50% | 69 | 57% | 104 | 86% |
| SINE | 10 | 80 | 33 | 24% | 33 | 24% | 72 | 52% |
| NOMN | 10 | 80 | 16 | 9% | 16 | 9% | 111 | 61% |
| WHMT | 10 | 80 | 36 | 49% | 39 | 53% | 52 | 70% |
| SHVA | 10 | 80 | 107 | 23% |  |  | 397 | 86% |
| ROMO | 12 | 80 |  |  |  |  |  |  |
| SINE | 12 | 80 | 61 | 44% | 61 | 44% | 77 | 55% |
| NOMN | 12 | 80 | 27 | 15% | 47 | 26% | 118 | 64% |
| WHMT | 12 | 80 | 48 | 65% | 57 | 77% | 69 | 93% |
| SHVA | 12 | 80 | 192 | 41% |  |  | 432 | 93% |
| ROMO | 15 | 80 |  |  |  |  |  |  |
| SINE | 15 | 80 | 62 | 45% | 62 | 45% | 83 | 66% |
| NOMN | 15 | 80 |  |  |  |  |  |  |
| WHMT | 15 | 80 | 48 | 64% | 61 | 82% | 69 | 93% |
| SHVA | 15 | 80 | 366 | 79% |  |  | 455 | 98% |

**Table F-17:** Summary of Nitrogen effects on growth as a percentage of trees

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case Study Area | Nitrogen Effects on Growth | | | | | | | | | | | | | | |
| >0% Growth | | | >5% Growth | | | > 10% Growth | | | >15% Growth | | | >20% Growth | | |
| 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg |
| CSCA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| GILA | <1% | <1% |  | <1% | <1% |  | <1% | <1% |  | 0% | <1% |  | 0% | 0% |  |
| NOMN | 17% | 17% |  | 4% | 9% |  | 2% | 3% |  | <1% | 1% |  | 0% | 0% |  |
| ROMO | 36% |  |  | 36% |  |  | 36% |  |  | 3% |  |  | 0% |  |  |
| SHVA | <1% | <1% | <1% | <1% | <1% | <1% | <1% | <1% | <1% | <1% | <1% | <1% | 0% | <1% | <1% |
| SINE | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| WHMT | 58% | 58% | 58% | 25% | 48% | 55% | 21% | 25% | 54% | 14% | 20% | 42% | 1% | 15% | 36% |

**Table F-18:** Summary of Sulfur effects on growth as a percentage of trees

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case Study Area | Sulfur Effects on Growth | | | | | | | | | | | | | | |
| >0% Growth | | | >5% Growth | | | > 10% Growth | | | >15% Growth | | | >20% Growth | | |
| 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg |
| CSCA | 78% | 78% | 78% | 26% | 77% | 77% | 1% | 58% | 63% | <1% | 10% | 53% | 0% | 1% | 4% |
| GILA | 60% | 60% |  | 60% | 60% |  | 59% | 60% |  | 54% | 54% |  | 50% | 50% |  |
| NOMN | 58% | 58% |  | 43% | 52% |  | 31% | 39% |  | 12% | 21% |  | <1% | 3% |  |
| ROMO | 39% |  |  | 39% |  |  | 39% |  |  | 4% |  |  | 3% |  |  |
| SHVA | 27% | 33% | 33% | 17% | 21% | 29% | 3% | 12% | 23% | <1% | 5% | 17% | 0% | 2% | 7% |
| SINE | 37% | 41% | 41% | 6% | 14% | 31% | 3% | 5% | 11% | 0% | 3% | 6% | 0% | <1% | 3% |
| WHMT | 55% | 55% | 55% | 53% | 55% | 55% | 37% | 55% | 55% | 34% | 42% | 42% | 15% | 36% | 36% |

**Table F-19:** Summary of Nitrogen effects on survival as a percentage of trees

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case Study Area | Nitrogen Effects on Survival | | | | | | | | |
| >0% Survival | | | >3% Survival | | | > 5% Survival | | |
| 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg |
| CSCA | 21% | 23% | 23% | 1% | 1% | 2% | 0% | 1% | 1% |
| GILA | 10% | 10% |  | 3% | 4% |  | 0% | 1% |  |
| NOMN | 4% | 4% |  | <1% | <1% |  | 0% | 0% |  |
| ROMO | 2% |  |  | 2% |  |  | 0% |  |  |
| SHVA | 17% | 20% | 34% | 3% | 5% | 8% | 1% | 2% | 6% |
| SINE | 1% | 1% | 1% | 0% | 0% | <1% | 0% | 0% | 0% |
| WHMT | <1% | 1% | 1% | <1% | <1% | <1% | 0% | <1% | <1% |

**Table F-20**: Summary of Sulfur effects on survival as a percentage of trees

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case Study Area | Sulfur Effects on Survival | | | | | | | | |
| >0% Survival | | | >3% Survival | | | > 5% Survival | | |
| 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg | 10 µg | 12 µg | 15 µg |
| CSCA | 93% | 93% | 93% | 2% | 33% | 72% | 1% | 11% | 61% |
| GILA | 84% | 84% |  | 51% | 49% |  | 37% | 39% |  |
| NOMN | 83% | 83% |  | 50% | 58% |  | 35% | 40% |  |
| ROMO | 81% |  |  | 81% |  |  | 81% |  |  |
| SHVA | 69% | 75% | 75% | 3% | 3% | 20% | 1% | 3% | 7% |
| SINE | 80% | 80% | 80% | 4% | 41% | 55% | 0% | 0% | 4% |
| WHMT | 92% | 92% | 92% | 40% | 76% | 76% | 36% | 60% | 61% |

**Table F-22:** Scaling Factors for Case Study areas.Scaling factors were calculated using EQ-2 and EQ-3 above.

|  |  |  |
| --- | --- | --- |
| **Case Study** | **Scaling Factor** | **Method/Notes** |
| CSCA | 0.93 | TDEP/Simkin |
| GILA | 1.09 | TDEP/CMAQ |
| NOMN | 1.05 | TDEP/Simkin |
| ROMO | 1.44 | TDEP/CMAQ - Estimated from adjacent wilderness areas |
| SHVA | 1.03 | TDEP/Simkin - Only for 12 and 15 ug scenarios |
| SINE | 1.5 | Updated 2014 – 2016 TDEP/2014 – 2016 CMAQ |
| WHMT | 0.83 | TDEP/Simkin |