Why Federal Land Managers in the Northwest are Concerned about Nitrogen Emissions

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Introduction:

The Northwest enjoys generally good air quality, especially when compared to the Eastern U. S. While there are still several nonattainment areas in the Northwest (for PM10 and CO), the large urban areas of the Puget Sound and Portland/Vancouver have been largely successful in addressing their air quality problems and are in attainment for all criteria pollutants. This is an important success story.

But this success in urban areas may leave our National Parks, Wilderness areas, and other protected lands vulnerable to air pollution impacts. In particular, attainment of the ozone standard and the urban focus of control strategies may lead regulators to conclude that additional NOx controls are not needed or appropriate. Further, a regulatory structure that does not include ammonia as a "regulated pollutant" and/or places it under the jurisdiction of agricultural agencies rather than within air quality agencies, means that little data is collected on this pollutant or its impacts. Together, these views may lead Northwest regulators to give control of N emissions a lower priority than do the Federal Land Managers (FLM) who are charged with protecting and preserving ecosystems.

Increases in N emissions are expected by 2020 due to continued rapid population growth in the region (as much as 50% population growth by 2020 in some areas), increased traffic from marine vessels, air cargo and passenger transport, truck transport (as much as 100% by 2020), and agricultural intensification (Schary 2003). In addition, global 'background' levels of many pollutants are increasing. Recent research suggests that trans-Pacific transport of Asian pollution has significant implications for NOx, ozone, and aerosol levels in the western United States (Jaffe 1999; Fiore 2002). Ozone in air arriving from the Eastern Pacific has increased by approximately 10 ppbv from the 1980s – as much as 30%. In some episodes of trans-Pacific transport, significant ozone enhancement has been measured (Jaffe 2003). This trend in ozone correlates with the increasing trend in global nitrogen oxide emissions, which is especially pronounced in Asia as shown below (Parrish, 2004).

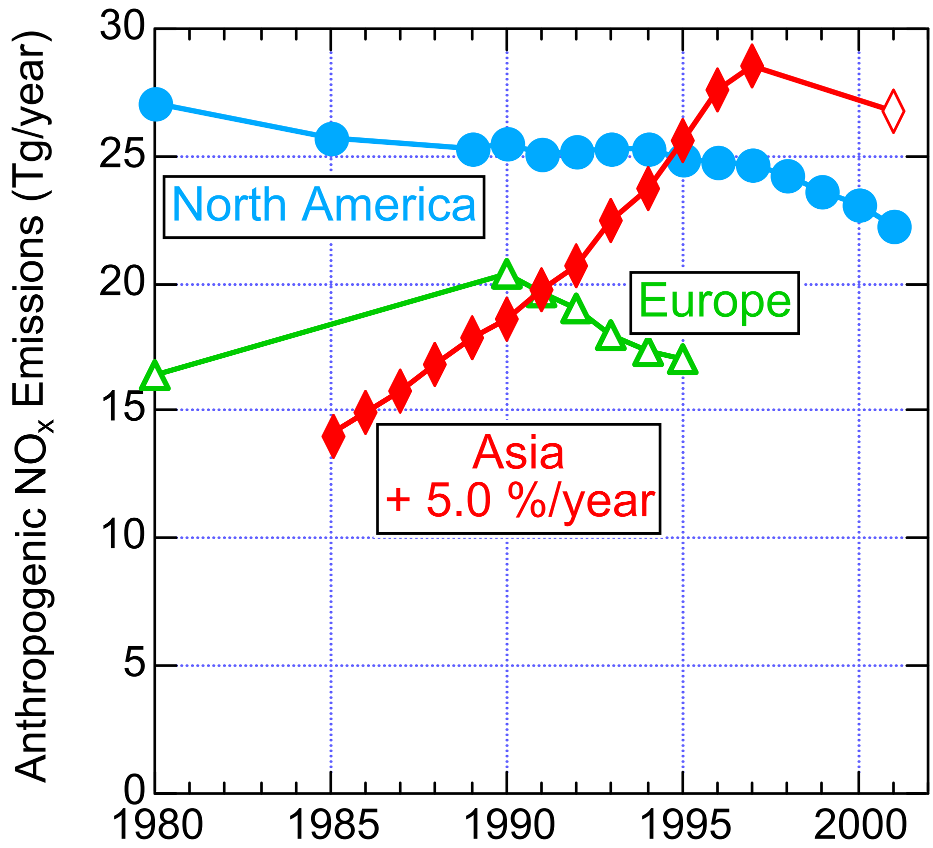

Figure 1: Trends in continental NOx emissions (Parrish, 2004)

<u>Ecosystem Effects</u>:

As ecosystem stewards, the focus of the Federal Land Managers (FLMs) is sometimes different from the urban and human health focus of our partners in the local, state, and federal regulatory agencies. We look not just at compliance with the health based standards but at potential ecosystem impacts that may occur at levels below the standard and at exposures beyond urban areas. Following are some of the ecosystem impacts and emission trends related to nitrogen emissions which lead FLMs in the Northwest to conclude that nitrogen emissions are, indeed, a growing problem:

1. <u>Ozone</u>: NOx, which is 70 to 90% anthropogenic in origin, is a precursor to ozone. The complex chemistry of ozone formation and the importance of the ratio of VOC to NOx results in ozone concentrations increasing with distance downwind from the urban pollution sources and with increasing elevation. This phenomenon is well documented, through both monitoring and modeling in the Puget Sound and Portland areas (Barna 2000, 2001; Cooper and Peterson 2000,

Brace and Peterson 1998). It has also been shown that reductions in VOC emissions lead to reductions in urban ozone levels but simply shift the ozone maxima downwind from the urban center to rural areas where anthropogenic NOx emissions, transported from urban areas and transportation corridors, react with local biogenic hydrocarbon emissions (Barna et al., 2000). Although VOC reductions appear to be most effective in reducing peak ozone levels within the urban centers, relying on VOC controls alone does not reduce the total amount of ozone produced but merely delays ozone formation until the urban air mass moves farther downwind. NOx reductions are needed to reduce ozone throughout the airshed. To reduce all ozone exposures (urban and rural) to desired levels, significant reductions will be needed in both VOC and NOx (Barna, Lamb, and Westberg, 2001).

Figure 2, illustrates that total ozone exposures generally increase with distance downwind from Puget Sound urban centers, as discussed above. The graph also suggests a possible shift towards increasing ozone levels over the past three to four years after fairly constant levels in the 1990s. See Figure 3 for the relative locations of the monitoring sites.

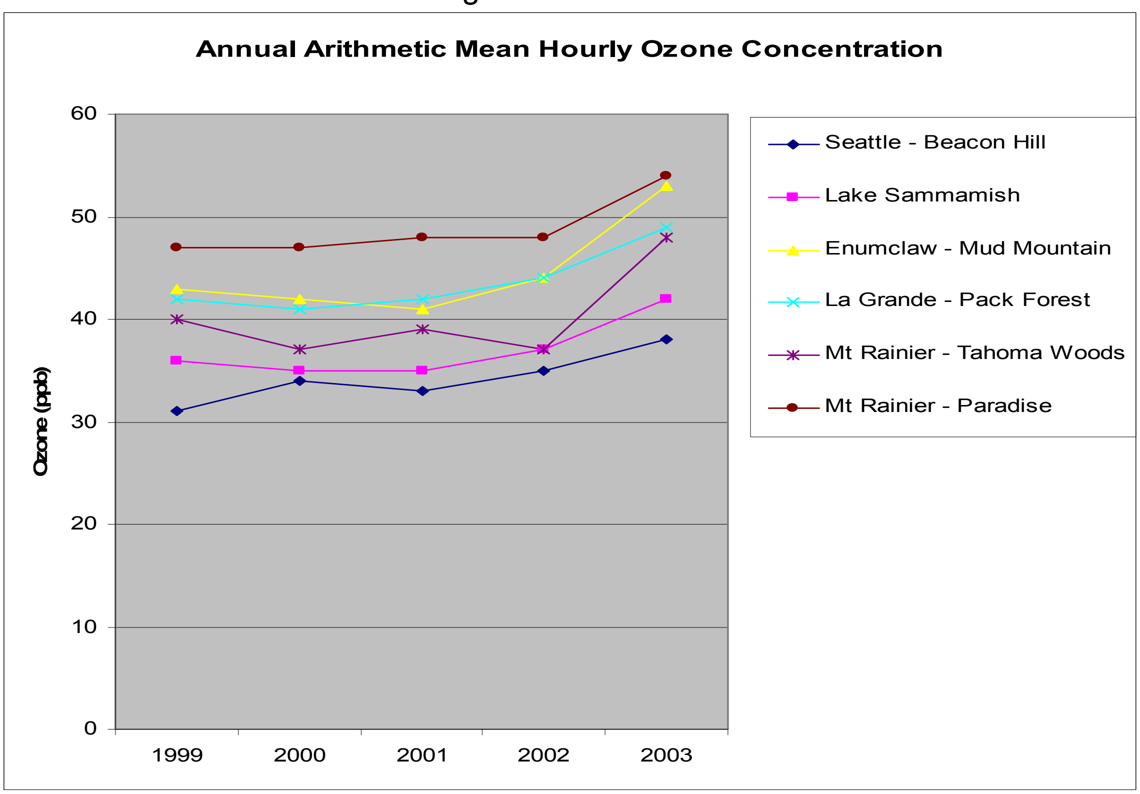

Figure 2: Annual arithmetic mean of hourly ozone concentrations at selected sites in the Puget Sound, based on data from the EPA Air Quality System (AQS) database - http://www.epa.gov/air/data/index.html

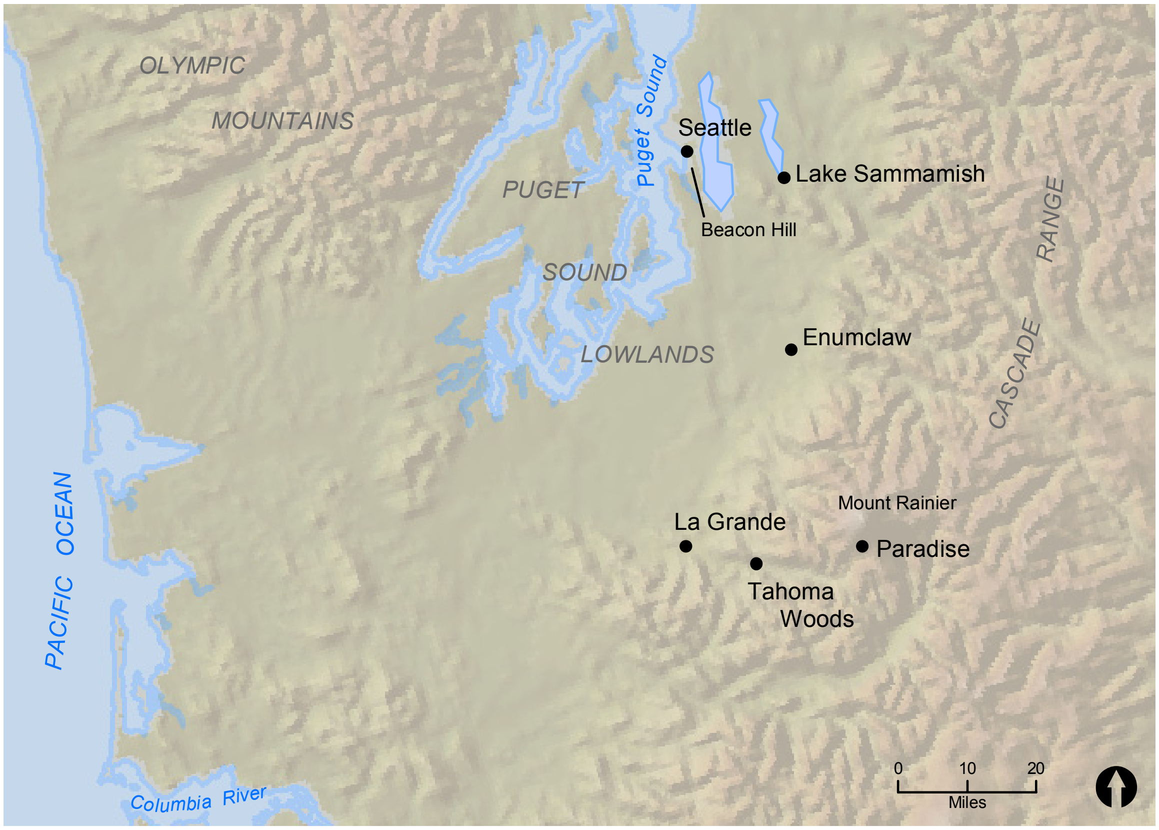

Figure 3: Locations of ozone monitoring sites from Figure 2.

The urban-VOC focused control strategy that shifts ozone from urban to rural areas is especially significant for Mount Rainier National Park where a pattern of elevated ozone with little diurnal variation (due, in part, to the absence of NO scavenging) is seen throughout the growing season at the Paradise monitoring site, with levels often exceeding 40 ppb. For example, Figure 4 shows a typical three day trace from August 2003 with little diurnal variation and chronic exposures at levels corresponding to between about 40 and 60 ppb.:

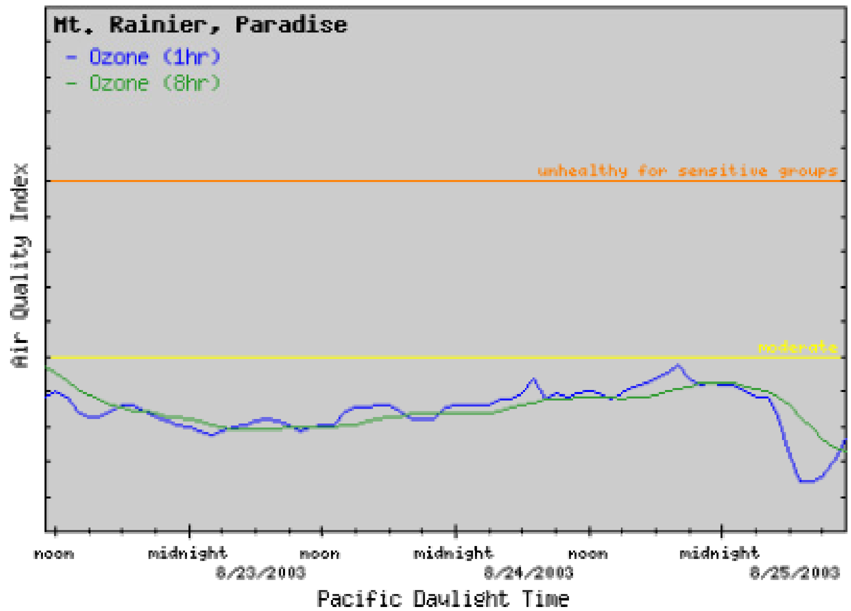

Figure 4: Unvalidated three day trace of 1 hour and 8 hour ozone levels at Paradise on Mount Rainier from the Washington Department of Ecology website.[1] The "Y" axis corresponds to EPA's Air Quality Index (AQI): the yellow line indicates an AQI of 50 which corresponds to 64 ppb; levels above an AQI of 50 are considered "moderate" and are a concern for people who are unusually sensitive to air pollution; the orange line indicates an AQI of 100 which corresponds to 84 ppb. Levels above an AQI of 100 (i.e., equal to or exceeding the 85 ppb standard) are considered "unhealthy for sensitive groups".[2]

Although these levels at Paradise do not threaten the federal ozone standard, they are significant ecologically, especially because of the lack of diurnal variation and relatively high concentrations during the morning hours when stomatal conductance is high and photosynthetic activity is greatest. Foliar injury on sensitive ponderosa pine in the San Bernadino mountains has been observed when the 24 hour average ozone concentrations were 0.05 to 0.06 ppm (EPA, 1996). In Europe, a cumulative indicator of ozone exposure above a 40 ppb threshold (AOT40) is used as a standard to protect crops and natural vegetation. EPA cites the threshold for visible injury for certain crops as an ozone exposure of 0.05 ppm for only several hours per day for more than 16 days. For trees and shrubs, the EPA identifies the limiting values for foliar injury as between 0.6 to 0.10 ppm for 4 hours (EPA, 1996).

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[1] Unvalidated data from Washington Department of Ecology website - https://fortress.wa.gov/ecy/aqp/Public/databypol.shtml

[2] Information on the AQI is from EPA's website - http://www.epa.gov/airnow/aqibroch/

In addition to chronic exposures, hourly ozone concentrations at Mount Rainier National Park can be among the highest in the state (e.g., 110 ppb measured at Tahoma Woods on July 24, 2004) and concentrations do occasionally exceed the 85 ppb 8 hour standard as shown in Figure 5:

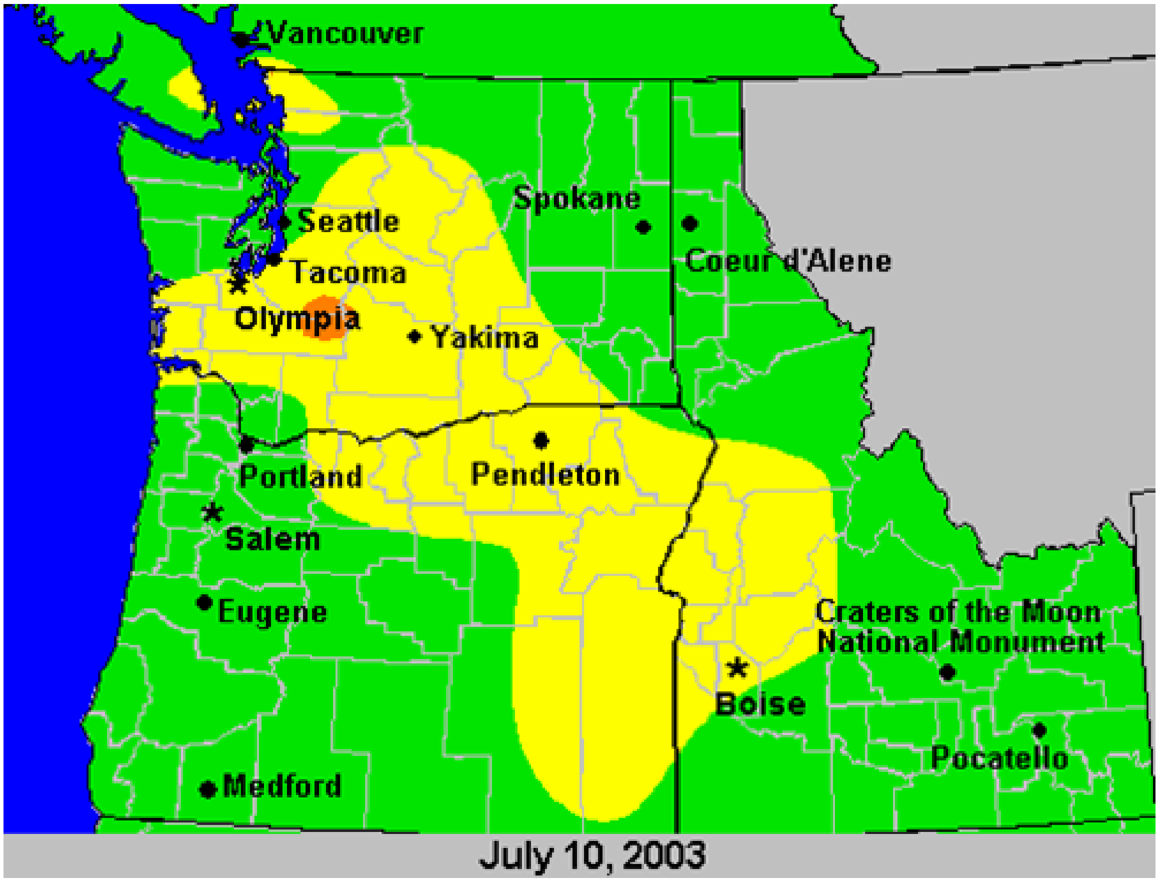

Figure 5: Ozone air quality index (AQI) map for July 10, 2003, from EPA AIRNow website - http://www.epa.gov/airnow/. The orange 'bulls-eye' over Mount Rainier represents an AQI of 101 or greater corresponding to ozone concentrations above the 8 hour standard of 0.08 ppm. The yellow areas represent an AQI of between 50 and 100 corresponding to values between 0.06 ppm and 0.08 ppm.

Re-evaluating the need for NOx reductions is especially important because of the trends discussed previously in trans-Pacific transport of emissions and growth in regional emissions. Small changes in background concentrations of ozone and ozone precursors could have a significant impact on the ability of the region to remain in attainment with the ozone standard[3] as illustrated by figure 6 based on Dan Jaffe's work (Parrish 2004):

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[3] Although the 85 ppb 8-hour ozone standard is occasionally exceeded, it has not yet been violated in the Northwest. A violation is based on the 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration.

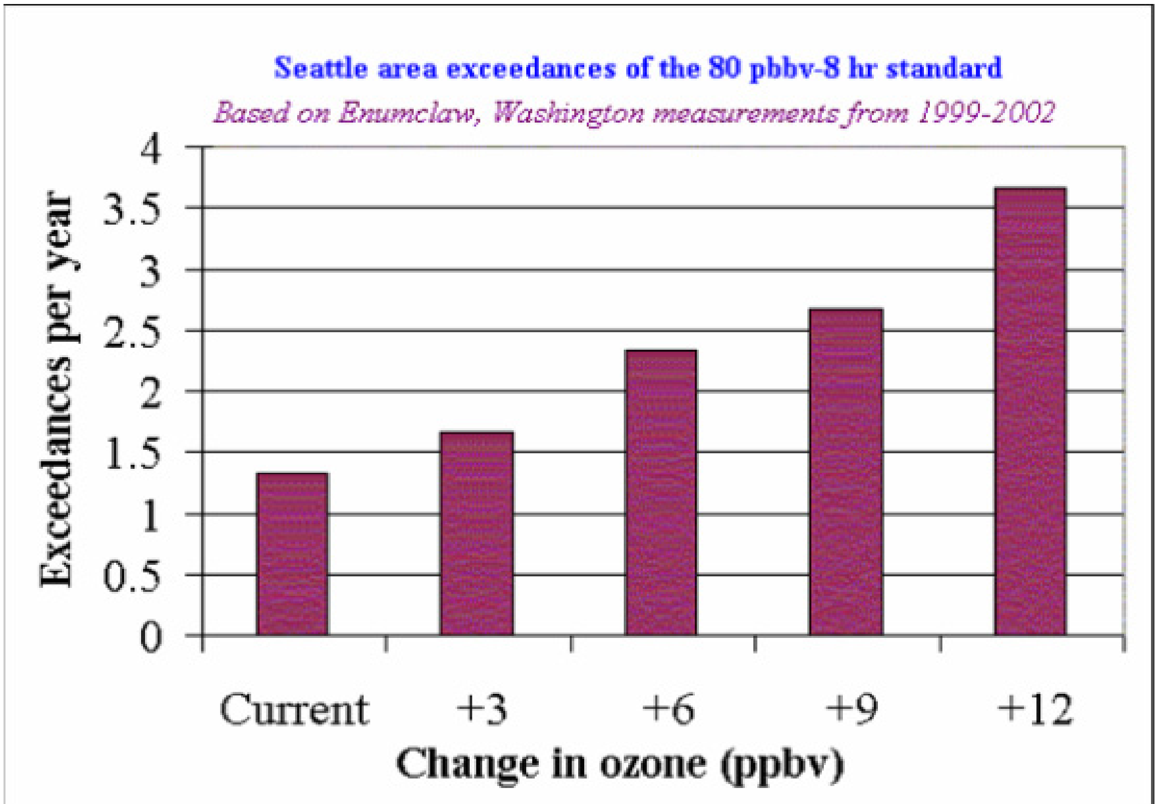

Figure 6: Effect of changes in background ozone levels on number of annual exceedances of the ozone standard at Enumclaw, Washington. Based on work by Dan Jaffe, University of Washington, Bothell, as presented by David Parrish, NOAA. A violation of the ozone 8-hour standard is based on the 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration.

This long range transport (LRT) may already be responsible for some measured exceedances of the standard in the Northwest. Dr. Jaffe's analysis of the June 6, 2003 ozone episode conjectures that long range transport played a role in the exceedance at Enumclaw that day, as shown below in Figure 7 (Parrish, 2004):

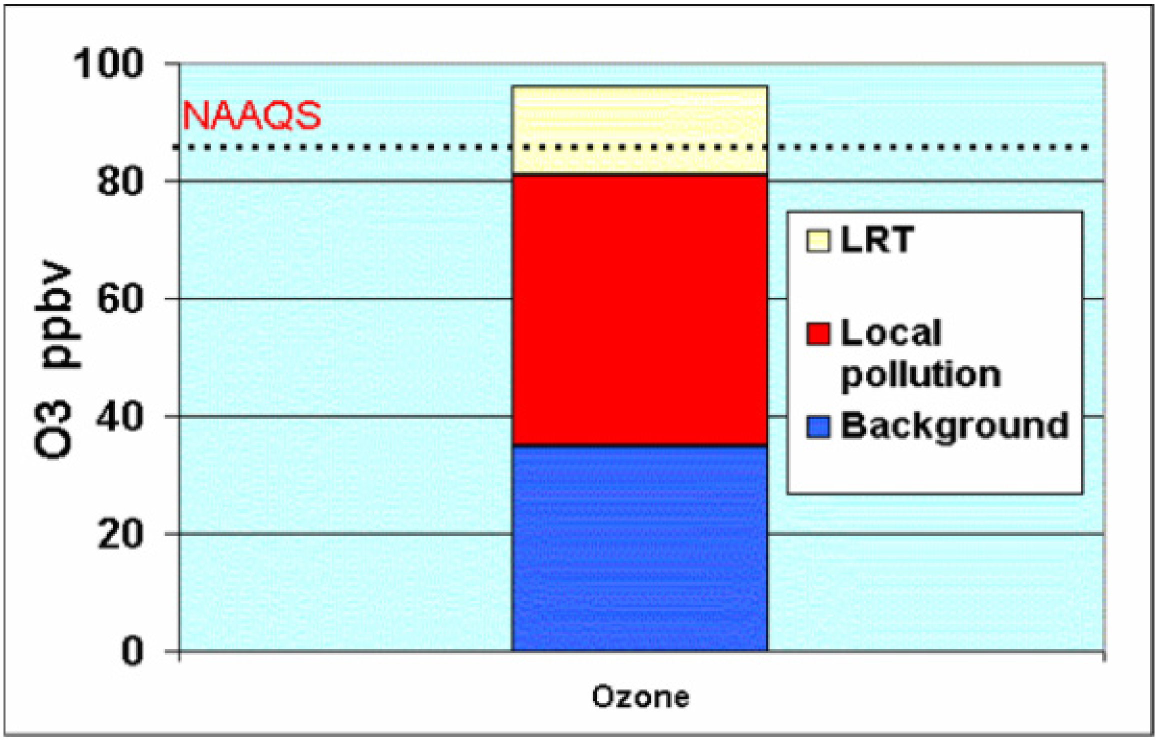

Figure 7: Role of long range transport (LRT) of emissions from Siberian forest fires on air quality June 6, 2003 at Enumclaw, Washington. Based on analysis by Dan Jaffe, University of Washington, Bothell, as presented by David Parrish, NOAA.

In addition, global climate change may also play a role in increasing ozone levels. Globally, the three hottest years on record have all been in the past six years – 1998, 2002, and 2003.[4] Temperatures in the Northwest have increased, on average, 1.5° F during the 20th century with the warmest decade occurring in the 1990s. Ozone formation increases as temperature increases. Warming is expected to continue at a likely rate of about 0.5° F/decade.[5]

2. Visibility: Atmospheric light extinction, a measure of visibility degradation, is caused in the Northwest primarily by sulfate, nitrate, and carbon aerosols. Nitrate aerosols from nitrogen emissions do not, on average, contribute the largest percentage to visibility degradation in the Northwest but still play a significant role, contributing about 6 to 14% of the fine mass at most federally protected sites on an annual basis. See, for example, figure 8.

[4] World Meteorological Organization
[5] Data on Northwest climate is from the University of Washington's Climate Impacts Group website - http://cses.washington.edu/cig/pnwc/pnwc.shtml.

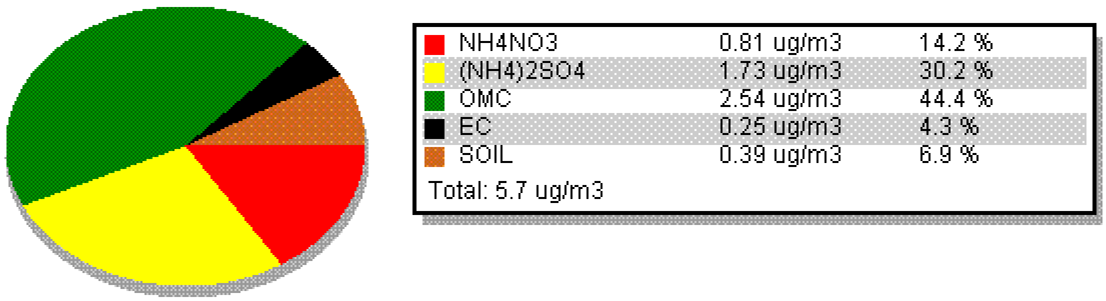

Figure 8: Fine mass contribution by species as an annual average in 2002 at the Olympic National Park IMPROVE site.

At some sites, though, secondary nitrates can contribute 20% of the fine mass and be the most significant cause of the visibility reduction, as an annual average. See, for example, Figure 9:

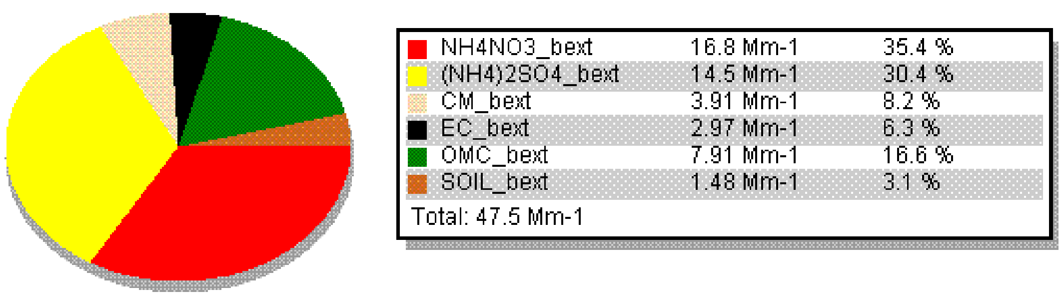

Figure 9: Percent contribution to visibility reduction, by species, as an annual average for 2001 at the Columbia River IMPROVE site.

On the worst visibility days, though, nitrates contribute a larger percentage to fine particle mass and to visibility degradation at most sites. On the worst visibility days, nitrates can contribute nearly half the fine mass and over half the visibility reduction. See for example Figures 10 and 11:

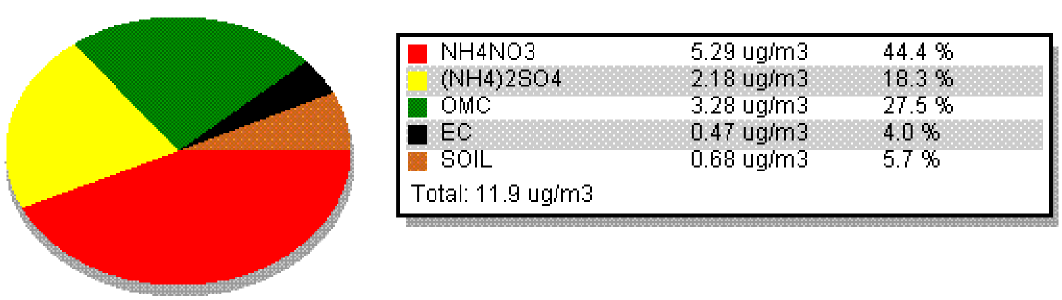

Figure 10: Fine mass contribution by species as an average of the 20% worst days in 2001 at the Columbia River IMPROVE site.

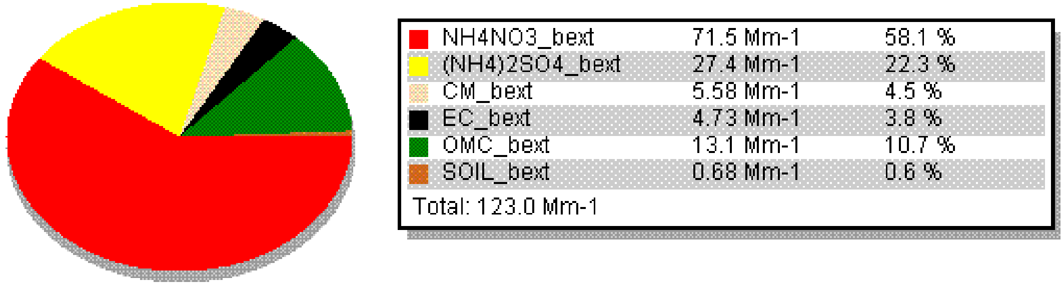

Figure 11: Percent contribution to visibility reduction, by species, as an average of the 20% worst days in 2001 at the Columbia River IMPROVE site.

Visibility has generally been improving in National Parks and Wilderness areas of the Northwest since the early 90s, especially on the 20% best days, and visibility is generally considered to be good. Within this good news story, though, there is cause for concern. Little or no improvement has occurred on the 20% worst days when nitrate generally plays a more significant role. And, despite a belief that air quality in general and visibility in particular is much better in the Northwest than in other parts of the country, some of our treasured public lands experience visibility no better than some of the most heavily polluted parks in Southern California such as Yosemite and Sequoia National parks. See Table 1 and Figure 12 for a comparison of annual standard visual range for several National Parks and USFS areas in the West:

	Standard Visual Range (km)			
	Annual Average	Best 20%	Mid 20%	Worst 20%
Sequoia National Park	91	193	72	38
Columbia Gorge	96	180	83	41
Snoqualmie Pass	140	248	126	70
Olympic National Park	142	242	121	77
Mount Rainier National Park	147	263	125	70
Yosemite National Park	148	268	126	61
Craters of the Moon	160	238	158	89
Three Sisters Wilderness	178	323	150	84
North Cascades National Park	188	310	172	97
Pasayten Wilderness	188	300	184	98
Crater Lake National Park	189	302	190	95
White Pass	219	325	219	120

Table 1: Standard visual range in kilometers for selected western sites from the VIEWS website – http://vista.cira.colostate.edu/views/. All data is for 2002 except for Sequoia NP which is 2001.

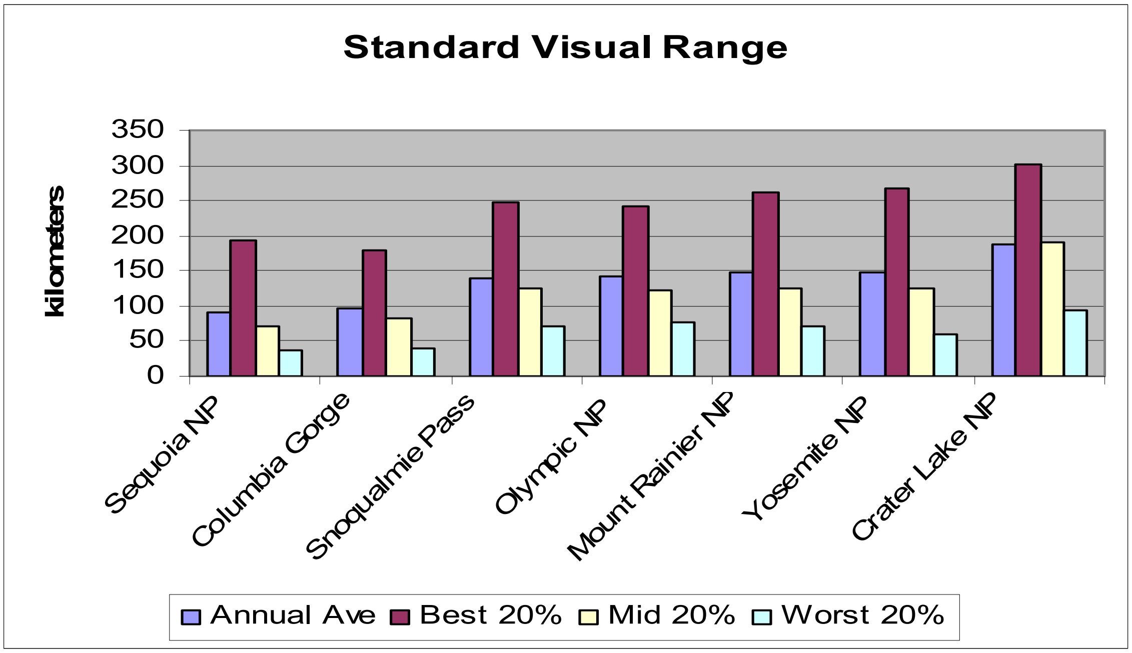

Figure 12: Selected sites from Table 1.

3. <u>Changes in Precipitation Due to Aerosol Pollution</u>: Both NOx and NH3 contribute to aerosol pollution. New research in California and Colorado is showing that aerosol pollution can significantly decrease rain and snow in mountainous regions downwind of urban centers. In California, eastward blowing aerosol pollution induces a precipitation deficit across the Sierra Nevada mountain range equal to about 1 trillion gallons of water a year.[6] Research done in Colorado showed that anthropogenic aerosols altered the microphysics of the lower orographic feeder clouds to the extent that the snow particle rime growth process was inhibited or completely shut off resulting in lower snow water equivalent precipitation (Borys, et al., 2003). These effects have profound implications for the economic health of the Northwest, as well as, implications for ecosystem health. These effects are likely to be devastating, especially when considered in combination with projected climate change impacts of shorter snow seasons and less total snow pack.

4. <u>Nitrogen Deposition</u>: Excluding urban areas, N deposition in the Northwest is generally low compared with deposition in other parts of the United States. Yet deposition is of concern to FLMs because of the sensitivity of some ecosystem components in the Northwest; the potentially extensive ecosystem impacts; and projections for increasing N deposition from a range of local, regional, and global sources. Forest ecosystems of the Pacific Northwest may be more sensitive to smaller additions of N than forests in other regions because Northwest forests

[6] Research by Daniel Rosenfeld of Hebrew University presented at the 2003 fall meeting of the American Geophysical Union in San Francisco, as reported in the December 13, 2003 issue of the Contra Costa Times - http://www.contracostatimes.com/mld/cctimes/news/7483219.htm?1c

are N limited, have not been subjected to intensive forest management practices, soils are shallow, and snowmelt is an important component of runoff (Eilers, 1994).

Annual wet N deposition reported by NADP (National Atmospheric Deposition Program) has been under 1.6 kg per ha each year at 8 of the 10 monitors in operation in the Pacific Northwest since the 1980s. Higher annual wet N deposition (up to 3.2 kg per ha) has been detected at only two monitors, Bull Run[7] and Marblemount. Significantly, these monitors are downwind of Portland and Seattle (and Vancouver, B.C.), respectively (Fenn 2003). Following is the NADP wet N deposition data from Marblemount (North Cascades National Park):

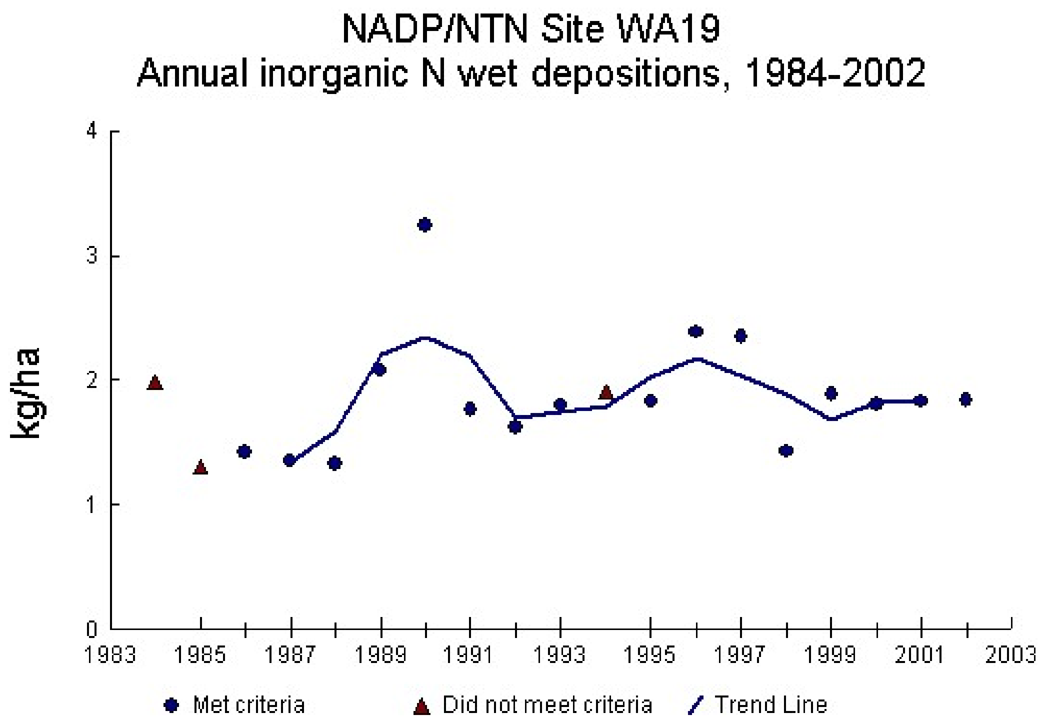

Figure 13: Annual wet N deposition at Marblemount Ranger Station, North Cascades National Park

Wet deposition is only part of the story, though. Total deposition is difficult to estimate and includes wet, dry, and cloud water deposition. The contribution from dry deposition from the CASTNet (Clean Air Status and Trends Network) site at Ross Dam near Marblemount is added to the wet deposition data from the NADP site at Marblemount and is presented in Figure 14.

[7] The Bull Run monitor was discontinued in October 2003. A nearby site in Washington, also downwind of Portland, began operating in May 2002.

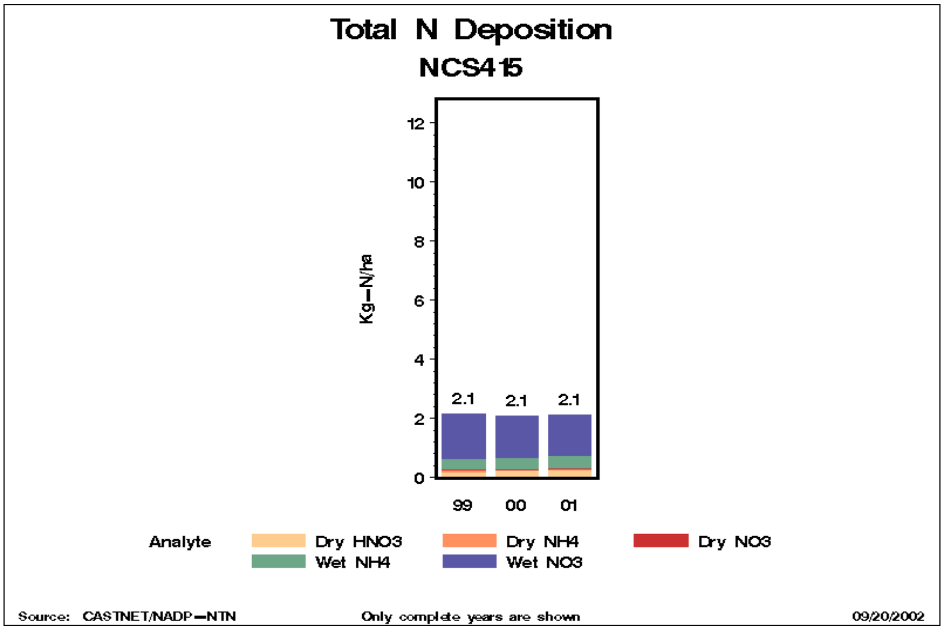

Figure 14: Annual wet and dry N deposition from Marblemount Ranger Station and Ross Dam in North Cascades National Park

But this is still only part of the total deposition picture. The lack of high elevation monitoring sites and cloud water measurements are major data gaps in the Northwest. Most monitors are located at relatively low elevations. Research shows that deposition generally increases with elevation; monitors at low elevations are likely to underestimate deposition at higher elevations. In a study over an elevational gradient in the Appalachian Mountains, cloud water deposition plus additional wet deposition due to increased precipitation at higher elevations resulted in deposition measurements 6-20 times greater compared with lower elevation sites (Baumgardner and others, 2003). Actual deposition (wet, dry, and occult or cloud) in the Cascades is likely to be many times greater than what is being measured in the lower elevation NADP and CASTNet monitoring sites.

Although N deposition values measured in the Northwest are generally much lower than are measured elsewhere in the country, there is evidence that these levels are already harming sensitive ecosystems. In the Northwest, sensitive organisms and communities respond to much lower input of N than seen elsewhere. Recent research (Geiser, in preparation), states that by the time nitrogen deposition reaches 2 kg/ha/yr, sensitive lichens are absent or sparse.

The Northwest has widespread populations of pollution-sensitive lichens that make important contributions to mineral cycling and soil fertility and are an integral part of the food web for large and small mammals, insects and birds. (Fenn et al., 2003) Some areas of the Northwest already exceed nitrogen deposition levels that are detrimental to some species of lichens over the long term as illustrated in figure 15 by the absence of pollution sensitive lichen species and the presence of nitrogen-loving lichen species.

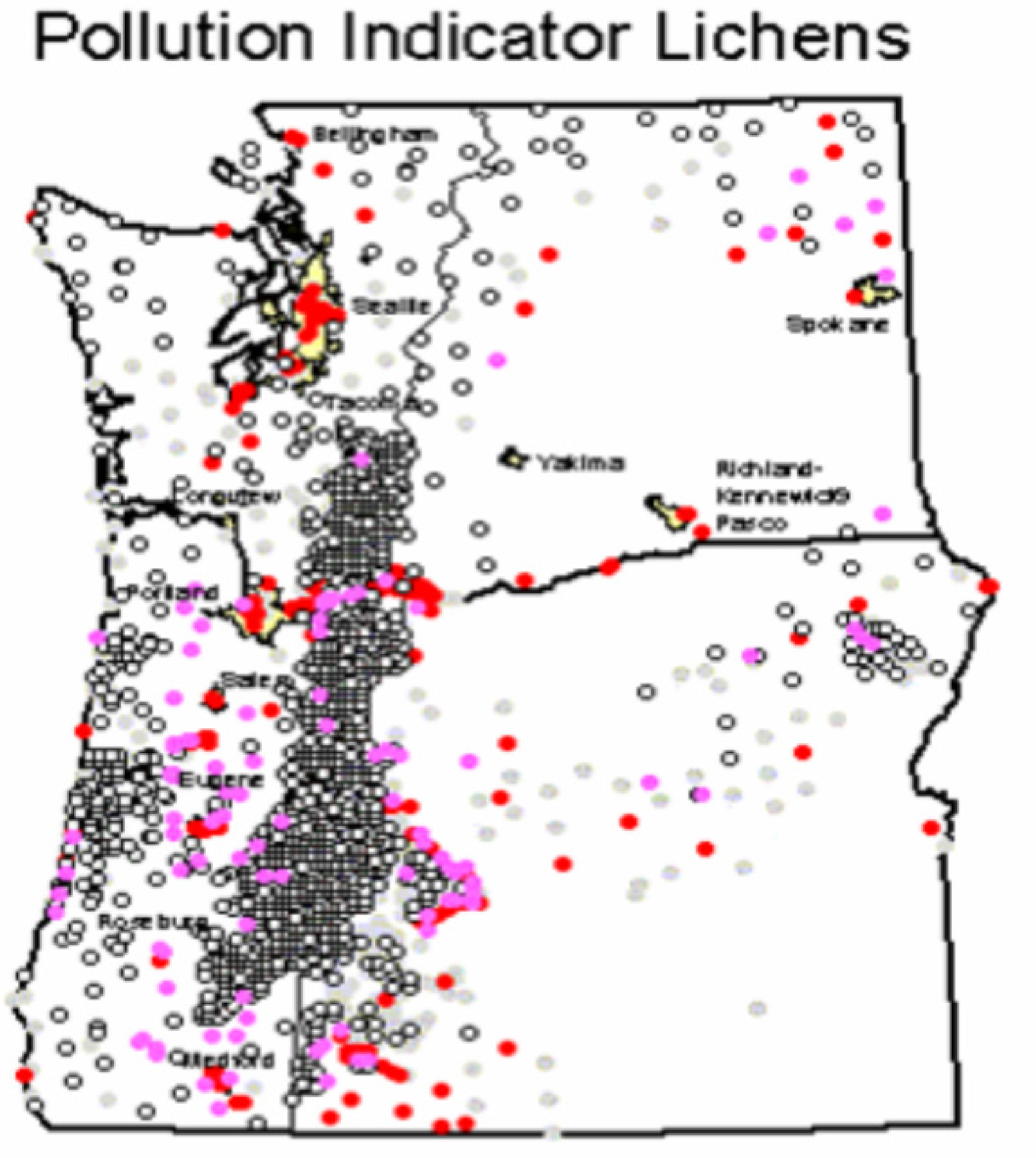

Figure 15: Red dots show locations where pollution loving or nitrophylouss species are present. Pink dots show locations where both nitrophilous and pollution-sensitive species are present. Open dots show where pollution-sensitive species were found and gray dots indicate that no special category species are present. The most commonly collected species were *Platismatia glauca, Hypogymnia inactiva, Alectoria sarmentosa* and *Letharia vulpina*, although 10 broadly distributed species were used in all (Geiser and Neitlich, 2003).

Nitrogen is a critical nutrient for many plant metabolic processes. Long-term deposition of elevated levels of nitrogen compounds may affect soil microbiological processes, resistance to insects and pathogens, winter injury in conifers, and foliar leaching. Perhaps more important are the potential effects of long-term nitrogen deposition on ecosystem structure and diversity. Nitrogen is a potential fertilizer that can be assimilated preferentially by some plant species; for example, plant species in a nitrogen limited system may be replaced by species that are better able to utilize nitrogen. Significant changes in alpine species composition have been recorded over the past two to five decades in the Rockies. These changes are suggestive of a biological response to six decades of elevated N deposition. In addition, several lines of evidence suggest that N deposition may be contributing to greater fuel loads and thus altering the fire cycle in a variety of ecosystem types (Fenn et al., 2003).

Nitrogen deposition can also lead to eutrophication, or increased lake productivity, associated with increasing nutrient loads to the lake. Alpine ecosystems of the Northwest are generally oligotrophic, poorly buffered and highly sensitive to acidic deposition and eutrophication (Eiler, 1994). Increasing nutrient loads stimulate growth of algae and other aquatic plants, which results in decreased lake transparency and oxygen depletion. Soils are also affected by N enrichment changing both the diversity and functioning of mycorrhizal fungi.

Nitrogen deposition is also associated with episodic acidification of surface waters associated with rapid release of accumulated NO_3^- in runoff from melting snow. Episodic acidification may be of particular concern because of the relative importance of nitrogen deposition and the extreme episodic nature of inputs from large snowmelt events and the rapid hydrologic response of watersheds in the Northwest. The acidification of soils and surface waters can contribute to increased mobilization and availability of aluminum which can be highly toxic to aquatic life.

Summary:

NOx and NH3 emissions can contribute to visibility impairment, ozone formation downwind of urban areas, and ecosystem degradation, including lake, stream, and soil acidification, eutrophication of lakes and streams, and changes in soil chemistry and vegetation. Alpine ecosystems of the Northwest are known to be oligotrophic, poorly buffered and highly sensitive to acidic deposition and eutrophication. The Northwest has widespread populations of pollution-sensitive lichens that make important contributions to mineral cycling and soil fertility and are an integral part of the food web for large and small mammals, insects and birds. Some areas of the Northwest already exceed nitrogen deposition levels that are detrimental to lichens over the long term and have lost sensitive lichen species.

Although stricter tailpipe emissions standards and the gradual phase-in of newer, cleaner vehicles will result in lower NOx emissions, this may be offset by continued growth in the region, significant increases in marine vessel and truck emissions, and by increases in NH3 emissions from agricultural sources and from late model vehicles equipped with three way catalysts. Further, Asian emissions of NOx may be as much as 25-50% of background levels and are projected to double again in the next 20 to 30 years (Fenn 2003).

Regulatory efforts to decrease nitrogen emissions will have the triple benefit of decreasing concentrations of tropospheric ozone (which harms both humans and plants), reducing the eutrophying impacts of elevated nitrogen deposition in aquatic and terrestrial ecosystems, and reducing fine particulate pollution and regional haze. This will result in considerable benefits for human and ecosystem health. However, to make serious improvements in air quality and to reduce nitrogen deposition inputs and effects on sensitive ecosystems, reductions of NOx emissions from traditional point sources such as power plants will not be sufficient. It will be necessary to reduce on-road and non-road mobile emissions sources which emit up to 90% of the NOx in urban areas of the Northwest and to reduce ammonia emissions from agriculture, an important but poorly quantified source of nitrogen in some areas.

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