Nitrogen Critical Loads in the Pacific Northwest, USA: Current Understanding and Data Gaps

Tonnie Cummings – National Park Service, Pacific West Region

Tamara Blett and Ellen Porter - National Park Service, Air Resources Division

Linda Geiser and Rick Graw – U.S. Forest Service, Pacific Northwest Region Air Program

Jill McMurray – U.S. Forest Service, Northern Region Air Program

Steven Perakis – U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center

Regina Rochefort – National Park Service, North Cascades NP

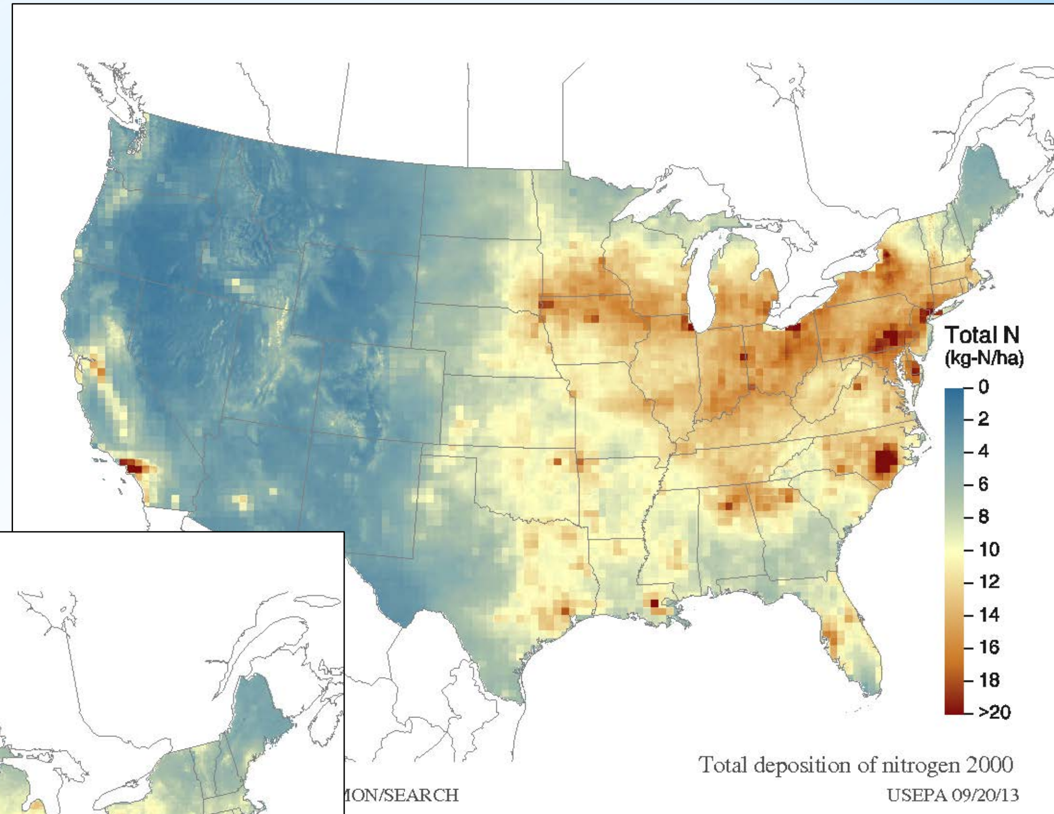
Definitions

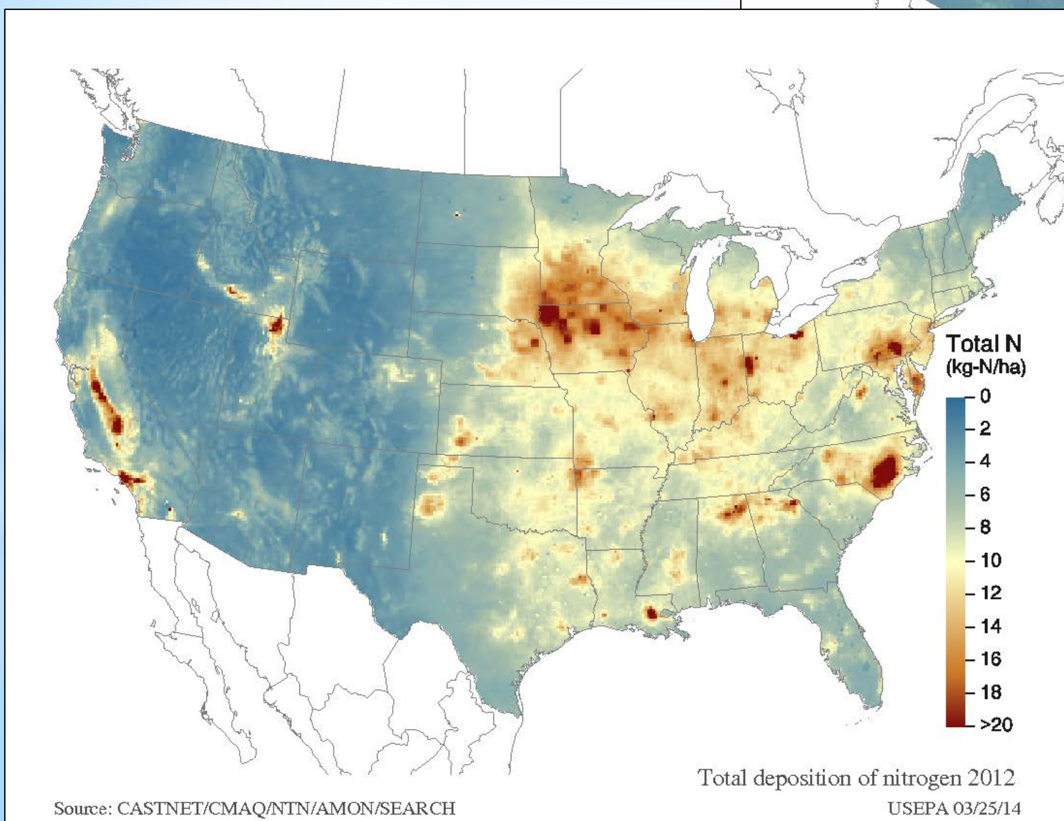
- A critical load is based on studies or modeling and is the amount of pollution below which harmful environmental effects are not expected to occur. (Science-based)

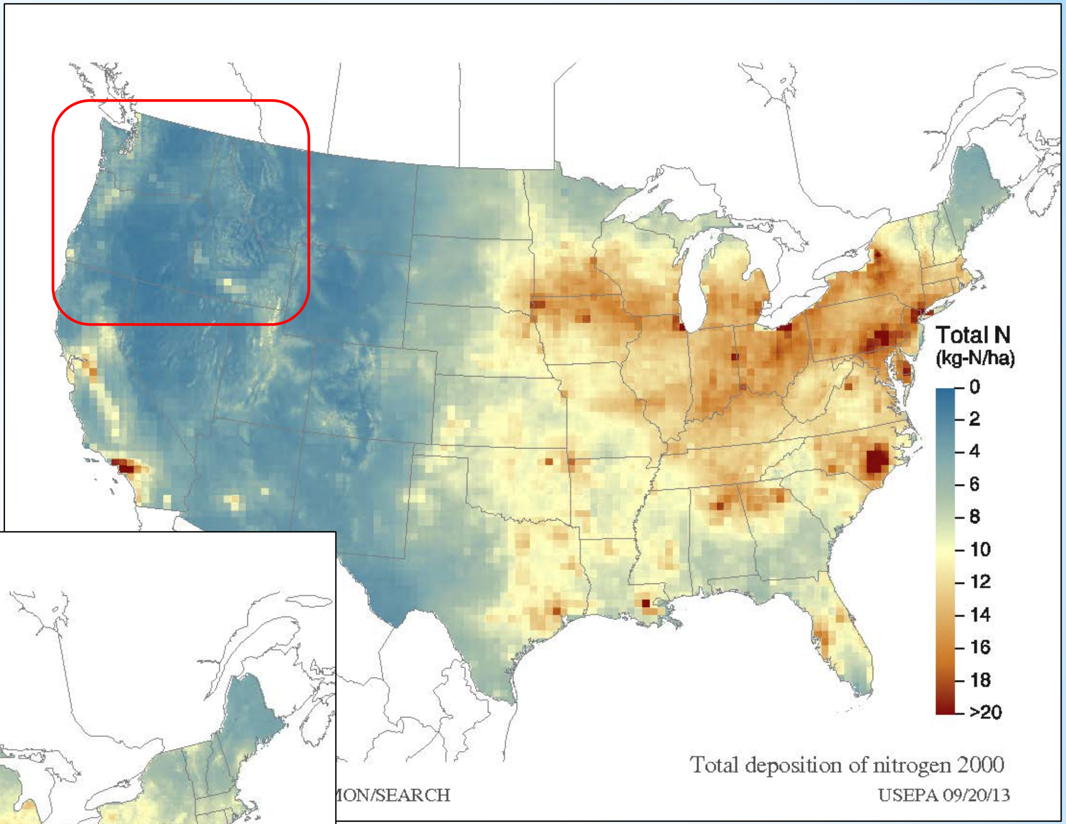
- A target load identifies an acceptable amount of pollution and is based on policy, economic, temporal, or other considerations. A target load may be higher or lower than a critical load. (Management decision)

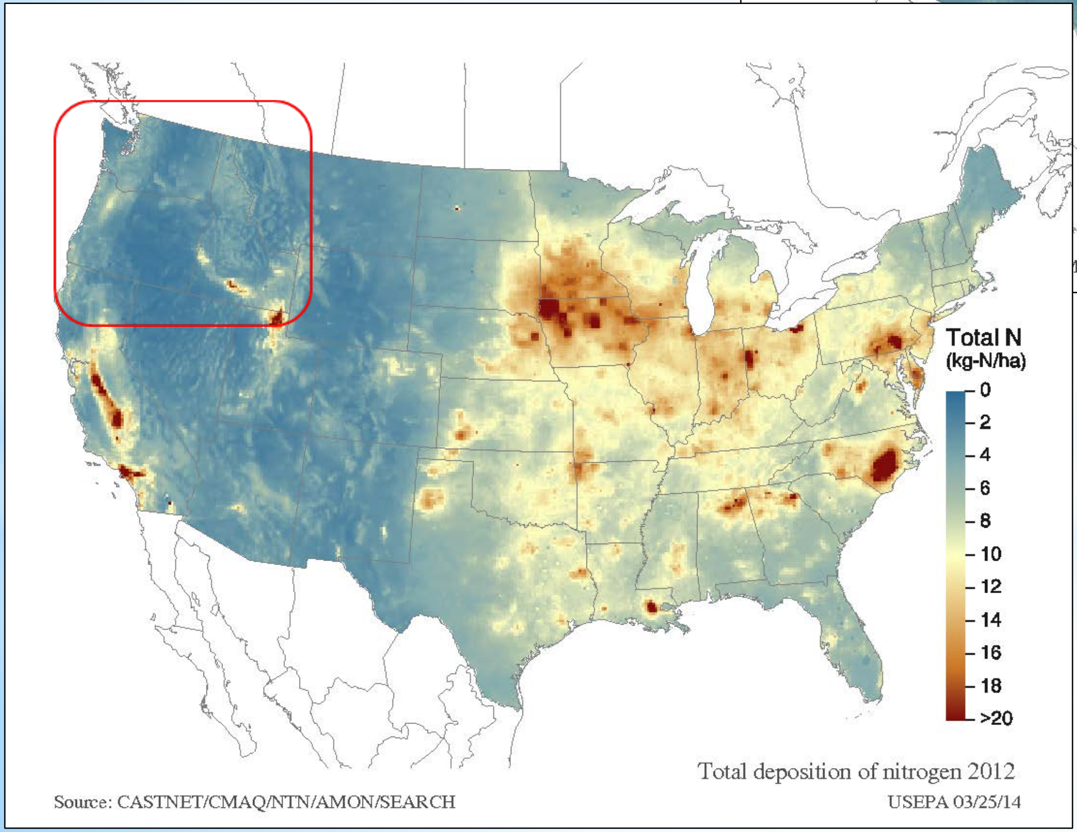
Why Did We Do This?

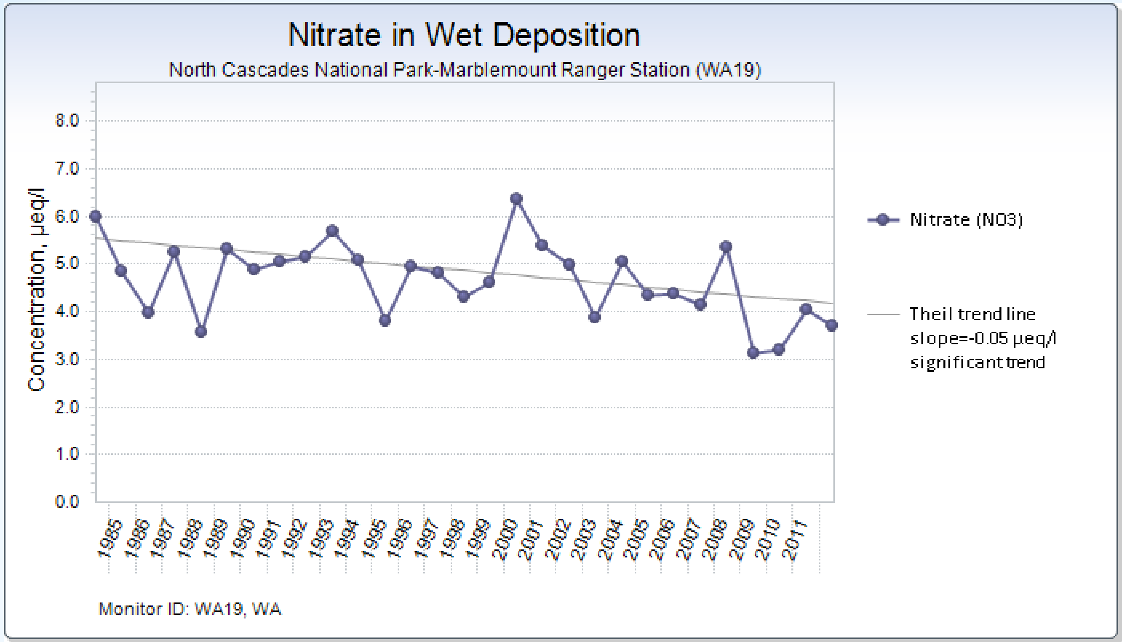
- NPS and USFS manage areas in Idaho, Oregon, and Washington with known or suspected nitrogen-sensitive resources and the agencies are mandated to protect those resources.
- A Pacific Northwest (PNW) Critical Loads Workshop in 2006 determined nitrogen deposition was a greater concern than sulfur deposition in the region.
- The 2011 report by Pardo et al. summarizing nitrogen critical loads nationwide concluded PNW-specific data were limited.
- While nitrogen deposition is relatively low in the PNW, studies from other areas, e.g., Rocky Mountain NP, found ecosystem effects at low deposition.
- several NADP sites in the region show decreasing trends in nitrate concentration, but no decline in ammonium concentration.

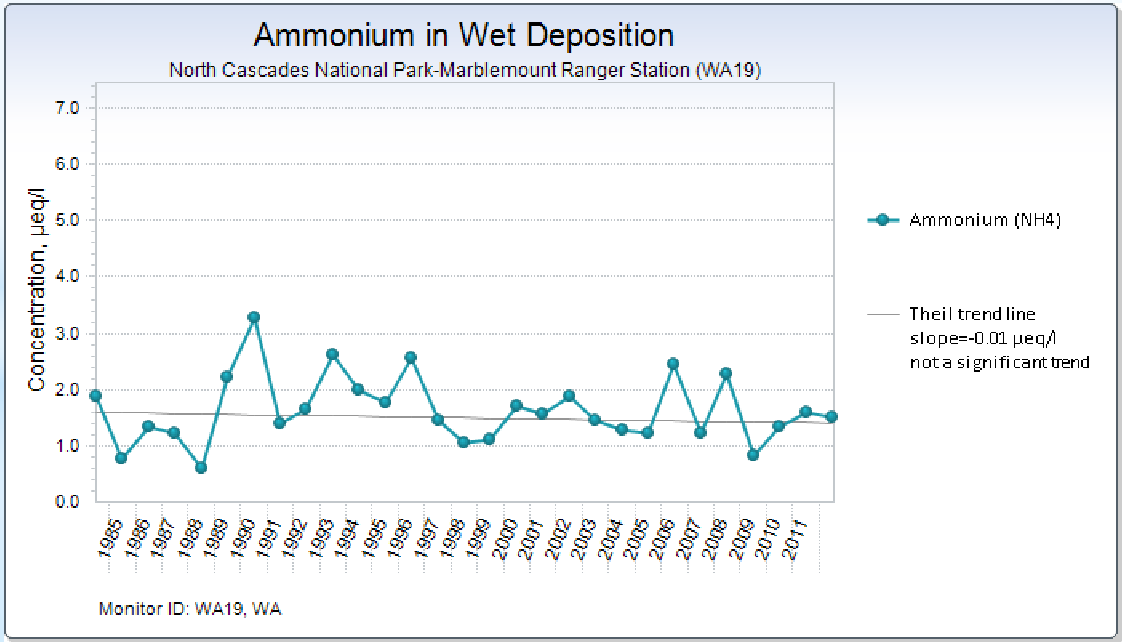

Total N
(kg-N/ha)
0
2
4
6
8
10
12
14
16
18
>20
Total deposition of nitrogen 2000
USEPA 09/20/13


Total N
(kg-N/ha)
0
2
4
6
8
10
12
14
16
18
>20
Total deposition of nitrogen 2012
Source: CASTNET/CMAQ/NTN/AMON/SEARCH
USEPA 03/25/14


Total N
(kg-N/ha)
0
2
4
6
8
10
12
14
16
18
>20
Total deposition of nitrogen 2000
ION/SEARCH
USEPA 09/20/13


Total N
(kg-N/ha)
0
2
4
6
8
10
12
14
16
18
>20
Total deposition of nitrogen 2012
Source: CASTNET/CMAQ/NTN/AMON/SEARCH
USEPA 03/25/14

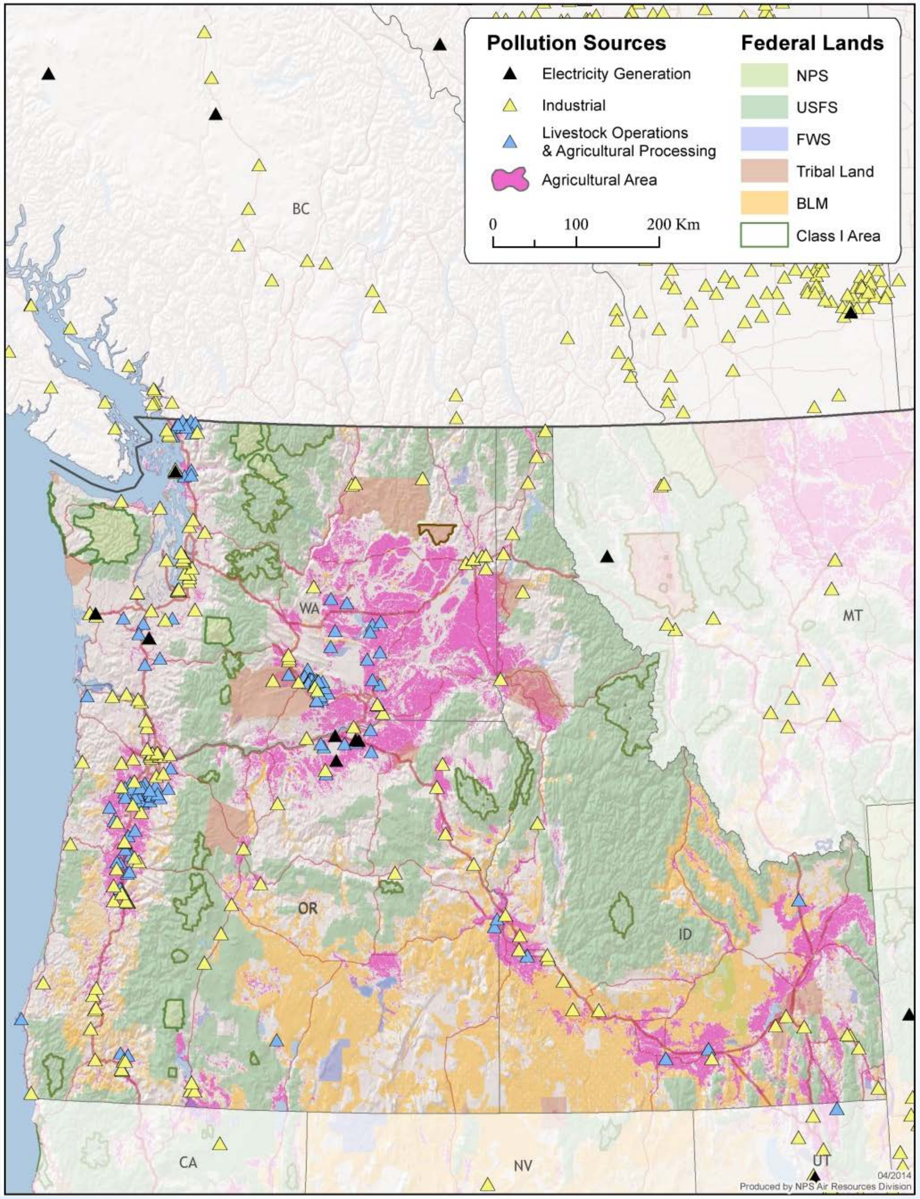

Nitrate in Wet Deposition
North Cascades National Park-Marblemount Ranger Station (WA19)
Concentration, µeq/l
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Nitrate (NO3)
Theil trend line
slope=-0.05 µeq/l
significant trend
Monitor ID: WA19, WA


Ammonium in Wet Deposition
North Cascades National Park-Marblemount Ranger Station (WA19)
Concentration, µeq/l
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Ammonium (NH4)
Theil trend line
slope=-0.01 µeq/l
not a significant trend
Monitor ID: WA19, WA

Strategy

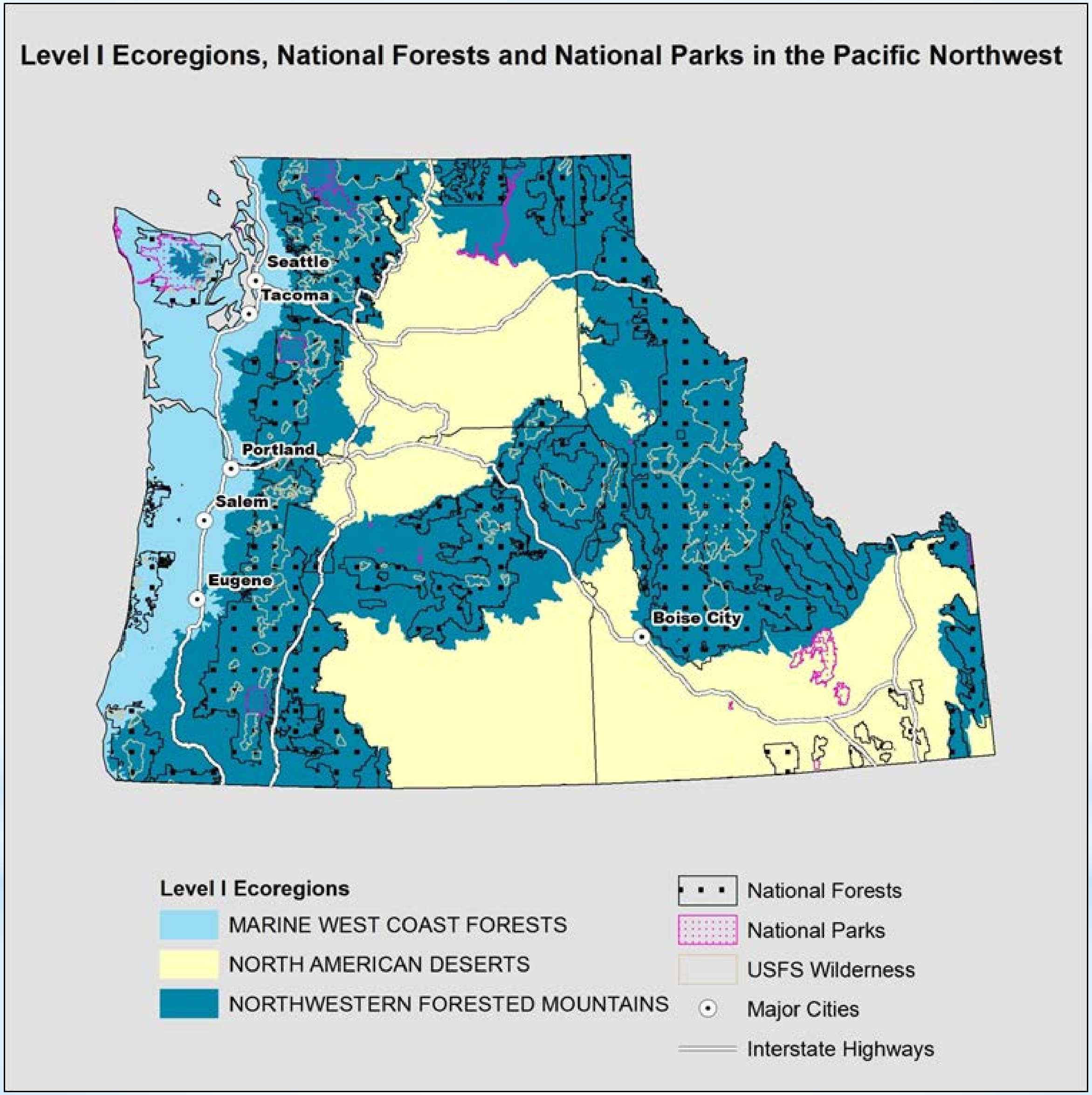
- We developed an approach for identifying and using nitrogen critical loads and target loads in the PNW.
- The first objective of the strategy was to publish a “state of knowledge” report that:
  - Discusses legal mandates for air quality protection
  - Describes the concept and use of critical and target loads
  - Summarizes current understanding about sources, deposition, effects, and critical loads in the region
  - Highlights current research efforts
  - Identifies and prioritizes additional data needs
  - Is useful to both subject matter experts and “lay” audiences

Map of Federal/Tribal Lands and Air Pollution Sources in the Region



Triangles designate sources that emit 100 tons per year or more of NO_x

Critical Loads Information is Organized by Ecoregion



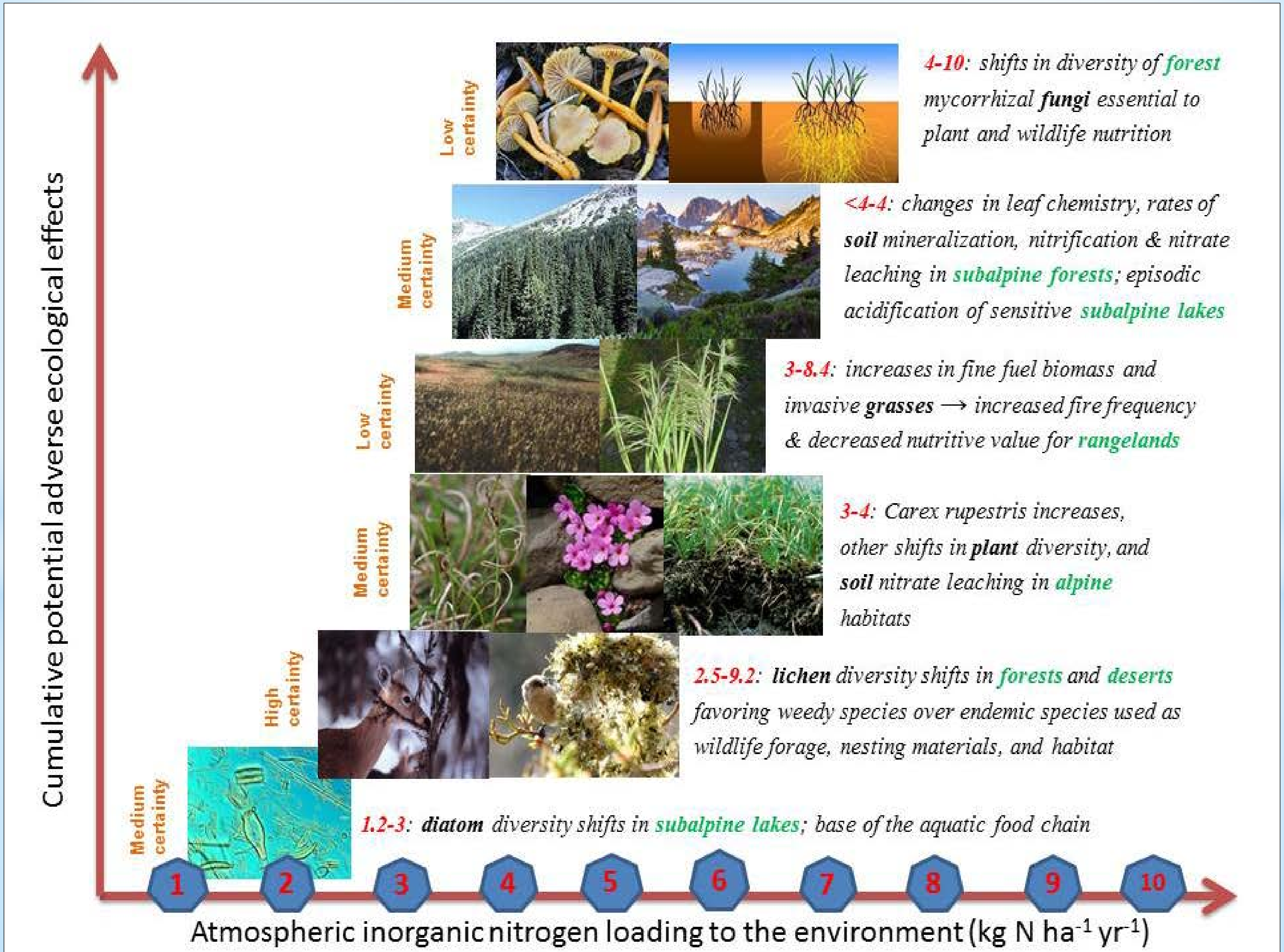
Nitrogen Critical Loads Most Representative of the PNW

Critical Load	Deposition Measure	Ecosystem Effect	Ecoregion/Area	Reliability for PNW	Reference
1.2	Wet N (PRISM corrected NADP)	Nutrient enrichment (diatoms)	Marine West Coast Forests/Washington	High	Sheibley et al., 2014
2.5-7.1	CMAQ modeled total N	Lichen community changes (40 percent composition of eutrophic species)	Northwestern Forested Mountains/Oregon and Washington	High	Geiser et al., 2010
2.7-9.2	CMAQ modeled total N	Lichen community changes (40 percent composition of eutrophic species)	Marine West Coast Forests/Oregon and Washington	High	Geiser et al., 2010
3	Modeled N	Lichen thallus N concentrations; cover of eutrophic lichens	North American Deserts/Columbia Plateau	Low	Geiser et al., 2008
3-8	Passive samplers and bulk deposition	Increase in cheatgrass and decrease in native forbs	North American Deserts/Upper Columbia Basin	Medium	Apel et al., 2014
3.1-5.2	N as canopy throughfall	Lichen community composition and sensitive species response	Northwestern Forested Mountains/ Oregon and Washington	Medium	Fenn et al., 2007
4	N as canopy throughfall	Lichen sensitive species response	Northwestern Forested Mountains/Montana and Wyoming	High	McMurray et al., 2013

Nitrogen Critical Loads Most Representative of the PNW

Critical Load	Deposition Measure	Ecosystem Effect	Ecoregion/Area	Reliability for PNW	Reference
1.2	Wet N (PRISM corrected NADP)	Nutrient enrichment (diatoms)	Marine West Coast Forests/Washington	High	Sheibley et al., 2014
2.5-7.1	CMAQ modeled total N	Lichen community changes (40 percent composition of eutrophic species)	Northwestern Forested Mountains/Oregon and Washington	High	Geiser et al., 2010
2.7-9.2	CMAQ modeled total N	Lichen community changes (40 percent composition of eutrophic species)	Marine West Coast Forests/Oregon and Washington	High	Geiser et al., 2010
3	Modeled N	Lichen thallus N concentrations; cover of eutrophic lichens	North American Deserts/Columbia Plateau	Low	Geiser et al., 2008
3-8	Passive samplers and bulk deposition	Increase in cheatgrass and decrease in native forbs	North American Deserts/Upper Columbia Basin	Medium	Apel et al., 2014
3.1-5.2	N as canopy throughfall	Lichen community composition and sensitive species response	Northwestern Forested Mountains/ Oregon and Washington	Medium	Fenn et al., 2007
4	N as canopy throughfall	Lichen sensitive species response	Northwestern Forested Mountains/Montana and Wyoming	High	McMurray et al., 2013

Cumulative Effects of Nitrogen Deposition in the Region



Current PNW Nitrogen Critical Loads Projects

Organization	Objective	Locations	Results Expected
University of Washington	Document effects of N fertilization on alpine/subalpine communities.	One site each at Mount Rainier, North Cascades, and Olympic National Parks	2015
University of Washington	Document N effects on mycorrhizal fungi in alpine/subalpine soil.	One site each at Mount Rainier and North Cascades National Parks	2014
Washington State University	Evaluate the response of three subalpine plant communities to N deposition.	One site at Mount Rainier NP	2015
USFS	Refine N CLs for changes in lichen communities using lichen N concentrations, IMPROVE data, and direct measurements of throughfall.	5,000 surveys in Idaho, Oregon, and Washington	northern Idaho, eastern Oregon and Washington in 2014 western Oregon and Washington in 2015
Washington State University, University of Wyoming, and USFS	Use N isotope ratios in lichens and NADP data to identify N emission sources and map deposition of N and ammonium vs. nitrate.	About 200 survey sites throughout the northwestern U.S. including Idaho, Oregon, and Washington	2016
Washington State University	Conduct nutrient enrichment studies in high elevation lakes to determine diatom N CLs.	Three sites each in Mount Rainier, North Cascades, and Olympic National Parks	2015
Washington State University	Use existing data to determine the influence of presence/absence of permanent snow or ice in the watershed on the water chemistry of high elevation lakes.	108 lakes at North Cascades NP	2014
Washington State University	Use existing data to develop and test models to predict lake sensitivity to N deposition.	108 lakes at North Cascades NP	2015
USGS Powell Center	Analyze FIA soils, understory vegetation, and tree data to better understand forest vegetation responses to N deposition.	About 500 surveys in Oregon and Washington	2016
USGS Powell Center	Analyze FIA soils, and tree and soil chemical data, to better understand forest biogeochemical response to N deposition.	All existing FIA and published available data for Oregon and Washington	2017

Current PNW Nitrogen Critical Loads Projects

Organization	Objective	Locations	Results Expected
University of Washington	Document effects of N fertilization on alpine/subalpine communities.	One site each at Mount Rainier, North Cascades, and Olympic National Parks	2015
University of Washington	Document N effects on mycorrhizal fungi in alpine/subalpine soil.	One site each at Mount Rainier and North Cascades National Parks	2014
Washington State University	Evaluate the response of three subalpine plant communities to N deposition.	One site at Mount Rainier NP	2015
USFS	Refine N CLs for changes in lichen communities using lichen N concentrations, IMPROVE data, and direct measurements of throughfall.	5,000 surveys in Idaho, Oregon, and Washington	northern Idaho, eastern Oregon and Washington in 2014 western Oregon and Washington in 2015
Washington State University, University of Wyoming, and USFS	Use N isotope ratios in lichens and NADP data to identify N emission sources and map deposition of N and ammonium vs. nitrate.	About 200 survey sites throughout the northwestern U.S. including Idaho, Oregon, and Washington	2016
Washington State University	Conduct nutrient enrichment studies in high elevation lakes to determine diatom N CLs.	Three sites each in Mount Rainier, North Cascades, and Olympic National Parks	2015
Washington State University	Use existing data to determine the influence of presence/absence of permanent snow or ice in the watershed on the water chemistry of high elevation lakes.	108 lakes at North Cascades NP	2014
Washington State University	Use existing data to develop and test models to predict lake sensitivity to N deposition.	108 lakes at North Cascades NP	2015
USGS Powell Center	Analyze FIA soils, understory vegetation, and tree data to better understand forest vegetation responses to N deposition.	About 500 surveys in Oregon and Washington	2016
USGS Powell Center	Analyze FIA soils, and tree and soil chemical data, to better understand forest biogeochemical response to N deposition.	All existing FIA and published available data for Oregon and Washington	2017

High Priority Data Needs Relative to Nitrogen Critical Loads in the PNW

Ecosystem	Information Needed	Rationale	Approach	Priority
Regionwide				
Aquatic/Terrestrial	Improved site-specific estimates of N deposition.	There are few deposition monitoring sites in the PNW and there are very few high elevation data.	Focusing on areas/resources with suspected high sensitivity, collect N deposition data.	High
Aquatic/Terrestrial	Identify interactions of N deposition and climate change that affect surface waters, soils, and vegetation.	Excess N deposition may exacerbate climate change-induced stress on species and ecosystems in many ways.	Conduct N fertilization experiments along climate gradients.	High
Marine West Coast Forests and Northwestern Forested Mountains				
Aquatic/Terrestrial	Determine the influence of natural lake, stream, and soil N levels on CLs.	Some lakes, streams, and soils in the PNW naturally have very high N levels due to N-fixing alders and geologic N sources.	Use background soil N gradients, fertilization studies or air pollution gradients to identify CLs.	High
Aquatic	Refine sensitivity ranges for high elevation lakes to N deposition.	There is a great deal of uncertainty regarding the number of lakes in the PNW that are more responsive to added N than to addition of other nutrients.	Use existing data to determine the percentage of lakes that are N-limited.	High
North American Deserts				
Terrestrial	Identify CLs for vegetation.	There is currently little information specific to the PNW.	Use fertilization studies and/or N deposition gradients.	High
Terrestrial	Determine N sensitivity of desert biological soil crusts.	Crusts are a critical component of the ecosystem because they stabilize soils, fix atmospheric N, and promote establishment of vascular plants.	Use fertilization experiments and/or N deposition gradients to identify and monitor sensitive lichen and moss species in crusts.	High

Strategy – Next Steps

- Publish a report that summarizes the state of knowledge on nitrogen critical loads in the PNW.
- Encourage and support nitrogen critical loads research.
- Develop a common rationale for determining target loads.
- Develop maps showing any areas that exceed critical loads and/or target loads.
- Solicit input from EPA, state air quality agencies, and other stakeholders.
- Implement use of critical loads and target loads through agency planning and policy mechanisms.
- If nitrogen critical loads/target loads are exceeded, work with stakeholders to identify sources that contribute to exceedances and achieve emission reductions.

Questions?

Tonnie_Cummings@nps.gov or 360-816-6201