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Review of "Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options"

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First, this document an excellent holistic view of the N-cascade and numerous negative environmental impacts of excess N in air, land, and water, and will be a foundation for finally addressing the issues in a comprehensive and effective manner.

As a reviewer, my main area of expertise is the impacts of atmospheric N-deposition on biodiversity (mainly in California) and the practical means to address the impacts in the short-term and long-term. I think a little more material on biodiversity impacts and policy responses would be a critical addition to the document, since the effects are a "1" in relevance. There is also some innovative processes, including Endangered Species Act consultations, underway that should be noted somewhere in the report (but I realize that I am providing far more background than could go into the document itself).

Review work by Fenn et al. (2003) compiled numerous impacts of N-deposition on biodiversity in the western US. Some of these include:

1) Loss of coastal sage scrub (CSS) in Southern California to invasions by annual grasses and subsequent changes in fire frequency, leading to losses of shrub cover and conversion to weedy annual grassland. CSS has already been reduced by ~90% due to urban and agricultural development and supports dozens of threatened and endangered species.
2) Invasion of desert scrub by annual grasses that create fine fuel loads that can carry fire across miles of desert lands, in places where such fires were nearly unheard of until recent decades. These fires threaten life and property in addition to converting rich desert scrub to weedy annual desert grassland.
3) Combined effects of ozone and N-deposition in Southern California montane conifer forests lead to changes in species composition, physiological disruption (needle lifetimes of < 1 year and continual buildup of litter), and increased fire risk, on top of climatic stresses.
4) Groundwater and surface discharges from heavily polluted watersheds in the LA Basin have extremely high levels of nitrate, including storm pulses and baseflow.
5) Atmospheric deposition on the order of 8-20 kg-N/ha/yr in the San Francisco Bay Area leads to annual grass invasions of nutrient-poor serpentine soils (Weiss 1999) that lead to losses of biodiversity, most notably the threatened Bay checkerspot butterfly (*Euphydryas editha bayensis*).
6) Montane meadows in Rocky Mountain National Park are losing wildflowers to native perennial grasses.
7) Aquatic biodiversity in ultra-oligotrophic lakes in western mountains is affected by quite low levels of atmospheric deposition (1.5 kg-N/ha/year wet).

A screening of the N-deposition exposure of listed (endangered, threatened, and rare) plants in California (Weiss 2006), suggests that a substantial fraction (~40%) of the listed flora in the state is exposed to > 5 kg-N/ha/year (from a 36 km CMAQ run for 2002). Many of these plants are on nutrient deficient soils such as serpentine. Many others are in vernal pools (seasonal wetlands). Grass and weed invasions are the primary mechanism of biodiversity loss. Many of the species are small annual forbs that are prone to being crowded out by increased grass and weed growth in many ecosystems.

There are many other examples outside of the Western US that need to be compiled, and I would suggest as a recommendation that a national N-deposition/biodiversity screening and assessment are needed.

Policy responses:

Overall, the ongoing critical loads process (CLAD) provides a means for addressing this problem in the long run. Note regional efforts like that at Rocky Mountain National Park to reduce emissions are starting, based on a finding of critical load for alpine lakes.

Impacts on threatened and endangered species fall under the jurisdiction of the US Fish and Wildlife Service. Since 1999, mitigation for impacts of powerplants, road widening, and urban development on Bay checkerspot butterflies and serpentine grasslands include land acquisition and management/monitoring endowments and the development of a regional Habitat Conservation Plan. The Endangered Species Act may be a powerful means for identifying and mitigating N-deposition impacts on protected species

It is the short-term mitigation and management needs of these ecosystems that desperately need attention, especially control of invasive species. In California cattle grazing has been effective in maintaining serpentine grasslands and vernal pools. Management of many ecosystems remains problematic- wildland weeds are hard to control and substantial resources are needed on the ground.

The emissions of ammonia from vehicles (catalytic converters) along heavily traveled roads creates high deposition corridors. Vehicular ammonia may be one of the more readily controllable sources, and the call for ammonia to be considered as a regulated pollutant

Measurement and modeling of N-deposition loads is critical for understanding highly local effects, such as roadsides, as well as regional plumes. Passive samplers provide inexpensive means for monitoring time-averaged concentrations. A 4 km CMAQ run for the California (Tonnesen et al 2006) has proven immensely valuable for N-deposition assessments at regional levels. Standards for project-based and cumulative impact assessments need to be developed.

Fenn, M. E., J. S. Baron, et al. (2003). "Ecological Effects of Nitrogen Deposition in the Western United States." Bioscience **53**: 404-420.

Tonnesen, G., Z. Wang, et al. (2006). Assessment of Nitrogen Deposition: Modeling and Habitat Assessment. Sacramento, CA, California Energy Commission, PIER Energy Related Environmental Research CEC-500-**2006**-032.

Weiss, S. B. (1999). "Cars, Cows, and Checkerspot Butterflies: Nitrogen Deposition and Management of Nutrient-Poor Grasslands for a Threatened Species." Conservation Biology **13**(6): 1476-1486.

Weiss, S. B. (2006). Impacts of nitrogen deposition on California ecosystems and biodiversity. Sacramento, CA, California Energy Commission, PIER Energy-Related Environmental Research CEC-500-2005-165.