Atmospheric Nitrogen Deposition: Implications for Park Managers

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Many National Parks can be impacted by air pollution emanating from urban areas. In particular deposition of atmospheric pollutants has the ability to impact even the most remote portions of National Parks and damage ecological and scenic resources. Atmospheric deposition of nitrogen is a special hazard, since, in addition to traditional concerns about acid rain, ecosystem fertilization and in turn its impact on terrestrial ecosystem health and biodiversity is a concern. This deposition can also impact aquatic ecosystems if increases in nitrogen deposition cause more nitrogen to be leached into streams and lakes.

The impact of nitrogen deposition on terrestrial and aquatic ecosystems depends on a number of variables including: meteorological variability, type of vegetation, hydrology, and proximity to the pollution source. To explain the variability of N deposition and its impact on different ecosystems we will discuss ongoing research in three different ecosystems, alpine lakes and tundra in the Front Range of the Rocky Mountains and the Sierra Nevada, conifer forests in southern California, and the coastal sage scrub of southern California. While these ecosystems are by no mean ubiquitous, they do have analogues throughout the United States and the Park system.

A comparison of alpine ecosystems in the Rocky Mountains and in the Sierra Nevada and their different exposure and response to atmospheric deposition can provide insight into the ecosystem sensitivity controls by ecosystem biomass, proximity to urban areas, and the importance of meteorological variability. Alpine ecosystems are sensitive to nitrogen deposition since there is very little soil and only sparse vegetation to cushion the impacts of atmospheric deposition. The eastern slope of the Front Range of the Rocky Mountains appears to have been impacted by changes in atmospheric deposition with stream NO_3^- concentrations much higher than on the western slope of the Rockies. Meanwhile, the alpine Sierra Nevada has exhibited no significant change in ecosystem dynamics or in stream water quality despite the large cities in California and their proximity to the mountains. The reason for this resilience may have to do with the asynchrony between when pollution is worst (summer) and when most precipitation occurs (winter). Much of the precipitation that occurs in the Sierra Nevada is winter time snow that comes from clean Pacific air masses. However, the Rockies appear to have higher rates of nitrogen deposition than the Sierra Nevada due in part to proximity to the Denver metroplex in combination with more summer rain which encourages the advection and later deposition of pollutants from the urban air mass. While the alpine Sierra Nevada is not currently impacted by nitrogen deposition the same may not be true of the conifer and chaparral zones of the range since dry deposition may play a more prominent role in these ecosystems.

Conifer systems demonstrate the importance of hydrological and meteorological processes and ecosystem biomass on ecosystem sensitivity to nitrogen deposition. In contrast to the sensitivity of alpine ecosystems the Ponderosa and Jeffrey Pine forests of southern California appear to be fairly resistant to increases in atmospheric nitrogen deposition. This resistance is despite the 40 kg nitrogen per hectare per year these forests receive (compared to about 2 in the Sierra Nevada and 4 in the Front Range). The interaction between hydrology and plant physiology appears to control the susceptibility of this ecosystem. Summer time dry deposition of particulates and nitrogen gases dominates deposition in this ecosystem. When winter rains arrive the vegetation is generally dormant, the rains flush the atmospheric deposition rapidly off the vegetation and out of the soil and send a large pulse of nitrate into the streams of the San Bernardino and San Gabriel Mountains. When the trees becomes active again in springtime the soil is depleted of plant available nitrogen and fertilization experiments have shown that the vegetation still responds to additional fertilization despite the high rates of nitrogen deposition. Additionally, conifer forests might be resistant because of the relative long life of conifer trees. These conditions indicate that the terrestrial component of the conifer ecosystem is resistant to the impacts of nitrogen deposition while the aquatic portion is sensitive. The large leaching of nitrate into streams might impact aquatic ecosystems through eutrophication (e.g. Lake Tahoe) or possibly direct toxicity of fish and amphibians.

Coastal sage scrub ecosystems may be among the most sensitive terrestrial environments due to their relatively closed nature and low biomass. Nitrogen deposition has been implicated in the replacement of native grasses and shrubs by invasive grasses, which has led to a decrease in biodiversity in areas of southern California previously dominated by coastal sage scrub vegetation. The coastal sage scrub is especially susceptible to nitrogen deposition due to the dry summer during which most nitrogen deposition occurs followed by moist winters that permit the growth of native and exotic species during the relatively warm winters of southern California. Unlike the conifer forests the sage scrub is biologically active during the winter and plants rapidly respond to the onset of winter rains with regrowth on shrubs and germination and growth for annual forbes and grasses. The exotic grasses are biologically designed to take advantage of the excess nitrogen provided by atmospheric deposition while the sage scrub is biologically designed to be a superior competitor in a nitrogen limited system. The excess nitrogen deposition thus fosters the growth of invasive grasses over that of the native vegetation. Due to low rainfall in the coastal sage scrub there is very little leaching of nitrogen out of the rooting zone of most vegetation and thus nitrogen deposition is available throughout the winter growing season.

From these three case studies a number of rules of thumb can be derived about the susceptibility of natural ecosystems to nitrogen deposition. The closer an ecosystem is to a large city the more likely it is that there could be ecosystem damage due to nitrogen deposition (e.g. Front Range of Rockies and coastal sage scrub). Ecosystems that are dominated by marine originating storms are less likely to be susceptible to deposition (e.g. Sierra Nevada). Terrestrial ecosystems that are dormant during the peak time of nitrogen deposition are less susceptible to the impacts of nitrogen deposition while aquatic ecosystems might be more susceptible (e.g. conifer forests of southern California). Systems with large long-lived biomass (e. g. conifer forest) are less susceptible to nitrogen deposition than ecosystems with low overall biomass (e. g. alpine tundra and coastal sage scrub). Systems with low rainfall are more susceptible to the effects of nitrogen deposition due to the lack of flushing of nitrogen out of the rooting zone of most plants (e.g. coastal sage scrub).

In all of these ecosystems work remains to be done on the occurrence of atmospheric nitrogen deposition and susceptibility to nitrogen deposition. Still enough evidence has been compiled for park managers to be concerned about the possible impacts of nitrogen deposition on the natural resources of our National Parks. Park Service units particularly those near urban areas (e.g. Rocky Mountain National Park, Sequoia-Kings Canyon National Park, Joshua Tree National Park, Yosemite National Park, and Saguaro National Park) should be aware of issues involving atmospheric deposition and resource managers should be encouraged to spend resources on studying the issue. The types of studies that might be done to understand the susceptibility of ecosystems to N deposition include – studies of water quality in the parks over a number of years, measurements of inorganic nitrogen concentrations in soils, and monitoring of vegetation in National Parks to investigate nutrient ratios of standing vegetation.

Figure 1 - Researchers prepare to conduct a survey of the quantity and quality of snow in the Emerald Lake watershed in Sequoia National Park. Sierra Nevada alpine watersheds appear to be unimpacted by atmospheric deposition due to the marine origin of much of the precipitation in the watershed.

Figure 2 - The Loch Vale watershed in Rocky Mountain National Park has played a prominent role in understanding the impact of nitrogen deposition on ecosystem dynamics. Due to thunderstorms which feed on air from the Denver area the Rocky Mountains appear to be more impacted by nitrogen deposition than the Sierra Nevada.

Figure 3 - The large standing biomass and winter dominated hydrology of conifer forests in California appears to reduce their susceptibility to nitrogen deposition.

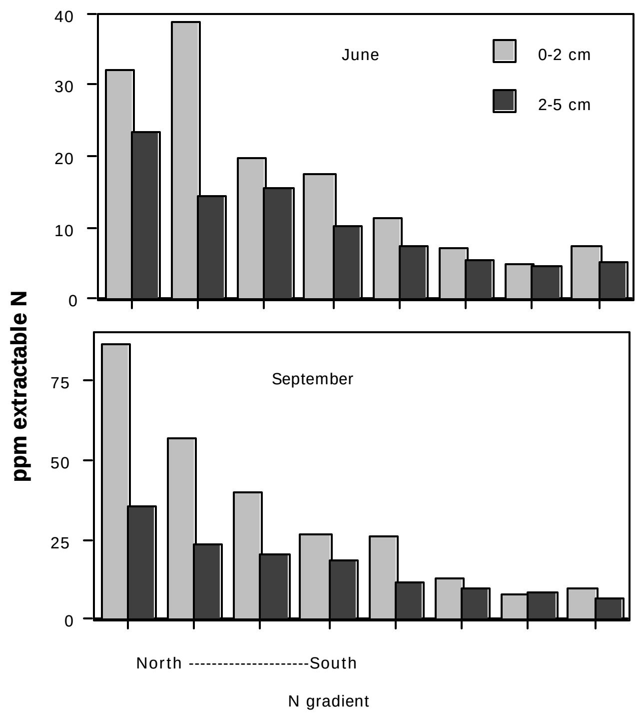

Figure 4. Soil nitrogen gradient in sites lying north to south in the Riverside-Perris Plain. Shown is total extractable nitrogen. These data are from the end of the rainy season (June) and the dry season (September). Biodiversity at these sites is inversely proportional to nitrogen concentrations in the soil with the highest biodiversity at the southern or clean end of the gradient and the lowest biodiversity at the dirty or northern end of the gradient.

Figure 5 - A degraded coastal sage scrub site near Riverside, California note smog in background.

Figure 6 - A healthy coastal sage scrub site in the San Jacinto mountains of southern California.