3
Impacts of Nr on Aquatic, Atmospheric, and Terrestrial Ecosystems

This chapter summarizes knowledge of the impacts of Nr on freshwater, coastal, atmospheric, and terrestrial ecosystems. Table ES-1 in the Executive Summary provides a more detailed presentation of the quantitative extent of Nr impacts on the environment.

3.1. Impacts on Drinking Water, Human Health, and Freshwater Biota

A detailed presentation on the impacts of Nr on various aquatic systems is presented in Appendix G. The EPA's Office of Water (U.S. EPA, 2007b) has noted the following impacts caused by excessive Nr in aquatic systems:

- Excessive nutrients (N and P) can cause negative ecological impacts to water bodies on a national scale by stimulating harmful algal blooms.
  - Algal blooms block sunlight and result in the destruction of submerged aquatic vegetation which serves as critically important habitat and food for many organisms.
  - Algal blooms eventually die off and consume dissolved oxygen from the water column which can lead to die off of aquatic organisms.
  - One result of algal blooms is decreased biological diversity and populations, including smaller populations of game and commercial fish.
  - Some blooms, considered harmful algal blooms or HABs, have a toxic effect on living organisms and are disruptive of ecosystem structure and transfer of energy to higher trophic levels.
- Excessive nutrients also pose public health risks.
  - Algal blooms can cause taste and odor problems in drinking water.
  - Hazardous algal blooms can cause respiratory distress and neurological problems in swimmers.
  - Excessive nitrates can cause "blue baby syndrome."
- Nutrient pollution is occurring at a national scale and has not been completely addressed.
  - 49 states and 4 territories have 303(d) listings due to nutrients, and about 50% of the states have greater than 100 water quality impairments due to nutrients.
  - Over 10,000 impairments are a result of nutrient pollution.

Finding 11: There is growing recognition of eutrophication as a serious problem in aquatic systems (NRC, 2000). The last comprehensive National Coastal Condition Report was published in 2004 (U.S. EPA, 2004) and included an overall rating of "fair" for estuaries, including the Great Lakes, based on evaluation of more than 2,000 sites. The water quality index, which incorporates nutrient effects primarily as chlorophyll-a and dissolved oxygen impacts, was also rated "fair" nationally. Forty percent of the sites were rated "good" for overall water quality, while 11% were "poor" and 49% "fair."

Recommendation 11. *The Committee recommends that EPA develop a uniform assessment and management framework that considers the effects of Nr loading over a range of scales reflecting ecosystem, watershed, and regional levels. The framework should include all inputs related to atmospheric and riverine delivery of Nr to estuaries, their comprehensive effects on marine eutrophication dynamics and their potential for management.*

Finding 12: Meeting Nr management goals for estuaries, when a balance should be struck between economic, societal, and environmental needs, seems unlikely under current federal law. Enforceable authorities over nonpoint source, stormwater, air (in terms of critical loads), and land use are not adequate to support necessary Nr controls. Funding programs are presently inadequate to meet existing pollution control needs. Furthermore, new technologies and management approaches are required to meet ambitious Nr control needs aimed at restoring national water quality.

Recommendation 12. *The Committee recommends that EPA reevaluate water quality management approaches, tools, and authorities to ensure Nr management goals are attainable, enforceable, and the most cost-effective available. Monitoring and research programs should be adapted as necessary to ensure they are responsive to problem definition and resolution, particularly in the development and enhancement of nitrogen removal technologies and best management practices, and continue to build our level of understanding and increase our ability to meet management goals.*

3.2. Impacts of Airborne or Atmospherically Deposited Nr on Human Health and Ecosystems

Six major atmospheric effects are associated with increased NO_x and NH_3 emissions, and two with N_2O emissions (Galloway et al., 2003). For NO_x and NH_3 emissions, the effects are:

- Decreases in atmospheric visibility caused by fine PM
- Elevated ozone concentrations that enhance the greenhouse potential of the atmosphere
- Serious ozone and fine particulate matter impacts on human health (Pope et al., 1995; Pope, 2000a,b ; Brook et al., 2003; Brunekreef et al., 2005; Pope, 2009)
- The important role that NH_3 plays in the direct and indirect effects of aerosols on radiative forcing and thus on global climate change (Penner et al., 1991; Seinfeld and Pandis, 1998; Lelieveld et al., 2001; Myhre, 2009)
- Decreased productivity of crops, forests, and natural ecosystems caused by ozone deposition
- Atmospheric deposition of NH, NH_3, NO_y, and organic forms of Nr that can contribute to ecosystem acidification, fertilization, and eutrophication

For N_2O, the effects are the greenhouse effect in the troposphere and O_3 depletion in the stratosphere.

3.3. Impacts of Nr on Terrestrial Ecosystems

As previously discussed, in many terrestrial ecosystems the supply of biologically available Nr is a key factor controlling the nature and diversity of plant life, and vital ecological processes such as plant productivity and the cycling of carbon and soil minerals. Human activities have not only increased the supply but enhanced the global movement of various forms of nitrogen through air and water. Appendix H presents information on the impact of Nr saturation on ecosystem function.

The primary source of excess Nr for most unmanaged terrestrial ecosystems is atmospheric deposition. This additional Nr causes a wide variety of sometimes beneficial effects (increased growth and productivity of forests, natural grasslands, and crops planted in nutrient deficient soils) and also sometimes adverse effects on terrestrial and aquatic ecosystems in many parts of the U.S. Forests and grasslands exposed to excess Nr can respond in numerous ways. General effects include the following (Woodman and Cowling, 1987; Cowling, 1989; Garner et al., 1989; Cowling et al., 1990; Vitousek et al., 1997a,b; Cowling et al., 2002):

- Increased productivity of forests soils, most of which are Nr-limited throughout the U.S. Nr deficiency of forest soils has been most fully quantified for pine forests in 14 southeastern states.
- Acidification of forest soils leading to decreased availability of nutrient cations including calcium, magnesium, and potassium and aluminum toxicity, established most clearly in the eastern U.S. and both central and northern Europe.
- Nr saturation of forest soils (which results in increased Nr release to the water draining the soils), presently occurring mainly in high-elevation forests of the eastern U.S. and southeastern Canada.
- Ozone-induced predisposition of forest trees to damage by fungal diseases and insect pests, most clearly established in the case of root disease and bark beetles in the pine forests of southern California.
- Ozone-induced inhibition of photosynthesis in both softwood and hardwood tree species most clearly established in controlled exposure studies in both the U.S. and Europe at ambient concentrations of ozone above 60 ppb. Such concentrations occur frequently throughout the eastern U.S. and southeastern Canada.
- Ozone-induced direct injury to foliage, most clearly established in the case of “emergence tip burn” in eastern white pine.
- Acidification-induced decrease in frost hardiness of high-elevation conifer forests, most clearly established in the case of red spruce in the northeastern U.S.
- Acidification-induced alteration of beneficial symbiotic relationships in forest soils, especially mycorrhizae, most clearly established in both northern and central Europe.
- Biodiversity losses in natural grasslands and forest areas caused by Nr-induced decreases in abundance of Nr-limited tree and grass species and replacement by Nr-loving weed species, most clearly established in both Minnesota and California, and even more vividly in The Netherlands.
- Decreases in visibility and increased haziness of the atmosphere at scenic vistas in national and state parks and wilderness areas.
- More leaching of Nr to aquatic systems via both groundwater and surface runoff—a cascade effect.