

# Air Quality Management in U.S. Fish and Wildlife Service Wilderness Areas

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**Abstract**—Proper management of air resources is vital to maintaining the wilderness character of an area. Air pollution can affect natural resources and has caused injury to vegetation, bioaccumulation of mercury in fish, eutrophication of coastal ecosystems and visibility impairment in U.S. Fish and Wildlife Service (FWS) wilderness areas. Sources of air pollution include power plants, incinerators, industry, automobiles, dust and fires. Emissions from these sources can be transported long distances and affect areas otherwise considered to be pristine. The FWS uses a combination of monitoring, special studies, participation in the regulatory process and review of new sources of air pollution in its air quality management strategy.

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The U.S. Fish and Wildlife Service (FWS) manages 20.7 million acres in 76 wilderness areas. These wilderness areas range in size from the eight-million acre Mollie Beattie Wilderness Area in Alaska to the two-acre Wisconsin Islands Wilderness Area in Wisconsin. Twenty-one of the wilderness areas managed by FWS in the National Wildlife Refuge System are designated Class I air quality areas (fig. 1) and receive special protection under the Clean Air Act (Public Law No. 101-549). Only a very small additional amount of air pollution (from 1977 levels) can be permitted in Class I areas.

Class I areas include the following federal lands that were in existence on August 7, 1977: national parks exceeding 6,000 acres; national wilderness areas exceeding 5,000 acres; national memorial parks exceeding 5,000 acres; and international parks. In addition, tribes have designated certain tribal lands as Class I. Congress gave the FWS and the other federal land managers for Class I areas an “affirmative responsibility to protect all those air quality related values (including visibility) of such lands...” (Senate Report No. 95-127, 95th Congress, 1st Session, 1977). Air quality-related values include vegetation, wildlife, water, soils, visibility and geological, archeological, historical and cultural resources. Despite this special protection, many of the resources in these areas are being impacted or have the potential to be impacted by air pollutants.

Common air pollutants of ecological significance include sulfur and nitrogen oxides, ammonia, ozone, particulate matter, volatile organic compounds and metals. These pollutants are either emitted directly from sources, including

power plants, incinerators, industries, automobiles and fires or, as in the case with ozone, are formed downwind of sources as emissions react and transform. Other downwind reactions produce fine aerosols and particles, including sulfates and nitrates, which may eventually be deposited into ecosystems.

Impacts to wilderness resources from air pollution include acidification of lakes, streams and soil; eutrophication of estuaries and near-shore coastal waters; direct toxicity to sensitive species; changes in species composition; changes in nutrient cycling; bioaccumulation of toxins in food chains; and visibility impairment.

Acidification may occur when sulfur and nitrogen compounds combine with moisture and transform to acids in the atmosphere, soil or water. Acids may be buffered by naturally occurring base cations, such as calcium and magnesium. However, in lakes, streams and soils with low amounts of base cations (or with high acid inputs), acid-neutralizing capacity is lost, and acidification occurs (National Acid Precipitation Assessment Program 1990a). Acid-sensitive species of fish and invertebrates, and the wildlife that depend on them, may be lost from the ecosystem. (Griffith and others 1995). In addition, increased acidity mobilizes metals, such as aluminum and mercury, that are toxic to plants and wildlife (National Acid Precipitation Assessment Program 1990b). In high-elevation spruce-fir forests increased acidity has resulted in winter foliar injury and subsequent dieback (Thornton and others 1994). Acidity may also cause changes in soil nutrient cycling (Aber and others 1995; Johnson and Lindberg 1992).

In addition to having an acidification effect nitrogen from air pollution may have a fertilizing effect on ecosystems (Vitousek and others 1997; Paerl 1993). Nitrogen can be deposited into ecosystems in the form of nitrates, ammonium ions and other compounds. In natural systems, including designated wilderness areas, nitrogen may cause an unwanted increase in primary production and a shift in species composition to nitrogen-loving species. In estuaries and coastal waters along the Atlantic and Gulf coasts, for example, excess nitrogen stimulates eutrophication characterized by algae blooms, decreased water clarity, deterioration and loss of sea grasses, and hypoxia (Ecological Society of America 1997). In some areas, this has resulted in the loss of important invertebrate, fish and wildlife species. Although much of the nitrogen entering estuaries is from terrestrial runoff, a significant portion comes from the atmosphere. In estuary studies to date, atmospheric nitrogen comprises from 10%-50% of the total nitrogen entering the system (Paerl 1995).

Certain air pollutants have a direct toxic effect on sensitive species. Ozone is the most important of the phytotoxic pollutants and enters the stomates of plants along with the normal constituents of air. Once inside the leaf, ozone (or

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Figure 1—U.S. Fish and Wildlife Service Class I areas.

its byproducts) reacts with cell membranes and other cell components, causing injury or death of leaf tissues. On broad-leaved plants, ozone injury may appear as dark stipples. On conifers, ozone injury may appear as chlorotic mottle (Chappelka and Chevone 1992). In addition, ozone may cause reductions in plant growth and reproduction (Manning and Krupa 1991).

Other air pollutants, including mercury and other toxic metals, bioaccumulate when deposited into ecosystems. Mercury, for example, can accumulate up the food chain by a factor of a million or more (Schroeder and Munthe 1998). Mercury tends to accumulate in aquatic food chains, reaching toxic levels in certain fish species (Facemire and others 1995). Wildlife and humans consuming such fish may be at risk of neurological and reproductive damage (U.S. Environmental Protection Agency 1997).

In addition to effects on plants, wildlife, water and soils, air pollutants reduce visibility. Fine particles of sulfates, nitrates, organics, soot and other compounds absorb or scatter light, reducing our ability to see wildland features clearly. Pollutant haze has become a common feature of the landscape (National Research Council 1993).

## Air Quality Management Strategy

To better understand the effects of air pollutants on FWS lands, and to ensure protection of air quality and air quality-related values, the FWS has developed an air quality management strategy. This strategy includes monitoring, special studies, participation in the regulatory development process and review and evaluation of new sources of air pollution near FWS areas.

## Air Pollutant Monitoring

The FWS conducts air quality monitoring in partnership with several national programs, including the National Atmospheric Deposition Program, the Mercury Deposition Network Program and the Interagency Monitoring of Protected Visual Environments Program. Because air pollutants tend to be well-dispersed in the atmosphere (in the absence of strong local sources), monitoring to characterize wilderness air quality is conducted in an adjacent nonwilderness area. Thus, impacts to the wilderness from monitoring activities are avoided.

**National Atmospheric Deposition Program (NADP)**—The NADP provides long-term spatial and temporal trend information on the concentration and deposition of major cations and anions (both natural and human-caused) in precipitation at over 200 sites nationwide. NADP, now in its third decade of collecting precipitation chemistry data, is a cooperative effort supported by national, state and local governmental agencies, State Agricultural Experiment Stations, universities and private organizations. Rain or snow is collected on a weekly basis and analyzed at a central laboratory for sulfate, nitrate, ammonium, calcium, magnesium, potassium, sodium, chloride, phosphate and hydrogen ions, as well as conductivity. Rainfall is also measured at the sampling sites, allowing deposition rates to be estimated. FWS supports NADP samplers at three Class I areas: Brigantine (part of the Edwin B. Forsythe National Wildlife Refuge-NWR- in New Jersey), Okefenokee NWR (Georgia), and Chassahowitzka NWR (Florida). The U.S. Geological Survey funds NADP samplers at five other national wildlife refuges including Salt Plains NWR (Oklahoma), Santee NWR (South Carolina), Hatchie NWR (Tennessee), Muleshoe NWR (Texas), and Attwater Prairie Chicken NWR (Texas).

NADP information and data are available at the NADP website: <http://nadp.sws.uiuc.edu>

Data from NADP indicate that the monitored FWS areas are experiencing elevated levels of air pollutants in deposition, as are many wilderness areas in the contiguous United States.

**Mercury Deposition Network (MDN) Program**—The MDN, a network of NADP, provides long-term spatial and temporal trend information on the concentration and deposition of total mercury in precipitation at nearly 40 sites nationwide. Samples are collected weekly, using trace metal protocols, and analyzed at a central laboratory. Methylmercury can also be analyzed. FWS supports two MDN sites: Okefenokee (Georgia) and Chassahowitzka (Florida).

MDN information and data are available at the NADP website: <http://nadp.sws.uiuc.edu/mdn/>

Elevated levels of mercury have been recorded in the rainfall at the FWS sites. Fish sampled from Okefenokee and Chassahowitzka also contain elevated mercury levels (Facemire and others 1995; Brim and others 1994).

**Interagency Monitoring of Protected Visual Environments (IMPROVE)**—In 1977, Congress established as a goal, "...the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution." (Public Law No. 101-549). In its 1993 report, "Protecting Visibility in National Parks and Wilderness Areas," the National Research Council concluded that visual range (a measure of visibility) in the western U.S. is one-half to two-thirds of the natural visual range (that is, without manmade air pollution). In the eastern U.S., the visual range is, on the average, only one-fifth of the natural visual range (National Research Council 1993). Visibility impairment occurs when fine particles and aerosols scatter or absorb light, that is, cause "light extinction." Light extinction is inversely proportional to visual range and is, therefore, much greater in the East than in the West (fig. 2).

In response to the goal set by Congress, federal land managers, together with the Environmental Protection Agency and regional and state organizations, developed the IMPROVE program. IMPROVE monitors visibility conditions at approximately 40 sites nationwide, primarily Class I areas. More sites (approximately 80) will be added in 1999-2000. An IMPROVE site includes a fine-particle sampler that measures the composition and concentration of fine particles in the air that reduce visibility. A site may also include an automatic camera to characterize haze and an optical instrument (such as a transmissometer or nephelometer) to measure light extinction or scattering.

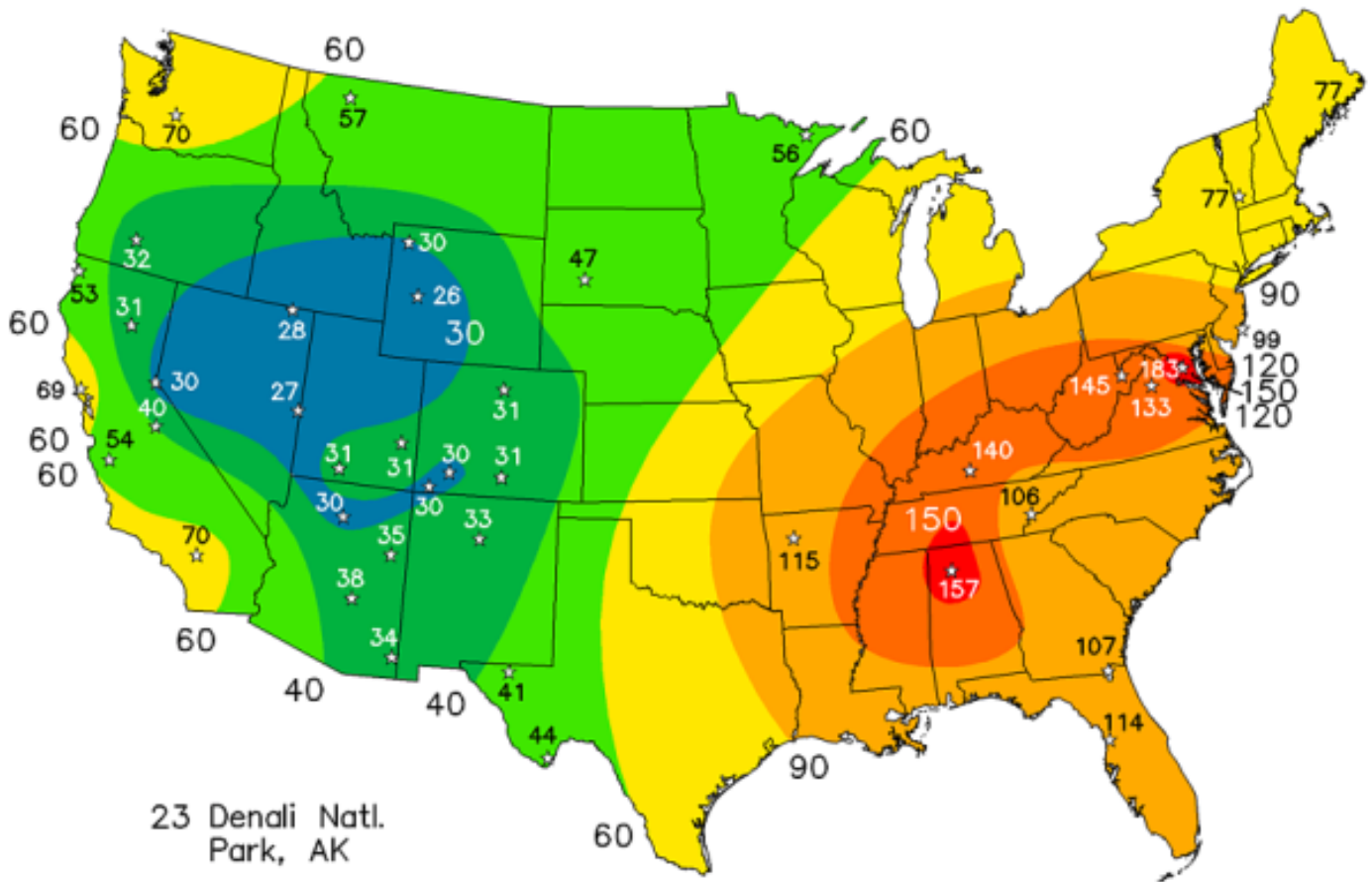
The Fish and Wildlife Service supports IMPROVE fine-particle samplers at five Class I areas: Brigantine (New Jersey), Cape Romain (South Carolina), Chassahowitzka (Florida), Moosehorn (Maine), and Okefenokee (Georgia). Data indicate that visibility at these sites is impaired much of the time. Sulfate particles (primarily from coal-burning power plants) cause most of the light extinction at these sites, which is typical of Eastern IMPROVE sites (National Acid Precipitation Assessment Program 1990d; Colorado State University 1996).

## Evaluation of Air Pollution Effects to Resources

In addition to monitoring the types and amounts of pollutants in the air and in deposition, the FWS conducts special studies to evaluate the effects of pollution on air quality-related values. These studies have focused on vegetation and water quality.

**Surveys of Vegetation for Air Pollution Injury**—Surveys have been conducted at a number of FWS Class I areas to date, to evaluate vegetation for symptoms of ozone injury. Ozone produces distinctive stippling and chlorosis on sensitive species that has been well characterized by controlled fumigations in open-top chambers. Observations by trained observers of similar symptoms in the field can be used to verify ozone injury. Ozone injury has been documented at most of the FWS Class I areas surveyed, including Brigantine, Cape Romain, Moosehorn and Mingo (Davis 1996; Davis 1998; Davis 1999a; Davis 1999b). Species affected include black cherry (*Prunus serotina*), wild grape (*Vitis* spp.), common milkweed (*Asclepias syriaca*), tree-of-heaven (*Ailanthus altissima*), ash (*Fraxinus* spp.), cucumbertree (*Magnolia acuminata*), flowering dogwood (*Cornus florida*), sassafras (*Sassafras albidum*), sweetgum (*Liquidambar styraciflua*), spreading dogbane (*Apocynum androsaemifolium*), trembling aspen (*Populus tremuloides*), pin cherry (*Prunus pennsylvanica*), serviceberry (*Aamelanchier laevis*), elderberry (*Sambucus canadensis*), and winged sumac (*Rhus copallina*), and salt-marsh cordgrass (*Spartina alterniflora*).

**Acidification Vulnerability Study**—Water chemistry of lakes in Moosehorn NWR and Wilderness was evaluated to determine the lakes' sensitivities to acidic deposition. Results indicated that although the lakes are sufficiently buffered to tolerate current loads of sulfates and nitrates, increases in loadings of these pollutants could



**Figure 2**—Light extinction coefficient, calculated from aerosol concentrations measured by IMPROVE (National Park Service Air Resources Division).

reduce buffering capacity and increase the risk of acidification (Kahl and James 1996).

**Eutrophication Vulnerability Study**—Water chemistry, phytoplankton and sea grasses have been examined from 1996 to the present at Chassahowitzka to evaluate nutrient and trophic status, phytoplankton species composition and density, and sea grass health and distribution. Table 1 summarizes water quality parameters for Chassahowitzka. In the first two years of the study, 1996-1997, water quality and trophic state were considered good. Water

clarity was high, and chlorophyll and nutrient concentrations were low. However, in 1998, water quality and trophic state were considered poor. Significant algae blooms were noted, with loss of water clarity and low dissolved oxygen concentrations. Nitrogen was found to be the limiting nutrient in this system (Dixon 1998). Further work will be conducted in 1999 to evaluate whether the poor water quality observed in 1998 affected sea grass health.

The studies described above were limited to a small number of FWS Class I areas. However, it is likely that other FWS areas are experiencing similar effects. For example, ozone injury to vegetation probably occurs in many FWS areas, particularly in the eastern U.S. and certain areas in the West (California), because of the high ozone concentrations that are typical of these areas. Atmospheric nitrogen is probably contributing to eutrophication at many FWS areas along the Gulf and Atlantic coasts. And, visibility impairment affects all FWS areas in the contiguous United States.

**Table 1**—Average water quality parameters for coastal stations in Chassahowitzka National Wildlife Refuge (Dixon 1998).

Date	Chlorophyll a micrograms/liter	IN:IP <sup>a</sup>	TSI <sup>b</sup>
May 1996	3	3	31
May 1997	2	5	30
September 1997	2	11	35
May 1998	18	4	60
July 1998	18	3	57

<sup>a</sup>Inorganic nitrogen:inorganic phosphorous (IN:IP) ratio below 10 indicates that phytoplankton growth is nitrogen-limited.

<sup>b</sup>Trophic State Index (TSI) value below 50 indicates good water quality. TSI above 50 indicates poor water quality.

## Participation in the Regulatory Development Process

The FWS routinely reviews and comments on legislation and rule-making regarding air quality, including recent regulations pertaining to ozone, particulate matter, regional haze and new source review. In addition, the agency

participates in regional air quality partnerships including the Grand Canyon Visibility Transport Commission, the Western Regional Air Partnership, and others. The FWS works with states to develop their State Implementation Plans for the Clean Air Act. Participation in these forums ensures that FWS concerns for air quality and air quality-related values under its jurisdiction are addressed.

## Review and Evaluation of New Sources of Air Pollution

The Environmental Protection Agency or state permitting authority is required to notify the FWS (or appropriate federal land manager) of any permit application from a major source of emissions that may affect a Class I area. The facility must (1) use best available emissions control technology, (2) demonstrate that emissions will not cause or contribute to violations of the National Ambient Air Quality Standards or Class I increments (the maximum allowable increase in a pollutant, designated by the Clean Air Act), and (3) demonstrate that emissions will not cause or contribute to adverse impacts to air quality-related values in the Class I area. The FWS, together with the National Park Service, has developed guidance for Class I area analyses that is available to air pollution permit applicants (Bunyak 1993). The FWS is given the opportunity to review and comment on the proposed source's control technology, air quality impacts and air quality-related values impacts. The FWS may recommend better control technology, lower emission rates or lower production rates to mitigate potential impacts to the Class I area. In addition, the agency may ask for additional analyses to provide adequate information to evaluate potential impacts. If its concerns are not addressed, and the FWS determines that there is potential for adverse impacts to a Class I area from the proposed source's emissions, the FWS may appeal the permit.

In summary, the air quality management strategy of the FWS is designed to increase understanding and ensure protection of air quality and air quality-related values on FWS lands. Continued progress in understanding air pollution and its effects will enable the FWS Air Quality Management Program to more effectively protect its wilderness resources.

## References

- Aber, J. D.; Magill, A.; McNulty, S. G.; Boone, R. D.; Nadelhoffer, K. J.; Downs, M.; Hallett, R. 1995. Forest biogeochemistry and primary production altered by nitrogen saturation. *Water, Air and Soil Pollution*. 85: 1665-1670.
- Brim, M.; Bateman, D.; Jarvis, R. 1994. Mercury concentrations in fishes of the Chassahowitzka National Wildlife Refuge. U.S. Fish and Wildlife Service Publication No. PCFO-EC 94-01. Panama City, FL.
- Bunyak, John. 1993. Permit application guidance for new air pollution sources. National Park Service Natural Resources Report 93/09. Denver, CO.
- Chappelka, Arthur H.; Chevone, Boris I. 1992. Tree responses to ozone. In: Lefohn, Allen S., ed. *Surface level ozone exposures and their effects on vegetation*. Chelsea, MI: Lewis Publishers: 271-324.
- Colorado State University. Cooperative Institute for Research in the Atmosphere. 1996. IMPROVE, Interagency Monitoring of Protected Visual Environments. Spatial and seasonal patterns and long term variability of the composition of the haze in the United States: an analysis of data from the IMPROVE network.
- Davis, Donald D. 1996. Evaluation of ambient ozone injury on the foliage of vegetation in the Edwin B. Forsythe National Wildlife Refuge, Brigantine, NJ: 1996 Observations. Pennsylvania State University.
- Davis, Donald D. 1998. Evaluation of ambient ozone injury on the foliage of vegetation in the Cape Romain National Wildlife Refuge, South Carolina: 1997 Observations. Pennsylvania State University.
- Davis, Donald D. 1999a. Evaluation of ozone injury on vegetation in the Moosehorn National Wildlife Refuge, Maine: 1998 Observations. Pennsylvania State University.
- Davis, Donald D. 1999b. Evaluation of ozone injury on vegetation in the Mingo National Wildlife Refuge, Missouri: 1998 Observations. Pennsylvania State University.
- Dixon, L. Kellie. 1998. Chassahowitzka National Wildlife Refuge Status and Trends. Mote Marine Laboratory Technical Report Number 579. Sarasota, Florida.
- Facemire, C.; Augspurger, T.; Bateman, D.; Brim, M.; Conzelmann, P.; Delchamps, S.; Douglas, E.; Inmon, L.; Looney, K.; Lopez, F.; Masson, G.; Morrison, D.; Morse, N.; Robison, A. 1995. Impacts of mercury contamination in the southeastern United States. *Water, Air, and Soil Pollution*. 80: 923-926.
- Griffith, Michael B.; Perry, Sue A.; Perry, William B. 1995. Macroinvertebrate communities in headwater streams affected by acidic precipitation in the Central Appalachians. *Journal of Environmental Quality*. 24: 233-238.
- Johnson, D.; Lindberg, S. (eds). 1992. *Atmospheric Deposition and Forest Nutrient Cycling*. Springer-Verlag, New York. 707 p.
- Kahl, Steve; James, Cary. 1996. *Lake Chemistry in Moosehorn National Wildlife Refuge, Maine, 1995*. Water Research Institute, University of Maine, Orono.
- Manning, William J.; Krupa, Sagar V. 1992. Experimental methodology for studying the effects of ozone on crops and trees. In: Lefohn, Allen S., ed. *Surface level ozone exposures and their effects on vegetation*. Chelsea, MI: Lewis Publishers: 93-156.
- National Acid Precipitation Assessment Program. 1990a. *Acidic Deposition: State of Science and Technology, Report 10, Watershed and lake processes affecting surface water acid-base chemistry*. Washington, D.C.
- National Acid Precipitation Assessment Program. 1990b. *Acidic Deposition: State of Science and Technology, Report 13, Biological effects of changes in surface water acid-base chemistry*. Washington, D.C.
- National Acid Precipitation Assessment Program. 1990c. *Acidic Deposition: State of Science and Technology, Report 16, Changes in forest health and productivity in the United States and Canada*. Washington, D.C.
- National Acid Precipitation Assessment Program. 1990d. *Acidic Deposition: State of Science and Technology, Report 24, Visibility: Existing and Historical Conditions—Causes and Effects*. Washington, D.C.
- National Research Council. 1993. *Protecting visibility in national parks and wilderness areas*. Washington, D.C.: National Academy Press. 466 p.
- Paerl, Hans W. 1993. Emerging role of atmospheric nitrogen deposition in coastal eutrophication: biogeochemical and trophic perspectives. *Canadian Journal of Fisheries and Aquatic Science*. 50: 2254-2269.
- Paerl, Hans W. 1995. Coastal eutrophication in relation to atmospheric nitrogen deposition: current perspectives. *Ophelia*. 41: 237-259.
- Schroeder, William H.; Munthe, John. 1998. Atmospheric mercury—an overview. *Atmospheric Environment* 32(5): 809-822.
- Thornton, F. C.; Joslin, J. D.; Pier, P. A.; Neufeld, H.; Seiler, J. R.; Hutcherson, J. D. 1994. Cloudwater and ozone effects upon high elevation red spruce: a summary of study results from Whitetop Mountain, Virginia. *Journal of Environmental Quality*. 23(6): 1158-1167.
- U.S. Environmental Protection Agency. 1997. *Mercury Study Report to Congress, Vol. VII: Characterization of human health and wildlife risks from mercury exposure in the United States*. EPA-452/R-97-009.
- Vitousek, Peter M.; Aber, John D.; Howarth, Robert W.; Likens, Gene E.; Matson, Pamela A.; Schindler, David W.; Schlesinger, William H.; Tilman, David G. 1997. Human alteration of the global nitrogen cycle: sources and consequences. *Ecological Applications*. 7(3): 737-750.