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# AIR POLLUTION THREATS TO NATIONAL PARKS

## In The Great Lakes Region


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*A Background Paper for*
*Great Lakes National Parks: A Conference*
*on Policy and Participation*

### Introduction

The National Parks and Lakeshores of the Great Lakes Basin are of special significance because they are accessible to the large population of the region in no more than one day's travel. This is much greater accessibility than most of the National Park System. However, industry and related activities are also associated with this population—agriculture, manufacturing, electricity generation and automobile travel. All of these, we are now finding, contribute to regional pollutant loads having the potential to affect the Great Lakes parks.

Data from Region V of the U.S. Environmental Protection Agency, covering most of the states bordering the Great Lakes[1], illustrates the problem. An indication of air pollution in this Region is available from the Council on Environmental Quality (CEQ) Annual Report (1979) which summarized monitoring data on criteria pollutants by region. In the region's 524 counties, 64% of the 67 counties with $O_3$ monitors were in violation of National Ambient Air Quality Standards, 24% of the 122 counties monitored for total soluble particulates and 11% of the 160 counties monitored for sulfur dioxide.

The Air Quality Control Region (AQCR) is the geographic unit for which the need for air quality control strategies are evaluated under the mandate of the Clean Air Act. Attainment of national ambient air quality standards is determined for each AQCR on the basis of the air quality within that region. Control strategies therefore are focused on local, ground-level pollution problems, which arise largely in connection with primary emissions, although ozone, a secondary product, also is considered. The strategy has been partially successful in terms of its original goals, but it has exacerbated a growing problem of reduced air quality in areas remote from the local pollutant sources. Although primary pollutants tend to be associated with high densities of industrial and vehicular sources in the metropolitan areas along the southern shores of Lakes Michigan, Huron and Erie, long-distance transport of fossil-fuel emissions and reaction products has subjected the entire region to incursions of acid deposition, and photochemical oxidants (chiefly ozone).

This paper discusses evidence for the occurrence of major air pollutants in the region, with emphasis on secondary pollutants subject to long-distance transport. The potential for pollutant impacts upon the natural resource values of the Great Lakes parks is also discussed.

## Primary Pollutant Loadings of Local Origin

Primary emission products for which there is evidence of direct effects upon organisms or materials include sulfur dioxide, nitrogen dioxide, other gases such as flourin, and heavy metals. Sources of these materials are usually local upwind industrial plants located within 2 to 40 km distance, depending on source strength. Primary pollutants directly affect resource values of Great Lakes parks principally where sources are located near park boundaries. This situation exists mostly near urban areas and in the southeastern part of the region. Thus, Indiana Dunes National Lakeshore and Cuyahoga Valley National Recreation Area lie in the vicinity of industrial pollution sources associated with concentrations of primary pollutants that reach levels high enough to affect natural resource values.

Sulfur dioxide is the best known pollutant in terms of plants. Effects of $SO_2$ upon crops and some forest species have been studied extensively in the laboratory and field. Reduction of growth, survival, and yield can occur at concentrations observed in large urbanized areas and near industry in the southern and eastern Great Lakes area. For example, field studies of forest responses to $SO_2$ indicate that reduced wood production in boreal coniferous forests results from chronic exposures to $SO_2$ at levels that seldom exceeded 0.2 parts per million (ppm) for half-hour periods (Legge 1980). The National Ambient Air Quality standard is 0.5 ppm during a 3-hour period. Exposure to 0.05 to 0.1 ppm $SO_2$ for a few hours can cause leaf injury and reduced needle length in white pine (Eckert and Houston 1980, Houston 1974). As discussed below, permissible levels of $SO_2$ in conjunction with regional ozone exposure can be associated with deleterious effects upon trees. Thus even where national ambient air quality standards are met, effects upon growth of vegetation can result from exposure to $SO_2$.

Limited evidence indicates that nitrogen dioxide is less toxic to plants than is $SO_2$ and current arguments for improved $NO_x$ control strategies are based partially upon the conversion of $NO_2$ into secondary pollutants such as acid rain and ozone. However, synergistic interactions with $SO_2$ have been demonstrated experimentally and may occur near pollutant sources. Heavy metals and fluorine frequently are associated with $SO_2$ in emissions from smeltering operations and are responsible for a range of inhibitory effects observed in adjacent forests (Freedman and Hutchinson 1980). Although elevated metal concentrations occur in polluted urban atmospheres, effects on non-human organisms are usually associated with high exposures occurring within a few km of a large source.

## Long-Range Transport of Pollutants

The fate of a pollutant emitted into the atmosphere depends on several factors, some meteorological and some a function of the pollutants themselves. As a consequence, deleterious pollutant effects may be expressed in rural areas where little pollutant emissions occur. In fact over most of the broader Great Lakes region, "long-distance transport" of pollutants and their reaction products is probably the major source of pollutant loadings. Long-range transport is facilitated by tall stacks, high wind, and a stable lower atmosphere (i.e., where the temperature increases with altitude). Absence of precipitation also increases the distance of transport.

Several types of meteorological factors influence long distance transport. The prevailing wind regime over much of the eastern United States and Canada is one of westerly winds. Hence the industrialized midwest seems to be a major source of air pollutants deposited elsewhere in the midwest, as well as in Pennsylvania and New York. However, exceptions to this pattern occur and incursions of polluted air into Wisconsin and Michigan has been linked to air masses originating southeastward in the Ohio River Valley (Bowen 1978, Wolff et al. 1981). This pattern is complicated by seasonal trends, such that there is a southerly component in the summer and a northerly component in the winter.

*The principal threats to resource values of the Great Lakes parks are associated with visibility reduction, effects of ozone on terrestrial vegetation, and acid deposition impacts upon the chemical balance of low-buffered watersheds.*

## Visibility Reduction

Recent studies have demonstrated that atmospheric reactions and long-range transport produce aerosol-sized particulate matter during periods of anti-cyclonic activity which are responsible for visibility reduction in most of the United States eastward from the prairie states.

The substances involved include sulfate and nitrogen compounds (nitrate, nitric and ammonium ions), photochemical exidants, fine particulate elemental carbon, organic carbon compounds (hydrocarbons) and trace elements. Collectively they contribute to atmospheric haze which exhibits light scattering properties. Over both urban and forested areas, sulfate aerosol has been observed as the predominant haze component, responsible for most of the light scattering (Weiss et al. 1977, Lioy et al. 1979). Over the last several decades, visibility in the eastern United States, including the entire Great Lakes area (Figure 1), has declined significantly in the warm months (Husar et al. 1981). Although natural sources of fine particles such as dust and water vapor contribute to visibility reduction, evidence suggests that most of the increased activity is attributable to anthropogenic sources transported thousands of kilometers from industrial source areas (Wolff et al. 1981, Ferman et al. 1981).

During the period of declining visibility, sulfur oxide emissions from electric utilities, the principal anthropogenic source, rapidly increased, peaking in the early 1970s (National Research Council 1981). Thus, future trends in visibility will depend principally on the emission control efficiency of coal-fired power plants and rates of coal consumption, since over 85% of atmospheric sulfur inputs in the eastern United States originate from human sources. For the present, parks where vistas are regarded as important scenic amenities, particularly in the southern and eastern parts of the region, are experiencing a decline in recreational value.

## Photochemical Oxidants and Their Effects

Photochemical oxidants, principally ozone ($O_3$), have been thought of until recently as pollutants of urban areas. However, it is now recognized that rural and forested areas several hundred miles downwind of urban areas are seriously influenced by persistent regional episodes of $O_3$ which affect the entire eastern United States region and adjacent Canada.

Typical ozone episodes in the eastern United States are associated with high-pressure systems that originate in Canada and move southeastward into the Midwest. As each system moves out of Canada, the air mass contains between 30 and 50 parts per billion (ppb) of ozone, but ozone is formed from oxidation of precursor emissions and accumulates within the air mass (Wolff et al. 1980).

These large-scale weather patterns frequently are associated with protracted periods of summertime air stagnation which account for ozone accumulations three to eight times greater than natural background over regions covering $10^3$ - $10^4$ $km^2$ (Wolff et al. 1980). For example, in 1976 an episode lasting over 10 days was associated with a high pressure system centered over western Lake

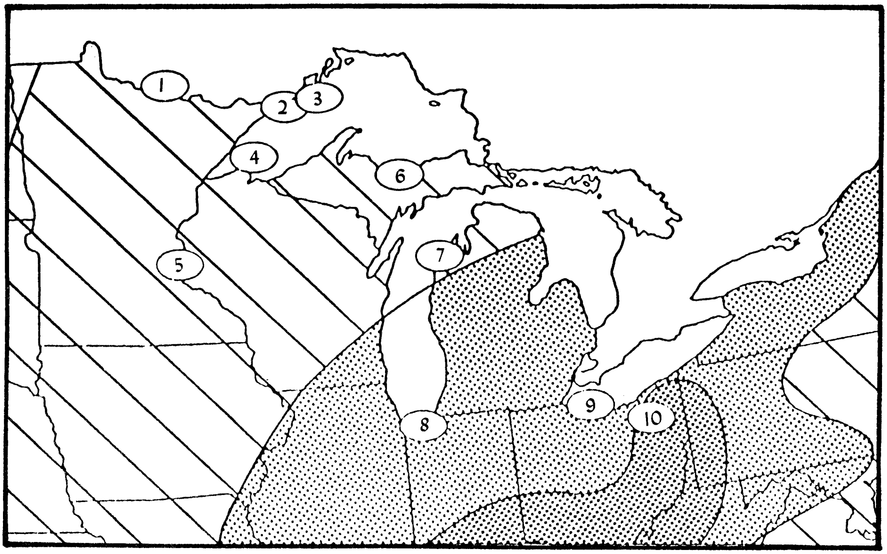


Figure 1. *Visual range (V) isopleths for non-urban areas, 1974-76. Visual range in northwestern Minnesota falls between 25 and 45 miles. Modified from Trijonis and Shapland (1979). Locations of park areas—1: Voyageurs; 2: Grand Portage; 3: Isle Royale; 4: Apostle Islands; 5: St. Croix; 6: Pictured Rocks; 7: Sleeping Bear Dunes; 8: Indiana Dunes; 9: Perry's Victory; 10: Cuyahoga Valley.*

*≤ V 10 miles*

*10 miles < V ≥ 15 miles*

*15 miles < V ≥ 25 miles*

Michigan which affected nearly the entire eastern United States (Figure 2). The region eastward from Minnesota accumulated $O_3$ concentrations reaching 60 to 150 ppb on eight days as the clockwise circulation over Lake Michigan expanded. Northern Michigan was exposed to enhanced $O_3$ levels on six days. Although high $O_3$ levels near southern Lake Michigan originated from local precursor sources, long-distance transport processes brought elevated $O_3$ concentrations into rural areas and blanketed entire agricultural and forested areas in most of the Great Lakes states. Similar episodes may occur from a few to a dozen or more times annually (Lioy and Samson 1979), depending on meteorological conditions. However, episodes are less frequent and reach lower $O_3$ concentrations in the northern and western portions of the Great Lakes region.

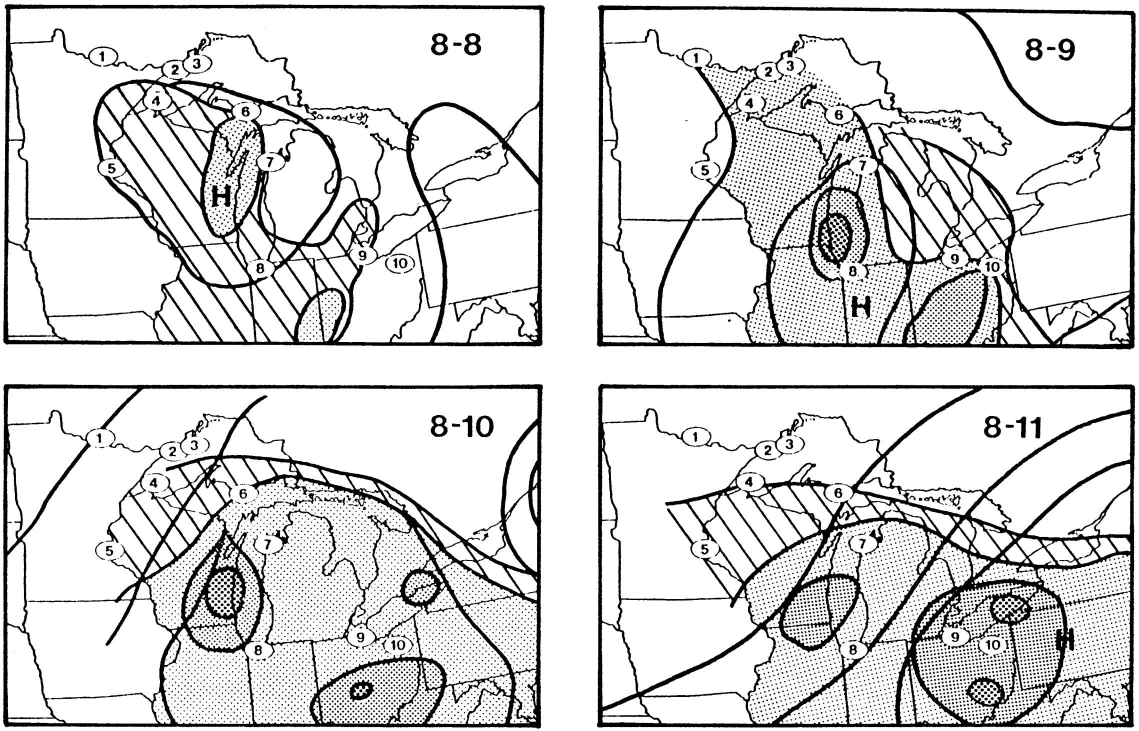


Figure 2. *Ozone concentration isopleths in the Great Lakes area in four days of an 11 day ozone episode in April 1976. Modified from Wolff et al. (1980). Such episodes occur each year in association with development of summertime anti-cyclonic weather conditions.*

*150–199 ppb* *100–149 ppb* *80–99 ppb* *60–79 ppb* *60ppb*

Photochemical exidants are recognized as the source of greatest economic loss to agriculture in the United States (SRI International 1981) and reports of reduced yields of crops come from as far north as central Minnesota (Kohut et al. 1977). Effects on native vegetation seldom have been estimated quantitatively at a regional scale, but recent evidence shows that in forested areas far from large pollutant sources, sensitive native trees are affected by regional $O_3$ accumulations. Treshow and Stewart (1973) observed that 24 out of 70 common native species were visibly injured by exposure to 0.25 ppm or less ozone for two hours.The authors suggested that growth and community vigor may be impaired in U. S. ecosystems by repeated exposures to lower concentrations.

Evidence for ozone-induced disease symptoms in white pine *(Pinus strobus)* was presented by Usher and Williams (1982) who reported that foliar chlorosis, necrosis and tip-burn associated with gaseous pollutants exposure occurred in 13 stands sampled from central Wisconsin to southern Indiana. Although $SO_2$ levels were high enough to interact synergistically with $O_3$ in urban areas and near industrial sources, the occurrence of typical foliar injury symptoms at rural Wisconsin and Indiana sites was attributed to regional $O_3$ exposures associated with air stagnation episodes.

Karnowsky (1980) showed that in the vicinity of a central Wisconsin power plant fitted with stack emission controls, differential mortality of white pine strains was associated with genetic sensitivity to air pollution. Prevalent $SO_2$ and $O_3$ exposures were low in terms of national air quality standards, yet foliar expression of air pollution injury was found in sensitive trees in 15 separate plots, and mortality rates of sensitive trees was two to five times higher than in more resistant strains.

Synergistic effects of the two gases observed in the Karnowsky study could explain the occurrence of effects at low concentrations (Dochinger et al. 1970), but in other forest areas, damaged trees have been found in the absence of $SO_2$ sources. Thus, increased mortality in white pine was observed over several years in Shenandoah National Park, Virginia, and in nearby states remote from large pollutant sources (Skelly at al. 1979). The forests there are exposed to elevated $O_3$ transported in high pressure systems originating hundreds of km upwind.

Other tree species that have been experimentally demonstrated to suffer reduced growth at concentrations of photochemical oxidants observed in parts of the Great Lakes area include quaking aspen *(Populus tremuloides)*, sycamore *(Platanus occidentalis)*, red maple *(Acer rubrum)*, and green ash *(Fraxinus pensylvanica)*, (Townsend and Dochinger 1974, Karnowsky 1976, Kress 1980). Thus, air pollution effects on forests in the more polluted southern and eastern Great Lakes may now be occurring at rates that could be documented through careful studies, while gaseous pollutant effects upon sensitive tree strains should be monitored in the northern and western portion of the region.

## Acid Precipitation

The chemistry of precipitation throughout eastern North America has changed significantly over the past few decades in association with the occurrence of sulfuric and nitric acids in the lower atmosphere (Galloway and Cowling 1978). Precipitation has become more acidic over this period according to data summarized by Likens (1976) and by Glass (1981). Current levels of acidity in precipitation in the Great Lakes region are strongly acidic (Figure 3), a condition which has raised concern about effects upon the integrity of aquatic and terrestrial resources (Stottlemyer 1981).

Within eastern North America are large areas in which the surficial soil material and bedrock types are identified as "potentially sensitive" because they have little ability to neutralize acids (Galloway and Cowling 1978). Effects on watersheds and aquatic resources are most strongly expressed in areas where elevated inputs of acid combine with low natural buffering of soils and water to reduce the pH of surface water, leading to the extinction of fish populations (Beamish 1976). A major question currently under investigation is whether alterations in water chemistry observed to date represent a time trend, thus suggesting that

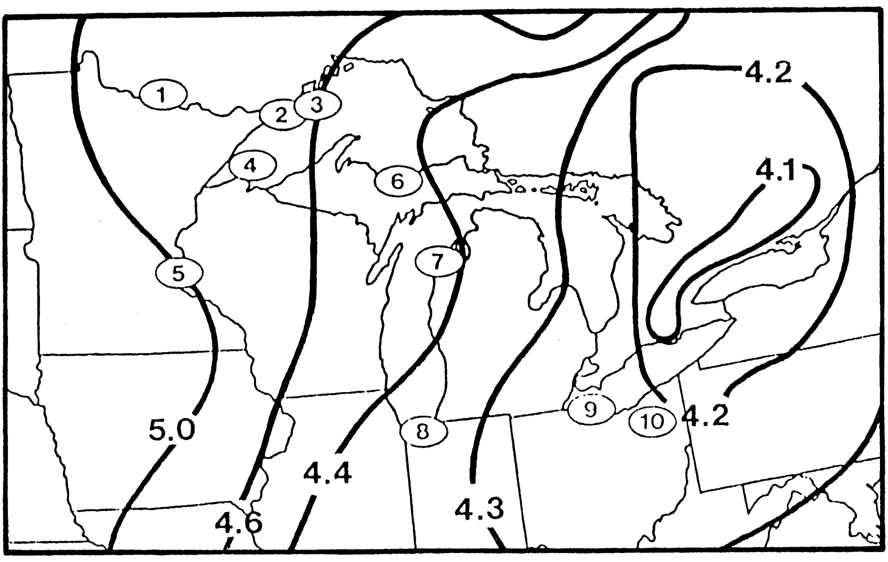


Figure 3. *Weighted averages of precipitation pH for the period April 1979 to March 1980. Data from the National Atmospheric Deposition Program. Modified from US-Canada Memorandum of Intent on Transboundary Air Pollution (1981).*

many more lakes will be affected in the future, or a steady-state of inputs and weathering, suggesting little increase in the extent of damage, even if current acid loadings continue.

The recently recorded effects on resources in sensitive areas are cause for concern in the northern highlands area stretching from northern Minnesota to northern Michigan including Voyageurs National Park, Grand Portage National Monument, the St. Croix National Scenic Riverway and Isle Royale National Park (U. S./ Canada 1981, Loucks et al. 1981, Stottlemyer 1981).

Many changes in aquatic life have been linked to the alteration of surface waters. Causal relationships appear to have been established with depressed pH for some species, but in most cases, the observed changes in biota are correlated with changes in pH. Acidification often has been accompanied by decreases in species diversity, changes in species dominance (Harvey et al. 1981), and changes in composition and metabolism of plankton communities and, therefore, the general structure of aquatic food chains.

Fish populations, in particular, appear to have been lost from some lakes in the Adirondacks and Ontario over the period of the past 40 years (Pfeiffer and Festa 1980, Harvey et al. 1981). Some lakes appear to be experiencing changes in fish populations now, while still others are in a healthy condition. In addition, many species of salamanders and frogs breed in temporary pools susceptible to pH depression when accumulated acid flushes rapidly during spring or fall storms. The danger that they may become locally extinct could hold important implications for other wildlife (Pough 1976).

Experimental studies indicate that many kinds of direct acid deposition effects are also possible in terrestrial systems ranging from damage to surface of leaves to leaching of essential nutrients from soils. However, acid rain impacts in sensitive watersheds appear first as reactions to the mobilization of soil aluminum. The solubility of this metal increases with increasing acidity. Soluble aluminum may be absorbed by plant roots or transported through the soil horizon to the water table at accelerated rates in the low-buffered soils subject to acid deposition.

Excess aluminum affects cell division in roots, causing inhibition of root growth leading to stubby and brittle roots. The accumulation of aluminum to toxic levels in forest stands in Germany subject to acid deposition (Ulrich et al. 1980) suggests that inhibition of root growth in certain forests on low buffered soils in the northern United States also may occur if elevated acid inputs continue. The significance of these processes to the acid-sensitive areas in the Great Lakes region however, has not been established, although evidence that these systems are particularly vulnerable to acid-alteration indicates that present acid inputs already may be eliciting effects (Glass and Loucks 1980).

## Summary of Air Pollution Threats

The susceptibility of the 10 parks to pollution-induced resource alteration is determined by two main factors: the presence of susceptible resources, and the loading rates of the various pollutants in relation to levels that cause resource impacts. Thus, although large populations of trees sensitive to photochemical oxidants are found at Voyageurs National Park, ozone effects are probably small because ozone accumulations appear to fall short of exposures known to cause effects. However lakes susceptible to acid-alteration are found in Voyageurs National Park, and increased acid deposition there suggests that significant resource impacts may already by underway. Similar concerns apply to Isle Royale National Park. Towards the south and east, gaseous pollutant impacts are to be expected because loadings are high enough to induce effects in susceptible species. Throughout the region, reduction in visibility has occurred over the past few decades with greatest resource impacts evident where scenic vistas are important.

Actual and potential pollutant threats based on present knowledge have been summarized in Table 1. Many studies now are underway that undoubtedly will advance understanding of chronic pollution effects. Thus, estimates of effects are subject to change as new research findings emerge. The future time trend in emission

Table 1. *Actual and potential air pollution induced threats to Great Lakes National Parks. ++ indicates that resource alterations are probably occurring now for specific pollutants indicated; + indicates significant potential for future effects in the next two decades unless major reductions in pollutant loadings occur.*

| | | SOURCES OF THREAT | | | |
|---|---|---|---|---|---|
| PARK | MAJOR NATURAL RESOURCES | VISIBILITY REDUCTION | $SO_2$ | $O_3$ VEGETATION EFFECTS | ACID DEPOSITION AQUATIC EFFECTS |
| Voyageurs | Forests, lakes, streams | + | | | ++ |
| Grand Portage | Forests, streams, vistas | + | | | ++ |
| Isle Royale | Forests, wildlife, streams, vistas | + | | | + |
| Apostle Islands | Forests, shore | + | | + | ++ |
| St. Croix | Forests, wildlife, streams | + | | + | + |
| Pictured Rocks | Forests, beach, outcrops, vistas | + | | + | + |
| Sleeping Bear Dunes | Beach, vegetation, vistas | ++ | | + | |
| Indiana Dunes | Beach, vegetation | ++ | ++ | ++ | |
| Perry's Victory | Vistas | ++ | | | |
| Cuyahoga Valley | Vegetation, vistas | ++ | ++ | ++ | |

rates of fossil fuel-based industry and transportation is certain to influence future pollutant impacts but the direction and magnitude of changes in trends are unclear. If present loadings are maintained over the next two decades, however, resource impacts would be expected to increase, and resource values to diminish in most park areas. Thus prospects for increased pollutant emissions in the eastern United States in response to greater fossil fuel combustion must be viewed as a threat to susceptible resources in the Great Lakes parks.

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