

First Annual Report of

**Polluted Parks in Peril:
The Five Most Air Polluted National
Parks in the United States**

compiled by

Harvard G. Ayers
Appalachian State University
Boone, North Carolina

A Report From
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**Appalachian Voices
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The Five Most Air Polluted National Parks in the United States**
(Compiled by Harvard G. Ayers, Appalachian State University)

Summary. Analysis of 1991-98 air pollution monitoring data from ten US National Parks shows that the five most polluted parks are, in order: 1) Great Smoky Mountains (Tennessee and North Carolina); 2) Shenandoah (Virginia); 3) Mammoth Cave (Kentucky); 4) Sequoia/Kings Canyon (California); and 5) Acadia (Maine) National Parks. The ranking is based on a combination of three pollutant-related measures for visibility, ozone pollution, and acid precipitation, all measured by National Park Service monitoring stations over the most recent eight years. This time period also represents the first eight years of results following the passage of the Clean Air Act Amendments of 1990. With noted exceptions, the analysis shows more serious degradation of air quality including risks to human and environmental health in the eastern US parks.

All of these parks are considered Class I areas under the Clean Air Act Amendments of 1977. Class I areas are afforded the greatest degree of air quality protection in the country under the Act.

The differences in the eastern and western pollution levels are attributed primarily to the burning of large amounts of coal, almost entirely at electricity generating stations. The coal burning produces emissions of two major pollutants, nitrogen and sulfur oxides. Both contribute to visibility degradation (about 70% of the problem) and substantially to the acid precipitation problem. The nitrogen oxides also are a major constituent of ozone. A large part of these sources derive from electric utility plants with grandfathered authority for high emissions of sulfur and nitrogen oxides under the 1977 Clean Air Act Amendments.

Trends in air pollution for the eight year study period are especially evident for the top three parks, Great Smoky Mountains, Shenandoah, and Mammoth Cave National Parks. Each of these parks has experienced significantly higher levels of pollution over the second half of the study period.

Introduction. Appalachian Voices, a non-profit conservation organization focused on protecting forests of the Appalachian Mountain region, has obtained air quality monitoring data from the National Park Service for ten National Parks across the United States. These data cover the period 1991-1998 and include records on visibility, ground-level ozone and acid precipitation. The sites for which data have been summarized, as well as the final rankings, are shown in Table

1, and their locations are shown on Map 1.

The goal of this analysis of National Park air quality data is to develop a composite measure, or Air Pollution Index, based on three data categories, and compare the results across eastern, midwest, and western National Parks. The result would allow the identification of the five most polluted National Parks including the trends of pollution in those parks over time. The three pollutants have been used with the following definitions and results.

Visibility. Visibility is recorded as the distance that one can see, measured in miles. Visibility data were taken from the IMPROVE (Interagency Monitoring Of Protected Visual Environments) aerosol monitoring program. The variable used in this analysis was the average of the 20% haziest days each year, for each National Park. For all five top National Parks, most of these days occur in the summer, the time of highest visitation. Thus, these are the conditions that the majority of the park visitors encounter. Visibility at the four eastern parks averaged about 15 miles over the eight-year period. This compares to the 60 mile visibility estimated in previous studies (Trijonis 1995), for the worst season (summer) if there are no anthropogenic air pollutants. The annual average (as opposed to worst-season visibility) for the four eastern parks is presently about 33 miles, compared to about 95 miles without human pollution.

Summer visibility at the eastern National Parks is poorer than other seasons because of the higher sulfate concentrations in the air, which combine with additional summer moisture to form the haze. These sulfate particles alone account for about 2/3's of the visibility impairment (Trijonis 1990). Also, sulfate levels are higher in the summer due mainly to additional electric generation by coal-fired utility plants to power air conditioners. Emissions from forests and other vegetation contribute somewhat to the haze, resulting in the naming of mountain ranges such as the Great Smoky Mountains and the Blue Ridge Mountains. But, these and other natural sources are only a small part of the present-day problem, especially in the haze-ridden East.

Mammoth Cave National Park has the poorest visibility of any National Park in the country (Table 1), with Shenandoah and Great Smoky Mountains National Parks close behind. Visibility at Mammoth Cave for the 20% worst days is 10.5 miles, which is less than 1/5 of what it would be without human pollution. The apparent reason for Mammoth Cave's haze is the proximity of the park to several of the country's most polluting coal-fired utilities in the nearby Ohio Valley. Shenandoah (11.7 miles) and Great Smoky Mountains (13.2 miles) are also downwind from electric utility plants. Acadia National Park (21.6 miles) is somewhat more distant from these sources, but has only about 1/3 of natural visibility.

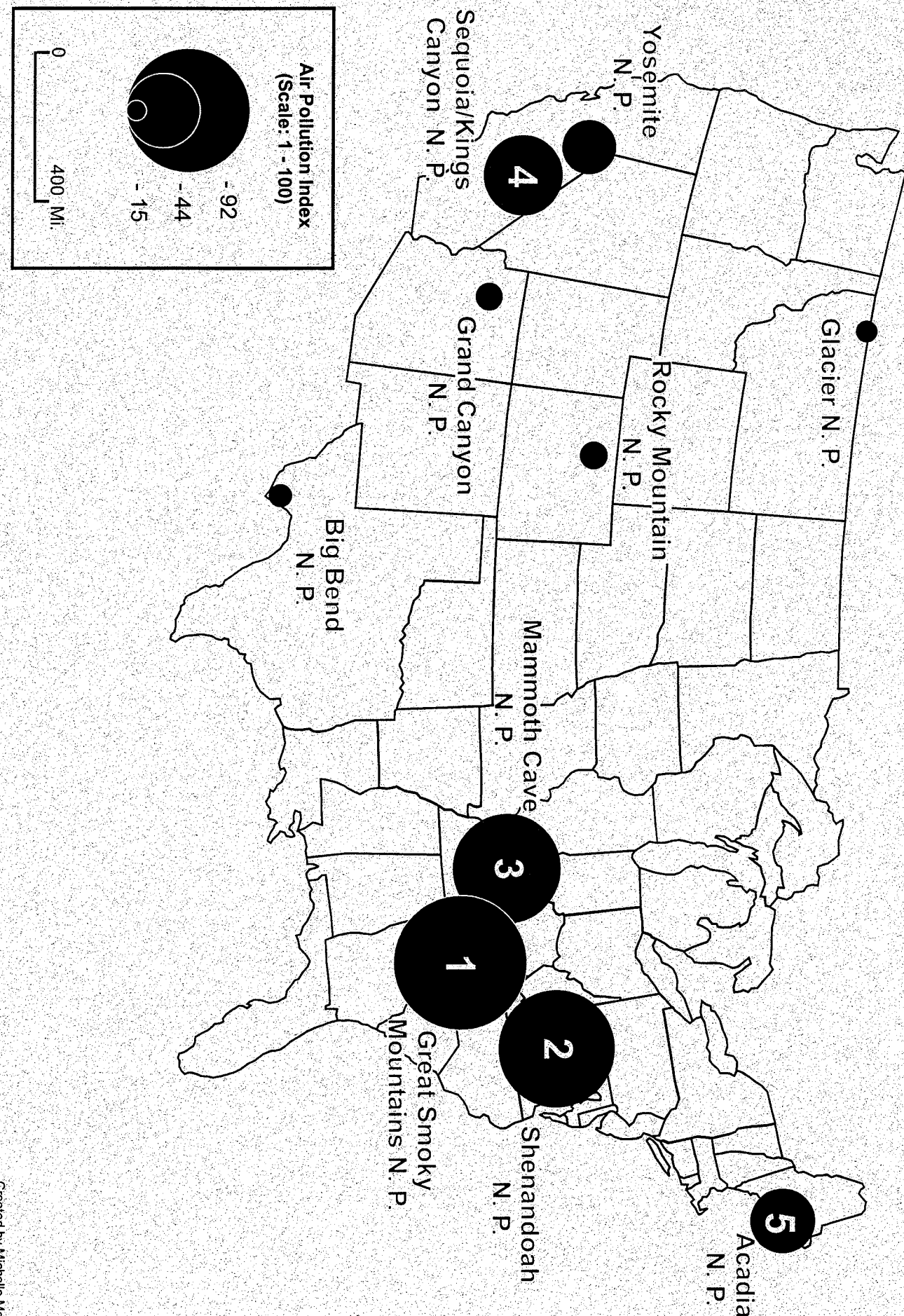
Sequoia/Kings Canyon National Parks, at 22.7 miles visibility, although slightly better than the eastern parks, is still much worse than has been projected for natural conditions. Western air, as a rule, is much dryer than eastern air, yielding an average annual visibility of about 150 miles (Trijonis 1990). In the absence of man-made pollution, worst season visibility should not be much less. Dust and nitrate particles are a much higher percentage of the haze in the west, since most of the utilities have converted from coal to natural gas, a low-sulfur fuel.

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Table 1. Air Pollution Index Based on 1991-1998 Data

Park	Visibility in Miles (20% Worst Days)	Acid Precipitation Kg/ha (NO ₃ + SO ₄)	Ozone (Sum of hourly values over 59 ppb)	Air Pollution Index - Scale 1-100	Rankings
Acadia	21.6	27.4	15,100	44	5
Big Bend	43.7	5.5	11,400	16	9
Glacier	35.7	5.8	900	15	10
Grand Canyon	72.5	5.2	35,900	19	8
Great Smoky Mountains	13.2	38.2	121,200	92	1
Mammoth Cave	10.5	36.1	37,300	75	3
Rocky Mountain	67.3	7.0	29,000	19	7
Sequoia/Kings Canyon	22.7	7.5	127,100	55	4
Shenandoah	11.7	31.1	87,300	80	2
Yosemite	43.4	3.7	98,200	37	6

Map 1. Ten National Parks in Study



Ozone. Concentrations of this pollutant are measured in ppb (parts per billion), while the risks to human health and forests usually are expressed in duration (hours) above a critical threshold, in this case the sum of all the hourly readings for the year, 60 ppb and above. Data for this study for ozone pollution were obtained from the National Park Service Gaseous Air Pollutant Monitoring Network.

The ozone concentration of 60 ppb was chosen as the cutoff because it is widely accepted as the lowest level at which significant damage occurs to sensitive vegetation, including some tree species. The figure for human health damage is generally believed to be about 80 ppb.

Because of its proximity to the agriculturally-oriented San Joaquin Valley and other areas of high population in central California, Sequoia/Kings Canyon National Parks had the highest ozone readings of all the National Parks in the study. Sequoia/Kings Canyon had an annual ozone season (April-October) average of 127,000 ppb hours.

Close behind at 121,200 ppb hours, was Great Smoky Mountains National Park. Next among the top five most polluted National Parks were Shenandoah (87,300), Mammoth Cave (37,300) and Acadia (15,100). While not high in other pollution measures, Yosemite had a high ozone reading of 89,200 ppb hours. For comparison, among monitored National Parks, Glacier National Park, located in northern Montana, was the lowest at 900 ppb hours.

Ozone in our National Parks has resulted in serious health concerns for vegetation and for humans. Shenandoah, Great Smoky Mountains, and Acadia National Park, in fact, issue ozone warnings to park visitors and staff. While the elderly and the very young, as well as anyone with a respiratory illness such as asthma, are especially susceptible to ozone, even the healthiest of humans can exhibit ozone symptoms such as scratchy throat, burning eyes, respiratory distress, and heart arrhythmia.

A total of 30 different plant species in Great Smoky Mountains National Park have clearly shown damage from ozone. The most ozone-sensitive plant species include black cherry and tulip poplar trees and tall milkweed and thornless blackberry, and many other species show moderate symptoms.

For Sequoia/Kings Canyon National Parks, Jeffrey and ponderosa pines are especially susceptible to ozone damage (Grulke and Miller 1994). The Giant Sequoia itself, after which the park was named, has been found to be sensitive (especially seedlings) to ozone at levels present almost constantly in the summer (Ewell and Gay 1993).

Natural levels of ozone would be expected to be always below 60 ppb, so any of the ppb hours calculated for this study would be caused by human pollution. The two pollutants that create ozone pollution are nitrogen oxides and volatile organic compounds (VOC's). Nitrogen oxides come from coal-burning industry (mainly electric utilities) and from motor vehicles, while VOC's come chiefly from motor vehicles, and in the East, also from vegetation.

Great Smoky Mountains National Park in 1998, recorded the largest single-year cumulative ozone exposure of any National Park in the U. S. for the eight year study period, with 189,600 ppb hours. At this level, the park had over two times the number of ppb hours over 60 ppb of even Atlanta, Georgia, the most ozone-polluted city in the eastern United States. While peak concentrations in Atlanta were higher than in the park, ozone in the city drops to near zero at night. Mountain locations, however, remain at high concentrations all day and night, sometimes for days at a time. While peak readings usually occur in the lowland cities in the mid to late afternoon, the highest readings in the mountains may be in the middle of the night, when city locations are very low. Like the eastern mountains, Sierra Mountain locations in the West such as Sequoia/Kings Canyon National Parks also have long periods of high ozone concentrations with no drop at night.

High ozone levels, like impaired visibility, occur in the peak park visitor months of the summer for all of the five most polluted National Parks. In many cases the two, high ozone and poor visibility, occur together. In the East, this is the case because pollutants build up when weather systems stall. While ozone is invisible, its associated pollutants, mainly sulfate particles, are the main constituents of the haze.

Acid Precipitation. Acid precipitation refers to the quantity of strong acid ions (sulfate and nitrate) in rain, snow, sleet, and even cloud water or fog that are deposited on the ground. Natural, unpolluted rainwater has a pH (a measure of hydrogen ion concentrations) of about 5.5. Since neutral on this scale is 7.0, natural rainwater is slightly acidic. Acid precipitation is only a part of total acid deposition, which includes the deposition of dry particles as well. The acid precipitation data used in this analysis were obtained from the National Atmospheric Deposition Program.

In the higher mountain locations over much of the East, including Great Smoky Mountains National Park, precipitation can be 10 to 100 times more acidic than natural rainfall (i.e. pH 4.5 or 3.5). The latter pH tends to be true of the cloud water, which hangs on the mountaintops for many days of the year. Cloud water in the park has been measured as low as pH 2.5 which is 1000 times more acidic than natural rainwater.

Great Smoky Mountains National Park had the highest deposition of acid precipitation for any National Park during the study period. A annual average total of 38.2 kilograms per hectare (about 34 pounds per acre) of nitrate and sulfate was measured. Mammoth Cave and Shenandoah National Parks were close behind with 36.1 and 31.1 kilograms per hectare respectively, while Acadia measured 27.4. Far behind are the western parks, with Sequoia/Kings Canyon National Parks having 7.5 kilograms per hectare.

This level of deposition is an important risk for soils, stream water, aquatic organisms, and vegetation. The amount deposited at Great Smoky Mountains National Park is three to four times the critical load above which sensitive soils and vegetation will be damaged (Schultze et al. 1989). The nitrate levels have, in fact, accumulated to the point that the soils in the park are saturated. Such high levels of soil nitrogen are associated with removal of critical nutrients

needed by vegetation and aquatic organisms such as calcium and magnesium. Also, scientists have found that normally inert aluminum goes into solution at the low pH levels, and in this state is toxic to vegetation and aquatic organisms. Thus, the combined effects of high nitrate levels and low pH both starve the plant of nutrients and poison them at the same time. Reduction of tree growth, reduction of disease and pest resistance, and even tree death, can occur. In most cases another agent such as drought, ice, winter cold, disease or pest attack is the final stress that kills the tree. Air pollution, which includes primarily acid deposition and ozone, thus leads to a condition in the trees similar to AIDS in humans.

Mortality of large numbers of some of the best known species in Great Smoky Mountains National Park also can be traced to the high levels combined air pollution. Park populations of flowering dogwood have been reduced by half or more, an outcome already linked to acid deposition (Anderson 1993). Fraser fir and red spruce, the dominant trees in the highest elevations of the park, are declining and dying over large areas, attributed in a recent government report to acid deposition (NAPAP 1998). American beech populations are also declining and dying. While each of these species has its own special disease or pest, many scientists believe that air pollutants are the underlying stressor, the common denominator of forest decline.

Methodology. This study evaluated National Park Service data from all the National Parks for which the three pollutant measures, visibility, ozone and acid precipitation are available. This included the ten National Parks listed in the two tables herein. Four are the eastern parks that emerge on the list of the top five most polluted National Parks. A fifth major eastern National Park, Everglades, was not included in the analysis, since it did not monitor visibility.

The ten National Parks were ranked using two different approaches. One was the calculation of an Air Pollution Index. The most polluted site was given a score of 100 for each of the three air pollution characteristics, visibility, acid precipitation, and ozone. The other nine parks were expressed as a percentage of the highest pollution level observed. The three percentages for each park were then averaged to give the Air Pollution Index. The highest possible index was thus 100, which would have meant that a park was the worst on all three characteristics. Average values ranged from 92 for Great Smoky Mountains National Park to 15 for Glacier National Park.

The alternate ranking approach calculated what statisticians the "standard deviation from the mean" for each of the three pollution measures (Table 2). These also were added together to get the ranking. The higher the standard deviation from the mean, the worse the pollution. Here, a value of zero indicates the average across all the parks. Individual park values ranged from +3.78616 for Great Smoky Mountains National Park to -2.93311 for Grand Canyon National Park.

These two approaches yielded different rankings among the cleaner parks, but not for the five most polluted parks. Numbers one through six were identically ranked. Numbers seven through ten shifted places. Because the study sought to identify the five most polluted National Parks, the

correspondence between the two approaches gives confidence in the rankings.

Conclusions. The overall results of this report indicate that, with notable exceptions in California, the worst National Park air pollution problems in the United States are mainly in the East. Four eastern National Parks comprise four of the five most polluted parks. A fifth, Everglades National Park, would, in all likelihood, rank sixth or seventh, but visibility data are not available.

One must ask why National Parks in the East are more polluted. Part of the answer is that while both the East and the West have large numbers of motor vehicles, the East alone burns large amounts of coal, almost entirely at electricity generating stations. The coal burning produces large amounts of two major pollutants, nitrogen and sulfur oxides. Both contribute to visibility degradation (about 70% of the problem) and substantially to the acid precipitation problem.

Both motor vehicles and coal burning contribute about equally to acid precipitation (in the form of sulfur and nitrogen compounds in precipitation), and roughly equally to the formation of ozone through the reaction of nitrogen oxides and volatile organic compounds with sunlight. Thus, in the West, without substantial sulfur pollution, the National Parks have maintained better visibility and much less acid precipitation. The high ozone readings at Sequoia/Kings Canyon and Yosemite National Parks are due to their proximity to centers of motor vehicle and agricultural nitrogen emissions in the Central Valley and the San Francisco Bay area.

Coal burning electric utilities in the East, thus, make up the principal difference in the pollution levels reported here. The problem is especially serious because of electric utility plants with grandfathered authority under the 1977 Clean Air Act. These plants produce from four to ten times the amount of pollution released from the newer, state-of-the-art power plants.

Pollution trends, at least in the East, are on the upswing despite the 1990 Clean Air Act Amendments. Great Smoky Mountains, Shenandoah, and Mammoth Cave National Parks all show an increase for an annual composite of the three air pollution measures (visibility, acid precipitation and ozone) taken over the eight year study period. Each of the three parks had a slight decrease over the first half of the study period followed by a steady increase for the second half. The increase is driven by steadily rising concentrations of ozone pollution. Both visibility and acid precipitation show no apparent trend either up or down, which is surprising, since sulfur emissions are said to be going down nationally as dictated by the 1990 Act. Figure 1 shows graphs for these three parks' annual composite values.

Trend analysis for Sequoia/Kings Canyon and Acadia National Parks were not attempted due to incomplete data. Sequoia lacked visibility data for 1991-1993. The calculation of a mean for the five years of available visibility data was possible, but trend analysis was not. Acadia was missing ozone data for 1998 as the station was moved to another location in the park. The 1998 data from the new station could not be used in conjunction with the data from the previous station. As with Sequoia/Kings Canyon, the calculation of a mean for ranking purposes was possible from the seven years of ozone data from the original station.

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Table 2. Standard Deviations for Air Pollution Values Based on 1991-1998 Data

Park	Visibility in Miles (20% Worst Days)	Acid Precipitation Kg/ha (NO _x + SO _x)	Ozone (Sum of hourly values over 59 ppb)	Deviation for Visibility	Deviation for Acid Deposition	Deviation for Ozone	Total of Three Standard Deviations	Rankings
Acadia	21.6	27.4	15,100	-0.56236	0.73596	-0.86949	0.42883	5
Big Bend	43.7	5.5	11,400	0.42166	-0.77742	-0.94750	-2.14659	8
Glacier	35.7	5.8	900	0.06545	-0.75669	-1.16888	-1.99103	7
Grand Canyon	72.5	5.2	35,900	1.70401	-0.79815	-0.43095	-2.93311	10
Great Smoky Mountains	13.2	38.2	121,200	-0.93638	1.48228	1.36749	3.78616	1
Mammoth Cave	10.5	36.1	37,300	-1.05660	1.33717	-0.40144	1.99233	3
Rocky Mountain	67.3	7.0	29,000	1.47247	-0.67377	-0.57643	-2.72267	9
Sequoia/Kings Canyon	22.7	7.5	127,100	-0.51338	-0.63921	1.49189	1.36606	4
Shenandoah	11.7	31.1	87,300	-1.00317	0.99164	0.65275	2.64757	2
Yosemite	43.4	3.7	98,200	0.40830	-0.90181	0.88257	-0.42755	6

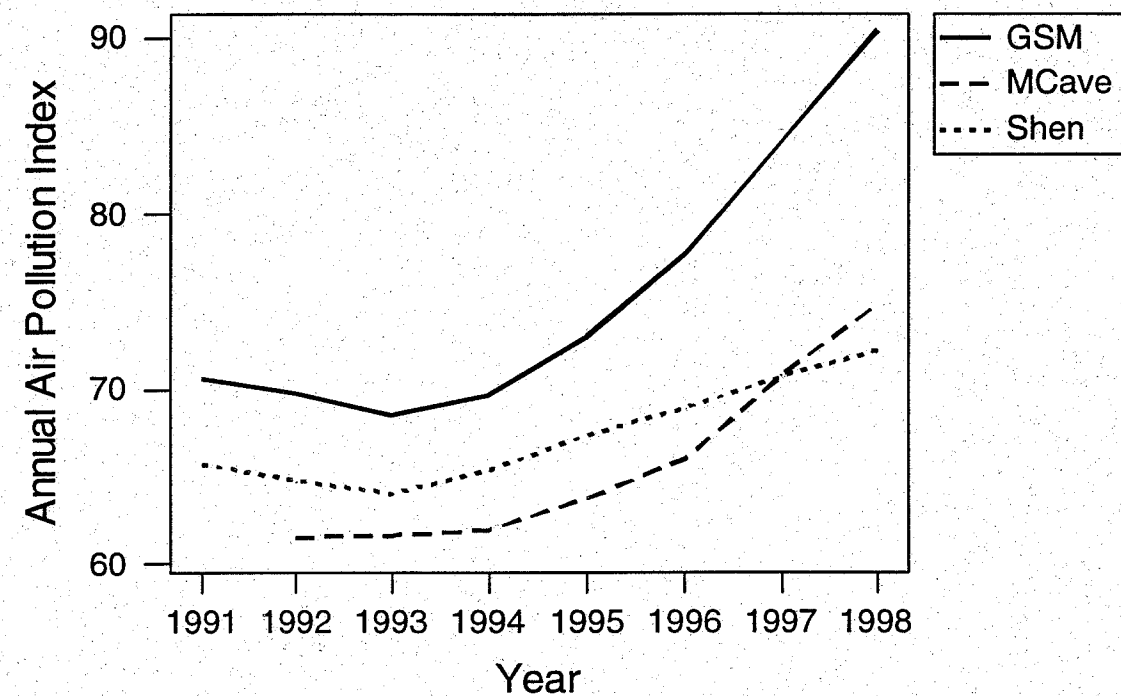


Figure 1. Air Pollution Trends

This report clearly indicates that a number of our country's National Parks have a serious air pollution problem. These Class I areas that are supposed to have the cleanest air in the country are in some cases, more polluted than the most polluted cities in their region. Clearly, significant reductions in the major pollutants (nitrogen, sulfur, and VOC's) will be necessary to protect the features that are the reasons that the public wants to visit these "crown jewels" of our country.

The most important cause of the air pollution at the National Parks and across the country is the burning of fossil fuels, chiefly coal and gasoline. In the East, the most important step that must be taken to clear the air in our National Parks is the reduction of emissions from coal-burning industry, mainly electric utilities. Without the first step of drastically reducing sulfur and nitrogen emissions from the older, grandfathered electricity producing power plants, little improvement will be seen in any of the measures of pollution used in this study, and more importantly, our National Parks will remain in peril.

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