

Overview of Air Pollution Effects On National Parks Vegetation in 1985

By James P. Bennett
NPS Air Quality Division

Known Air Pollution Effects on Vegetation in National Parks – 1985

Park	Pollutant	Vegetation Effects
Acadia NP	Ozone (Four exceedances of NAAQS* in 1983 & 1984; the maximum hourly average during these years has been 0.14 ppm.)	Over 95% of 300 eastern white pine trees studied in 1984 showed some slight injury. Almost 30% of the injury was 20% foliar damage or greater. The injury appears to be correlated with decreased width of tree rings, i.e. growth.
Shenandoah NP	Ozone (No exceedances of NAAQS since 1980. However, maximum hourly averages during summers reach as high as 0.12 ppm; monthly means are increasing by .003 ppm.)	Widespread foliar injury in 1982 & 1984 on white pine, tulip poplar, black locust, wild grape, clematis and milkweed. Injury on the most sensitive species (milkweed) occurred on 90% of the plants observed each year. About 8% of the least sensitive species (black locust) were injured. The injury appears to be correlated with decreased productivity and plant diversity. Tree mortality is abnormally high.
Shenandoah NP	Sulfur oxides and heavy metals (Levels of SO ₂ are about 20% of the 3 hour NAAQS and 30% of the 24 hour NAAQS.)	Elevated concentrations of sulfur and lead are found in lichens. At some sites, the concentrations are above the normal range for lichens from unpolluted areas. Such concentrations have been associated with lichen decline and food web effects in other studies.
Great Smoky Mountains NP	Ozone (Data collected by TVA show numerous exceedances of NAAQS; however, latest data collected by Tennessee show attainment of NAAQS.)	Between 25-30% of eastern white pine trees show injury. Preliminary evidence indicates that sensitive genotypes may be disappearing and that growth is decreasing.
Saguaro NM	Ozone (No exceedances of NAAQS since 1982; hourly average has reached .110 ppm during the summer.)	Almost all of 225 ponderosa pine trees studied in 1984 showed some injury, with the average foliar injury being almost 12%. Some slight injury was also observed on oak and walnut trees.
Sequoia NP	Ozone (The maximum hourly average during the summer has consistently exceed or equalled NAAQS since 1981.)	Over one-third (36%) of 540 ponderosa pine trees studied periodically since 1980 show moderate to severe injury. Injury is also common on oak trees. Foliar symptoms, like ozone injury observed in laboratory studies, have been recently observed on giant sequoia seedlings in the park.
Santa Monica Mountains NRA	Ozone and Sulfur Dioxide (Summer 1984 ozone levels exceeded NAAQS on numerous occasions with the highest hourly average being 0.22 ppm.)	Air pollution injury averaged 40% of all injury on 7 species. The injury has been related to reduced biomass production and subsequent soil destabilization and fire fuel loading. In portions of the park lichens are no longer found, indicating long-term exposures to SO ₂ .
Indiana Dunes NL	Ozone and Sulfur Dioxide (Numerous exceedances of ozone NAAQS in recent years; highest O ₃ hourly average recorded has been 0.16 ppm; SO ₂ concentrations are 73%, 64% & 47% of 3 hour, 24 hour, and annual NAAQS.)	Foliar injury is common on 16 species studied in 1984 including white and jack pines. Injury is greater on juveniles than adults. Growth of jack pine juveniles and white pine adults is reduced in areas highest in ozone. Lichens are also no longer found here, indicating long-term exposures to SO ₂ .
Cuyahoga Valley NRA, Saratoga NHP & Acadia NP	Ozone	In a common fumigation exposure study, injury on quaking aspen genotypes from these parks was significantly less than injury on aspen genotypes from Voyageurs & Isle Royale NPs, indicating that sensitive genotypes are absent and that the species gene pool is affected.

*National Ambient Air Quality Standards (NAAQS):
Ozone: 0.12 ppm/1 hour/1 day
Sulfur Dioxide: 0.50 ppm/3 hour; 0.14 ppm/24 hour; 0.03 ppm/annual average
All reported values are from NPS monitors physically located in National Parks.

Four years ago I initiated the Biological Effects Program for the Air Quality Division by starting a number of projects for detecting effects (*Park Science* 2: 10). Enough time has passed since the program's inception to begin summarizing some of the findings. The accompanying table summarizes known biological effects from field studies in about 10 national park units, and biomonitoring results in many more parks. The three columns name the parks containing the effects, the pollutants causing the effects and recent observed concentrations, and the effects themselves.

Observing effects of pollutants on plants accomplished two purposes: biomonitoring of the presence of pollutants, and translating this into actual biological effects. Most air pollutants cause specific types of foliar injury which can be diagnosed in the field . . . the types of spots on the leaves can tell you which pollutants were present and which caused the injury. Thus, identification of these spots is one means of monitoring the presence of pollutants.

In addition, however, the injury itself is a biological effect. The pollutants were present at concentrations high enough to affect cells in obvious ways. For example, ozone concentrations above 0.08 ppm cause a dark purple stippling on the top surfaces of leaves. Each stipple, or spot, is actually a dead cell. If enough of this type of injury occurs, it usually means that less obvious but more serious effects also are taking place. Such effects include growth reductions, premature leaf abscission, reduced flowering, decreased fruit weights, and more. These are the types of effects described in one part of the table, while biomonitoring results appear in the other part.

It is clear from the table that the worst effects in the national parks are the results of elevated levels of ozone. This pollutant is widespread in the eastern U.S. and California. Our milkweed survey indicates that ozone is present in at least 20 parks in the eastern U.S. at concentrations above the foliar injury threshold for this species (about 0.06 ppm). The same might be said for California since ponderosa pine also is sensitive to ozone at about this concentration.

The next important air pollutant in the national parks from the point of view of biological effects is actually a whole class of pollutants – the heavy metals. Elevated levels of lead are common in organisms in several parks, probably due to the lead in automobile emissions.

This table only summarizes what is known about existing effects found in field studies on terrestrial vegetation from gaseous and particulate air pollutants, and specifically excludes terrestrial and aquatic effects from acidic precipitation. The effects of acid rain on high-elevation eastern forests is greatly talked about today, but very little is actually known about it. Many studies are underway in several eastern parks to establish clear cause and effect relationships for acid rain.

The worst effects are not found in the parks that are designated Class I under the Clean Air Act. Instead, Indiana Dunes and Santa Monica Mountains, both Class II parks, show severe effects but have a lesser degree of protection under the act. They do indicate, however, that severe effects could occur in

research notes

Editor's Note: Beginning with this issue, Park Science will be devoting a specially designated space to research projects contemplated or recently underway. The new section, entitled **Research Notes**, was suggested by Editorial Board Member Gary Davis in the interest of promoting better communication among scientists about research that is in the planning stage or still is being conducted.

Davis proposes that **Research Notes** might also make available space for those who wish to propose a research topic or who are asking for assistance in obtaining ideas, methods, literature, study sites, or whatever, for a particular project. For instance, Davis and William L. Halvorson, a research biologist at Channel Islands National Park, are considering writing a review article about long-term research in National Parks and would be interested in receiving information for such an article. Readers able to shed light, furnish answers, or otherwise respond to the information given or requested in the **Research Notes** space would respond directly to the individual who placed the Note. In this way, information asked, offered, given, and received will get fastest and widest circulation.

Erosion on Santa Barbara Island

Erosion is a serious problem on Santa Barbara Island, the smallest 260 hectares (or 642 acres) of the

the Class I parks if pollutant concentrations are allowed to reach the levels found in INDU and SOMO.

Our most important study is that mentioned in the last entry in the "effects" table. This study compares the sensitivities of different genotypes of the same hardwood tree species from many different eastern parks. Evidence being analyzed indicates that the genotypes from the more polluted parks are less sensitive than those from more pristine parks. This indi-

Biomonitoring

The following parks are either exhibiting elevated concentrations of the indicated elements in biosphere organisms or components, or frequent foliar injury from gaseous pollutants. The ecological significance of this is unknown but it does indicate anthropogenic influences are presented.

Park	Pollutant	Biosphere Organism or Component
20 Eastern Parks	Ozone	Common milkweed: foliar injury.
Hampton NHS Gettysburg NMP Fredericksburg/ Spotsylvania NMP Petersburg NB	Ozone	Black cherry, white ash, wild grape, sassafras, tulip poplar, dogwood, milkweed, witchhazel, redbud, white pine, Austrian pine: foliar injury.
Isle Royale NP Theodore Roosevelt NP Everglades NP Shenandoah NP Great Smoky Mountains NP	Sulfur	Lichens: abnormally high concentrations.
Shenandoah NP	Lead	Lichens: abnormally high concentrations.
Great Smoky Mountains NP	Lead	Leaf litter: abnormally high concentrations.
Big Thicket NP	Sulfur, heavy metals	Spanish moss: abnormally high concentrations.
Mt. Rainier NP	Arsenic	Subalpine fir foliage: abnormally high concentrations.
Great Smoky Mountains NP	Heavy metals	Red spruce: abnormally high concentrations in tree rings.

Channel Islands off the coast of southern California. For approximately 80 years prior to its becoming part of Channel Islands National Monument in 1938, the island was heavily impacted by sheep, goats, rabbits, cats, farming (including plowing and burning) and the introduction of exotic plant species. Since 1980 when Channel Islands National Park was created, the NPS has been conducting an extensive inventory and monitoring program.

One aspect of the research/management program is a study of the erosion on Santa Barbara Island; its causes and feasible cures. Because of past land-use practices, the island vegetation is now primarily an exotic-species dominated grassland and interspersed with patches of shrubs, both native and exotic. These patches vary in size and density throughout the island, but both aspects are increasing now that the grazers have been removed from the island (rabbits were present until 1981). The erosion apparently was caused by a combination of the change from native vegetation cover to exotic species brought about by farming, and the burrowing rabbits, that caused further reductions of plant covering on the soil.

The island soils are primarily heavy clay vertisols and mollisols, which exhibit fairly strong shrink-swell characteristics. Burrowing and denuding of the area served to increase the soil's tendency toward tunnel erosion. The result has been an extensive pattern of gullies with occasional patches (up to 2.7 hectares or 6.6 acres) of sheet erosion where the top soil has

cates that selection is favoring tolerant genotypes and that sensitive ones are being removed from the existing populations. This is extremely important for natural resource managers in the parks to know because it indicates that the natural gene pools are being diminished. Thus, fitness of species is lowered; the whole fabric of natural ecosystems can unravel should this continue.

been completely removed.

This study is a joint effort on the part of Bill Halvorson (Channel Islands NP), Denny Fenn (CPSU, Texas A&M), and Lynn Whittig (UC-Davis). It includes analyses of the specific characteristics of the soil and of vegetation, and germination and growth experiments using indigenous seeds. The concern is that the Park be able to amend the soil by changing nutrient content, structure, and/or organic matter content as needed, and that a ground cover of native species be restored, all without introducing any new gene pools to the island. Understanding the soil-vegetation interrelationships will greatly enhance our ability to solve the erosion problem, and also will aid in our attempts to restore to the greatest extent possible, the native plant and animal communities of the island.

CONTACT: Gary Davis, Channel Islands NP, 1901 Spinnaker Dr., Ventura, CA 93001.

Dudleya traskiae

Channel Islands National Park currently is studying what appears to be a success story involving the Endangered Species Act. The Santa Barbara Island live-forever, *Dudleya traskiae* (Rose) Moran, is a succulent, perennial plant whose natural distribution is limited to Santa Barbara Island. It was listed as Endangered by the U.S. Fish and Wildlife Service (USFWS) in April 1978 (FR 43 17916). This status was deemed appropriate based on the fact that the past land-use practices, including farming, burning, and introduction of rabbits, had reduced the presence of *Dudleya traskiae* to such an extent that in 1970 it was thought to be extinct in the wild; however, it was rediscovered in 1975 as one population of a few individuals.

The NPS, meanwhile, had initiated an intensive effort to eradicate the rabbits, which were the primary cause of the near demise of a number of native plant species on the island. Complete removal of the rabbits was accomplished in 1981. Following that, Park personnel conducted surveys for the live-forever in 1982, 1983, and 1984. These surveys indicated a trend of increasing numbers and range for the species, which is still restricted to rocky sea and canyon bluffs of moderate to vertical slope.

In late 1984, while the USFWS's recovery plan was undergoing final review, a study of the population dynamics and habitat requirements of *Dudleya traskiae* was initiated by Bill Halvorson and Ronilee Fowler of Channel Islands. Support for the study has come from the USFWS and the State of California Dept. of Fish and Game's Endangered Species Program in the form of botanists giving their time in consultation and in partial funding of the research. The study will map populations and individuals, record habitat characteristics, and determine population dynamics for this species.

This information was not available for inclusion in the recovery plan and therefore will be essential to the carrying out of the plan's objective to restore the Santa Barbara Island live-forever to 95 percent of the suitable potential habitat with vigorous and self-sustaining populations. Though it appears to be expanding again, the successful long-term management of this extremely rare species requires the completion of this coordinated, jointly-funded research effort. Upon completion we're hoping to show not only successful recovery of an endangered species, but a successful venture into three-way interagency cooperation.

CONTACT: Bill Halvorson, Channel Islands NP, 1901 Spinnaker Dr., Ventura, CA 93001.