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Contaminants study provides window onto airborne toxic impacts in western U.S. and Alaska national parks

Results and implications of the Western Airborne Contaminants Assessment Project

By Colleen Flanagan

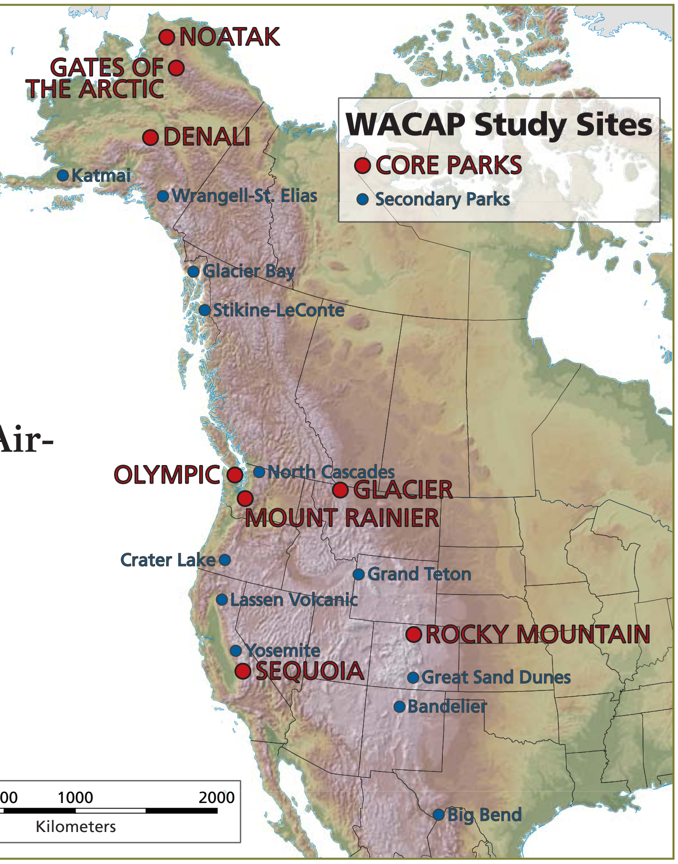

Figure 1. Sampling locations for the Western Airborne Contaminants Assessment Project. All sites are administered by the National Park Service except for Stikine-LeConte Wilderness (Tongass National Forest, Alaska), which is managed by the USDA Forest Service.

TRANSPORT AND DEPOSITION OF atmospheric contaminants have been recognized as a possible threat to aquatic and terrestrial ecosystems for several decades. Studies in the 1970s and 1980s on air quality and acidic precipitation first demonstrated the concept of long-range transport of airborne contaminants in the United States. Numerous other airborne contaminant threats to ecosystems and humans that depend upon them were subsequently identified. The presence of contaminants in remote Arctic ecosystems with no local or watershed sources of contaminants confirmed the risk of long-range atmospheric transport. High-elevation and high-latitude areas were identified as areas of particular peril due to the tendency of contaminants, such as some pesticides, to migrate to colder alpine and Arctic areas and deposit with the annual snowpack.

Given the above concerns, as well as the persistence and toxicity of these contaminants in the environment, the bioaccumulative properties of many compounds that magnify concentrations at higher levels of the food chain, and federal legislation that requires protection of the natural parks in perpetuity, the National Park Service (NPS) conducted the multiagency Western Airborne Contaminants Assessment Project (WACAP) from 2002 to 2007 to determine the risk from airborne toxic compounds to national park ecosystems and food webs. Concentration of contaminants in air, snow, water, lake sediment, lichen, conifer needles, and fish was determined from sampling two sites/lakes in eight core park units: Denali National Park and Preserve (Alaska), Gates of the Arctic National Park and Preserve (Alaska), Glacier National Park (Montana), Mount Rainier National Park (Washington), Noatak National Preserve (Alaska), Olympic National Park (Washington), Rocky Mountain National Park (Colorado), and Sequoia and Kings Canyon National Parks (California). More limited assessments focusing on vegetation and air were conducted in 12 secondary parks (fig. 1).

Airborne contaminants detected

Released in spring 2008, the WACAP study (Landers et al. 2008) indicated that numerous airborne contaminants, including mercury and pesticides, were detected at measurable levels in ecosystems at 20 western U.S. and Alaskan national parks from the Arctic to the Mexican border. The study provides an initial indication of the scale and distribution of contami-


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WACAP investigators make their way into park backcountry at Sequoia and Kings Canyon national parks in midwinter to collect snow samples for airborne contaminant analysis.

The study provides an initial indication of the scale and distribution of contaminants across a wide geographic area.

nants across a wide geographic area. Key findings from the study indicate that out of more than 100 organic contaminants tested, 70 were found at detectable levels. Though concentrations of most of these contaminants were below levels of concern, others appear to be accumulating in sensitive resources such as fish. For some contaminants, high concentrations in fish exceeded fish-eating wildlife or human health consumption thresholds developed by the U.S. Environmental Protection Agency (EPA) and others.

The three contaminants found in park ecosystems of highest concern for human and wildlife health were:

1. Mercury—a heavy metal emitted through processes such as burning coal for electricity, known to cause neurological and reproductive impairment;

2. Dieldrin—an acutely toxic insecticide banned from use in the United States since 1987, known to decrease the effectiveness of the immune system and reduce reproductive success; and

3. DDT—an insecticide banned in the United States since 1972 that also impacts the reproductive system.

Mercury levels in fish at Alaska's Noatak National Preserve were a cause of great concern as the average concentration in fish was above the EPA human health threshold for consumption. Gates of the Arctic, Olympic, Mount Rainier, and Sequoia national parks each also had some individual fish that exceeded the threshold.[1] Investigators also assessed the risk to fish-eating wildlife and found that mercury concentrations in fish at all eight core parks exceeded health thresholds suggested for birds. Mercury concentrations were also above health thresholds for some fish-eating mammals at some parks (fig. 2, next page).

Dieldrin concentrations in some individual fish exceeded the health threshold for recreational[2] fishermen at Rocky Mountain, Sequoia, and Glacier national parks. All core national parks except Olympic contained some fish with dieldrin concentrations that exceeded health thresholds for subsistence fish consumption. Average DDT concentrations in fish exceeded the human risk threshold for subsistence fishers and the bird health threshold at Sequoia and Glacier national parks (fig. 3, next page).

[1] The EPA and other agencies define the contaminant health threshold for mercury for 70 kg (154 lb) adults who consume 2.3 eight-ounce fillets of these fish per month for a lifetime.

[2] Because different populations of humans consume fish at different rates, contaminant health thresholds for dieldrin and DDT are different for recreational and subsistence fishing. The values are calculated for 70 kg (154 lb) adults. For recreational fishing, it is assumed that 2.3 eight-ounce fillets are consumed every month for a lifetime; for subsistence fishing, it is assumed that 19 eight-ounce meals of whole fish are consumed every month. Based on these estimated amounts of fish consumed, the contaminant health thresholds for dieldrin and DDT are concentrations of exposure that would raise the risk of cancer above 1:100,000.

Researchers also found some individual "intersex" trout (i.e., male fish testes contained oocytes, a female reproductive structure) at Rocky Mountain and Glacier national parks. Some male fish also exhibited underdeveloped testes and elevated levels of the estrogen-responsive protein vitellogenin, and some fish had reproductive structures sufficiently altered such that reproduction may be unlikely. Elevated vitellogenin levels and intersexuality in fish are common biomarkers used as evidence of response to exposure to certain contaminants (e.g., dieldrin and DDT) that mimic the hormone estrogen. The weight of evidence for reproductive disruption in these national park ecosystems is substantial, but because the sample size was small, WACAP established neither the extent of the problem nor the correlation between fish reproductive effects and contaminant concentrations.

Additionally, current-use pesticides and other compounds, such as the commonly used flame retardant coating for fabric PBDE, were detected in fish and sediment at all eight core parks. According to sediment records, particularly at Rocky Mountain and Mount Rainier national parks, these compounds are increasing at rapid rates over time but concentrations in fish did not exceed human or wildlife health consumption thresholds. Exposure to PBDEs may affect liver, thyroid, and neurobehavioral development.

This research suggests that the contaminants found in WACAP are carried in air masses from sources that are both local and as far away as Europe and Asia. The presence of some contaminants in snow is

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Figure 2. This graph shows the concentrations of mercury in fish, as compared to human and fish-eating wildlife contaminant health thresholds. Fish whole-body total mercury averages (bars) and individual fish (circles) are based on wet weight from all WACAP park lakes and contaminant health thresholds for human and piscivorous wildlife fish consumption. The average mercury concentration in fish sampled at Noatak exceeded the human consumption threshold, while some fish at Gates of the Arctic, Olympic, Mount Rainier (LP19), and Sequoia (Pear) also exceeded the human consumption threshold. The average mercury concentration in fish in all lakes sampled at all parks exceeded the kingfisher health threshold, and the average mercury concentration at Noatak, Gates of the Arctic, Denali (Wonder), Olympic (PJ and Hoh), Mount Rainier (LP19), and Sequoia (Pear) exceeded all wildlife (otter, mink, and kingfisher) thresholds. Data are plotted on a $\log_{10}$ scale.

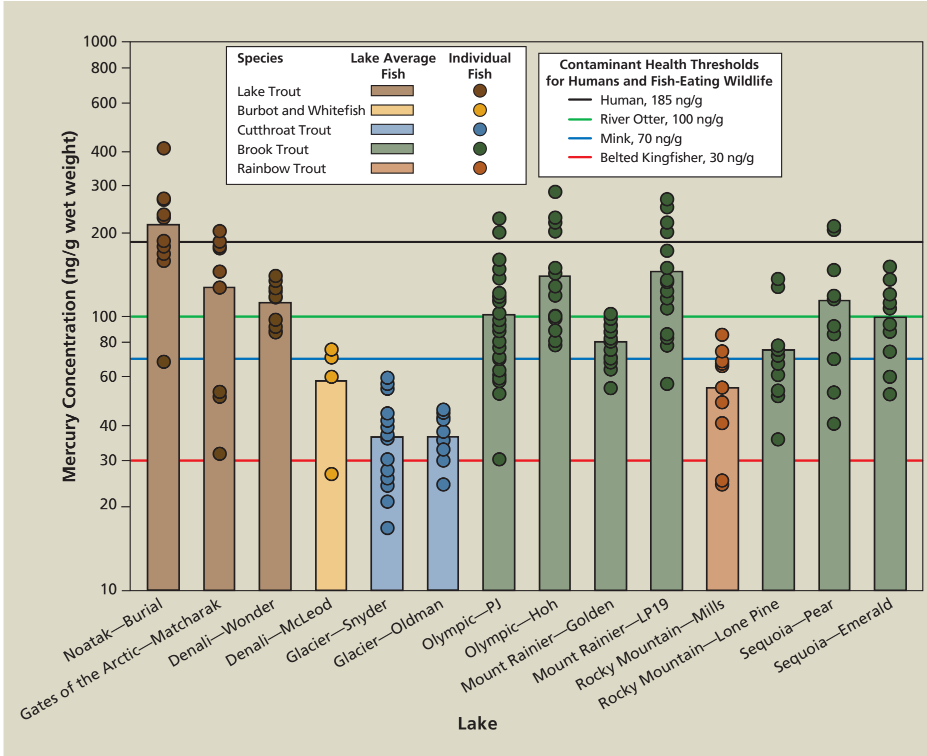
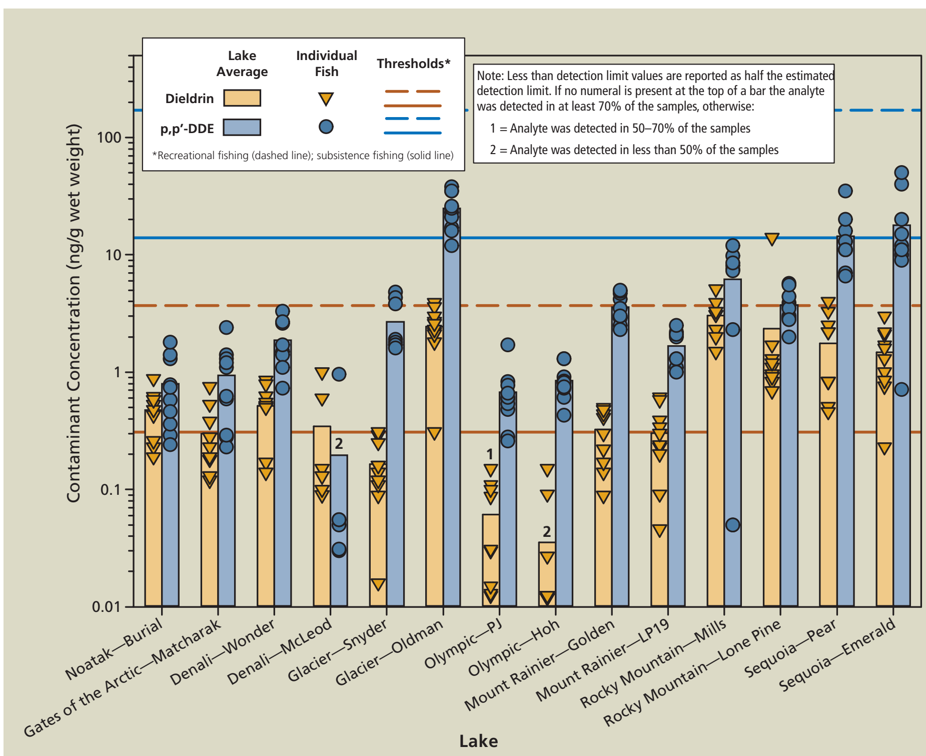


Figure 3. This graph shows the concentrations of historic-use pesticides (dieldrin and p,p′-DDE, a by-product of DDT most commonly found in fish) in fish, as compared with human thresholds for recreational and subsistence fishing. Symbols represent concentrations in individual fish and the bars denote lake averages. Some fish from Glacier, Rocky Mountain, and Sequoia exceeded contaminant health thresholds for dieldrin for recreational fishing. The average concentration of dieldrin in fish from Noatak, Denali, Glacier (Oldman), Mount Rainier (Golden), Rocky Mountain, and Sequoia, and some fish from Gates of the Arctic and Mount Rainier (LP19), exceeded contaminant health thresholds for subsistence fishing. The average concentration of p,p′-DDE in fish from Glacier (Oldman) and Sequoia exceeded contaminant health thresholds for subsistence fishing. Exceedances imply that human lifetime consumption may increase risk of developing cancer by more than 1 in 100,000. Data are plotted on a $\log_{10}$ scale.



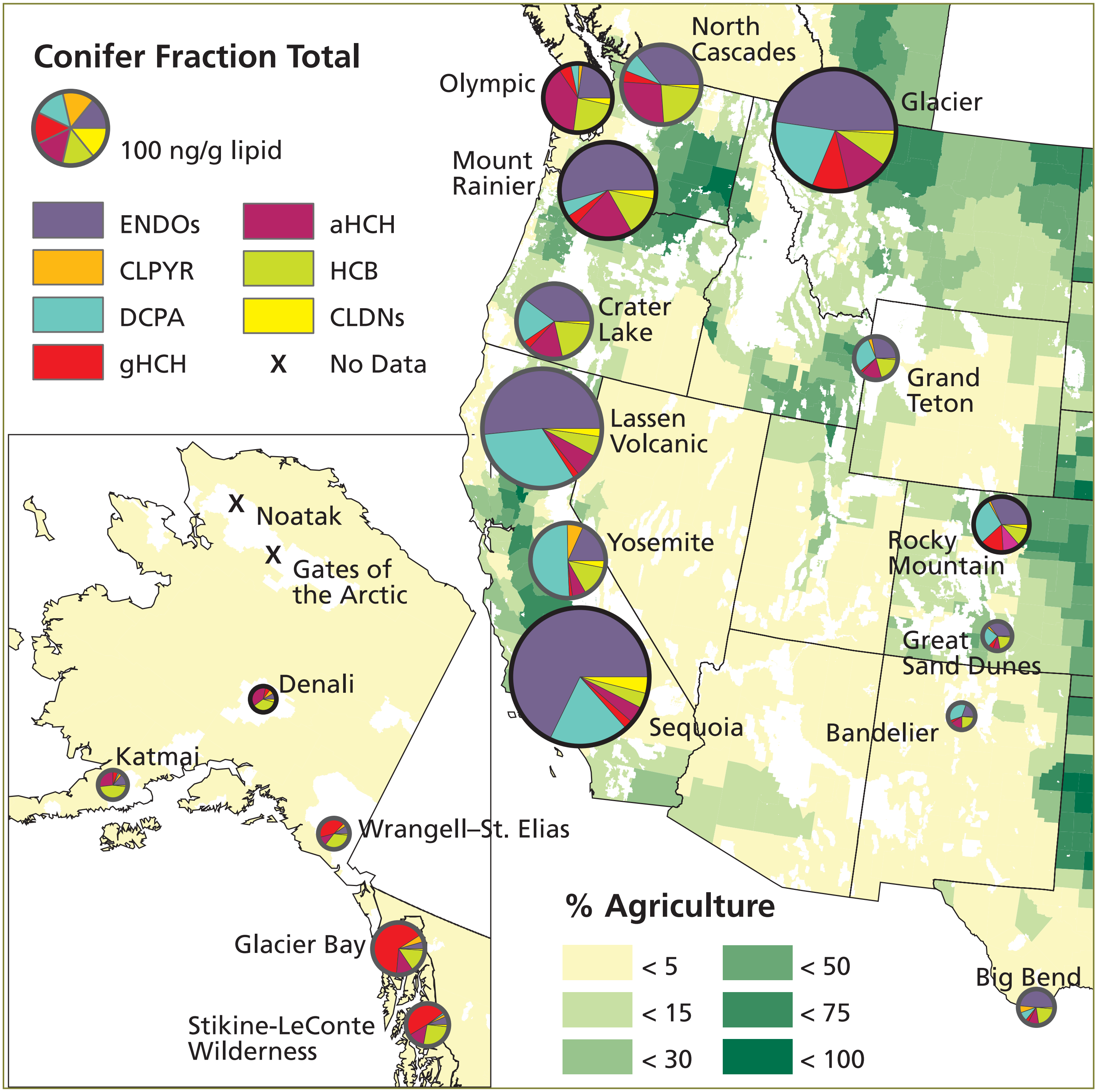


Figure 4. This illustration depicts pesticide concentrations (ng/g lipid) in conifer needles from core and secondary WACAP parks as compared to agricultural intensity. Circle area is proportional to total pesticide concentration. Light to dark green shading indicates increasing agricultural intensity. White shading indicates national forests or parks. Current-use pesticides endosulfan and dacthal dominate pesticide concentrations in parks in the conterminous United States, where most agriculture occurs. Historic-use pesticides comprise a relatively large fraction of the total pesticide concentration in Alaska, although the total pesticide concentrations are lower. Conifers were not present in Noatak and Gates of the Arctic. Circles outlined in black represent the core study parks. Pesticide groups include the current-use pesticides endosulfans (ENDOs), chlorpyrifos (CLPYR), dacthal (DCPA), and lindane (gHCH), and historic-use pesticides a-HCH, HCB, and chlordanes (CLDNs).

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well correlated with the proximity of each park to agricultural areas, identifying these areas as probable major sources of some pesticides that end up in park ecosystems (fig. 4, previous page). Concentrations of industrial contaminants (e.g., mercury and combustion by-products such as PAHes) were also highest in parks where local and regional point sources produce these contaminants. For example, at Glacier National Park, where PAH concentrations in vegetation, snow, and sediments were one to two orders of magnitude greater than at any other site, source "fingerprints" strongly suggest influence from a nearby aluminum smelter.

Unexpected findings

Project researchers initially hypothesized that a majority of contaminants found in western national parks would originate from eastern Europe and Asia and travel across the Pacific Ocean to the western United States. While this study provided evidence that this phenomenon does occur, particularly in Alaskan parks, analysis of snow concentration data showed that contaminant contributions from trans-Pacific sources were small in most WACAP parks compared with contributions from other sources closer to parks.

Additionally, given fish consumption advisories on major waterways and commercial fisheries throughout the conterminous United States and Alaska, it is well known that toxins found in fish can threaten human health. However, it was not expected that concentrations would exceed human and wildlife risk thresholds in the national parks, ironically celebrated as some of the most pristine ecosystems in the United States.

Implications of results

Prior to the Western Airborne Contaminants Assessment Project, scant published evidence of regional or long-range atmospheric sources of toxic pollutants reaching remote western park ecosystems existed. Further, even less was known about the potential impacts of contaminants in these ecosystems. Dr. Dixon Landers of the U.S. Environmental Protection Agency, the project's lead scientist, indicated that "WACAP findings add considerably to the state of the science concerning contaminant distribution and effects in remote ecosystems of the western United States and Alaska."

Study results have been widely shared with federal, state, and local agencies, as well as stakeholders. These efforts have resulted in follow-up research and exploration of cause-and-effect relationships between contaminant concentrations and impacts in ecosystems. Study findings may also be relevant to areas outside of national parks. In an effort to facilitate communication and to foster research and monitoring initiatives on toxins in the environment, Glacier National Park hosted an interagency, post-WACAP contaminants workshop for the state of Montana in spring 2008. Sequoia, Yosemite, and Lassen Volcanic national parks followed by hosting a Sierra Nevada–Southern Cascades Contaminants Workshop in spring 2009. These workshops resulted in increased awareness, research and monitoring plans, public outreach and educational efforts, and collaborative partnerships with state and federal agencies expressing interest in furthering research on contaminants. Additionally, an ongoing follow-up study is investigating the extent of reproductive disruption in fish across western and Alaskan national parks via fish tissue analyses of biological effects and chemical concentrations. The implications of WACAP findings are also being considered in numerous venues, including a National Academy of Sciences review panel on the international transport of air pollutants, the Stockholm Convention on Persistent Organic Pollutants, the NPS Office of Public Health, and the U.S. Environmental Protection Agency.

Methods developed by WACAP scientists also furthered the science. Identification of new field and analytical lab techniques allowed detection of very low concentrations of organic compounds in snow, lake water, and sediment. Moreover, a new computer program allowed quantification of the severity of tissue damage from mercury in fish livers and spleens. Such scientific breakthroughs were subsequently published in peer-reviewed journals for application by other research teams.

In addition to the release of the final project report, a database containing all the

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WACAP by the numbers	
Study sites	28
National park areas studied	19
Partnering agencies/institutions	21
Researchers involved	29
Duration (years)	6
Field days	± 238
Scholarly research articles published	10 (and more anticipated)
Media outlets that reported WACAP findings	>200
Contaminants identified that are of highest concern	3
Approximate cost to NPS and cooperators	$6 million
Funding sources (within NPS)	13
Boats purchased	1
Pounds of dry ice used	1,500
Pounds of snow collected	10,000
Cups of coffee consumed	± 9,047
Debilitating knee injuries	1

physical, chemical, and biological data collected in the study will be made available on NPS and EPA Web sites later in 2009. These data can then be used by managers and scientists worldwide to conduct future comparisons with other studies.

A wake-up call

Whether amidst frozen tundra at Noatak, temperate rainforest at Olympic, or alpine environs at Rocky Mountain, the preserved remoteness of national parks unfortunately does not indicate these areas are as pristine as once thought. Findings convey a cautionary message that increases awareness and illustrates the potential deleterious consequences of toxic air contaminants upon natural resources legally mandated to remain unimpaired. "The results are very sobering and we hope the information contributes to science-based decisions on the regional and global use of pesticides," said Craig C. Axtell, superintendent at Sequoia and Kings Canyon national parks. WACAP was designed as a screening-level assessment that has provided a window onto contaminants of concern in respective parks and regions. The results not only offer impetus for more in-depth studies but also shed light on the risk to national park resources, cultivating future efforts to coordinate with regulatory entities that may identify strategies to reduce contaminant loads from U.S. and international sources.

Acknowledgments and further information

WACAP was funded primarily by the National Park Service and coordinated by the Air Resources Division staff in Lakewood, Colorado. Other participating institutions included the U.S. Environmental Protection Agency, U.S. Geological Survey, USDA Forest Service, Oregon State University, and the University of Washington. National park resource managers worked with scientists from the collaborating agencies to plan and conduct the study. The report, fact sheet, publications, and more can be accessed at http://www.nature.nps.gov/air/Studies/air_toxics/wacap.cfm.

WACAP citation

Landers, D. H., S. L. Simonich, D. A. Jaffe, L. H. Geiser, D. H. Campbell, A. R. Schwindt, C. B. Schreck, M. L. Kent, W. D. Hafner, H. E. Taylor, K. J. Hageman, S. Usenko, L. K. Ackerman, J. E. Schrlau, N. L. Rose, T. F. Blett, and M. M. Erway. 2008. The fate, transport, and ecological impacts of airborne contaminants in western national parks (USA). EPA/600/R-07/138. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, Oregon.

About the author

Colleen Flanagan *(colleen_flanagan@nps.gov) is an ecologist with the National Park Service Air Resources Division (ARD) in Lakewood, Colorado. Formerly at Rocky Mountain National Park, she joined the Air Resources Division in 2007. Under the leadership of WACAP project coordinator Tamara Blett (NPS-ARD), a contributing correspondent to this story, she continues to explore science and policy avenues for WACAP outreach and follow-up studies.*