Western Airborne Contaminants Assessment Project

National Park Service
U.S. Department of the Interior
Air Resources Division

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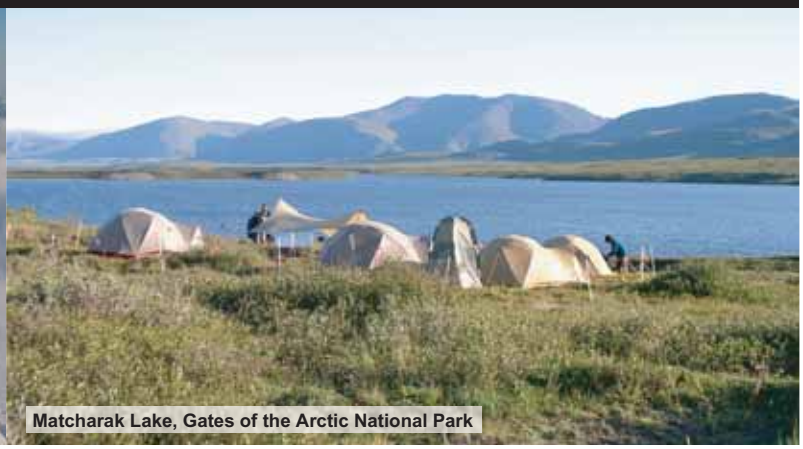
Mount Rainier National Park



Matcharak Lake, Gates of the Arctic National Park

PROJECT OBJECTIVES

- **Determine if contaminants are present in western national parks**
- **If present, determine where contaminants are accumulating (geographically and by elevation)**
- **If present, determine which contaminants pose a potential ecological threat**
- **Determine which indicators appear to be the most useful to address contamination**
- **Determine the sources for contaminants measured at the national park sites.**

BACKGROUND

The Western Airborne Contaminants Assessment Project (WACAP) was initiated to determine the risk to ecosystems and food webs in western national parks from the transport of airborne contaminants. WACAP is designed and implemented by the National Park Service's Air Resources Division in cooperation with many western national parks, U.S. Environmental Protection Agency, U.S. Geological Survey, USDA Forest Service, and several universities.

Airborne contaminants can pose serious health threats to wildlife and humans. Some toxic compounds "biomagnify," meaning that small concentrations in air, water, snow, and plants can result in larger concentrations at higher levels of the food web, like fish and mammals. Biological effects of airborne contaminants include impacts on reproductive success, growth, behavior, disease, and survival. Subsistence hunters and gatherers in Alaska depend on wild food sources that may be affected by airborne contaminants.

The contaminants of concern are compounds referred to as semi-volatile organic compounds (SOCs). This group contains a variety of persistent organic pollutants (POPs) such as PCBs and DDT. The element mercury behaves similarly to SOCs and is also being investigated by WACAP along with other metals. These materials are direct or indirect products of human industrial activity and can be transported thousands of miles in the atmosphere. In some cases, the SOCs can be deposited to aquatic or terrestrial ecosystems and then re-emitted back into the atmosphere. Some of these materials have physical properties that permit them to accumulate, preferentially, in colder areas of the global environment. This phenomenon is termed "cold fractionation" and has been observed for some forms of PCBs, HCHs, and even mercury. Therefore, high-elevation and high-latitude ecosystems may be at greater risk from the accumulation of these toxic compounds, simply because they are colder than other locations.

PROJECT OVERVIEW

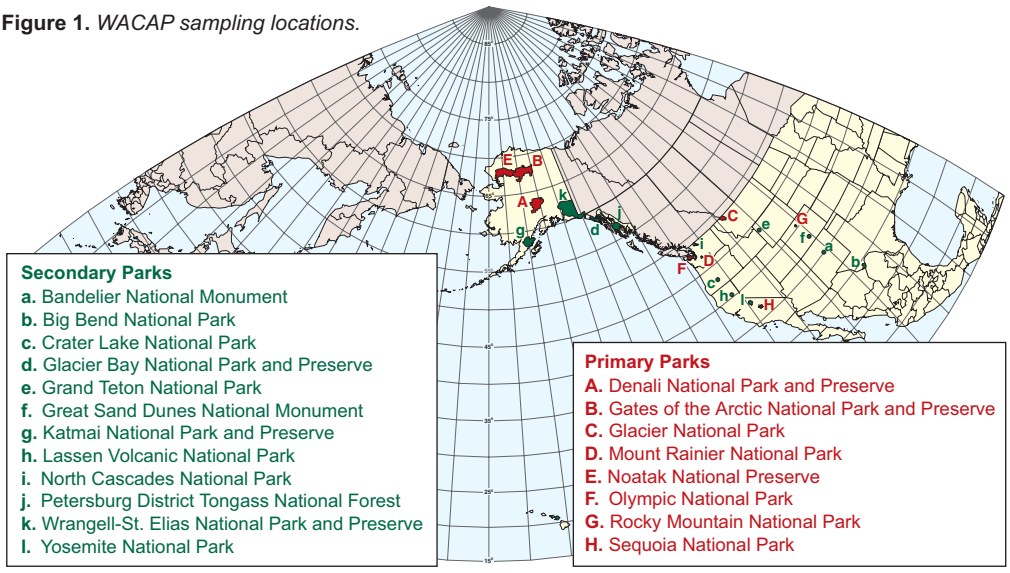
WACAP research is centered on eight national parks in the West, representing a latitudinal gradient as well as a coastal-to-interior gradient. Figure 1 shows WACAP sampling locations. The red parks represent the primary parks where the most intensive sampling occurs. Those colored green represent secondary parks where only vegetation samples will be taken. At each of the primary parks, two small, relatively high-elevation lake watersheds have been selected. Samples are being collected at these sites to reveal where and to what extent airborne contaminants are deposited on the landscapes, and how contaminants may be distributed within food webs.

CONTAMINANT SAMPLING

There are a variety of ecosystem indicators that have proven reliable in other studies for providing information about contaminant accumulation and impacts in terrestrial and aquatic systems. WACAP is collecting samples of the indicators shown in Table 1. Samples are carefully analyzed in state-of-the-art laboratories. Provided with each indicator in Table 1 is information regarding expected results from the specific indicator.

A broad suite of persistent organic pollutants, used by humans for decades, such as PCBs, DDT, HCHs, and HCB, are being measured in the indicators at each site. Many of these compounds are now banned in the United States, and finding them in park ecosystems

Figure 1. *WACAP sampling locations.*



Secondary Parks
- **a.** Bandelier National Monument
- **b.** Big Bend National Park
- **c.** Crater Lake National Park
- **d.** Glacier Bay National Park and Preserve
- **e.** Grand Teton National Park
- **f.** Great Sand Dunes National Monument
- **g.** Katmai National Park and Preserve
- **h.** Lassen Volcanic National Park
- **i.** North Cascades National Park
- **j.** Petersburg District Tongass National Forest
- **k.** Wrangell-St. Elias National Park and Preserve
- **l.** Yosemite National Park

Primary Parks
- **A.** Denali National Park and Preserve
- **B.** Gates of the Arctic National Park and Preserve
- **C.** Glacier National Park
- **D.** Mount Rainier National Park
- **E.** Noatak National Preserve
- **F.** Olympic National Park
- **G.** Rocky Mountain National Park
- **H.** Sequoia National Park

may indicate that they originate in other countries or re-volatilize from historically contaminanted United States soils.

"Current-use chemicals," including some pesticides and flame retardants, are also assessed. Mercury is of key interest and is analyzed in all materials (except water) along with other metals in specific indicators.

Currently, in the project timeline (see below), WACAP has completed two-thirds of scheduled field sampling and is halfway through the project. WACAP researchers have visited five of eight parks, collecting samples from eight of fourteen lake systems. Now that samples have been collected and analytical methods have been tested and confirmed adequate, samples are being rapidly analyzed for organic and inorganic contaminants. The sections that follow briefly highlight details of selected early results of the analysis of key WACAP indicators. More information is available on the WACAP website (see page 4).

SNOW Measure of direct atmospheric loading, collected annually. In many alpine sites, 50–90% of the annual precipitation is snow.
FISH Direct measure of food web impacts and food web bioaccumulation.
WATER Measure of hydrophilic current-use chemicals.
LAKE SEDIMENT Provides historic trends (~150 yr) of contaminant loading to the watershed.
LICHEN Direct measure of food web impacts and metals bioaccumulation.
VEGETATION (e.g., willow bark) Collected along altitude gradients in all 19 parks, measure of ecosystem exposure, and comparisons within and among sites, parks, and elevations.
SUBSISTENCE NATIVE FOODS Direct measure of food sources (moose) used by subsistence users.

Table 1. *WACAP indicators.*

Snow – Snowfall provides the majority of annual precipitation in high-altitude and high-latitude areas of the western United States. The seasonal snowpack that accumulates during the fall, winter, and spring contain a record of chemicals deposited during the snow-covered season. By collecting a full-depth column of the snowpack near the time of maximum snow accumulation, estimates of seasonal atmospheric deposition inputs can be made.

Figure 2. *National park natural resource specialists sampling snowpack in Mount Rainier National Park in 2003. Samples are obtained from the vertical sides of a snow pit using clean field techniques to avoid contamination.*

During 2003 and 2004, a total of 47 samples from eight parks were collected for organic and inorganic contaminants (Figure 2). Selected snow results for SOCs are presented in the SOC section.

Two years of mercury concentration data for snowpack samples reveal spatial patterns in mercury deposition. Mercury concentrations in samples from the Alaskan parks tend to be quite variable. This variability is likely related to the shallow depth of snowpacks at low-elevation inland sites in Alaska, and relatively large amounts of windblown dust in the snowpack. Even when concentrations were moderately high in Alaskan snow, total atmospheric loading of mercury via snow was not large. These concentrations are likely because the volume of snow deposited to the Alaskan sites is quite low compared to sites in the lower 48 states. Along the west coast of the lower 48 states, most of the parks had a fairly low concentration of mercury, while inland sites at Glacier and Rocky Mountain National Parks had somewhat higher concentrations of mercury which were related to higher concentrations of particulates.

Fish – Airborne contaminants have been detected in alpine aquatic ecosytems and fish in Canada and Europe by other investigators. However, little information exists for similar occurrences in the United States despite the preferential deposition of some contaminants to high-elevation and polar ecosystems. The fish component of WACAP focuses on determining the impacts and appropriate indicators of contaminant exposure in fish. In the summer of 2003, salmonid fishes from five lakes in Sequoia, Rocky Mountain, and Olympic National Parks were captured and assessed for endocrine disruption, physiological impairment and, in some lakes, contaminant loads. General health, histopathology, age, and sex steroids were also determined. In summer 2004, fish were collected from four lakes in Alaska (Figure 3).

Endocrine disruption occurs when fish are exposed to contaminants that resemble the hormones naturally produced in the animal. Consequences for exposure to individual animals range from mild to severe. However, if exposure occurs at the proper time, reproductive fitness may also be impaired, suggesting

Project Timeline

2002	2003	2004	2005	2006	2007
PILOT STUDIES Design & methods development	**WATERSHED SAMPLING** Rocky Mountain & Sequoia National Parks	**WATERSHED SAMPLING** Denali, Gates of the Arctic, & Noatak National Parks	**WATERSHED SAMPLING** Mt. Rainier, Olympic, & Glacier National Parks	**COMPLETE ALL LAB ANALYSES**	
	Lichen pilot study in Sequoia	Moose tissue sampling in Alaska	Supplemental vegetation sampling	**FINAL DATABASES, INTERPRETIVE REPORT, AND PUBLICATIONS**	
	SNOW SAMPLING IN ALL PARKS				

population-level effects. To measure endocrine disruption, blood plasma vitellogenin (Vg) in male and immature female fishes is assessed. Vg is an egg-yolk precursor protein, made in response to estrogen, and normally found in maturing female fish. However, when found in male and immature female fish it is indicative of exposure to estrogen-like compounds.

To assess physiological impairment, macrophage aggregates (MA) are measured. These are accumulations of pigmented cells found in response to numerous stressors, including contaminants. MAs serve as a bioindicator for general contaminant exposure in the kidney, liver, and spleen.

Taken alone, plasma Vg and kidney, liver, and spleen MAs provide valuable clues to the possible biological impacts of airborne pollution. When correlated with complete contaminant load profiles, they can indicate the consequences of contaminant concentrations in fish tissue, suggestive of overall ecosystem health.

Figure 3. *WACAP scientist disects tissue samples from a Lake Trout collected in Denali National Park.*

Sediment – Lake sediments are being collected, dated with ^{210}Pb and other radioisotopes, and analyzed for physical and chemical characteristics, metals, and SOCs to determine decade-scale histories of loadings to the WACAP lakes. Trends in loadings are evaluated based on the amount of contaminants deposited per year in the sediment record over the last 100 years or more. High pre-industrial background concentrations of some metals indicate natural watershed sources while man-made organic compounds (such as SOCs) should only appear in more recent (i.e., post-industrial) sediments and are usually deposited via airborne transport.

Sediment sampling (Figure 4) and analysis steadily progressed through 2003 and 2004. The samples from 2003 have been dated and analyzed for physical characteristics. Sediment dating is used in combination with other analyses to determine when contaminant loading or other indicators of human influences in the watershed occurred (Figure 5).

Figure 4. *A scientist prepares to remove a successfully collected sediment core from the coring device suspended over the open-bottom sampling bay of the inflatable research raft on Burial Lake, Noatak National Preserve, in arctic Alaska.*

Atmospheric Transport – Since there is strong westerly flow of air masses in the middle latitudes, it is anticipated that long-range contaminant transport from distant sources in Asia will be important in explaining some of the WACAP results, but contributions from other sources (such as regional and local) will also be considered. In particular, air mass transport from major agricultural regions in California, Mexico, and Canada could be important in explaining the presence of pesticides that are observed in some of the WACAP parks. The primary goal of the atmospheric component of WACAP is to identify transport of air masses from potential source regions that may be affecting western national parks.

The HYSPLIT model of atmospheric transport is used to develop back trajectories to the various WACAP sites (Figure 6). This model uses meteorological data to calculate 10-day back trajectories. In simple terms, a back trajectory provides the path that an airmass has taken over the past ten days. It can then be determined if an airmass has traveled over a known pollution source region. The HYSPLIT model is used to calculate at least five years of back trajectories for each WACAP site. These thousands of trajectories will be "clustered" into patterns of atmospheric transport over each site. The clusters can be thought of as the upstream "airshed" for each park.

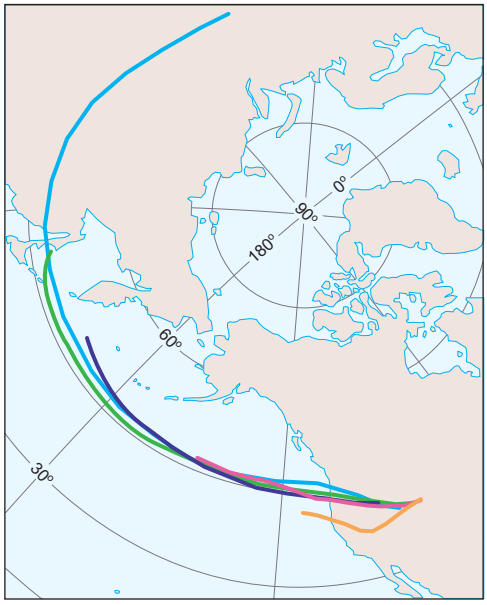


Figure 6. *10-day back-trajectory clusters for Rocky Mountain National Park, based on meterological data from 1998-2003.*

Semi-volatile Organic Compounds – The analysis of WACAP samples for SOCs are key to addressing the WACAP goal and all five of the WACAP objectives. Some preliminary results are shown in Figures 5, 7, and 8. Through interpretation and integration of these results, an understanding of the environmental chemistry of SOCs in WACAP parks is being developed.

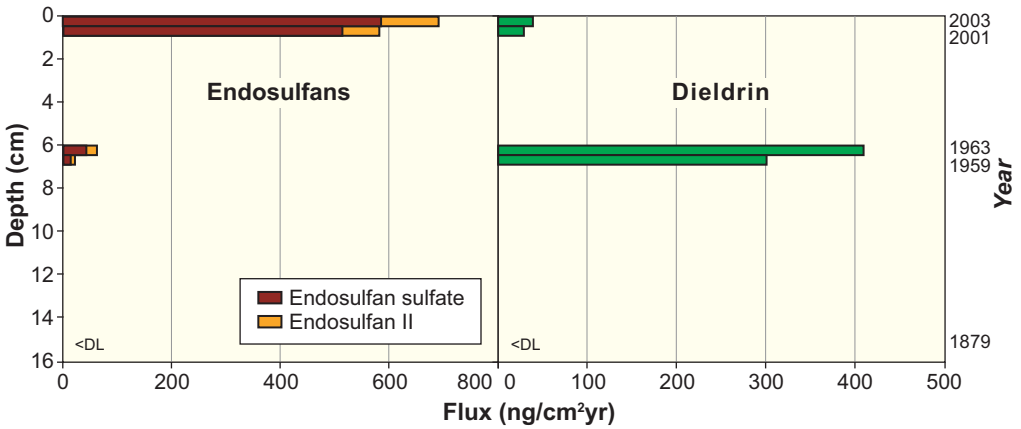


Figure 5. *Current-use (endosulfans) and banned (dieldrin) pesticide concentrations in the dated Pear Lake (Sequoia National Park) sediment core collected in 2003. Endosulfan was first used in the United States in 1956 and continues to be used today. Dieldrin was first used in 1948 and was banned in the United States in 1974. Results of sediment core dating show that endosulfan concentrations are increasing over time, while dieldrin concentrations are decreasing with time in Pear Lake. <DL shown on each graph for 1879 means below detection level.*

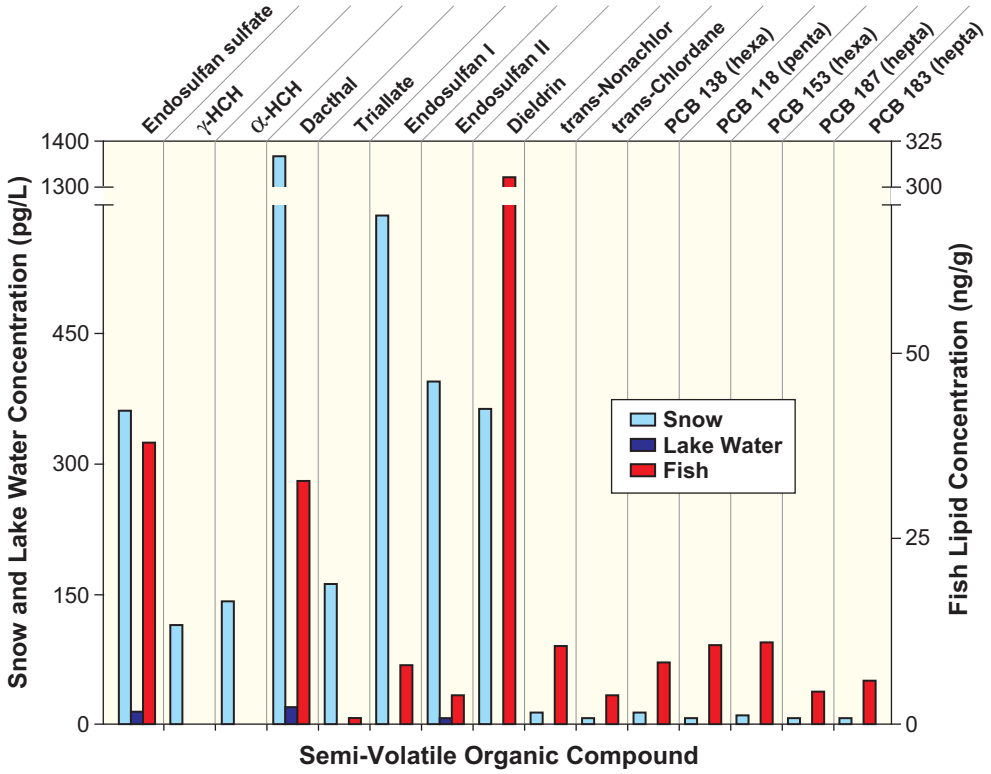


Figure 7. *Concentrations of several different SOCs from 2003 in snow, lake water, and fish tissue are shown from Mills Lake, Rocky Mountain National Park. The SOCs on the left side of the horizontal (x) axis are water-loving (dissolve readily in lake water or precipitation), while the SOCs on the right side are lipid-loving (less soluble in water and tend to accumulate in fish lipids).*

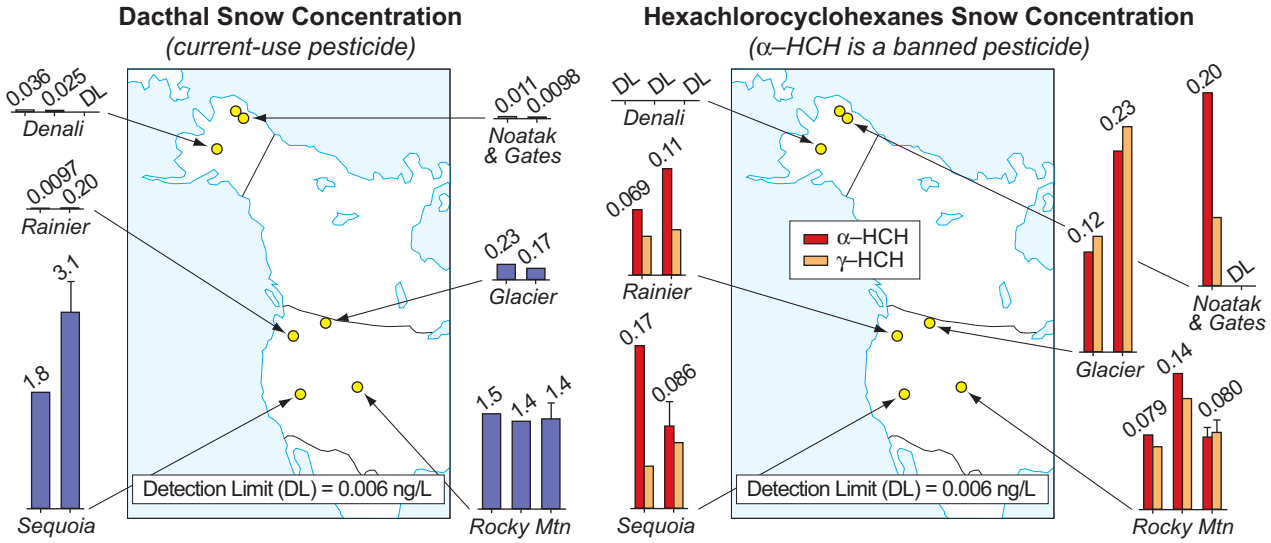


Figure 8. *Dacthal is a current-use pesticide and has much higher concentrations in snow near agricultural regions (Sequoia and Rocky Mountain National Parks) than in remote sites in Alaska. The hexachlorocyclohexanes are banned (α-HCH) or are being phased out (γ-HCH, also known as lindane) in North America. The HCH concentrations in snow are more uniform throughout the WACAP parks and have lower concentrations in snow than those found for the current-use pesticide, dacthal in Sequoia and Rocky Mountain National Parks. Units are nanograms per liter.*

SUMMARY

WACAP is beginning to produce substantive information that addresses the goals of the project. Information from a variety of converging themes demonstrate that current-use and banned chemicals are present in western national parks. Information on the ecological impacts and the probable sources of these contaminants is also beginning to emerge. As WACAP scientific research continues, these initial results will be further evaluated, scrutinized, and interpreted. Scientific publications and an interpretive report will be produced in the future years of WACAP. A complete, documented database will be constructed and made widely available for future comparisons and interpretations.

FOR FURTHER INFORMATION CONTACT

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WACAP website
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