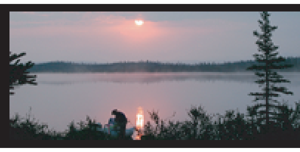
Western Airborne Contaminants Assessment Project – Results



National Park Service
U.S. Department of the Interior
Air Resources Division
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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**
- **If contaminants are present, determine the source of air masses most likely to have transported contaminants to national park sites.**

Fish samples were important ecological indicators of contaminant effects.

INTRODUCTION

The Western Airborne Contaminants Assessment Project (WACAP) was initiated to determine the risk from airborne contaminants to ecosystems and food webs in western national parks. Analysis of the concentration and biological effects of airborne contaminants in air, snow, water, sediment, lichen, conifer needles, and fish was conducted from 2002 through 2007 in eight core parks in the West and Alaska. Researchers selected six west coast and Alaska parks (Noatak, Gates of the Arctic, Denali, Olympic, Mount Rainier, and Sequoia) and two parks in the Rocky Mountains (Rocky Mountain and Glacier; Figure 1). Two sites/lakes were selected for sampling in each park, with the exception of Noatak and Gates of the Arctic where one site was sampled in each, as the parks are adjacent, for a total of fourteen sites.

Semi-volatile organic compounds (SOCs) and metals were the primary focus of the study. The SOCs fall into four general classes, current-use pesticides (CUPs), North American historic-use pesticides (HUPs), industrial/urban-use compounds (IUCs), and combustion byproducts. The primary metal of concern was mercury.

Seven ecosystem components (air, snow, water, sediment, lichen, conifer needles, and fish) were selected for sampling. Concentrations of contaminants in air can be readily compared between sites both within this study and with other studies. In many of the high-altitude and/or high-latitude sites studied, snow can represent a potentially major pathway for input of contaminants to ecosystems. Lake water samples provide an overview of watershed chemical and physical characteristics that can help in interpreting the contaminants data. Lake bottom sediments show historical patterns of change over time in contaminant deposition. Vegetation samples can be used to determine spatial gradients of contaminants, and also to provide information about contaminants that may accumulate in ecosystems through litterfall. Fish can biomagnify contaminants in their tissues which can result in toxic effects in the fish themselves, and in birds, animals, and humans who consume the fish.

Ecosystem contaminants data were examined in combination with other data to determine the probable sources of contaminants (i.e., local, regional, or global). In order to identify potential sources of contaminants to parks, air flow patterns to parks were assessed through a process known as back-trajectory analysis.

In addition to the eight "core" parks sampled, researchers identified twelve "secondary" parks/monuments/preserves/wilderness areas for more limited assessment (Bandelier, Big Bend, Crater Lake, Glacier Bay, Grand Teton, Great Sand Dunes, Katmai, Lassen Volcanic, North Cascades, Stikine-LeConte Wilderness, Wrangell-St.Elias, and Yosemite). In these areas, vegetation samples were collected over an elevational gradient, and passive air sampling devices (PASDs) were deployed for one year for SOC analyses as a means of further enhancing spatial interpretations.

The U.S. Environmental Protection Agency, U.S. Geological Survey, U.S. Forest Service, Oregon State University, and University of Washington worked in partnership with the National Park Service on this project. The information acquired will be used to enhance scientific understanding of the global fate, transport, and associated ecological impacts on sensitive ecosystems of airborne contaminants in western parks. It will also help the National Park Service determine what actions may be needed to further understand, mitigate, or communicate impacts of potential effects of contaminants in national parks.

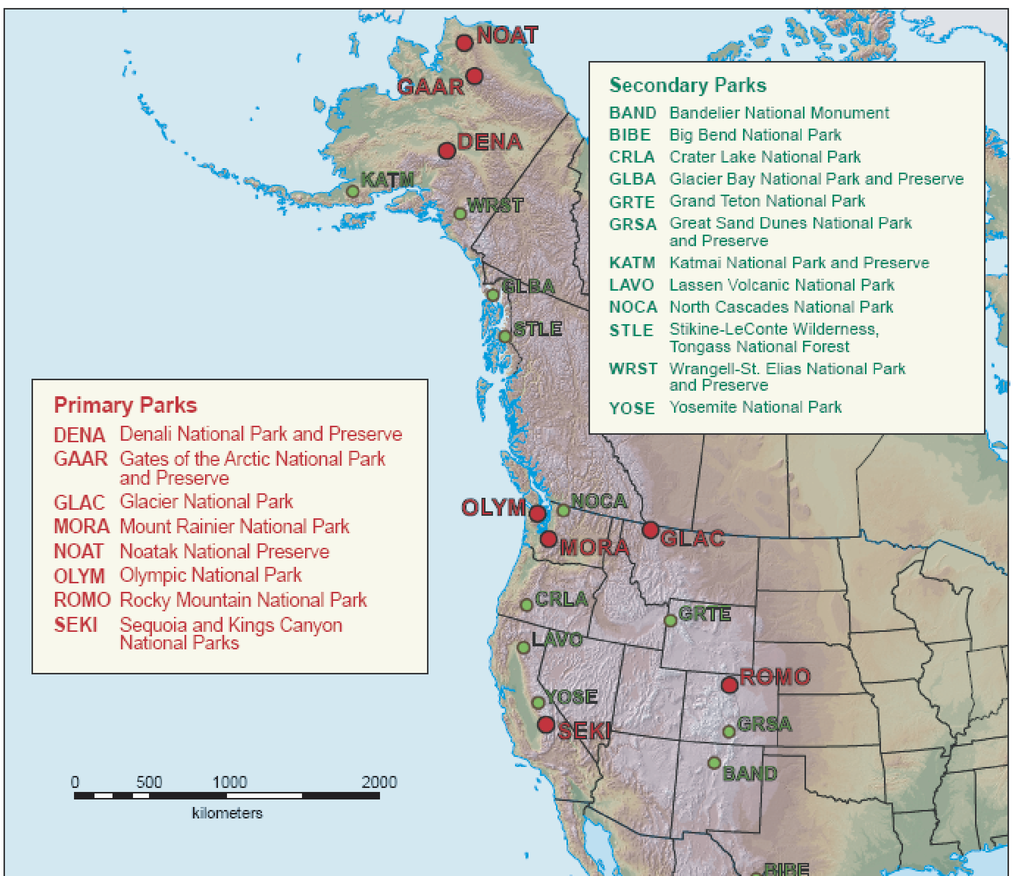

Figure 1. *WACAP sampling locations.*

KEY FINDINGS

Are contaminants present in western national parks?

Out of over 100 SOCs tested (excluding PBDEs measured in sediments and fish), 70 were found at detectable levels in snow, water, vegetation, sediment, and/or fish. Based on high concentrations detected, bioaccumulation documented, and/or their toxic persistent characteristics in the environment, six contaminants of highest concern were identified for the eight core park ecosystems. These are mercury, dieldrin, DDT, PCBs, chlordane, and PAHs. Other contaminants identified as a future potential concern because they are in current use, are present at comparatively high concentrations in vegetation, and/or they are increasing over time in sediment cores are: PBDEs, endosulfans, chlorpyrifos, and HCH.

A passive air sampling device (PASD) collects data about airborne contaminants.

What are the contaminants, and where do they come from?

MERCURY
Mercury is a naturally occurring element, but it is also emitted from the combustion of fossil fuels (coal) and the burning of hazardous wastes. Humans are primarily exposed to methylmercury which impairs neurological development in fetuses, infants, and children. The various forms of mercury are considered to be persistent, bioaccumulative, and toxic (PBT) pollutants by USEPA.

DIELDRIN
From 1950 to 1974, dieldrin was used to control insects on citrus, corn, cotton, and as a wood preservative and termite control. Most uses of dieldrin were banned in 1987 in the U.S. and it is a PBT pollutant. Dieldrin decreases the effectiveness of the immune system, decreases reproductive success, and may cause cancer or birth defects.

DDT
The insecticide DDT was banned in the U.S. in 1972, and along with its byproducts, is considered a probable human carcinogen and a PBT chemical by USEPA. DDT, and its most common byproduct, p,p'-DDE, reduces reproductive success.

PCBs
PCBs were used in the U.S. as hydraulic fluids, plasticizers, adhesives, and fire retardants and most uses were banned in the U.S. in 1979. PCBs are PBT chemicals and potential health effects include changes in liver function and cancer.

CHLORDANE
Chlordane was an insecticide that was used on corn, citrus, and vegetables and as a termiticide in homes. In 1988, all commercial uses of chlordane were cancelled in the U.S. Chlordane is a PBT chemical and potential health effects include damage to liver and cancer.

PAHs
Polycyclic Aromatic Hydrocarbons (PAH) are combustion products formed by industrial processes, wildfire, vehicles, and even from grilling meats. PAHs are rapidly transformed to other chemicals in fish, wildlife, and humans. Some PAHs are PBT chemicals and cause cancer and developmental and reproductive effects.

PBDEs
Polybrominated diphenyl ethers (PBDEs) are flame retardant additives in plastics, textiles, and other materials. Production began in the 1970s and continues to date. PBDEs are found at low levels all over the environment, including in biota, human tissues, and breast milk. Exposure affects liver, thyroid, and neurobehavioral development.

ENDOSULFANS
Endosulfan is a contact poison used to control insects on food crops such as fruits, vegetables, and grains. It is also a wood preservative. Endosulfan causes neurotoxic effects and is an endocrine disruptor. It is a current-use pesticide in the U.S. and is persistent in the environment.

CHLORPYROFOS
This is a broad-spectrum current-use pesticide used on cockroaches, grubs, flies, termites, fire ants, lice, cutworms, etc. It is toxic to the nervous system, but it is unknown whether it is a carcinogen in humans.

HCHs
Lindane (gHCH) is a pesticide that is currently used as a pre-planting seed treatment in the U.S., after most other agricultural uses were restricted in 1983. aHCH is no longer used as a pesticide in the U.S. Potential health effects of lindane include effects on the liver and the nervous, cardiovascular, and immune systems.

Where are contaminants accumulating (geographically and by elevation)?

Contaminants were higher near individual sources or source areas. Pesticide concentrations for both historical and current-use compounds were highest in parks and park watersheds closest to agricultural areas. Concentrations of industrial contaminants (e.g., mercury and PAHs) were highest in parks where local/regional point sources produce these contaminants.

The study found evidence that contaminants tended to accumulate at higher elevation areas of the parks. This finding is consistent with the concept of "cold fractionation," where some compounds move up to colder and colder elevations over time. This information may help researchers select future sites in parks where higher concentrations of contaminants may be found.

Contaminants were found to differentially bioaccumulate in ecosystems (higher concentrations in older compared to younger conifer needles and fish; 3-7x higher concentrations in conifer needles, lichens, and fish compared to snow or water). Bioaccumulation of contaminants in ecosystems has been shown in other studies, but not at these regional scales in remote ecosystems in the western U.S. Figure 2 illustrates the geographic distribution of pesticide concentrations in needles.

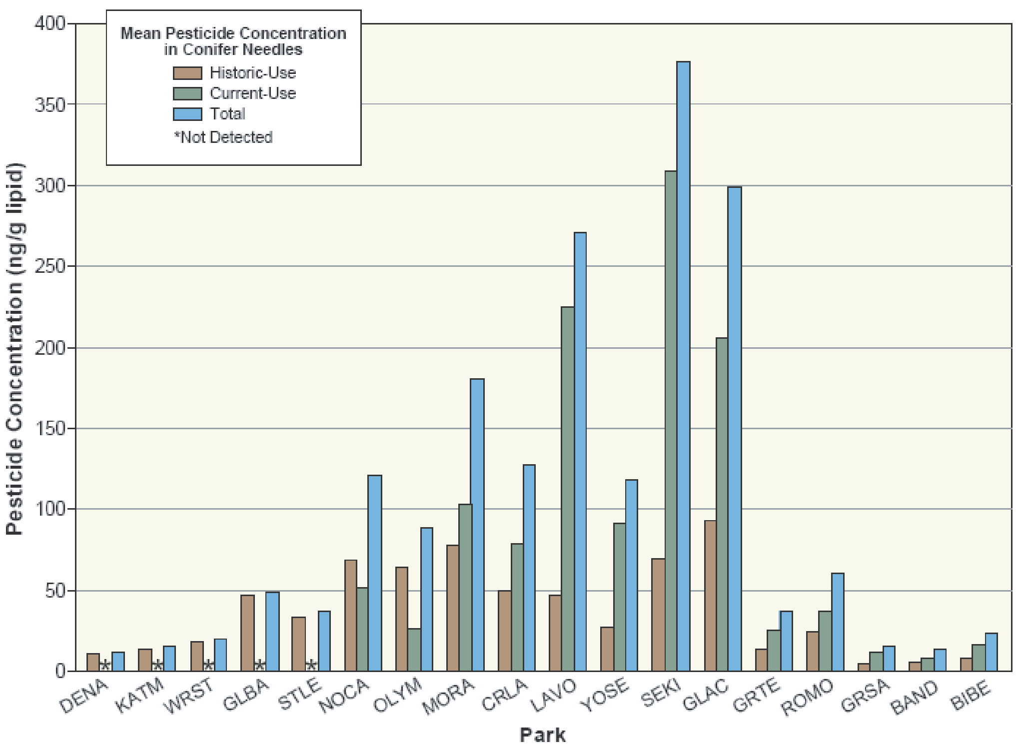

Figure 2. *Mean concentrations of historic-use (HCB, HCHs, chlordanes, DDT, dieldrin) and current-use (trifluralin, triallate, chlorpyrifos, dacthal, endosulfans) pesticides in two-year-old conifer needles from WACAP parks. Parks are ordered, left to right, from north to south along the Pacific Coast (DENA — SEKI), and from north to south in the Rocky Mountains (GLAC — BIBE). Current-use pesticides were not detected in Alaska parks, comprised about one-third to one-half the total pesticide concentrations in northern Washington, and most of the pesticide burden elsewhere. Total pesticide burdens (current-use + historic-use) were highest in national parks of Washington, Oregon, California, and Montana.*

Which contaminants pose a potential ecological threat?

Mercury, dieldrin, and DDT are the contaminants found in western park ecosystems that are likely to pose the greatest ecological threat. When mercury is biologically converted to its toxic form (methylmercury), it can readily bioaccumulate and biomagnify in food chains, causing detrimental effects on humans, fish, and other organisms. The average mercury concentration in fish exceeded the health threshold for human consumption at Burial Lake in Noatak, and some individual fish exceeded the human health threshold at an additional five lakes, including Matcharak Lake at Gates of the Arctic (Figure 3). Although mercury deposition was relatively low in the Arctic parks (NOAT and GAAR), in-lake biological processes which vary among lakes likely contributed to higher rates of mercury bioaccumulation. Mercury concentrations in fish exceeded contaminant health thresholds for fish-eating wildlife at various parks, also evident in Figure 3.

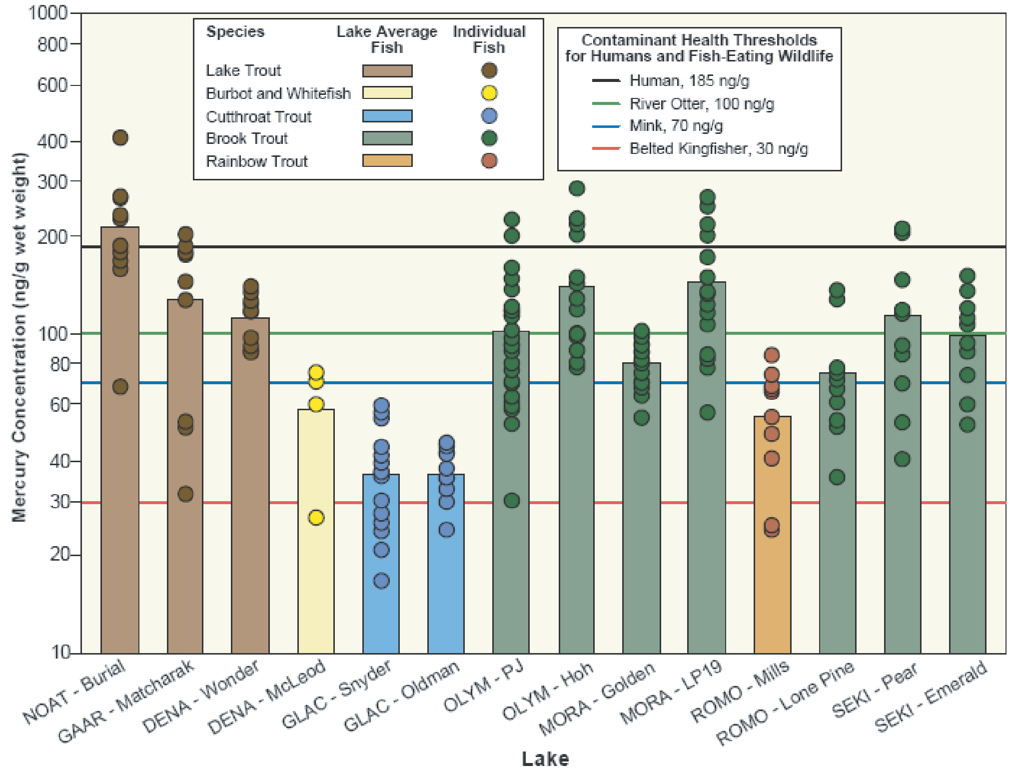

Figure 3. *Whole-body total mercury averages (bars) and individual fish (circles) based on wet weight from all WACAP park lakes and contaminant health thresholds for human and piscivorous wildlife fish consumption. The average mercury concentration in fish at NOAT exceeded the human consumption threshold, while some fish at GAAR, OLYM, MORA-LP19, and SEKI-Pear also exceeded the human consumption threshold. The average mercury concentration in fish in all lakes at all parks exceeded the kingfisher health threshold, and the average mercury concentration at NOAT-Burial, GAAR-Matcharak, DENA-Wonder, OLYM-PJ, OLYM-Hoh, MORA-LP19, and SEKI-Pear exceeded all wildlife thresholds. Data are plotted on a* log_{10} *scale.*

Scientists prepare a sediment core for analysis.

Figure 4 illustrates that concentrations of dieldrin found in fish from some parks exceeded USEPA recreational and subsistence fishing cancer risks for humans, and DDT concentrations in fish (i.e., p,p'-DDE) exceeded human health thresholds for subsistence fishing. Additionally, while dieldrin concentrations in fish did not exceed wildlife health thresholds, DDT concentrations in fish exceeded the risk to kingfishers at Sequoia & Kings Canyon and in Oldman Lake at Glacier National Parks. Dieldrin and DDT are both historically-used insecticides that are potentially carcinogenic, and both are endocrine-disrupting compounds that may have also contributed to intersex symptoms evident in a few fish from Rocky Mountain and Glacier National Parks. Dieldrin and DDT are persistent in the environment and continue to re-volatilize from historically contaminated soils.

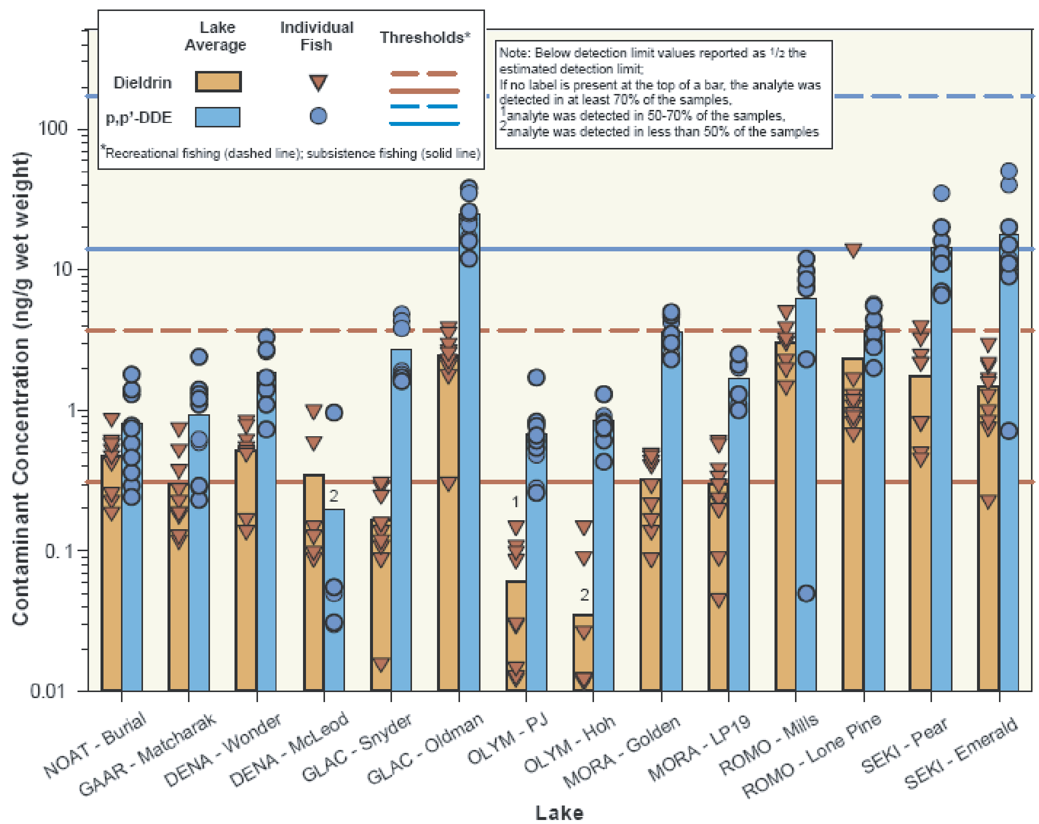

Figure 4. *Concentrations of historic-use pesticides (dieldrin and p,p'-DDE, a byproduct of DDT most commonly found in fish) in individual fish (symbols) and lake averages (bars) compared to human health thresholds for fish consumption (USEPA, 2000) for recreational and subsistence fishing. Some fish from SEKI, ROMO, and GLAC exceeded contaminant health thresholds for dieldrin for recreational fishing. The average concentration of fish from SEKI, ROMO, DENA, NOAT, MORA- Golden and GLAC- Oldman, and some fish from MORA- LP19 and GAAR, exceeded contaminant health thresholds for dieldrin for subsistence fishing. The average concentration of fish from SEKI and Oldman Lake in GLAC exceeded contaminant health thresholds for p,p'-DDE for subsistence fishing. Exceedances imply that a lifetime consumption may increase risk of developing cancer by more than 1 in 100,000. Data are plotted on a* log_{10} *scale.*

Which indicators appear to be the most useful to assess contamination in western national parks?

The ecological indicators found to be most useful in assessing contamination in this study were fish, sediments, and conifer needles. Fish were important as an indicator of biomagnification of contaminants and potential impacts to food webs. Sediments provided a historical context, documenting changes in contaminants over time and retaining clues about contaminant sources. Second-year conifer needles proved to be an effective measure of current contaminant concentrations over large spatial scales, providing a basis for comparison between many sites concurrently.

A researcher collects snowpack samples from the sides of the snow pit, avoiding contamination.

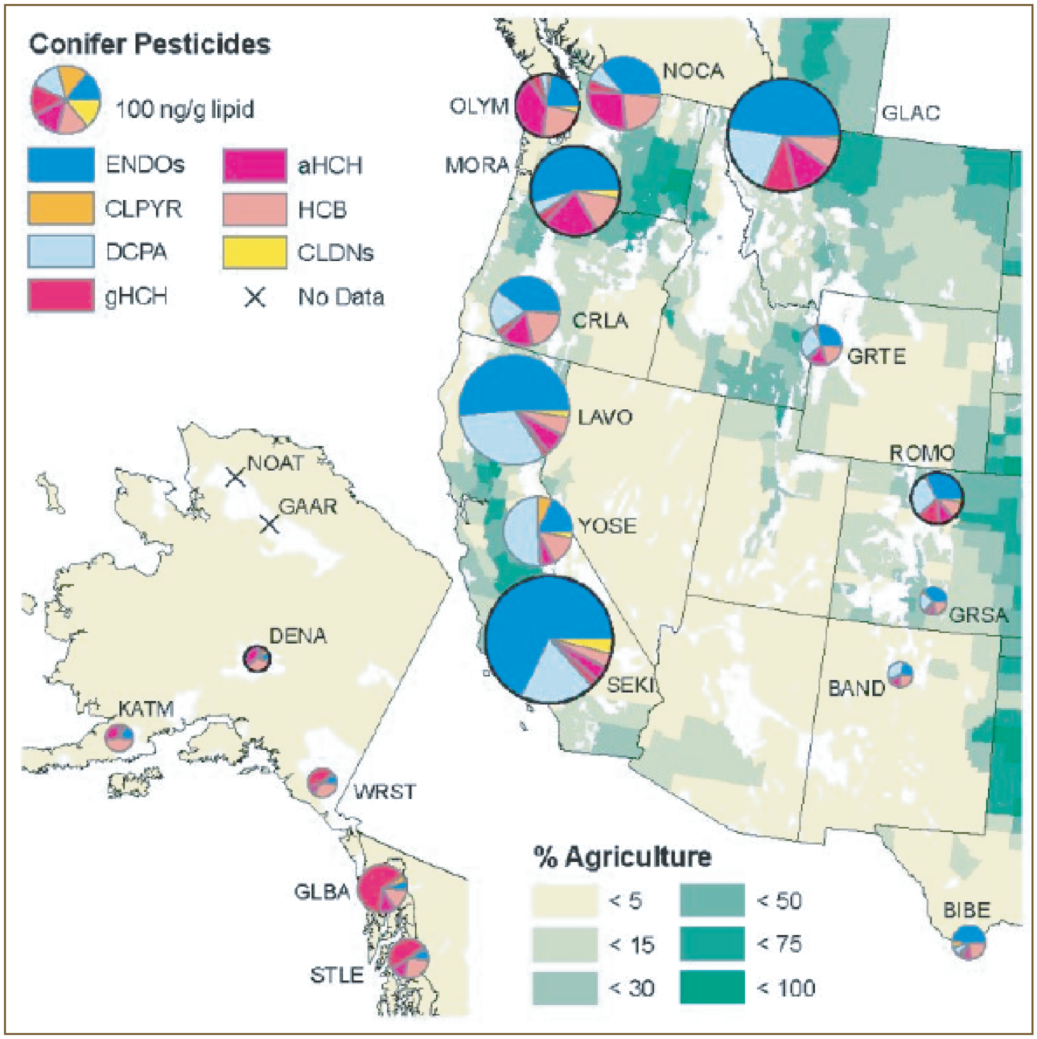

Figure 5. *Pesticide concentrations (ng/g lipid) in conifer needles from core and secondary WACAP parks overlaid on a map of agricultural intensity (US Department of Agriculture, National Agriculture Statistics Service, 2002). Circle area is proportional to total pesticide concentration. Light to dark 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 are relatively more important in Alaska, although total contaminant concentrations are lower. Conifers were not present in NOAT and GAAR. Circles outlined in black represent the core parks. Pesticide groups are endosulfans (ENDOs), chlorpyrifos (CLPYR), dacthal (DCPA), g-HCH and a-HCH (gHCH and aHCH), HCB, and chlordanes (CLDNs).*

What are the likely sources of contaminants?

The sources of contaminants in western national parks are from as far away as Europe and Asia, and as near as the local county. Agricultural areas are probable major sources of current-use and historical-use contaminants in parks located in close proximity (within 150 km) to these areas (Figure 5), such as Sequoia, Rocky Mountain, and Glacier. In Alaska, there are few local/regional sources of contaminants, and deposition of contaminants is primarily influenced by global atmospheric transport.

WHAT IS NEXT?

The results from this project should add considerably to the state of the science about contaminant transport, flux, and biological and ecological effects in remote ecosystems in the western U.S. However, it also serves to raise many additional questions. Future potential work may help identify contaminant pathways and document the extent and magnitude of specific ecological effects.

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Members of the WACAP team on site in Alaska.

The final WACAP report with greater detail, is now available on the website:

http://www.nature.nps.gov/air/Studies/air_toxics/wacap.cfm

This website will also provide a link to the complete WACAP database with all raw data collected for the project.