Mercury in Fish from National Parks
across the Western U.S. and Alaska

What is this study about?

Mercury (Hg) is a toxic, global contaminant that threatens ecosystem and human health. Human activities have increased atmospheric concentrations 3-5 fold during the past 150 years. Airborne Hg enters environmental cycles in complex ways, resulting in the contamination of even remote places. The National Park Service (NPS) protects some of the most pristine and sensitive wilderness in North America. There is concern that atmospherically deposited Hg could threaten the ecological integrity of aquatic communities in the parks and the wildlife that depend on them. In this study, the NPS and U.S. Geological Survey examined Hg concentrations in more than 1,400 freshwater fish from 86 sites across 21 national parks in the western U.S., extending over a 4,000 km distance.

Do fish in parks contain mercury?

Yes - mercury was detected in all fish. Mercury concentrations in fish were generally low, but were elevated in some instances. Across all parks, sites, and species, fish mercury concentrations ranged from 9.9 to 1,109 ng/g wet weight (ww) with a mean of 77.7 ng/g ww. Fish mercury concentrations vary greatly both among and within parks, suggesting that patterns of mercury risk are driven by processes occurring at site-specific, local, and global scales.

Where and when were fish collected?

Fish were collected from mainly remote, high elevation waters in 2008–2012 by NPS personnel following standardized protocols. Whereas most of the sites were only sampled during one of four years, 10 lakes within four parks were sampled in two separate years in order to examine temporal variation within a subset of lakes. Over one-third of the total samples were collected from Rocky Mountain and Mount Rainier national parks (NPs; Figure 1). Samples were sent to U.S. Geological Survey (USGS), Forest and Rangeland Ecosystem Science Center, Contaminants Ecology Lab in Corvallis, OR, for mercury analysis of muscle tissue and data interpretation.

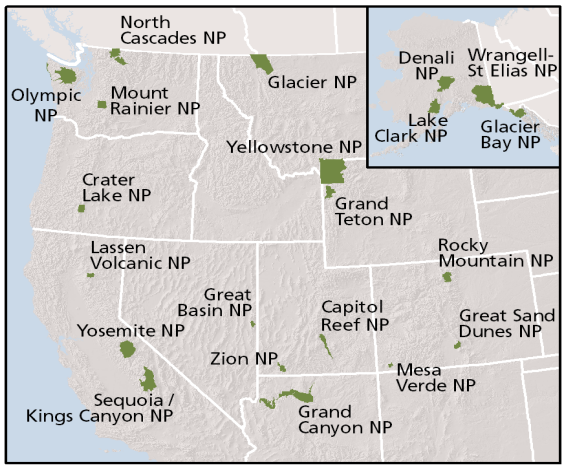
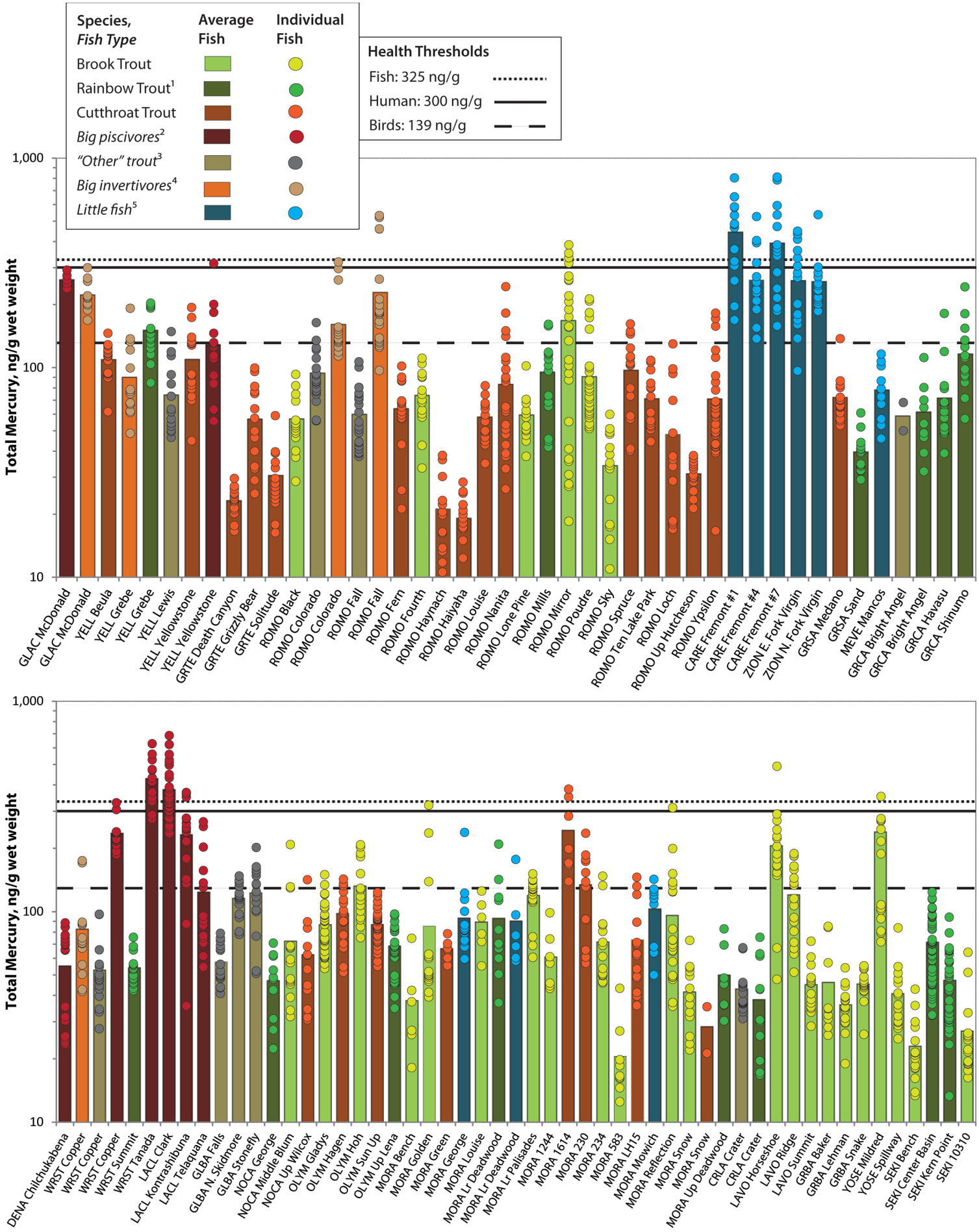


Figure 1. Spatial distribution of the 21 national parks sampled in this study. Size of circle represents percentage of total dataset (n=1,486).

How do mercury levels in fish compare to health thresholds?

Across all fish sampled, only 5 percent of the fish had Hg concentrations exceeding the benchmark associated with toxic effects on fish. However, 35 percent of the fish sampled were above a benchmark for risk to sensitive fish-eating birds such as osprey. Four percent of sport fish exceeded the U.S. Environmental Protection Agency's (EPA's) human health criterion, a particular concern for children and women of child-bearing years. Capitol Reef, Lake Clark, Wrangell-St. Elias, and Zion national parks all contained sites in which the majority of fishes exceeded benchmarks for the protection of human and wildlife health (Figure 2).

April 2014



[1] including *golden trout;* [2] *lake trout, northern pike, bull trout;* [3] *Kokanee, brown trout, Dolly Varden;* [4] *suckers, Arctic grayling, lake whitefish;* [5] *sculpin, speckled dace, stickleback*

Figure 2. Total mercury in average fish muscle tissue (bars) and individual fish (circles), by species in wet weight (ww), compared to health benchmarks established for fish toxicity (325 ng/g ww), highly sensitive fish-eating birds (139 ng/g ww), and human consumers (300 ng/g ww; EPA criterion). Wildlife benchmarks were converted from a whole-body basis to the equivalent concentration in muscle tissue according to Peterson et al. 2007 (ES&T 41(1): 58-65). Parks are ordered by decreasing latitude (Top graph=Intermountain Region; Bottom graph=Alaska/Pacific West Regions) and park abbreviations can be referenced to park name in Table 1. Data are plotted on a $\log_{10}$ scale.

Brook Trout

Table 1: Park Abbreviations

Capitol Reef	CARE
Crater Lake	CRLA
Denali	DENA
Glacier	GLAC
Glacier Bay	GLBA
Grand Canyon	GRCA
Grand Teton	GRTE
Great Basin	GRBA
Great Sand Dunes	GRSA
Lassen Volcanic	LAVO
Lake Clark	LACL
Mesa Verde	MEVE
Mount Rainier	MORA
North Cascades	NOCA
Olympic	OLYM
Rocky Mountain	ROMO
Sequoia-Kings Canyon	SEKI
Wrangell-St. Elias	WRST
Yellowstone	YELL
Yosemite	YOSE
Zion	ZION

What does this study tell us about the Hg risk to mammals?

Although we did not directly assess risk to mammals such as mink and river otter, the benchmarks chosen for fish-eating birds correspond closely with the no-observed-affect level (NOAEL) benchmark for dietary mercury in mammalian wildlife (110 ng/g ww). Thus, our data suggest that mammals may also be at risk to Hg where these thresholds are exceeded.

How does size and species influence fish mercury concentrations?

Fish length can be used as a surrogate for age: The larger the fish, the older it is. Older fish are particularly at risk to Hg contamination given the increased susceptibility for bioaccumulation over a long time period. Further, the trophic level of fish and length of food chain can also influence Hg levels. For example, predatory fish are more likely to have elevated contaminant concentrations due to biomagnification within the food web. In this study, the standard length of fish ranged from 34–648 mm, representing 16 different species that occupy trophic positions ranging from forage (prey) fish to top predator. In order to account for the effects of size and species on fish Hg concentrations, we normalized the Hg concentrations, allowing for more meaningful spatial comparisons among parks. We classified fish species into three different size categories (50 mm, 200 mm, and 400 mm). The mean Hg concentrations of each fish size class differed among the parks. Hg concentrations in fish species assigned to the largest size class were highest at Wrangell-St. Elias NP. Within the mid-sized class, Yellowstone NP had the highest fish Hg concentrations. Among the smallest size class, fish Hg concentrations were highest at Zion NP. Interestingly, the mean values of the smallest fish class from Zion and Capitol Reef NPs are comparable to Hg levels in parks with the largest fish (Figure 3). This is noteworthy because it is expected that prey fish from the smallest fish class would not contain Hg concentrations at or near the magnitude of Hg concentrations in predatory fish from the largest fish class.

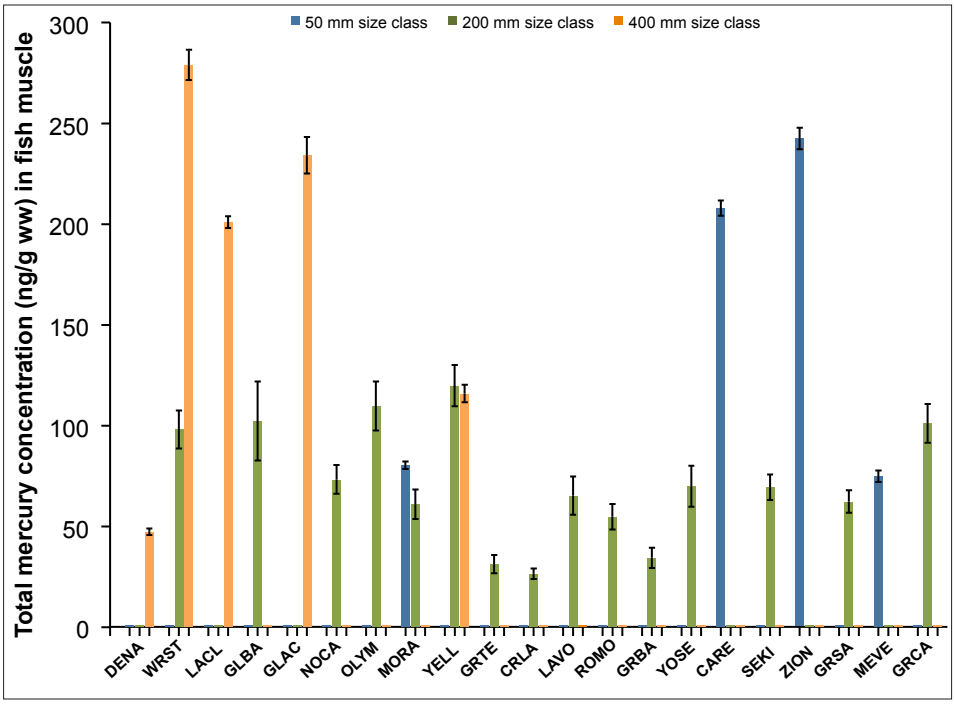


Figure 3. Size normalized least square (LS) mean total Hg concentration in fishes from 21 national parks in the western U.S. Blue bars are LS means for fish species normalized to 50 mm size, green bars are LS means for fish species normalized to 200 mm size, orange bars are LS means for fish species normalized to 400 mm size. Parks are ordered by decreasing latitude and park abbreviations can be referenced to park name in Table 1.

How did this study address the influence of fish size on mercury risk?

We modeled size-specific Hg risk to estimate specific lengths at which most fish exceed each health benchmark. For example, 50 percent of the individuals in three brook trout populations (LAVO Horseshoe, ROMO Mirror, YOSE Mildred) were modeled to exceed the moderately sensitive fish-eating bird threshold at a mean size of 261 mm. Size-specific risk for other populations and health benchmarks was also estimated.

Lake Clark NP&Pres., Alaska

How did this study address site-to-site variability?

We addressed this issue by sampling two parks (Mount Rainier and Rocky Mountain NPs) intensively, with 17 and 19 different sites in each park, respectively. This higher resolution sampling revealed up to 20-fold variation in size-normalized fish Hg concentrations among lakes within an individual park. Results suggest that the limited number of sites sampled in most other parks (2-3) is inadequate to fully characterize mercury risk, and multi-site sampling is necessary.

Why should we care?

Mercury is harmful to human and wildlife health, and is among the most widespread environmental contaminants in the world. Over 16 million lake acres and 1 million river miles are under fish consumption advisories due to Hg in the United States and 81 percent of all fish consumption advisories issued by the EPA are because of Hg contamination. Exposure to high levels of this toxin in humans may cause damage to the brain, kidneys, and the developing fetus. Pregnant women and young children are particularly sensitive to the effects of mercury. Elevated mercury concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, or reproductive success. The spatial breadth of this study facilitates the most thorough understanding of Hg bioaccumulation patterns in fishes of western and Alaskan national parks to date. Results suggest that although risk may be low in many locations, there are concerns about the impact of Hg on humans and wildlife at other sites. The data suggest further study of key ecological endpoints in Capitol Reef, Glacier, Lake Clark, Lassen Volcanic, Wrangell-St. Elias, Yosemite, and Zion NPs are warranted due to high levels of Hg in fish from these areas. Neither the USGS nor the NPS regulate environmental health guidelines, but the NPS is coordinating with state officials regarding potential fish consumption advisories. State guidelines consider both the risks associated with Hg exposure and the benefits of fish consumption. Parks are also encouraged to work with the NPS Office of Public Health. In addition to its scientific contributions, this study serves as a baseline by which decreases in Hg emissions under the Mercury and Air Toxics Standards can be assessed for effectiveness in removing Hg from the environment.

Where does mercury come from?

Although there are natural sources of mercury such as volcanoes, most of the mercury that affects parks comes from burning fossil fuels like coal in power plants. Waste incinerators, oil and gas wells, and mining operations are other human-caused sources of mercury. In the atmosphere, mercury travels long distances as tiny particles and gases. It settles to the ground by falling in rain and snow or landing as dust particles. In the environment and particularly in wetlands, mercury is transformed into a more toxic form, methylmercury, that can bioaccumulate and biomagnify in organisms.

What's next?

Variation in site-specific fish Hg concentrations within individual parks suggests that more intensive sampling in some parks will be required to effectively characterize Hg contamination in western & Alaskan national parks. Future targeted research and monitoring across park habitats would help identify patterns of Hg distribution across the landscape and facilitate informed management decisions aimed at reducing the ecological risk posed by Hg contamination in sensitive ecosystems protected by the NPS.

For more information:

Eagles-Smith, C.A., Willacker, J.J., Flanagan Pritz, C.M., 2014, Mercury in fishes from 21 national parks in the Western United States- Inter and intra-park variation in concentrations and ecological risk: U.S. Geological Survey Open-File Report 2014-1051, 54 p. http://dx.doi.org/10.3133/ofr20141051.

Websites: http://fresc.usgs.gov/ and www.nature.nps.gov/air/studies/ToxicEffects.cfm