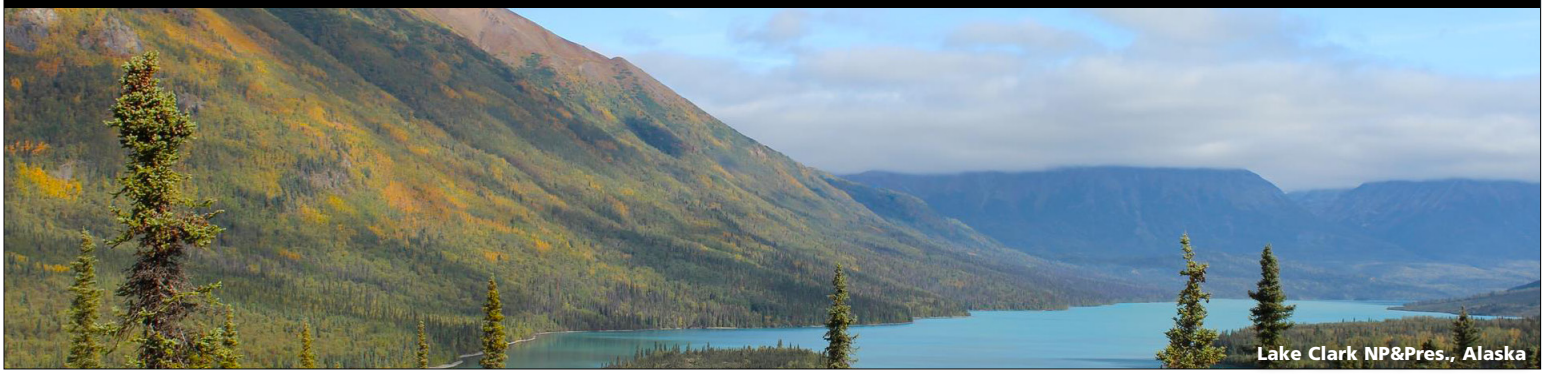
Mercury in Fish from National Parks
across the Western U.S. and Alaska



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. Across all parks, sites, and species, fish total Hg (THg) concentrations ranged from 9.9 to 1,109 ng/g wet weight (ww) with a mean of 77.7 ng/g ww. Fish THg concentrations vary greatly both among and within parks, suggesting that patterns of Hg risk are driven by processes occurring at site-specific, local, and global scales.

Where and when were fish collected?

Fish were collected from remote high elevation waters in 2008, 2009, 2011, and 2012 by NPS personnel following standardized protocols. Over one-third of the total samples were collected from Rocky Mountain and Mount Rainier national parks (NPs; Figure 1). 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. Samples were sent on dry ice to U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Contaminants Ecology Lab in Corvallis, OR, for mercury analysis of muscle tissue and data interpretation.

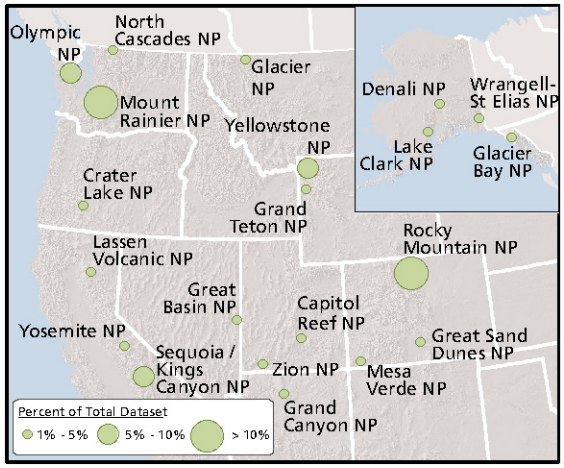


Figure 1. Spatial distribution of the 21 national parks sampled in this study. Size of circle represents percentage of total dataset (n=1,486).

How do mercury levels in fish compare to health thresholds?

Across all fish sampled, only 5 percent of the fish had THg 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. Six percent of fish exceeded the U.S. Environmental Protection Agency's (USEPA's) human health criterion, a particular concern for children and women of child-bearing years. Zion, Capital Reef, Wrangell-St. Elias, and Lake Clark national parks all contained sites in which the majority of fishes exceeded benchmarks for the protection of human and wildlife health (Figure 2).

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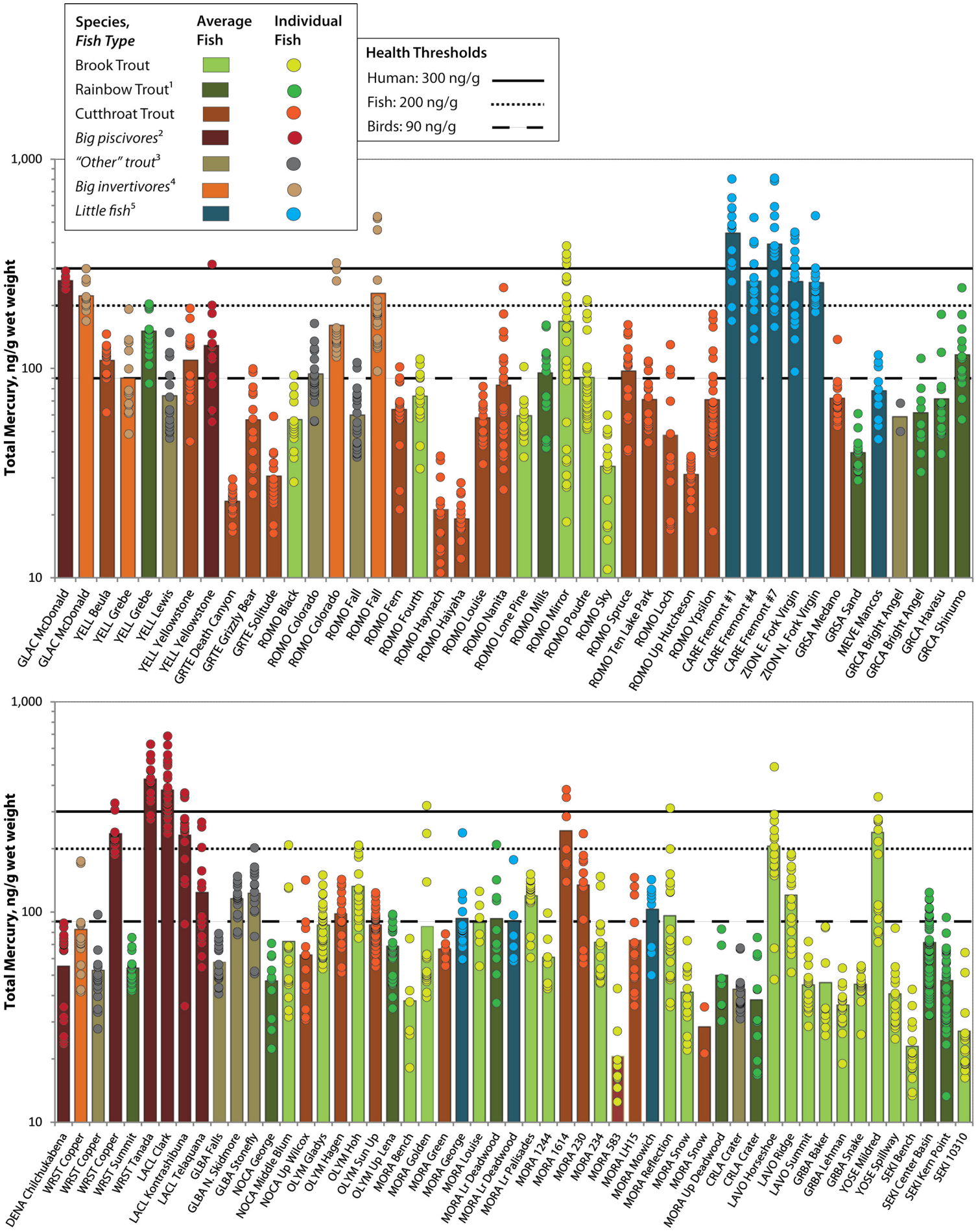

[1] including *golden trout;* [2] *lake trout, northern pike, bull trout;* [3] *Kokanee, brown trout, Dolly Varden;* [4] *suckers, Arctic grayling, lake whitefish;* [5] *sculpin, speckled dace, stickleback*

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 (200 ng/g ww), highly sensitive fish-eating birds (90 ng/g ww), and human consumers (300 ng/g ww; USEPA criterion). 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.

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 THg concentrations, we normalized the THg 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 THg concentrations of each fish size class differed among the parks. THg 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 THg 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.

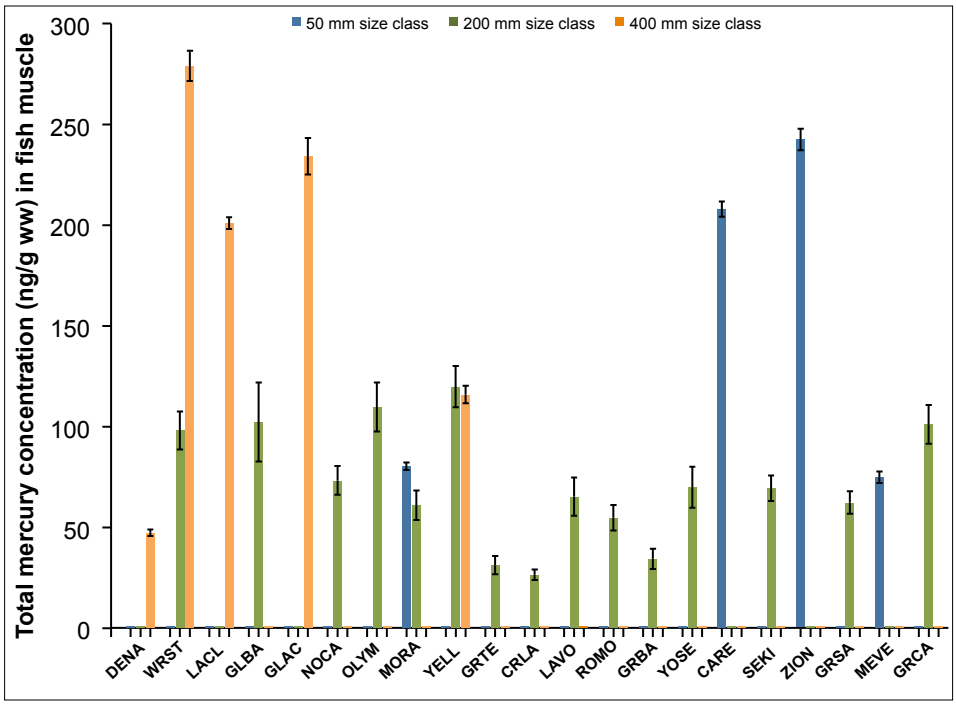

Figure 3. Size normalized least square (LS) mean THg concentration in fishes from 21 national parks in the western U.S. Blue bars are LS means for fish species normalized to 50 mm size, green bars are LS means for fish species normalized to 200 mm size, orange bars are LS means for fish species normalized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

How does mercury risk vary with fish size?

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.


Grand Teton NP, Wyoming

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 THg 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 toxic. It can affect numerous physiological processes in vertebrate wildlife and humans, particularly neurological function, but it can also harm cardiovascular, renal, and endocrine systems. Although the toxicological responses are specifically damaging to developing individuals, elevated Hg exposure can also impair reproduction in adults. Symptoms can occur at exposure levels commonly observed in the environment, and can result in reduced foraging efficiency, survival, or reproductive success. The unprecedented spatial breadth of this study facilitates the most thorough understanding of Hg bioaccumulation patterns in fishes of western and Alaskan national parks to date. Our results suggest that although risk may be low in many locations, there are substantial concerns about the impact of Hg on fish, birds, wildlife, and humans in other locations. The data presented here suggest that further study of key ecological endpoints in Capitol Reef, Zion, Lassen Volcanic, Yosemite, Wrangell-St. Elias, Lake Clark, and Glacier NPs are warranted due to high levels of Hg in fish from these areas. More than 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 USEPA are because of Hg contamination. National parks are encouraged to work with state agencies and the NPS Office of Public Health to issue fish consumption advice and communicate guidance regarding mercury in fish. Advisories and related warnings consider both the risks and benefits of consuming fish. Lastly, the information in this study will serve as a baseline by which decreases in Hg emissions under the Mercury and Air Toxics Standards (MATS) can be assessed for effectiveness in removing Hg from the food chain.

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 THg 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