Dragonfly Mercury Project—A Citizen Science Driven Approach to Linking Surface-Water Chemistry and Landscape Characteristics to Biosentinels on a National Scale

Mercury is a globally distributed pollutant that threatens human and ecosystem health. Even protected areas, such as national parks, are subjected to mercury contamination because it is delivered through atmospheric deposition, often after long-range transport. In aquatic ecosystems, certain environmental conditions can promote microbial processes that convert inorganic mercury to an organic form (methylmercury). Methylmercury biomagnifies through food webs and is a potent neurotoxicant and endocrine disruptor. The U.S. Geological Survey (USGS), the University of Maine, and the National Park Service (NPS) Air Resources Division are working in partnership at more than 50 national parks across the United States, and with citizen scientists as key participants in data collection, to develop dragonfly nymphs as biosentinels for mercury in aquatic food webs. To validate the use of these biosentinels, and gain a better understanding of the connection between biotic and abiotic pools of mercury, this project also includes collection of landscape data and surface-water chemistry including mercury, methylmercury, pH, sulfate, and dissolved organic carbon and sediment mercury concentration. Because of the wide geographic scope of the research, the project also provides a nationwide "snapshot" of mercury in primarily undeveloped watersheds (fig. 1).

Dragonflies spend their larval stages in aquatic habitats, and then molt and emerge as terrestrial adults. They are an important connection between aquatic and terrestrial environments. (Photograph by Sarah Nelson, University of Maine.)

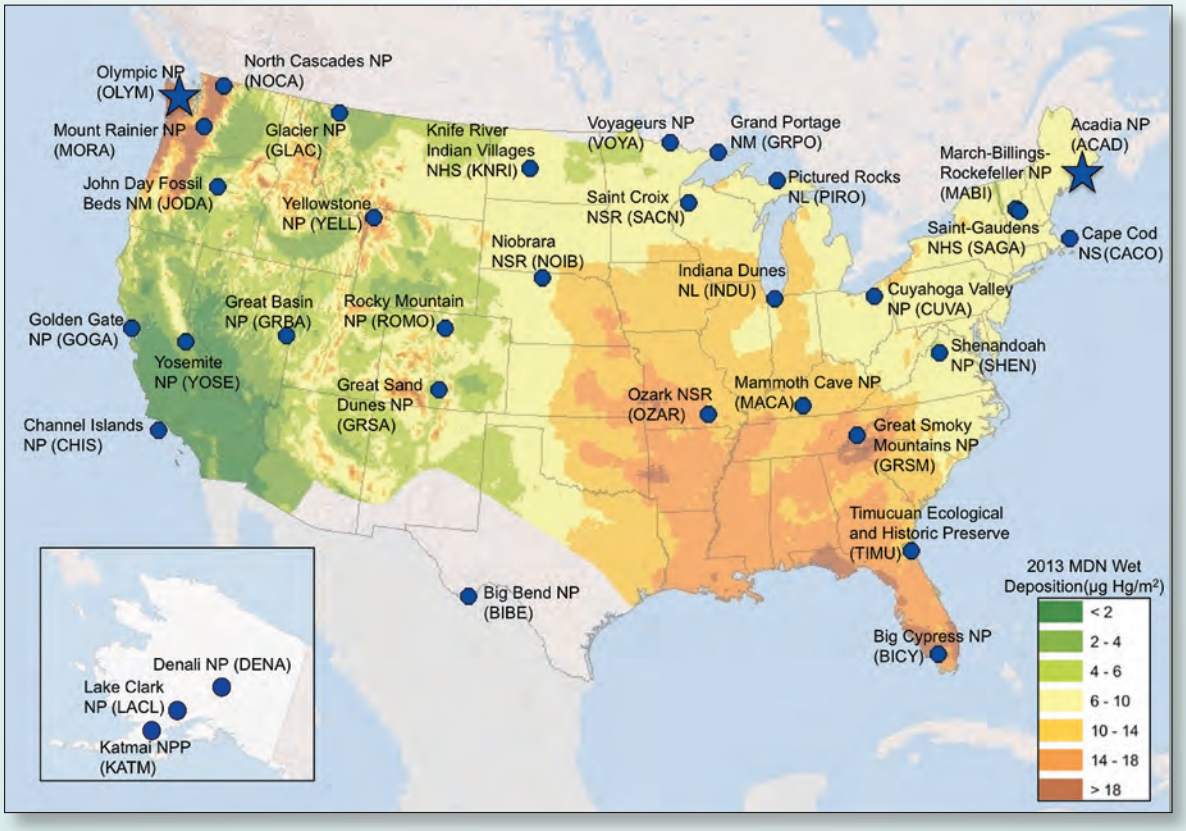

Figure 1. Map showing 34 national parks sampled as part of the Dragonfly Mercury Project during 2014. The project expanded from 12 national parks participating in a pilot effort in 2012 to more than 50 national parks participating in 2015. Olympic and Acadia National Parks, denoted with a star, were sampled more frequently (4 times per year) and with greater spatial coverage (more than 10 sites) than the other national parks. Estimates of mercury wet deposition from 2013 are provided by the National Atmospheric Deposition Program, Mercury Deposition Network (http://nadp.sws.uiuc.edu/mdn/).

Citizen scientists identify and measure dragonfly larvae at Great Smoky Mountains National Park.

Citizen Science Contribution

The broad geographic coverage of this science is possible because of the participation of citizen scientists working in each national park. In 2014, the Dragonfly Mercury Project benefited from the help of 824 citizen scientists contributing 3,951 hours to this effort (fig. 2).

Scientists from the USGS and University of Maine develop the study design, sampling protocol, and training materials. Each participating national park provides NPS staff from their resource management or interpretive division, or they link with other partners, such as a teacher from the community. These staff coordinate, train, and lead citizen scientists in collecting samples.

Citizen scientists include:

- Student volunteers (middle school to university)
- Youth volunteers (for example, from NPS Youth Conservation Corps)
- Members of NPS volunteer programs and participants in NPS visitor programs
- Girl Scouts of the U.S.A. and Boy Scouts of America
- Teachers from the NPS Teacher-Ranger-Teacher program
- Interns from Mosaics in Science program

Citizen scientist dragonfly team at Golden Gate National Recreation Area.

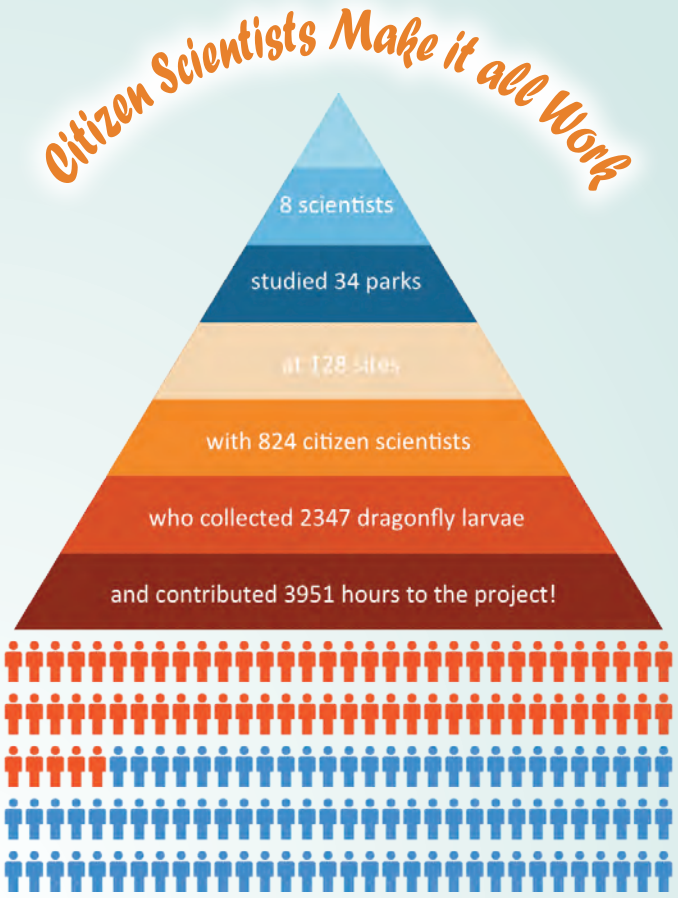

Figure 2. The partnership between citizen scientists and professional research scientists results in a valuable outdoor and educational experience for the citizen scientists as they participate in carefully designed studies. In turn, they make a valuable contribution to the professional research scientists by contributing samples collected from remote locations throughout the United States. This partnership maximizes efficient use of public science resources, and serves as a vehicle to inspire for the nation's next generation of scientists.

2014 Examples of Data Collected

Example data from the 2014 sampling show dragonfly nymph total mercury concentrations among and within sites (fig. 3).

Surface-water chemistry (such as pH and dissolved organic carbon) and site-specific landscape characteristics (such as geology and land cover) help identify ecosystem conditions that are sensitive to mercury methylation and have a high risk for mercury bioaccumulation in sentinel biota.

Repeated sampling at selected sites in Olympic and Acadia National Parks allows scientists to investigate the temporal variability in dragonfly total mercury concentrations (fig. 4).

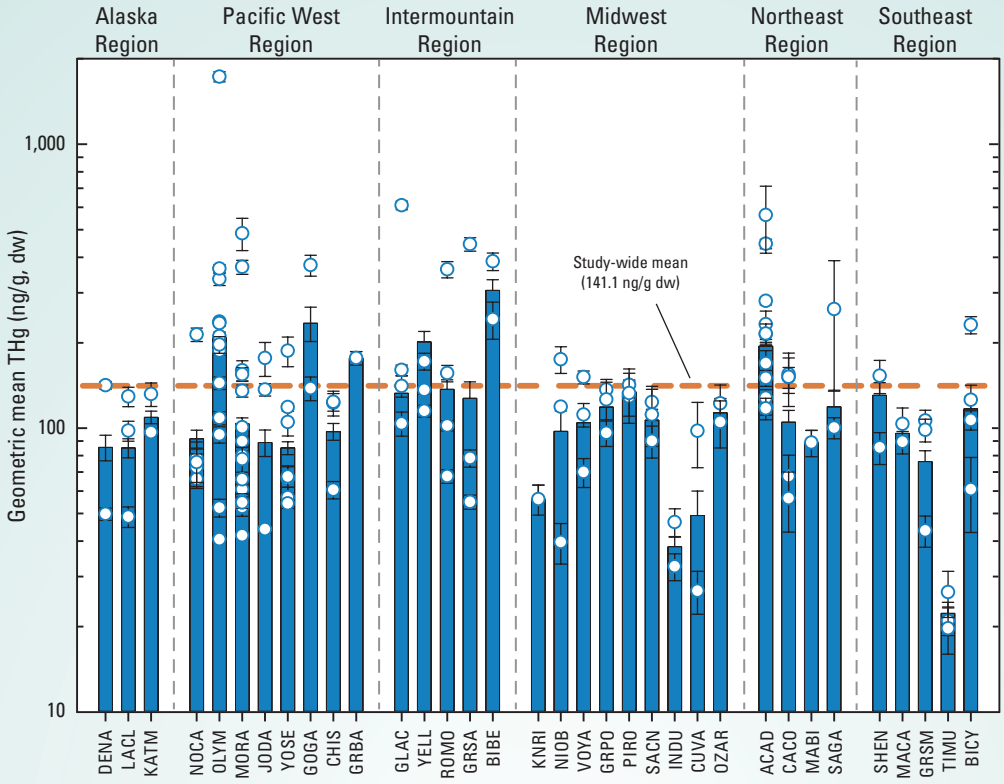

Figure 3. Geometric mean of dragonfly larvae total mercury (THg) concentrations by national park (bars) and by site within national parks (dots), 2014. Error bars represent standard error. Note the data are displayed on a log scale. Values are in nanograms per gram dry weight (ng/g, dw). See figure 1 for park abbreviations.

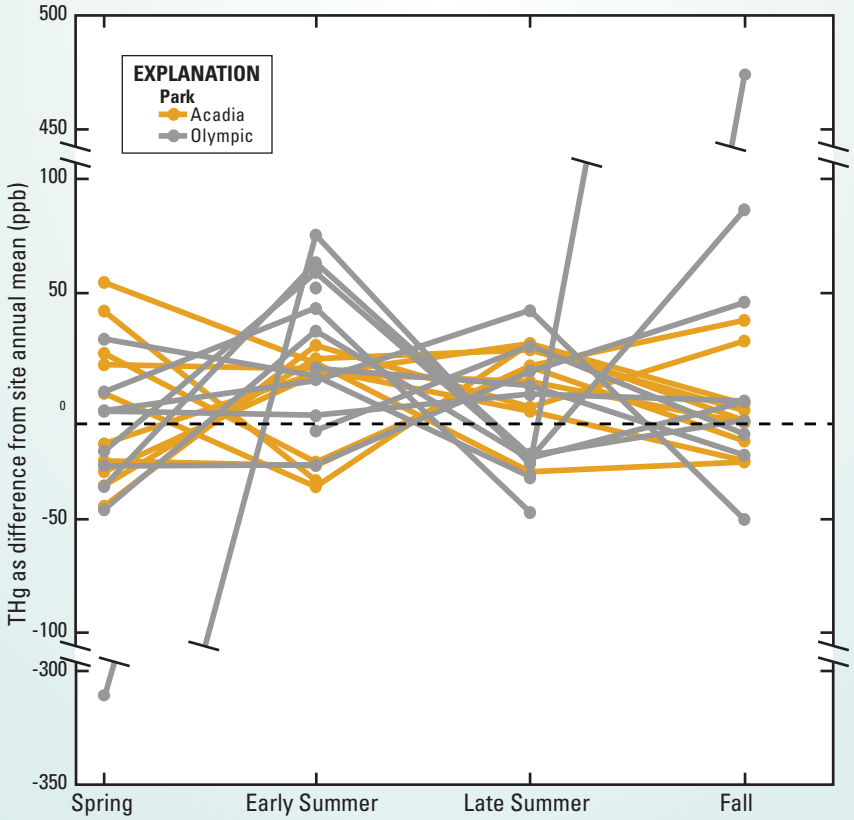

Figure 4. Example data of relative seasonal concentrations of total mercury (THg) in dragonfly larvae represented as the difference from the site-specific annual mean in parts per billion (ppb), Acadia and Olympic National Parks, 2014.

Methods

1. Specially designed sampling kits devised to streamline and simplify sampling by citizen scientists are prepared in advanced at USGS and University of Maine laboratories, then shipped to participating national parks.

2. Citizen scientist groups are coordinated and led by NPS staff in field sampling of

Water—collected using "clean hands-dirty hands" method. One person keeps their hands "clean" and handles the collection vessel while the other gets their hands "dirty" collecting and preparing the sample. This minimizes the risk of samples being contaminated in the collection process.

Sediment—collected using mini-corers to sample the upper 2 centimeters of stream or lake sediment; 3 replicates per water body.

Dragonfly nymphs—typically collected at 3 water bodies per national park, with 20 specimens individually captured and analyzed per water body.

Site characterization—recorded field notes, coordinates, and observations.

3. Samples are shipped to USGS and University of Maine laboratories for analyses:

   - Dragonfly nymphs—analyzed for total mercury and methylmercury.
   - Water—analyzed for total mercury, methylmercury, dissolved organic carbon, pH, anions, and conductivity.
   - Sediment—analyzed for total mercury.

Sampling supplies and identification guides are provided by the project leads, and citizen scientists sample under the guidance of natural resource professionals at each park.

What's Next?

Expansion of geographic coverage. Observations made in some areas, like the arid southwest which is targeted for 2015 sampling, suggest a range of sources and processes may be responsible for driving elevated mercury in biota across national parks. Expanded geographic coverage for sample collection will help evaluate this possibility.

Coordination with available fish data. In national parks where fish and dragonfly larvae are sampled, we will determine the strength of associations between concentrations of mercury in dragonfly larvae and in fish.

Long-term monitoring of dragonfly larvae as biotic sentinels. Long-term monitoring provides the scientific evidence needed to determine how ecosystems are responding to changes in environmental conditions. The goal is to develop a national scale educational opportunity that benefits our scientific understanding in support of natural resource management.

Citizen science enhances public understanding of and interest in science. Educational research with Schoodic Institute at Acadia National Park considers how students evaluate data and think about the scientific process. This provides the information necessary to determine that our approach maximizes the educational aspect of this research for the citizen scientists involved.

Species Identification using DNA Barcoding. Our interpretation of mercury results is potentially hindered by influence of dragonfly species because of difference in diet and life history. There are many species of dragonflies, and they can vary in life history and diet. Distinguishing species to the extent possible is important for interpretations of the results of this research. Consequently, we use DNA barcoding, where the DNA sequence of difficult-to-identify immature dragonflies are matched to global DNA databases based on adult dragonflies that are more often collected and more easily identified to the species level.

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For additional information visit the project Web site:
http://www.nature.nps.gov/air/studies/air_toxics/dragonfly/index.cfm

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