Six-legged Scouts:

Dragonfly larvae provide baseline data to evaluate mercury in parks nationwide

Rocky Mountain NP, CO

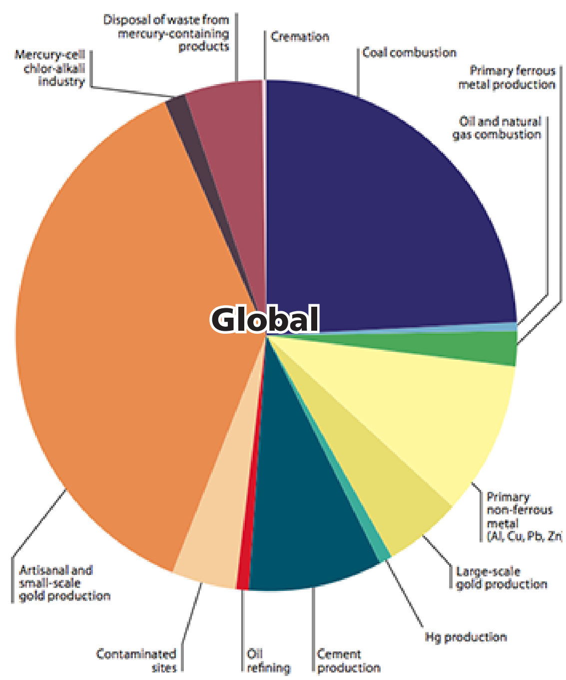
What is mercury and why are parks involved?

Mercury is a global pollutant that threatens resources the National Park Service (NPS) is charged with protecting. Concentrations of mercury (Hg) in fish and other biota exceed human and wildlife health thresholds in many national parks across the United States. Efforts by resource managers to focus conservation work in areas of highest risk to humans, fish, and wildlife are hampered by significant variability in Hg concentrations from site to site—even among neighboring lakes, streams, or wetlands. This project is evaluating how dragonfly larvae might be used as bio-sentinels for Hg nationwide. The study started in a handful of national parks in 2010–2011, and included 12 parks in the 2012 pilot year. This project brief reports on a NPS-wide expansion to 22 parks during 2013. Citizen scientists, working with park staff at each park, collected and submitted samples for Hg analysis.

Where does mercury come from?

There are both natural and anthropogenic (human-caused) sources of Hg emissions to the atmosphere. Once in the air, Hg can travel great distances from where it was emitted, so even protected places like national parks receive Hg through atmospheric deposition (rain, snow, and dust particles in air that reach the ground). According to global models, current anthropogenic sources (Figure 1) contribute ~30% of emissions to air, natural sources contribute ~10%, and re-emission from soil and surface waters contributes the remainder. This re-emission is largely from legacy pollution; thus it can be considered anthropogenic as well (UNEP 2013). Once on the ground, Hg enters a complicated cycle in soils and waterbodies, and ultimately some Hg bioaccumulates in organisms and biomagnifies up food chains.

Pictured Rocks National Lakeshore, MI



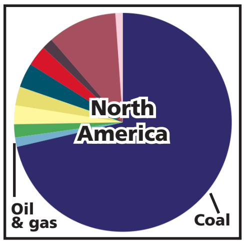
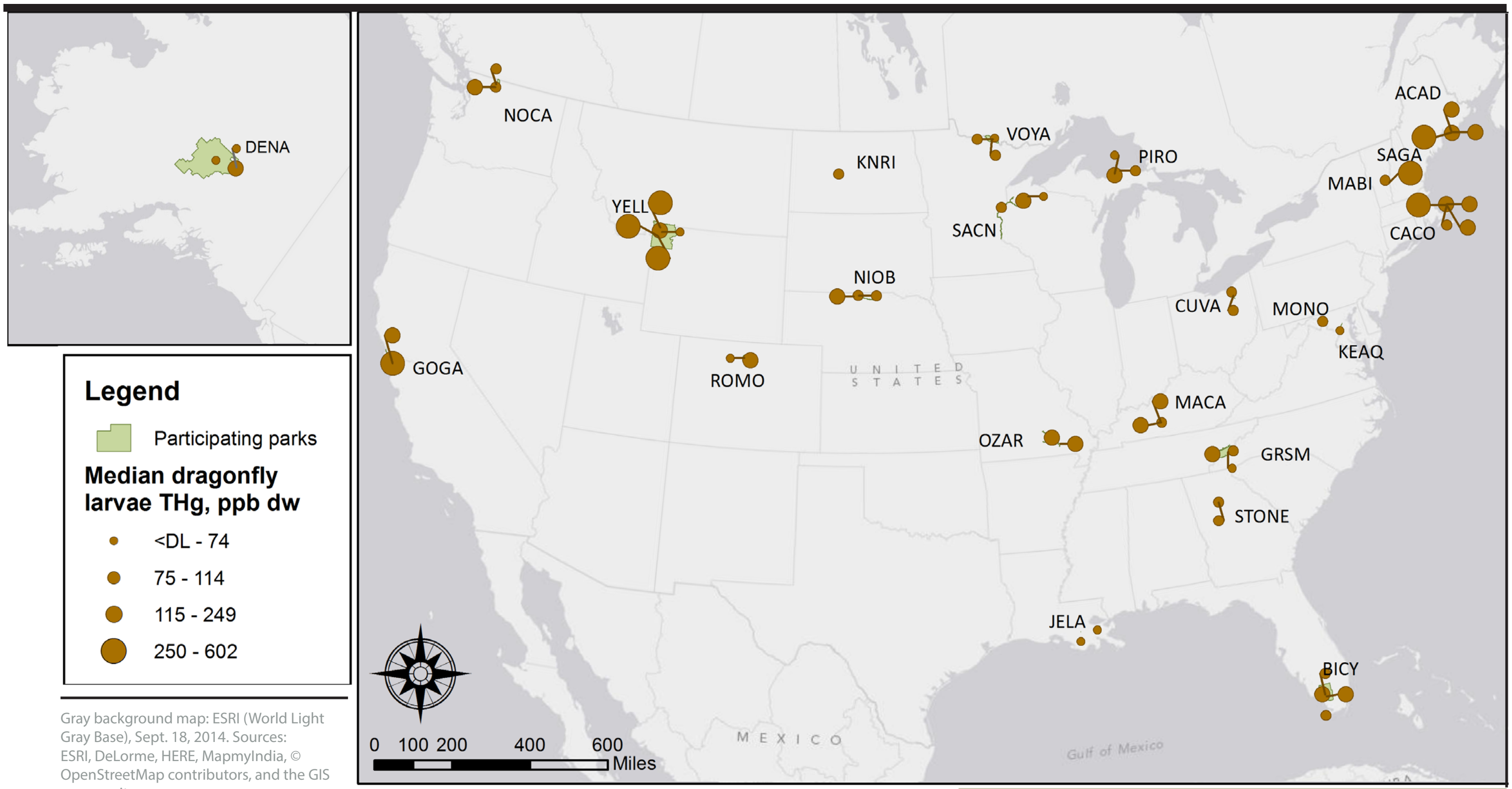


Figure 1. Relative contributions to global estimated emissions from air from anthropogenic sources in 2010. In North America (left), stationary combustion of coal, oil, and gas comprises nearly 2/3 of emissions. Figure sources: UNEP, 2013.



Gray background map: ESRI (World Light Gray Base), Sept. 18, 2014. Sources: ESRI, DeLorme, HERE, MapmyIndia, © OpenStreetMap contributors, and the GIS community.

Figure 1. Total mercury (THg) concentrations in dragonfly larvae collected from 22 national parks (plus one state park) during 2013. Most parks had multiple sampling sites, shown on the map as multiple dots. Even within a park and in close proximity, THg concentrations in dragonfly larvae could be highly variable and site-specific.

2013 Data summary

- Sites with the greatest dragonfly larvae total mercury (THg) concentrations were located in New England, as well as western sites that could be influenced by regional or local influences.
- In 2013, 22 national parks plus one state park participated in the project. Over 775 dragonfly larvae samples from 60 distinct sites were analyzed. THg concentrations ranged from below the detection limit to 844 parts per billion (ppb), on a dry weight (dw) basis. The median ± SD* concentration for THg in dragonfly larvae was 112±124 ppb, dw (see Figure 3).
- In 2012, 12 national parks participated. The median ± SD THg concentration was 125 ± 77 ppb, dw. The 2012 THg concentrations ranged from below detection limit to 447 ppb, dw.
- The medians for the two years were similar, but the standard deviation and the range were much larger in 2013 than 2012, meaning there is more variability in the dataset for 2013.
- *Why more variability in 2013?* We approximately doubled the number of parks, and had better spatial coverage in 2013 than in 2012. Some parks and sites are in very different ecosystems, giving us greater variability in the data. For example, YELL had some of the greatest concentrations of THg measured. Potential Hg sources in YELL could be geothermal features (Hall *et al.* 2006) or wildfires upwind of the park, in addition to atmospheric deposition from distant sources.

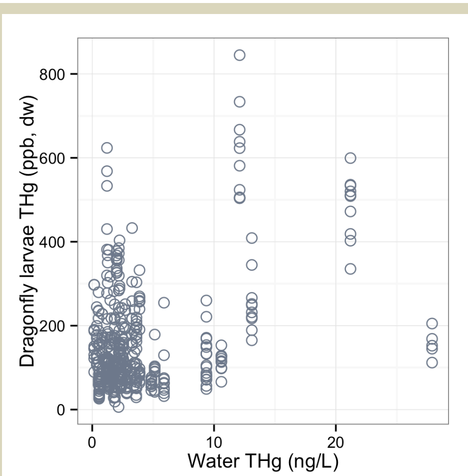


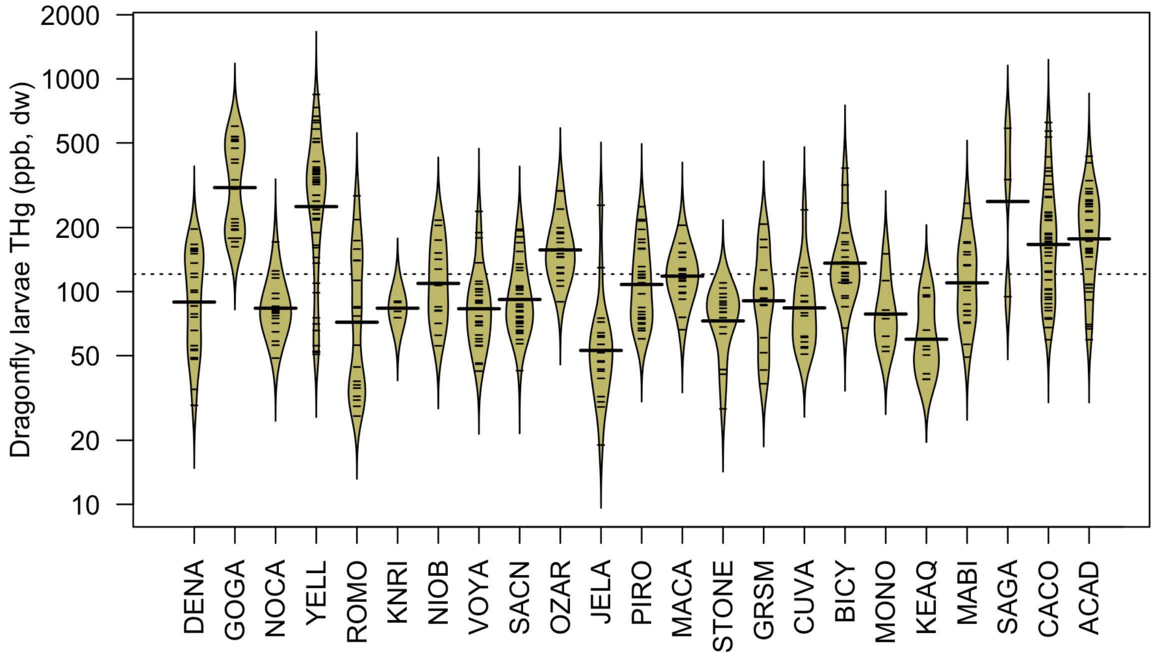
Figure 2. How does water mercury relate to mercury in dragonfly larvae?

In 2013, we sampled each waterbody (ponds, lakes, streams, and wetlands) to determine the concentration of mercury (total mercury, THg) in the water, as well as THg in dragonfly larvae inhabiting the waterbody. There was only a slight correlation between water THg and dragonfly larvae THg, meaning that we need to continue investigating other factors that more strongly relate with mercury in dragonfly larvae and other biota.

Big Cypress National Preserve, FL

* Standard deviation is abbreviated SD, and is a measure of variability, or the spread of the data.

Figure 3. What is the distribution of THg data across all participating parks? This graph is a beanplot showing total mercury (THg) in dragonfly larvae in parts per billion, dry weight (ppb, dw) for each park. The graph is ordered from west to east, reading left to right. Each tan-colored 'bean' is a density trace, showing the distribution of the data. The thin black lines within each bean show the actual observations (concentrations of THg), and the thicker black line is the average THg concentration for each park. Note that the top of the bean is greater than the maximum value of the actual data for each park; likewise, the bottom of the bean is lower than the minimum observed value. The dotted line across the plot shows the overall average THg concentration for 2013.



What affects relative mercury concentrations in dragonfly larvae?

- Both 2012 and 2013 had meaningful differences in the concentration of mercury in dragonfly larvae among sites – even among sites within the same park.
- We are building a baseline data set, and testing some hypotheses about how chemistry and landscapes might affect mercury. The 2013 data are being used in statistical models that allow us to test several factors that might interact synergistically to define patterns in mercury concentrations. This is important because no single chemical or landscape variable in the 2012 or 2013 data is able to explain the pattern of Hg in dragonfly larvae (see Figure 2). These statistical models point to longitude (a west-east gradient), DOC (dissolved organic carbon, generally a natural substance in water), and to a lesser extent, pH (acidity of the water), dry weight (mass of each dragonfly), and the concentration of mercury in the water itself as variables that influence mercury in dragonfly larvae.
- Species guild and length may also affect Hg levels in dragonfly larvae. Richness and abundance data will help better address those influences.

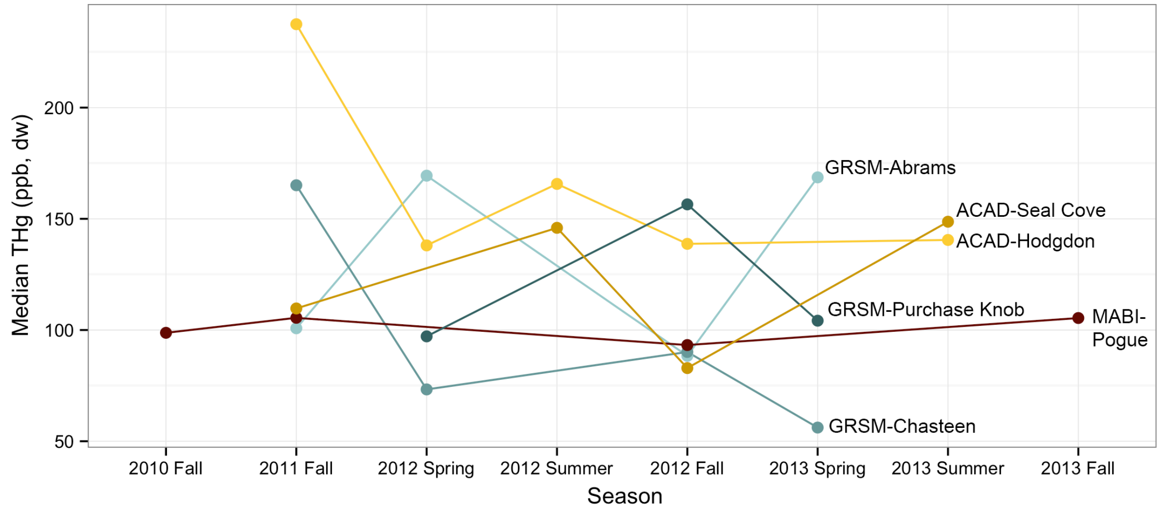
Park abbreviations

ACAD	Acadia National Park
BICY	Big Cypress National Preserve
CACO	Cape Cod National Seashore
CUVA	Cuyahoga Valley National Park
DENA	Denali National Park and Preserve
GOGA	Golden Gate National Recreation Area
GRSM	Great Smoky Mountains National Park
JELA	Jean Lafitte National Historic Park & Preserve
KEAQ	Kenilworth Park and Aquatic Gardens
KNRI	Knife River Indian Villages National Historic Site
MABI	Marsh-Billings-Rockefeller National Historic Park
MACA	Mammoth Cave National Park
MONO	Monocacy National Battlefield
NIOB	Niobrara National Scenic River
NOCA	North Cascades National Park
OZAR	Ozark National Scenic Riverways
PIRO	Pictured Rocks National Lakeshore
ROMO	Rocky Mountain National Park
SACN	Saint Croix National Scenic Riverway
SAGA	Saint-Gaudens National Historic Site
STONE	Stone Mountain State Park, Georgia
VOYA	Voyageurs National Park
YELL	Yellowstone National Park

What do the data mean for human or wildlife health?

We are not quite sure what the data mean for human or wildlife health. This study is one of the first to use invertebrates (dragonfly larvae) in this way. Work is underway to summarize deleterious endpoints to fish and wildlife species, and to develop an informed understanding of the ecological risk of Hg in varying taxonomic groups, for a given park and habitat. Moreover, Haro *et al.* (2013) sampled dragonfly larvae and fish in six parks in the Great Lakes region, and found dragonfly larvae could be used as surrogates for fish Hg. Sampling conducted in 2014 will link water, sediment, and dragonfly data and help determine how closely dragonfly mercury concentrations are coupled with these other media. Part of the strength of this project, especially going forward, is that we are sampling multiple media. Scientists can make the strongest inferences when we have multiple lines of evidence all pointing in the same direction.

Figure 4. Is there a seasonal pattern in total mercury (THg) in dragonfly larvae? Yes. This graph shows median total mercury (THg) in dragonfly larvae collected at three parks: MABI, ACAD, and GRSM. These three parks helped pilot the project, and have at least three years of data. At MABI, sampling has occurred each fall and median THg has remained constant. At ACAD and GRSM, samples were collected in spring, summer, and fall, and seasonal variability is apparent in the data.



Ongoing research – why do we need long-term data?

This project began as part of a program linking high school teachers and scientists. In 2010, a class from Woodstock, VT sampled at MABI (pond site) and has returned to the site each year (Figure 4). Their annual samples provide the longest-term record in our database. Sites at GRSM (streams) and ACAD (ponds) have been sampled for three years, with seasonal collections that raise questions about variability within years and in different types of waterbodies. New research in 2014 is targeting these temporal questions in addition to analyzing spatial patterns.

How are citizen scientists involved?

The citizen scientist study of mercury in dragonfly larvae project engages students, teachers, and park visitors in the collection of dragonfly larvae for mercury analysis and taxonomic identification. One goal of the project is to support the NPS Call to Action, by enlightening a new generation of citizen scientists about the connection of all living things and the influence humans have upon natural systems. Over 265 citizen scientists participated in the project during 2013, from coast to coast. Citizen scientists ranged from middle school classes to families visiting the parks to Youth Conservation Corps fieldcrews and adult volunteers from the local community. In total, they contributed approximately 1,700 hours to this research and related field projects during 2013. In addition to advancing science and our understanding of the spatial distribution of Hg risk, the legacy of data use and application with citizen scientists has led to a focus on data literacy. NPS interpreters, resource management staff, or non-profit partners led field excursions to sample dragonflies, coordinated with project scientists, and provided interpretive programs related to mercury and aquatic macroinvertebrates. Staff at Schoodic Institute at Acadia National Park developed interpretive materials for use in participating parks (available on website below).

What's next?

Further expansion of the project – and continued collection over a number of years – will help us understand more about the data, and the other factors we need to consider to better interpret the dragonfly mercury concentrations. In collaboration with the U.S. Geological Survey, Dartmouth College, and the University of Wisconsin-LaCrosse, we are coordinating sampling at close to 50 national parks where dragonfly larvae, water chemistry, and sediment are being collected to build on these baseline data and investigate how these factors are linked.

For more information:

Sarah Nelson
sarah.j.nelson@maine.edu
Colleen Flanagan Pritz
colleen_flanagan@nps.gov

Project website:
http://www.nature.nps.gov/air/Studies/air_toxics/dragonfly/index.cfm

Funding for the 2013 study is provided by the National Park Service; the pilot project was funded by the University of Maine. Continuing research is funded by the U.S. Geological Survey-NPS Water Quality Partnership.

References

Hall, BD, ML Olson, AP Rutter, RR Frontiera, DP Krabbenhoft, DS Gross, M Yuen, TM Rudolph, JJ Schauer, 2006. *Sci Tot Environ* 367(1): 354-366.

Haro, RJ, SW Bailey, RM Northwick, KR Rolfhus, MB Sandheinrich, JG Wiener, 2013. *Environ Sci Technol* 47(15): 8148-8156.

UNEP, 2013. Global Mercury Assessment 2013. UNEP Chemicals Branch, Geneva, Switzerland. http://www.unep.org/publications/contents/pub_details_search.asp?ID=6282