Community science monitoring of mercury in NH and VT aquatic ecosystems using dragonfly larvae as biosentinels PI: Dr. Celia Chen Co-PIs: Dr. Sarah Nelson, Dr. Kate Buckman

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Abstract

This project expanded a concurrent Dartmouth-led community science collection of dragonfly larvae for mercury biomonitoring into the White and Green Mountain National Forests, and continued collections at locations that were part of the program for the previous 10 years. This effort provided spatial mercury data for NH and VT, states that are susceptible to hotspots of mercury bioaccumulation but lack consistent long-term monitoring. The utilization of community science efforts provided benefits of increased investment in and knowledge of local ecosystems. Most importantly, the biomonitoring provided baseline and temporal data to enhance understanding of mercury fate in NH and VT forested ecosystems.

Rationale

Mercury (Hg) pollution is a persistent and prevalent threat to environmental health across the globe. In aquatic systems, inputs of inorganic Hg can transform into the more toxic and bioavailable organic form, methylmercury (MeHg). MeHg biomagnifies in aquatic food webs and can be transferred to terrestrial food webs. Humans and wildlife alike can suffer detrimental neurologic, cardiovascular, and immune effects as a result of exposure to MeHg. Mercury is of concern in northern New England due to relatively enhanced atmospheric inputs from long-range transport and legacy point-source pollution. Moreover, the forested rural landscapes in NH and VT may enhance both transformation of inorganic Hg to MeHg and subsequent uptake into aquatic food webs relative to those in more developed areas[1]. Thus, these seemingly pristine ecosystems are vulnerable to Hg pollution, and host numerous MeHg hotspots[2, 3]. While there have been multiple Hg sampling efforts in NH and VT including studies examining Hg bioaccumulation in varied aquatic ecosystems (e.g.[2, 4, 5]), fish sampling by state agencies, and a former atmospheric Hg long-term monitoring station on Mt. Mansfield, to our knowledge there are no current sustained efforts to monitor Hg in biota in the region beyond state-led opportunistic fish sampling.

For the past thirteen years Dartmouth College has led a high school community science project utilizing dragonfly larvae (nymphs) to examine Hg bioaccumulation in water bodies near participating schools in NH and VT. This effort was adapted from a Schoodic Institute-University of Maine inquiry-based curriculum designed by Dr. Sarah Nelson which subsequently evolved into the National Park Service Dragonfly Mercury Project (NPS DMP) focused on understanding Hg risks in US national parks using dragonfly nymphs as biosentinels. Community science, also called citizen science, is a useful educational, monitoring, and research tool[6]. The contributions of community science to ecological monitoring are extensive: for example, citizen scientists collected over half of the observations and a majority of years' worth of water quality data in seven states[7], and over 4,500 citizen scientists participated in the NPS DMP through 2019,

producing the most extensive dataset for Hg in biota of which we know[8]. However, sampling in the NPS DMP has been limited to national parks and thus does not represent many prevalent ecosystem types across the Northeast, including those with current or past forest harvests, point-source pollution, and industrialization, all of which are represented in the past Dartmouth nymph sampling efforts.

In parallel with the NPS DMP, Dartmouth has continued to focus on NH and VT high schools using the dragonfly project as a tool to increase knowledge of Hg in local ecosystems, engage students in authentic science, and promote data literacy within the participating classrooms. Community engagement in projects such as these increases personal investment in the outcomes and enhances connections to the community and environment[9]. By design, the project connected participating communities, the AMC, and the NPS DMP to broaden the impact beyond a single sampling event. Despite its initial implementation as a community science educational program and not a biomonitoring project, the Dartmouth program has collected over 700 individual nymph Hg concentrations from nine water bodies in VT and multiple sites within seven aquatic systems in NH since 2010 prior to this project. These sites ranged from undeveloped forested areas, to relatively urban streams, to a river directly impacted by a Hg Superfund site which is near the White Mountain National Forest (WMNF). The ability to compare nymph tissue concentrations across a range of environments is a strength of the project and the data collected to date are a valuable time series of data points to add to our ability to monitor Hg in these two states. These student-collected data were shared with the NPS DMP through Dartmouth's academic partnership and used in published research to establish dragonfly nymph concentrations as predictors of water body Hg impairment and risks posed by fish concentrations to human and wildlife health[8].

This Forest Ecosystem Monitoring Cooperative (FEMC) project grew our school-based collection efforts throughout NH and VT, and expanded community science Hg monitoring efforts into both the WMNF and the Green Mountain National Forest at sites of interest to the US Forest Service (USFS) and Appalachian Mountain Club (AMC) in order to establish baseline data for monitoring in these forested ecosystems, determine air and water resource quality, and assist in management decisions. This project supported FEMC goals of conducting long-term monitoring of forest health by utilizing the past archive and proposed expansion of nymph Hg data in NH and VT to assess temporal trends and spatial patterns that may indicate impaired water quality or increased risk for Hg bioaccumulation. It complements past FEMC funded projects assessing Hg bioaccumulation in montane forests in northern New England and assessing Hg concentrations in amphibians.

Approach

This project used methodology that has been implemented over the past 13 years of the Dartmouth DMP. We collected 10-20 nymphs per site across 16 sites. This included sites previously sampled with high schools and added at least four sites within the WMNF and GMNF. Field collections occurred in September and early October and followed a similar protocol to that used by the NPS DMP[10]. Additions to the NPS DMP protocol included ancillary water quality measurements and targeted site descriptions prior to the nymph collections. Collectors used LaMotte Water TesTab® kits to perform colorimetric assays of pH, nitrate, ammonia, phosphate, and dissolved oxygen. Qualitative descriptions of water clarity, substrate

composition, surrounding landscape and vegetation, and water body location and type were all recorded on a provided sample sheet. Nymphs were individually bagged using "Clean Hands, Dirty Hands", length measured, and taxonomic family identified to the best of the collector's ability prior to freezing.

Before shipping frozen samples to Dartmouth, collectors were required to enter their site and nymph data into Anecdata.org, a freely accessible online citizen science platform maintained by the Mt. Desert Island Biological Lab. This process generates a unique identifier for each nymph to be analyzed, linking it to both the collection site description and the subsequent Hg concentration data. Samples were shipped overnight to the Chen Lab at Dartmouth, where they are processed for analysis in a trace metal clean room. Each nymph family ID was verified, the sample rinsed with 18 megaohm ultra-pure water, weighed for wet weight, freeze-dried (Labconco Freezone 4.0), and weighed for dry weight. Dried samples were analyzed at Dartmouth for total Hg concentration using a Direct Mercury Analyzer (Milestone DMA-80) with standard reference materials (NRC DORM-4 and TORT-3) utilized for quality control. Prior to analysis, an interlaboratory calibration was performed to ensure the Dartmouth DMA met USGS's quality assurance/quality control standards. Additionally, a subset of the largest samples were identified and sent to the USGS national laboratory used for NPS DMP analysis to confirm inter-lab analysis compatibility. Resulting data were uploaded to Anecdata where project participants could download the entire data set from 2010 onwards or select portions as they chose. The data have also been shared with partners at the USFS and NPS DMP.

Activities

During the 2021 field season we successfully sampled dragonfly larvae for total mercury analysis from sites across NH and VT both with and without assistance from school groups and community members. Science classes from five different schools attempted dragonfly larvae sampling at nine locations in six different water bodies. Students were able to collect larvae from all but one of their sites. We hosted successful collection events at two additional sites (not within National Forests) with the participation of community volunteers. Within the Green Mountain National Forest, we visited five different waterbodies of interest to our Forest Service partners in order to assess suitability for larval collection. Multiple sites did not have suitable habitat for dragonfly larvae, or the water level was too high to access. We successfully sampled one site within the Green Mountain National Forest. We conducted sampling at two additional sites in White Mountain National Forest through funding and participation from the Appalachian Mountain Club. Two sampling days with a Youth Conservation Corps crew working with White Mountain National Forest and interns from AMC resulted in two sample sets.

During the 2022 field season we again successfully sampled dragonfly larvae for total mercury analysis from sites across New Hampshire and Vermont. As in the previous year, science classes from five different high schools attempted dragonfly larvae sampling at seven locations in six different water bodies. Students were able to collect larvae from all but one of their sites. We hosted another successful collection event at an additional site (not within National Forests) with the participation of community volunteers. With Dartmouth students, and interns from the National Park Service, we further successfully sampled two sites within the Green Mountain

National Forest, and two sites at National Historic Parks. In partnership with AMC, the US Forest Service, and students from Plymouth State University, two sites in the White Mountain National Forest were also successfully sampled.

Accomplishments

Between students and community members we were able to engage over 200 community scientists in dragonfly larvae collections in 2021. We also presented the goals and preliminary results (at the time) of our 2021 sampling efforts at the FEMC conference in December 2021. In 2022, we were able to engage over 150 community scientists in dragonfly larvae collections, and successfully collected over 170 larvae across thirteen sites.

Data Management

As noted above, all site data gathered by community scientists was entered into the project database on Anecdata.org prior to sample submission. This project has a unique URL (https://anecdata.org/projects/view/791) and is searchable through the broader Anecdata portal. Mercury concentration data was matched with each sample on this platform once analyzed and passing quality control checks. Anecdata.org as a whole is accessible to anyone and is maintained by the Mt. Desert Island Biological Laboratory, however Christine Gardiner is the current Dartmouth dragonfly mercury project administrator and oversees data entry and metadata notes. Anyone who asks to join the project through Anecdata will have unrestricted access to the collected mercury and ancillary data. Data is also being shared with USFS, NPS, and USGS partners for inclusion in their agency databases.

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