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BIODIVERSITY RESEARCH INSTITUTE:

Songbird Research from Sphagnum Bog to Alpine Summit

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Population declines of migratory songbird species throughout their range are well documented and have been associated with a complex variety of stressors, including, but not limited to: environmental pollution; habitat loss, conversion, and fragmentation; energy development and generation; and climate change. To better understand these and other potential impacts on songbird populations, biologists from Biodiversity Research Institute (BRI) collect scientific data to address these stressors through studies that target mercury exposure and effects assessments, determine movement and distribution patterns, and integrate findings with conservation and management strategies. Through an emphasis on neotropical migrant species, BRI has conducted research at various locations within the United States, particularly the northeastern U.S., as well as study sites in Central and South America, the Caribbean Islands, and China. With an overarching approach centered on the assessment of environmental stressors on wildlife health, BRI songbird studies are designed to advance scientific knowledge and to contribute valuable data to inform policy, assist in management decisions, and establish conservation initiatives for local, regional, and global songbird populations.

MERCURY CONTAMINATION & WILDLIFE HEALTH

Mercury (Hg) contamination in aquatic and terrestrial ecosystems is increasingly recognized as a widespread issue that poses considerable reproductive, behavioral, and physiological risks to wildlife populations. As a global pollutant that enters ecosystems from both local and distant emission sources, such as coal-fired power plants, mercury is released into the atmosphere and deposited upon the landscape in an inorganic, biologically unavailable state. Micro-organisms, primarily residing within the soils, then convert inorganic mercury to an organic form, methylmercury (MeHg), which is highly toxic and which has the ability to be transferred through food webs and biomagnify within species positioned at high trophic levels, such as songbirds. Designated by the U.S. Environmental Protection Agency as a Persistent, Bioaccumulative, and Toxic (PBT) pollutant, methylmercury has become a globally-recognized conservation concern due to its ability to biomagnify and bioaccumulate within the environment and cause adverse health effects to wildlife and people.

To date, most studies about mercury in wildlife have focused on top-predator, fish-eating birds, such as the Common Loon, because methylmercury biomagnifies and bioaccumulates to high levels within their tissues (see Schoch this issue). However, research has demonstrated that songbirds foraging on prey with an aquatic food web base can also bioaccumulate methylmercury at concentrations similar to or greater than fish-eating birds. Songbirds inhabiting upland forests not associated with aquatic environments have also been found to exhibit elevated body burdens, particularly high-elevation boreal species (see Glennon and Seewagen in this issue). Additionally, numerous toxicology studies have documented that songbirds are sensitive and susceptible to the multi-systemic effects of methylmercury, including: endocrine and immune system disruption, skewed sex ratios, altered songs, reproductive impairment, asymmetrical feather growth, reduced body condition, and decreased survival rates. Therefore, BRI has developed a number of regional studies to better quantify baseline exposure levels and to assess the impacts of atmospheric mercury deposition within a wide range of songbird species and habitat types. By utilizing songbirds as indicators of ecosystem mercury contamination, this research will improve our abilities to more accurately define and monitor levels of methylmercury bioavailability across the landscape, which is crucial to evaluate the risk this PBT poses to regional songbird communities.

In the northeastern United States, a region widely impacted by atmospheric mercury deposition, BRI biologists have conducted intensive field studies focusing on the exposure levels and adverse health effects of methylmercury on resident and migratory songbird populations. The North Woods provide essential habitat for a variety of songbird species of conservation concern from wetland-obligate, Rusty Blackbirds (*Euphagus carolinus*; see McNulty et al. this issue), to high-elevation specialist, Bicknell's Thrush (*Catharus bicknelli*). Unfortunately, environmental conditions in the Northeast, such as elevated mercury

deposition rates, thin soils, abundant wetlands, and highly acidic habitats, which are pervasive in the Adirondack Park, create a combination of factors ideal for efficiently converting atmospherically deposited mercury into the toxic and bioavailable form, methylmercury. Consequently, research has designated portions of the Adirondack Park as a "biological mercury hotspot," which is defined as an area that is subject to high mercury deposition rates and possesses landscape characteristics that promote the uptake of methylmercury into aquatic and terrestrial food webs. Overall, the relatively intact ecosystems of the Adirondack Park serve a significant role as a vital and important area for the conservation of boreal songbird species. BRI research conducted at study sites in the Adirondack Park is designed to further understand the complexities and dynamics associated with the biomagnification and bioaccumulation of methylmercury through food webs as a means to protect its wildlife species from the detrimental impacts of mercury contamination.

BRI PROJECT METHODOLOGIES AND RESEARCH RESULTS

To assess methylmercury concentrations in songbird communities at the landscape level, BRI field biologists use standard methodologies for collecting data and samples at each study site. Sampling generally occurs during the months of June and July, which correlates with periods of peak breeding activity for Northeast songbird species. Insectivorous songbirds are captured using non-lethal, mist-netting techniques, which includes decoys and playback calls to encourage a territorial response. During processing, each bird is banded, weighed, morphological measurements are recorded, blood and feather samples are collected for mercury and isotope analysis, and individuals are released back into their territories. Each songbird is fitted with an aluminum U.S. Geological Survey (USGS) leg band that contains a unique number, and these records are submitted to the USGS Patuxent Wildlife Research Center for use in the North American Bird Banding Program. Songbirds are banded during processing as a means to identify individual birds during future on-site captures or if found at another location during its life history. If captured again, the band serves as an individual record of its history and may yield information related to life span, dispersal and migratory patterns, and wintering or breeding site fidelity. To determine individual mercury concentrations, songbird blood samples are collected using sterile collection techniques and are reflective of recent dietary uptake of methylmercury, thereby representing available methylmercury levels in a particular area, such as a breeding territory. In contrast, feather samples represent long-term mercury exposure and are indicative of methylmercury body burdens over the bird's lifetime, as well as dietary uptake during periods of feather molt.

To date, BRI biologists have captured, sampled, and analyzed data from over 11,000 songbirds across a wide variety of habitats and species in 37 states. In the Adirondack Park, 948 songbirds from 41 species have been captured from 2006-2015. In total, 916 blood and feather samples have been analyzed to examine mercury concentrations among songbirds that represent many habitat types on a mix of public and private Adirondack lands. Overall

findings have indicated that wetland songbirds are at the greatest risk to the impacts of mercury contamination, particularly those species that primarily consume insects during the breeding season, which include Adirondack Park songbirds such as: Olive-sided Flycatcher (*Contopus cooperi*), Carolina and Marsh Wrens (*Thryothorus ludovicianus and Cistothorus palustris*), Lincoln's Sparrow (*Melospiza lincolnii*), Northern and Louisiana Waterthrushes (*Parkesia noveboracensis and P. motacilla*), Palm and Canada Warblers (*Setophaga palmarum* and *Cardellina canadensis*), and Rusty Blackbirds. The BRI database provides critical information relating to regional species sensitivity, in addition to geographic locations and specific habitats of concern, and provides a foundation to direct future research initiatives.

REGIONAL SONGBIRD PROJECTS

Beginning in 1999, BRI biologists initiated research at study sites across the northeastern United States to identify at-risk songbird species, classify sensitive habitat types, and assess the impacts of mercury deposition within a variety of ecosystems. Based on the results of this large-scale research effort and the clear need to further characterize the impacts of mercury contamination on wildlife populations, BRI and The Nature Conservancy began a five-year project in 2013, sponsored by the New York State Energy and Research Development Authority (NYSERDA), to monitor mercury concentrations in New York State songbird communities. To evaluate how environmental mercury loads are changing over time in New York, songbirds are sampled on an annual basis at established long-term research sites within the Adirondack Park, Catskill Mountains, and Long Island. Within each of these areas, songbirds are targeted in a number of diverse habitats, ranging from forested cover types to highly-acidic sphagnum bogs, to model and project the effects of habitat type on methylmercury availability and uptake by songbirds inhabiting those locations. Data from these annual monitoring sites are supplemented with survey efforts from other regions in New York State that have been prioritized as sensitive sites or regions with limited songbird mercury data, as a means to fill in existing information gaps and aid in the identification of additional biological mercury hotspots. The overall goals of this long-term project are to further quantify and monitor songbird mercury concentrations across a diverse range of habitat types, and effectively assess the impacts of recent changes in mercury emissions policies on wildlife and ecological health across New York State (e.g., the newly instituted Mercury and Air Toxics Standards Rule) (USEPA, 2011).

Utilizing mercury and stable isotope technology, BRI initiated a two-year study in 2015, funded through a research grant by the Northeastern States Research Cooperative (NSRC), to identify the primary source types of mercury being deposited in Adirondack ecosystems. This research builds upon a similar study, led by BRI in 2014, which examined mercury isotope signatures in songbird samples from tidal marsh and pine barren habitats on Long Island and sphagnum bogs and upland forests in the Adirondack Park, in order to identify and differentiate atmospheric mercury source types within each region. To expand upon this initial study and further investigate the sources of atmospheric mercury deposition

within Adirondack food webs, BRI biologists began an intensive survey in 2015 at three long-term study sites by collecting samples, which include: precipitation, soils, invertebrates (prey items), and songbird blood and feathers. An overall synthesis of these research efforts will allow scientists to advance understanding of the major sources of regional atmospheric mercury in the Adirondack Park and contribute a greater working knowledge for policy initiatives designed to control and reduce mercury emissions.

As part of a collaboration between Syracuse University and BRI, and funded through a NYSERDA Environmental Monitoring, Evaluation, and Protection (EMEP) Graduate Fellowship and NSRC Graduate Research Grant, a dissertation project was conducted to identify pathways of methylmercury bioaccumulation in terrestrial habitats at several sphagnum bog, hardwood forest, and high-elevation boreal systems in the Adirondack Park. This project was designed to build upon the results of regional songbird mercury research established by BRI (Evers and Lambert, 2005) and Chris Rimmer (Rimmer et al., 2005, 2010), which identified sphagnum bog and montane forests as sensitive habitats where elevated songbird blood mercury concentrations had been documented. All study sites were intensively sampled multiple times during the breeding season, and samples were representative of the various compartments within the associated food webs, including: soils, leaf litter, fresh vegetation, forest-floor invertebrates, and songbird blood and feathers. Collected samples were analyzed for methylmercury, total mercury and stable isotope signatures to better define methylmercury biomagnification and trophic connectivity among songbirds and their prey items within Adirondack Park food webs. These data will be utilized to complement ongoing research projects and provide much-needed information on the connections between mercury deposition and terrestrial ecosystems in the Adirondack Park.

In an effort to link year-round mercury exposure for neotropical songbird species between their Northeast breeding grounds and tropical wintering areas, BRI has established the Neotropical Connections Mercury Network. This initiative examines songbird mercury concentrations at multiple wintering areas to better define the impacts of mercury deposition in tropical ecosystems and lifetime methylmercury exposure for some species. Such investigations are especially critical now because of the dramatic increase in artisanal small-scale gold mining in Latin America, an activity which often uses high amounts of mercury to amalgamate gold particles. Since 2007, BRI has banded 938 songbirds at 34 study sites within six Latin American countries (Belize, Costa Rica, Mexico, Nicaragua, Panama, and Puerto Rico). Of this total, 867 blood and feather samples have been analyzed for mercury concentrations from 162 tropical species. For long-distance migrant songbirds, like the Northern Waterthrush, which winter and breed within wetland habitats that often have elevated methylmercury production, elevated mercury exposure is occurring year-round. Therefore, data from this BRI project will aid assessment of the physiological impacts of mercury on long-distance migrants that overwinter in the tropics. It is anticipated that data will also be collected to link current research endeavors with long-term banding stations

(e.g., Monitoreo de Sobrevivencia Invernal/Monitoring Overwintering Survival [MoSI] networks), other avian conservation efforts (e.g., Partners in Flight Program with Cornell Lab of Ornithology), and protected reserves (e.g., Runaway Creek Nature Reserve in Belize). Ultimately, this information will be developed into a regional map of biological mercury hotspots that can be used by scientists and policy makers to significantly improve an understanding of the ecological connections between mercury deposition and wildlife health in tropical ecosystems. Such information will be critical for monitoring the changes of environmental mercury loads after the new global mercury treaty, the Minamata Convention, goes into effect (i.e., projected around mid-2016)(UNEP, 2015).

FUTURE DIRECTIONS

Global mercury emissions have increased dramatically since the onset of the industrial age, a trend that has been observed using museum specimens of seabirds. However, the trend in mercury exposure for terrestrial birds has been largely unexplored, particularly within wetland breeding songbird species that are experiencing population declines and that exhibit high mercury concentrations in the Northeast. Beginning in the fall of 2015, BRI will begin working with the Harvard Museum of Natural History and the Harvard School of Public Health in Boston, and the American Museum of Natural History in New York City to analyze archived museum songbird specimens for historical patterns and trends in mercury exposure. Several wetland songbirds have been selected and include species that breed in the Adirondack Park, such as: Olive-sided Flycatcher, Palm Warbler, and Rusty Blackbird. Data from this study will track changes in songbird methylmercury body burdens prior to industrialization (i.e., the late 1800s) for comparison with current feather concentrations from wetland breeding birds in New York State.

As Northeast bogs are generally considered to be hotspots for mercury methylation and subsequent locations for high-mercury songbirds, BRI began a collaborative effort with the Smithsonian Institute in 2015, at locations in Maine and New Hampshire, to determine the extent to which mercury may be playing a role in the widespread decline of the Olive-sided Flycatcher. Currently listed by the NYS Department of Environmental Conservation as a High-Priority Species of Greatest Conservation Need, Olive-sided Flycatcher population levels have declined in the Northeast at alarming rates. Limited data exist on the mercury body burden of this species, and the sampling of adults for blood and feathers will allow researchers to infer information about methylmercury uptake on their breeding and wintering grounds. Geolocators, lightweight tracking devices used to record songbird movement, will also be non-invasively attached to adults to document year-round habitat utilization and migratory patterns. This work is affiliated with research being conducted across North America by the Olive-sided Flycatcher Working Group and will begin in the Adirondacks during the summer of 2016.

In summary, songbirds are now recognized as critical indicators of mercury in terrestrial ecosystems due to the ability of insectivore food webs to biomagnify methylmercury to levels that can adversely impact physiological health, behavior, reproductive success, and survival rates across a wide variety of species and habitats. Research projects conducted by the Songbird Program of Biodiversity Research Institute contribute scientific data that are critical to improve understanding of the complex and dynamic connections among methylmercury availability, environmental factors, and the ecology of songbird species in an effort to inform policy initiatives and conservation efforts that aim to reduce the impacts of mercury contamination on wildlife health.

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