Developing an exposure profile for mercury in breeding birds of New York and Pennsylvania, 2005

(Report BRI 2006-11)

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Executive Summary

Atmospheric deposition of sulfur, nitrogen and mercury (Hg) has potential widespread and profound ramifications on the health of forest ecosystems and their inhabitants. It is critical that the impact of these pollutants and the ecological response be determined. Here we define a template to demonstrate the potential landscape-level effects of acidification on the transfer and fate of methlymercury (MeHg) in songbirds of northeastern North American. In time, these same effects will be linked with pools of available calcium (Ca). For this pilot effort, we had scientific, conservation, and policy oriented goals. Scientifically, there are new and compelling reasons for studying MeHg availability in northern forests, particularly in areas at high elevation or having acidic conditions. For conservation purposes, the long-term decline of some neotropical migrant songbirds may be linked to environmental stressors within their breeding range. It is plausible that elevated MeHg levels and depleted available Ca levels, particularly within acidic environments, are negatively contributing to the viability of their populations. Lastly, this line of investigation contributes to the policy arena in two ways: (1) documenting a potential spatial gradient of Hg and Ca availability across an area that has major Hg emission sources to the West (i.e., the Ohio River Valley) and lower emissions in the East (i.e., most of New York and New England) and (2) linking to a forthcoming national Hg monitoring plan.

To understand Hg and Ca pathways, we sampled three compartments: organic soils, Ca-rich and likely high Hg invertebrates, and breeding forest songbirds (e.g., thrushes, vireos, and warblers). Only songbird blood Hg levels are presented here. We designated 11 sampling stations across New York and Pennsylvania. In 2005, we captured and sampled 178 individuals of 26 species including 93 thrushes.

Although all thrush species were of interest because of our intention to normalize thrush blood Hg levels across species, we were able to sample 35 Wood Thrushes from seven sites (our target indicator species for low to moderate elevations) and 11 Bicknell's Thrushes from one site (our target indicator species for high elevations). Blood Hg levels in thrushes varied by geographic area, elevation, and likely trophic level. Based on very preliminary results, thrush Hg levels converted into Wood Thrush blood Hg tended to be higher in the Catskill Mountains. High elevation thrush blood Hg levels tended to be higher than thrushes in low elevations from the same mountain slope. Other songbirds with elevated blood Hg levels were upper canopy foragers (e.g., Red-eyed Vireo) and species regularly associated with riparian areas (e.g., Louisiana Waterthrush). Larger songbirds indicate risk to MeHg availability is greater than smaller songbirds from the same foraging guild. Although blood Hg levels in forest songbirds are more elevated than traditionally considered, based on available science, levels remain below likely negative reproductive impacts. What remains to be investigated is the influence of moderate Hg levels on songbird populations in areas that are deficient in Ca.

Wood Thrushes remain our primary bird indicator because (1) they had blood Hg levels higher than associated thrushes and most other songbirds, (2) preliminary evidence indicates strong relationships with soil pH and available Ca levels and (3) they have shown major distribution and density declines throughout New York and the Appalachian Mountains and are now nearly absent from the Adirondack Mountains.

We expect three major outcomes from this proposed study: (1) a better understanding of the dynamic relationship within terrestrial, acid-impacted ecosystems for Hg and Ca, (2) a spatial gradient for linking major Hg emission sources in the Ohio River Valley with rates of MeHg availability in New York and New England and (3) added value to a forthcoming national Hg

monitoring efforts and identification of biological hotspots. Should scientific evidence from this effort implicate major Hg emission sources with associated biological Hg hotspots, the primary premise behind the U.S. Environmental Protection Agency's 'Cap-and-Trade" rule will be challenged and the current more rigorous Hg emission rule proposed by New York will be further supported.

1.0 Introduction

Air pollution has been linked to adverse effects in wildlife, including impairing reproductive success in songbirds (Saldiva and Bohm 1998, Llacuna et al. 1993, Janssens et al. 2003). Specifically, wet atmospheric deposition of acidifying emissions (i.e., nitrogen and sulfur oxides), has been linked to declines of bird species in Europe (Graveland 1990, 1998) and, recently, the United States (Hames et al. 2002). This phenomenon may be the result of depletion of soil pools of extractable calcium (Ca) by leaching (Driscoll et al. 2001), leading to decreases in the abundance of Ca-rich invertebrate prey used by breeding female birds as necessary supplemental sources of Ca during egg production and when feeding nestlings (Graveland 1996, Graveland and Drent 1997). The study by Hames et al. (2002) is particularly relevant and compelling for follow-up efforts within our study; based on logistic regression analysis that accounted for several habitat-related variables, they found a particularly strong negative relationship between acid rain and the predicted probability of Wood Thrush breeding evidence. Findings also indicate further insult to breeding populations in areas that are at high elevation, with low pH soils, and exhibiting fragmentation of forest habitat.

Acid rain and related lowering of soil pH not only reduces calcium availability it adds sulfates. The addition of sulfates is known to increase methlymercury production in wetlands. In Minnesota, the estimated MeHg flux from an experimentally dosed wetland increased 2.4x (Jeremiason et al. 2006). Therefore, Hg increases in the environment are driven not only by the amount of Hg deposited, but by sulfate as well.

The negative effects of Hg are well documented for aquatic ecosystems – through the biomagnification of biologically-active methyl mercury (MeHg) (Evers et al. 2003, 2005). Although studies of Hg cycling in terrestrial ecosystems are limited, uplands soils have considerable capacity to store large quantities of atmospherically deposited Hg, particularly in the forest floor (Mason et al. 1994). Recently, new and compelling evidence connects MeHg availability in upland forests with acidic soils; regressions based on spatial models of atmospheric Hg deposition across terrestrial ecosystems in the Northeast predicted 50% of the variation in Bicknell's Thrush blood Hg levels (Rimmer et al. 2005). For the first time, scientists in the Northeast are realizing that the problem of MeHg availability in the environment is not restricted to aquatic habitats.

Other recent work suggests that accumulation involves absorption of gaseous Hg stomatally, incorporation by foliar tissue, with subsequent release of Hg in litterfall (Ericksen et al. 2003). While litterfall may represent the bulk of Hg input to forested ecosystems, the wash-off of dry-deposited Hg species in throughfall, direct deposition in precipitation, and uptake of dissolved Hg by roots with translocation to foliar tissue may also play roles (Rea et al. 2002). Total Hg inputs to eastern forests may largely be incorporated in the leaf-litter and forest floor, where it is available to invertebrates, such as gastropods (snails and slugs), isopods (woodlice), myriapods (millipedes), and to predators, such as centipedes (myriapods) and spiders (arachnids). The abundances of many of the Ca-rich prey species decline with declines in soil pH. This pattern can have important ramifications on the health of songbird populations, particularly on females laying eggs and on the growth of hatchlings.

Based on these and other studies, the complex and potentially synergistic relationship of sulfur-driven acidification, associated soil Ca depletion, and MeHg enhancement may lead to potentially important anthropogenic, landscape-level impacts to forest songbirds, such as thrushes. The incorporation of Hg from the leaf litter by invertebrates feeding on leaf tissues and by predaceous invertebrate species (centipedes and spiders) feeding on these detritivores, leads to potentially elevated Hg levels in songbird species. Thus, breeding bird populations in eastern forests, in particular thrushes and songbirds found in acidified habitats such as subalpine and bog habitats, may be at greatest risk. The potential largescale loss of songbirds would likely have profound ramifications on the functional abilities of forests as sustainable ecosystems – not only making them more prone to diseases and insect infestations, but creating a notable, empty silence. Perhaps Rachel Carson best described the ramifications of such happenings when she said, "what we do to the animals we do to ourselves" (Carson 2002).

2.0 Project Goals and Supporting Objectives:

For this project we have scientific, conservation, and policy oriented goals. **Those met in 2005 are in bold**. Scientifically, there are new and compelling reasons for studying MeHg availability in northern forests, particularly in areas at high elevation or impacted by acidic deposition. For conservation purposes, the long-term decline of some neotropical migrant songbirds may be linked to environmental stressors within their breeding range and it is plausible that elevated MeHg levels and soil available Ca depletion, particularly within acid-impacted environments, are negatively contributing to the viability of their populations. Lastly, this line of investigation contributes to the policy arena by: (1) documenting a potential spatial gradient across an area that has major Hg emission sources to the West (i.e., the Ohio River Valley) and lower values in the East (i.e., most of New York and New England) and (2) links to a forthcoming national Hg monitoring plan. Supporting objectives for 2005 and the future are:

1. **Assess the health of environments that may be especially vulnerable to acid rain and two resulting factors (a) increased MeHg production and availability** and (b) depleted available soil calcium levels that additionally may act synergistically;

2. **Establish a network of sampling stations across New York and eventually other areas of the northern forest and Appalachian Mountains to spatially document and monitor MeHg** and Ca availability gradients;

3. Link efforts with the national Hg monitoring plan.

3.0 Study area

A total of eleven sampling locations were targeted for songbirds with an emphasis on thrush species in New York and Pennsylvania (Figure 1). In New York, we sampled five sites in the Catskill Mountains, which include, Belleayre, Devil's Tombstone, Hunter Mountain-west, Millbrook, and Plateau Mountain. In addition, we sampled thrushes and other songbirds in

Allegany State Park, Black Rock Forest, Brookfield Forest, Institute of Ecosystem Studies' grounds, Shawangunk Mountains, and Tug Hill in New York and Tott's Gap in Pennsylvania.

In the Catskill Mountains, five sampling locations were targeted. Four were at moderate elevations and included (1) Devil's Tombstone, (2) western side of Hunter Mountain, (3) Millbrook and (4) Bellayre, while one was at a high elevation on Plateau Mountain.

In southeastern New York, three sampling locations were targeted: (1) Black Rock Forest, (2) Shawangunk Mountains, and (3) the grounds at the Institute of Ecosystem Studies (IES). IES is located in continuous eastern deciduous forest in Dutchess County, New York, contains large Veery and Wood Thrush breeding populations (Hermit Thrushes are also present) and is the location of on-going studies since 1998. Pilot data collection in 2004 yielded blood Hg levels in 22 thrushes (10 Wood Thrushes, 12 Veeries) across mesic and xeric sites. We found significant differences between species (Wood Thrush > Veery, $p = 0.016$) and near significant differences in soil types (xeric > mesic, $p = 0.08$) despite low sample sizes between habitats. Exchangeable Ca, measured in the organic soil layer also differed widely (4.06 - 24.16 cmolc/kg) but did not differ significantly between habitats ($p > 0.40$). Further analysis from IES is discussed later in this report.

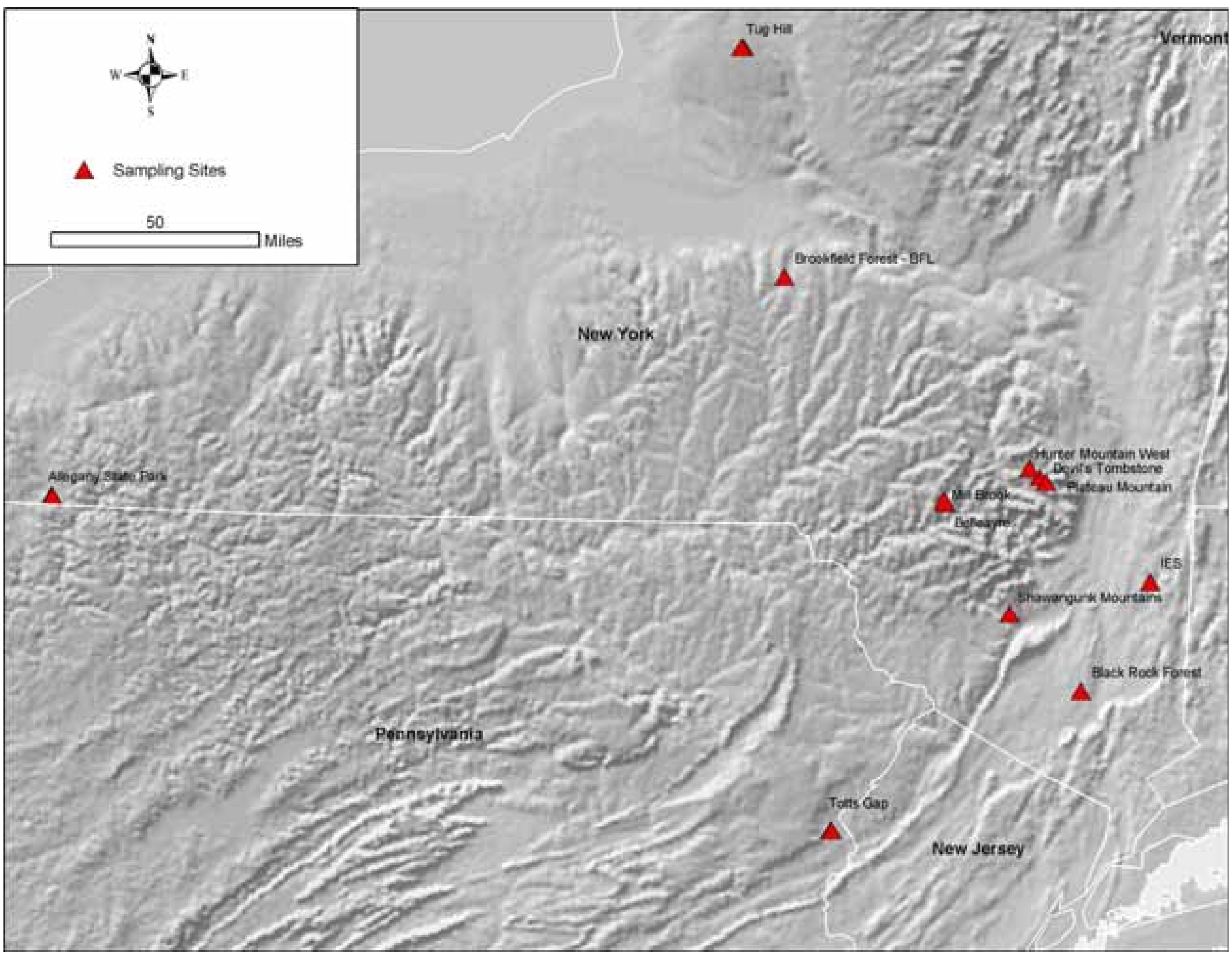

Figure 1. Distribution of sampling locations in New York and Pennsylvania, 2005.

In central New York, regular, co-occurring breeding populations of Wood Thrushes and either Hermit Thrushes or Veeries are found at most sites. Tug Hill has a low to moderate elevation (180 m -290 m) with moderate Hg deposition (*41*) and high acid ion deposition (*3*) (mean soil pH of 3.9 and mean available Ca of 560 mg/Kg, n=10). Pilot sampling in 2004 found a mean blood Hg level for Hermit Thrush of 0.09 +/- 0.02 ug/g (n=5). The Brookfield State Forest has moderate elevation (480 m - 550 m) with moderate Hg deposition and moderate acid ion deposition (mean soil pH of 4.2 and mean available Ca of 737 mg/Kg, n=10).

The Allegany Plateau in Allegany State Park in New York and Pennsylvania were new sites with little existing biochemical data available.

4.0 Methods

4.1 Species emphasis

We emphasized capture and sampling of the Wood Thrush at low elevation sites and Bicknell's Thrush at high elevation sites. Other songbirds captured were also banded and sampled.

4.2 Bird Capture and Sample Collection

We captured thrushes and other songbirds using mist nets in concert with decoys, playback of conspecific territorial vocalization, and playback of a flock of small birds mobbing a small owl (Gunn et al 2000). Both playbacks elicit a strong response from territorial breeding birds, allowing reliable captures. Sampling efforts were timed for June and July to allow time for depuration of Hg body burdens that could reflect winter and/or migratory MeHg uptake (as indicated in Bicknell's Thrush; Rimmer et al. 2005). We used 8-10, 12m mist nets with a 36mm mesh size designed to harmlessly catch songbirds. We used playback recordings and decoys to attract target birds to the mist nets. Nets were placed on 6 m metal poles. The nets were checked every 20-40 minutes. Captured birds were removed and placed in cotton holding bags until processing. All birds were released unharmed 15-45 minutes after capture. Birds were captured during both dawn and dusk periods.

All birds were measured using standard wing, tail, tarsi, bill, and mass measurements, and banded with USFWS bands. We also collected information on age, sex, and body condition,

which is indicated by the external thickness and extent of fat. For all birds we used 26 gauge disposable needles to puncture a cutaneous ulnar vein in the wing to collect a small blood sample. We also collected second secondary feathers from adults and selected juveniles for Hg analysis. Each blood sample was collected in a 75 uL capillary tube, which was then sealed on both ends with Crito-seal or Critocaps ® and placed in a labeled plastic 7 cc vacutainer. Generally, 2-4 capillary tubes half-filled with blood were taken. The feathers were placed in a labeled plastic bag. All samples were stored in a field cooler with ice, and samples were later transferred to a freezer/refrigerator (blood in the freezer, feathers in the refrigerator).

4.3 Non-bird Sample Collection

We also collected soil (0-2.5cm) and invertebrate samples from each location (Appendix I). Soil Ca and Hg levels will be determined, as well as invertebrate Hg levels, at a later time. Analysis of these samples were outside of the scope of this specific study.

4.4 Sample Analysis

Laboratory analysis was conducted by Texas A&M Trace Element Research Lab (TERL), College Station, Texas. Blood samples were analyzed for total mercury using direct mercury analyzer DMA 80 by Milestone Inc. Mercury concentrations are presented on a wet weight (ww) basis. Instead of analyzing methylmercury (MeHg) levels we focused on total Hg because it is less costly, and approximately 95% of total Hg in songbird blood is in MeHg form (Rimmer et al. 2005).

5.0 Results and discussion

The 2005 sampling effort focused on the wood thrush (*Hylocichla mustelina*). This neotropical migrant is experiencing significant negative population trends; postulated as being partly related to availability soil Ca deficiencies (Hames et al. 2002). Because the Bicknell's Thrush (*C. bicknelli*) is restricted to mountaintops where cloud and fog acidic and Hg deposition occur, in addition to increased precipitation due to orographic effects, this species serves as an indicator of the effects of high levels of both acidic and Hg deposition (Rimmer et al. 2005) and was therefore emphasized for high elevation areas. We also focused on more common species such as the Hermit Thrush (*Catharus guttatus*) and the Red-eyed Vireo (*Vireo olivaceus*). Their ubiquitous distribution provides a greater comparative ability over geographic areas.

Although we chose neotropical migrant thrush species and other songbirds that are of high priority to environmental trustees, such as Partners in Flight, many songbird populations are exhibiting negative population trends that apparently are not wholly linked with neotropical wintering areas. For example, the rusty blackbird (*Euphagus carolinus*) has experienced continental declines of over 95% since the 1970s (Greenberg et al. 2005). Because a related species, the red-winged blackbird (*Aegalius phoenicius*) has recently been shown to have mean blood Hg levels ~10x higher than associated songbirds and 3x higher than associated piscivores, wetland-associated blackbirds and other songbirds are of high conservation concern and will be emphasized in the future. How species react to air pollution within their breeding habitat may vary (Eeva et al. 1997); in some cases there can be toxicological impacts to the physiology, reproductive success or survival of individuals within the study population in other cases normal food supply and nutrient rates can be disrupted and ultimately reduce fitness and breeding success.

The following description of our findings illustrates our sampling efforts, blood Hg exposure for thrushes and other associated songbirds, ability to normalize thrush Hg levels for the Wood Thrush, a comparison with known Hg threshold levels in songbirds, and a description of the relationship between MeHg and Ca availability.

5.1 Sampling effort

We collected blood samples for Hg analysis from 178 birds, representing 26 species in eight families at 10 locations across New York and one location in Pennsylvania (Table 1). Mean blood Hg levels for adults ranged from 0.02 ug/g, ww (Indigo Bunting) to 0.17 ug/g, ww (Louisiana Waterthrush). Because this was an exploratory effort, sample sizes were generally low, except for thrush species, Ovenbird, and the Red-eyed Vireo.

Table 1. Species, number, age, Hg levels, and ancillary natural history and conservation information for 2005 sampling effort.

Species	n	Age	Mean ± SD	Range	Family	Partners In Flight Conservation Rank	Food Guild	Forage Habitat	Elevation
American Redstart	6	A	0.06 ± 0.02	0.02 - 0.09	Parulidae	8	Foliage	Upper Canopy	Low to Mid
American Robin	4	A	0.03 ± 0.01	0.03 - 0.04	Turdidae	5	Ground	Litterfall	Low
	2	J	0.03 ± 0.02	0.01 - 0.04					
Bicknell's Thrush	11	A	0.08 ± 0.03	0.05 - 0.14	Turdidae	18	Ground	Sub-canopy	High
Black-and-white Warbler	1	A	0.05		Parulidae	9	Bark		Low to Mid
Black-capped Chickadee	3	A	0.03 ± 0.02	0.01 - 0.04	Paridae	6	Bark		All
Black-throated Blue Warbler	2	A	0.05 ± 0.02	0.03 - 0.06	Parulidae	12	Foliage	Upper Canopy	Low to Mid
Black-throated Green Warbler	2	A	0.08 ± 0.04	0.05 - 0.11	Parulidae	11	Foliage	Upper Canopy	All
Blue-headed Vireo	2	A	0.11 ± 0.04	0.08 - 0.14	Vireonidae	8	Foliage	Upper Canopy	Mid to High
Common Yellowthroat	1	A	0.11		Parulidae	8	Foliage	Sub-canopy	Low
	1	J	0.06						
Dark-eyed Junco	1	A	0.03		Emberizidae	8	Ground	Litter	High
Eastern Towhee	1	A	0.08		Emberizidae	11	Ground	Litterfall	Low
Gray Catbird	1	A	0.06		Mimidae	9	Foliage	Sub-canopy	Low to Mid
Hermit Thrush	14	A	0.05 ± 0.02	0.01 - 0.09	Turdidae	6	Ground	Sub-canopy	Middle
	3	J	0.03 ± 0.01	0.02 - 0.04					
Hooded Warbler	1	A	0.03		Parulidae	13	Foliage	Sub-canopy	Low
Indigo Bunting	1	A	0.02		Cardinalidae	11	Foliage	Sub-canopy	Low
Louisiana Waterthrush	2	A	0.17 ± 0.01	0.16 - 0.18	Parulidae	13	Water		Low
	3	J	0.20 ± 0.04	0.17 - 0.24					
Magnolia Warbler	2	A	0.06 ± 0.00	0.06 - 0.06	Parulidae	8	Foliage	Upper Canopy	Mid to High
Ovenbird	12	A	0.07 ± 0.08	0.01 - 0.30	Parulidae	10	Ground	Litter	Low to Mid
	1	J	0.01						
Red-eyed Vireo	29	A	0.11 ± 0.06	0.04 - 0.29	Vireonidae	7	Foliage	Upper Canopy	Low to Mid
	5	J	0.06 ± 0.01	0.05 - 0.07					
Song Sparrow	1	A	0.13		Emberizidae	8	Water		Low to Mid
Swainson's Thrush	11	A	0.07 ± 0.02	0.03 - 0.10	Turdidae	10	Ground	Sub-canopy	Middle
Tufted Titmouse	1	A	0.06		Paridae	8	Bark		Low to Mid
	1	J	0.04						
Veery	9	A	0.03 ± 0.01	0.01 - 0.04	Turdidae	11	Ground	Sub-canopy	Low
	4	J	0.01 ± 0.01	0.00 - 0.03					
White-breasted Nuthatch	3	A	0.07 ± 0.01	0.07 - 0.08	Sittidae	6	Bark		All
Wood Thrush	29	A	0.07 ± 0.03	0.01 - 0.16	Turdidae	14	Ground	Litterfall	Low
	6	J	0.03 ± 0.02	0.01 - 0.08					
Yellow-rumped Warbler	2	A	0.07 ± 0.01	0.07 - 0.07	Parulidae	6	Foliage	Upper Canopy	Mid to High

* Partners in Flight Conservation Rank is based on Rich et al. (2004).
** Latin names for species are listed in Appendix IV.

5.2 Mercury exposure in thrush species

A total of 93 thrushes representing 46 individuals of the two target thrush species were captured and sampled. Because blood Hg levels in adults is regularly significantly higher than juveniles (Evers et al. 2005), sampling and analysis of adult individuals was targeted. A total of 79 adult thrushes (85%) were sampled. Although the Wood Thrush and Bicknell's Thrush were emphasized for sampling because of the relatively high conservation rankings by Partners in Flight (14 and 18, respectively), often other thrush species were captured and sampled with the intent to normalize all thrush blood Hg levels into a Wood Thrush blood Hg unit.

Wood Thrush: This neotropical migrant is well known for being impacted by habitat fragmentation and associated increases in nest predation and parasitism (Robinson et al. 1995, Trine 1998), including areas in New York (Driscoll and Donovan 2004). However, only recently have other threats, such as those related to air pollution, been identified. Hames et al. (2002) found a strong negative effect of acid rain and breeding Wood Thrushes. Acidification of forested landscapes and negative impacts on forest songbird breeding populations are known elsewhere as well, including areas in Europe (Graveland 1998).

Our 2005 capture effort resulted in 35 Wood Thrushes sampled for Hg analysis (29 adults and 6 juveniles) at seven sites. Blood Hg levels in adults had a mean of 0.07 +/- 0.03 ug/g, ww and ranged from 0.01 to 0.16 ug/g, ww and juveniles had a mean of 0.03 +/- 0.02 ug/g, ww and ranged from 0.01 to 0.08 ug/g, ww (Table 1, Figure 2).

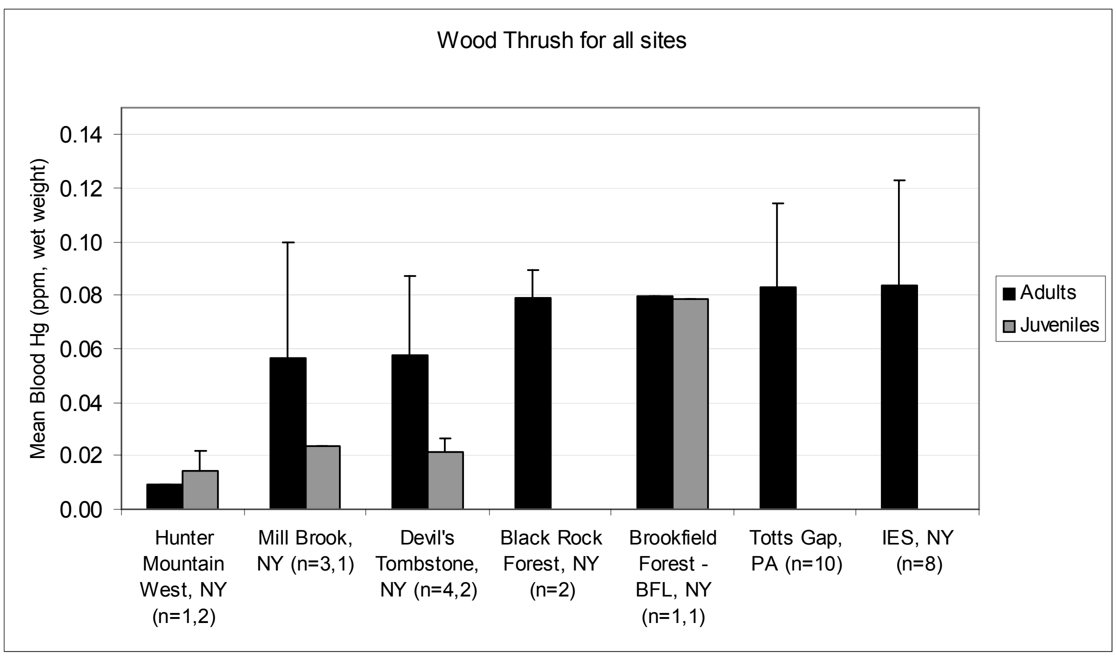

Figure 2. Comparison of blood Hg levels of Wood Thrushes in New York and Pennsylvania, 2005.

Small sample sizes of adult Wood Thrushes from this initial effort makes spatial comparisons difficult for statistical robustness. To statistically characterize each location an estimated 26 individuals of one age class is needed (based on fixed precision analysis using the mean and variation from Totts Gap and a percentage of relative precision value [PRP] of 25%, which means that the upper and lower confidence limits will fall within 25% of the mean with a 95% certainty[1]) (Sutherland 1996). By normalizing blood Hg levels of various low to moderate

[1] If we used 20% PRP a sample size for each location of 35 Wood Thrushes is needed.

elevation thrush species into a Wood Thrush, a preliminary spatial analysis can be conducted (see section 5.6).

Although only preliminary Wood Thrush Hg results from a limited number of locations are available, the geographic patterns of air pollution deposition and sensitive habitats (i.e., poorly buffered soils in montane areas) indicate a correlative relationship with changes in Wood Thrush presence and breeding intensity (Figure 3). Based on standard breeding bird atlas efforts for the two time periods, Wood Thrush breeding populations indicate dramatic negative changes including (1) presence in the Adirondack Mountains has declined in spatial extent as well as number of blocks with confirmed breeding (currently, there are very few areas with confirmed breeding in the Adirondack Mountains) and (2) density of blocks with confirmed breeding has declined substantially in the Catskill Mountains and several other areas of New York. A regionwide analysis of biological hotspots based on piscivorous birds and mammals included parts of the Adirondack and Catskill Mountains (Evers et al. In Review). Although that analysis did not include potential methlymercury availability and impacts on insectivores and northern forests, the overlap of biological hotspots of Hg for piscivores and concerns for insectivores in the same areas are compelling for further monitoring of species like the Wood Thrush.

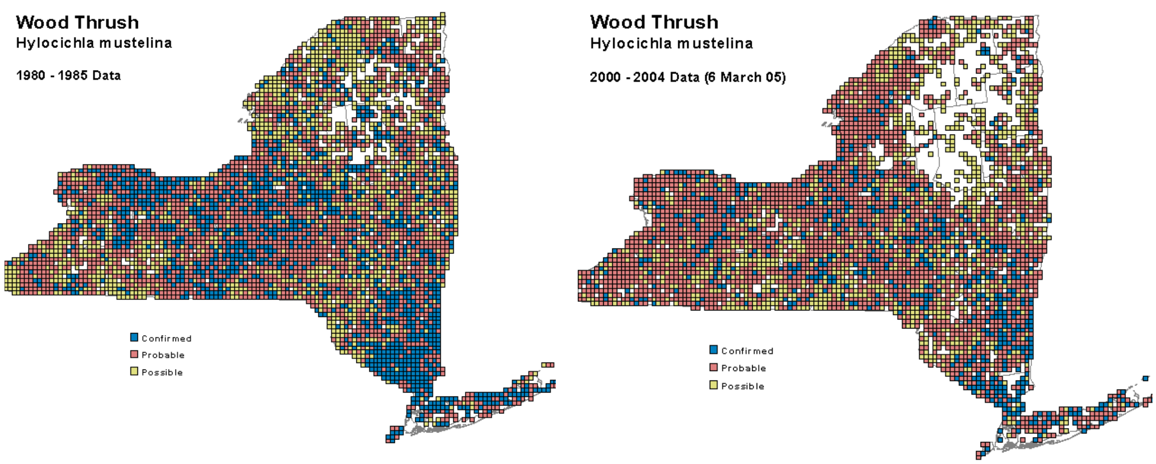

Figure 3. Breeding distribution of the Wood Thrush based on the Breeding Bird Atlas for NY (NYDEC 2006).

Bicknell's Thrush: This neotropical migrant is also a species of high conservation concern (Partners in Flight rank of 18 out of 20). It is the bird with the highest conservation concern in the Northeast (Rich et al. 2004). The Bicknell's Thrush is relegated to breeding in subalpine areas of conifer-dominated forests with elevation thresholds that are latitudinally controlled (Lambert et al. 2005); in the U.S., lowest elevations occupied are in northern Maine at 750m, while in the southernmost extent of its range in the Catskill Mountains the Bicknell's Thrush generally breeds on mountains 1,100 m or higher (Rimmer et al. 2001). While the Wood Thrush serves as our indicator for methlymercury availability in low to moderate level sites, the Bicknell's Thrush indicates high elevation levels.

Only one site was included in the 2005 sampling effort. The mean blood Hg level on Plateau Mountain was 0.08 +/- 0.03 ug/g (ww) with a range of 0.05 to 0.14 ug/g, ww (n=11) (Table 1). This site is lower than many sites in New England (Rimmer et al. 2005). To statistically characterize each location an estimated 21 individuals of one age class is needed (based on fixed precision analysis using the mean and variation from Plateau Mountain and a percentage of relative precision value [PRP] of 25%, which means that the upper and lower confidence limits will fall within 25% of the mean with a 95% certainty[2]) (Sutherland 1996).

Unlike the Wood Thrush, the distribution and density of confirmed breeding by the Bicknell's Thrush in the Adirondack and Catskill Mountains is relatively similar between the two time periods of data collection by the New York Breeding Bird Atlas.

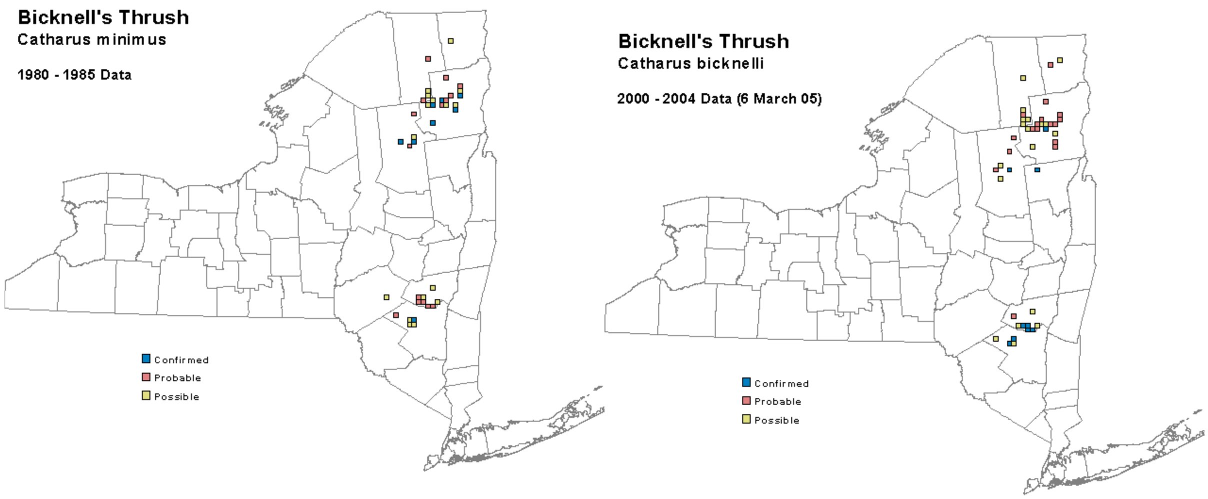

Figure 4. Breeding distribution of the Bicknell's Thrush based on the Breeding Bird Atlas for NY (NYDEC 2006).

5.3 Comparing thrush blood Hg exposure

There were six thrush species sampled for mercury levels in 2005 at 12 separate sites. Individuals of all species likely were breeding within the areas of capture (with two exceptions[3]). The Wood and Hermit Thrushes were best represented at these sites. The study-wide distribution of blood Hg levels from low to high were generally: Veery < American Robin < Hermit Thrush < Swainson's Thrush < Wood Thrush < Bicknell's Thrush (Figure 5).

Thrush Hg exposure is likely dictated by (1) foraging technique, (2) prey selection, (3) body size, (4) elevation of breeding habitat, and (5) soil moisture. These factors may be additive or antagonistic. In the American Robin, averaging 76g and is the largest thrush, its blood Hg levels tended to be similar to the much smaller Veery (31g). Robins likely forage on prey items that are in lower trophic levels (e.g., earthworms). The foraging technique and prey selection of Wood Thrushes is likely different than the American Robin and is comprised of higher trophic level prey items (e.g., beetles and centipedes) (Holmes and Robinson 1988), because Wood Thrushes (48g) are approximately 37% lighter than robins. There are also gradients of soil chemistry that tend to become more acidic and less buffered as elevation increases. High elevations are more prone to higher Hg deposition (Miller et al. 2005) and their geochemistry likely predisposes habitats to higher methlymercury production and availability (as indicated by Rimmer et al. 2005). Therefore, high elevation species such as the Bicknell's Thrush (28g) and even the Swainson's Thrush (29g) have proportionally higher Hg levels than associated low-elevation mountainside neighbors. Lastly, moisture has an important role in methlymercury

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[2] If we used 20% PRP a sample size for each location of 27 Bicknell's Thrushes is needed.

[3] The Hermit Thrush from the Shawangunk Mountains and the Wood Thrush from Hunter Mountain – west.

availability to thrushes and other songbirds. Areas with more mesic soils are likely to have thrushes with higher Hg body burdens than the same species with territories on xeric soils. At the IES site, the Veery was sampled in both mesic and xeric soils and those individuals in habitats with mesic soils had higher blood Hg levels. Although Hermit Thrushes average 30g and are similar to size with the Bicknell's and Swainson's Thrushes, indications are that Hermit Thrushes have lower Hg body burdens. This may be because Hermit Thrushes generally inhabit drier forests tracts (Holmes and Robinson 1988).

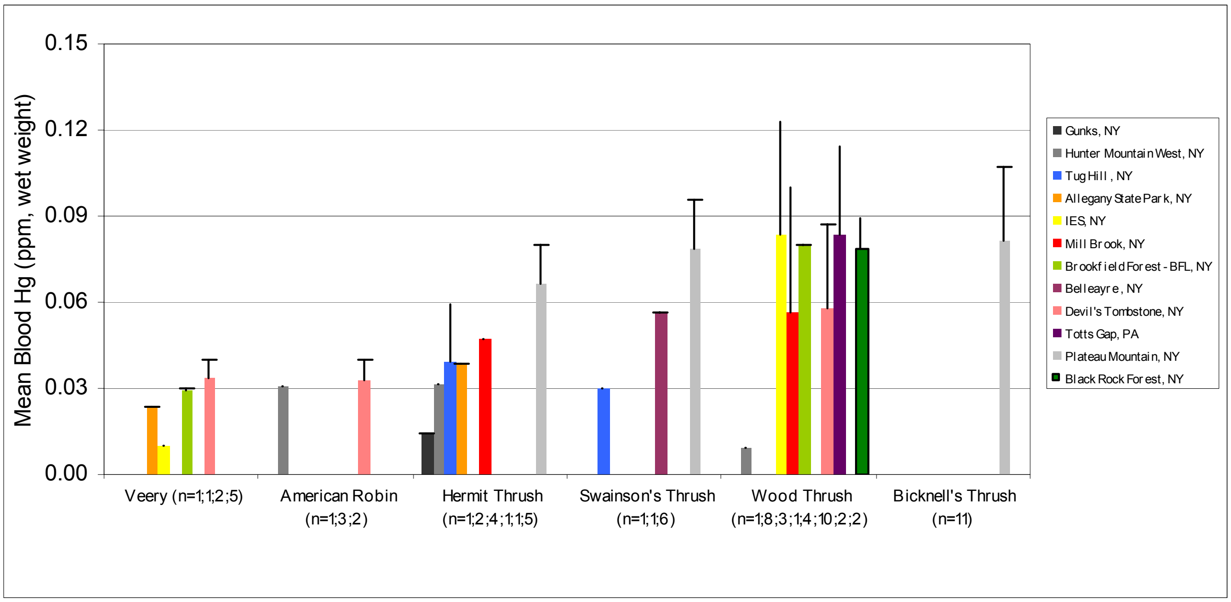


Figure 5. Adult thrush blood Hg levels by NY and PA location.

Although there are subtle differences in foraging strategy among the thrush species, we normalized blood Hg levels for thrushes within the same site to attain standard blood Hg levels for the Wood Thrush in low elevation areas and the Bicknell's Thrush in high elevation areas (Table 2). This process provides a comparable method for comparing thrush Hg exposure with larger sample sizes and therefore is the basis for our first attempt at developing a spatial gradient for New York.

Table 2. Within-site comparisons of thrush species for normalizing non-target thrushes to target thrush blood Hg levels.

Target Thrush	Non-target Thrush	Conversion Factor to Target Thrush
Low Elevation		
Wood Thrush	Hermit Thrush	1.19
	Am. Robin	1.75
	Veery	2.21
High Elevation		
Bicknell's Thrush	Swainson's Thrush	1.04
	Hermit Thrush	1.23

Within-site comparisons are based at multiple sites, however only the Plateau Mountain site provides the ability to relate the deposition of Hg and its subsequent availability on one mountainside (Figure 6). At the base of Plateau Mountain at approximately 2,000 feet, is Devils Tombstone State Park Campground and the site of sampling efforts for the Wood Thrush. Capture and sampling efforts in 2005 resulted in the ability to compare the blood Hg levels from three species with overlapping breeding territories. The Wood Thrush had the highest Hg body burden of the three thrush species. Approximately 2,000 feet above this site was the capture and sampling area for three other thrush species. The Bicknell's Thrush has the highest mean Hg body burden. All thrush species Plateau Mountain tended to have higher Hg body burdens than those at Devil's Tombstone State Park and provides evidence for higher MeHg availability as elevation increases.

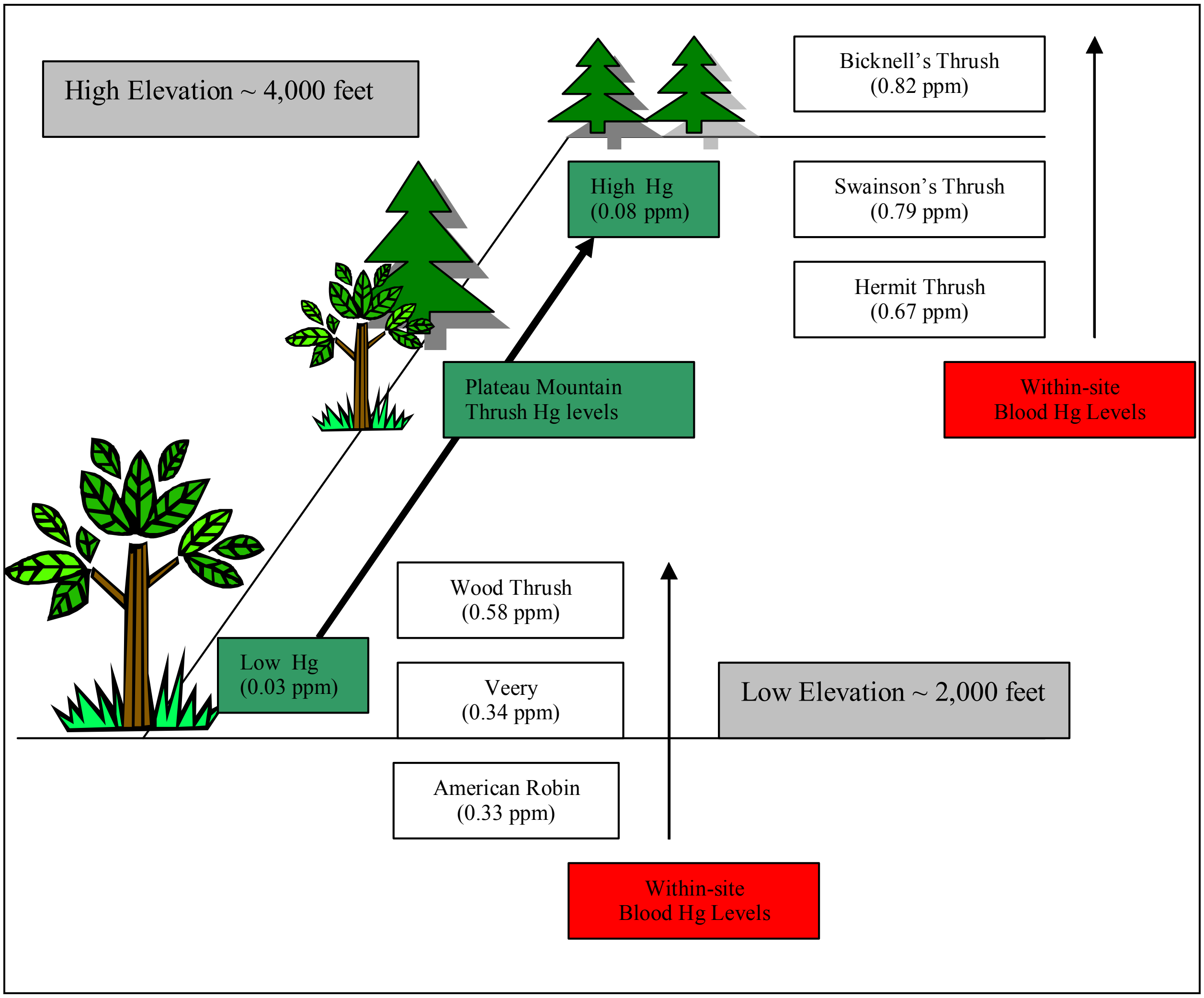


Figure 6. Comparison of thrush blood Hg levels on Plateau Mountain, New York.

To provide some geographic context to the New York and Pennsylvania thrush body burdens of Hg, comparisons are made with Maine, New Hampshire and Vermont (Figure 7). Generally, blood Hg levels in thrush species from the 2005 New York and Pennsylvania sampling effort were similar to New England sites for the Veery, Hermit Thrush, Swainson's thrush, and Wood Thrush. There appears to be significant differences between the two geographic areas for the American Robin and Bicknell's Thrush. Small samples limit statistical comparisons, but higher levels in Maine generally follow known geographic trends of methylmercury availability in other birds, such as the Common Loon (*Gavia immer*) (Evers et al. 2003). Such established geographic trends rely on many environmental variables including point source proximity, habitat sensitivity, and hydrological management and may not necessarily all apply to forest songbird geographic patterns of Hg levels.

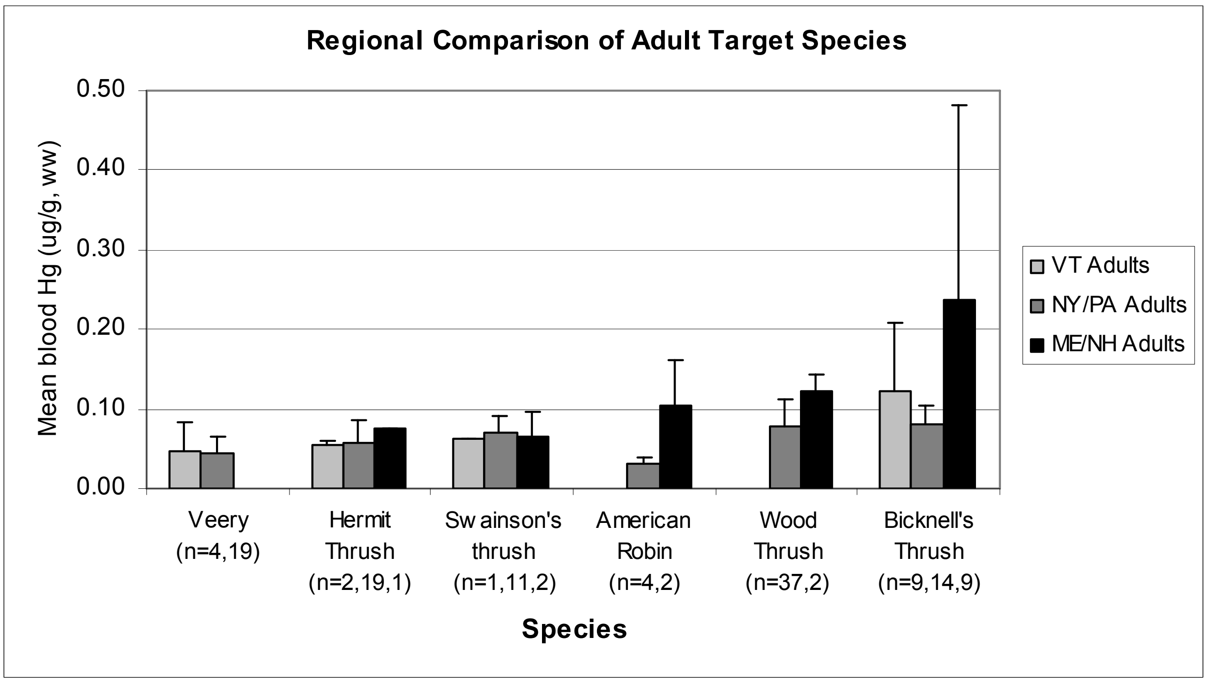


Figure 7. Comparison of thrush blood Hg levels across New York and New England.

5.4 Mercury exposure in non-target species

Because there are few comparative studies on Hg body burdens in songbirds and other avian insectivores, an effort was made to sample many of the songbirds captured. In addition to the 93 thrushes captured and sampled, an additional 85 individuals (74 Adults and 11 juveniles) representing 20 species were also sampled for blood Hg levels. Although emphasis was on sampling the Louisiana Waterthrush because of its likely high risk to recently demonstrated methlymercury availability in upper watershed streams (Bank et al. 2005), we also opportunistically sampled a relatively large number of Red-eyed Vireos (n=29) (Table 1, Figure 8). Both of these species and the Blue-headed Vireo demonstrated relatively high Hg body burdens compared to other forest songbirds.

Although Red-eyed Vireos are upper canopy inhabitants, they regularly responded to the mobbing calls of our playback recordings and were easily sampled.

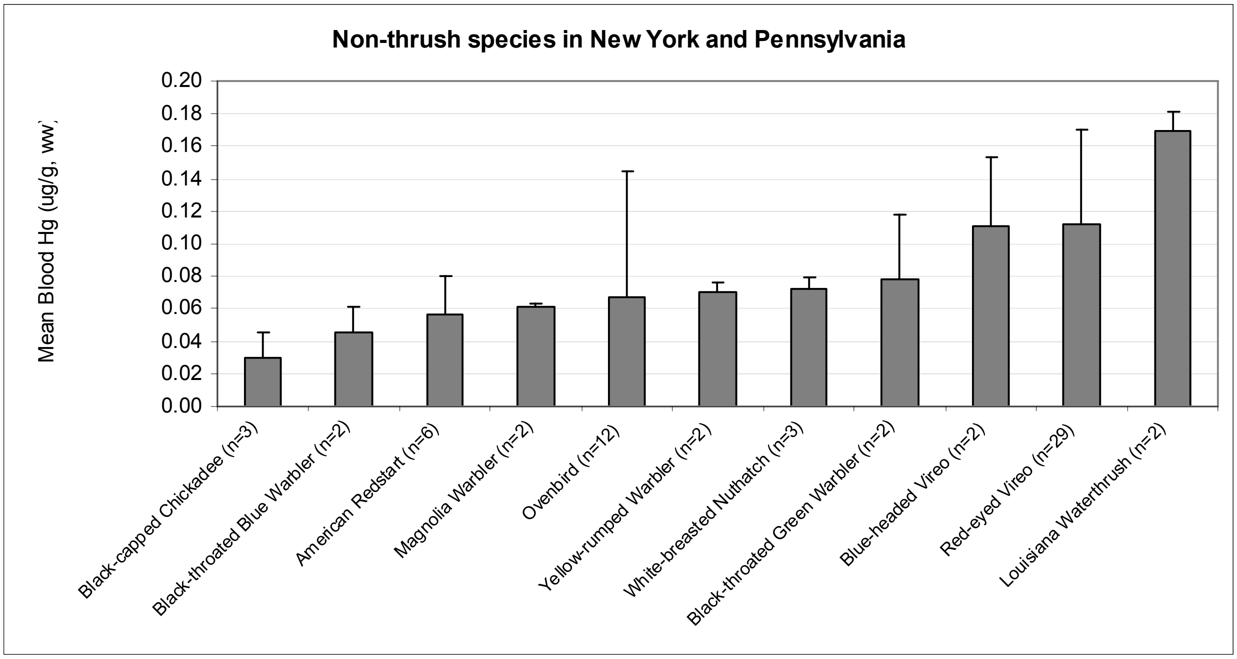
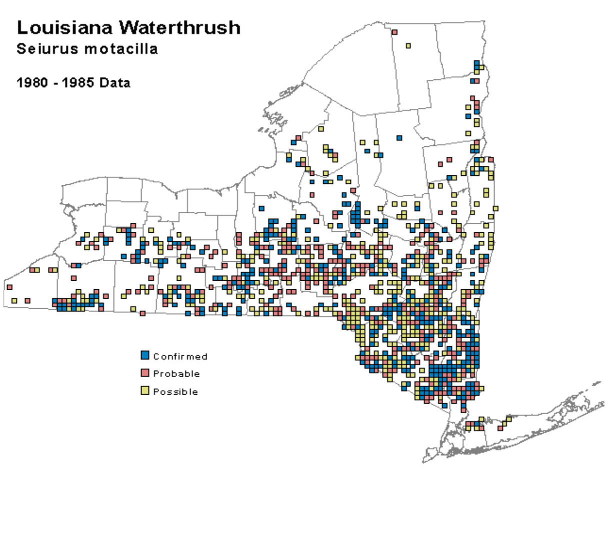


Figure 8. Comparison of blood Hg levels for non-target songbirds.

One of the larger warbler species, the Louisiana Waterthrush is of particular interest under this effort as it is a neotropical migrant of high conservation concern (Rich et al. 2004) and because of its relatively large size and aquatic-based food preferences it is of concern for impacts within acidic habitats. It forages at the water's edge for the following insect families: Chironomids, Coleopterans, Diplopods, Ephemeropterans, Hemipterans, Neuropterans, Plecopterans, Stratiomyiids, Tipulids, and Trichopterans (Robinson 1995). It also forages on snails and other mollusks, arachnids, amphibians, and small fish. These prey items likely explain its relatively high Hg body burdens that exceeded thrushes (Figure 5) and non-thrush species (Figure 8). Comparisons of breeding bird atlas data for the first (1980-1985) and second (2000-2004) periods indicates a substantial loss of overall breeding range, density, and confirmed breeding.



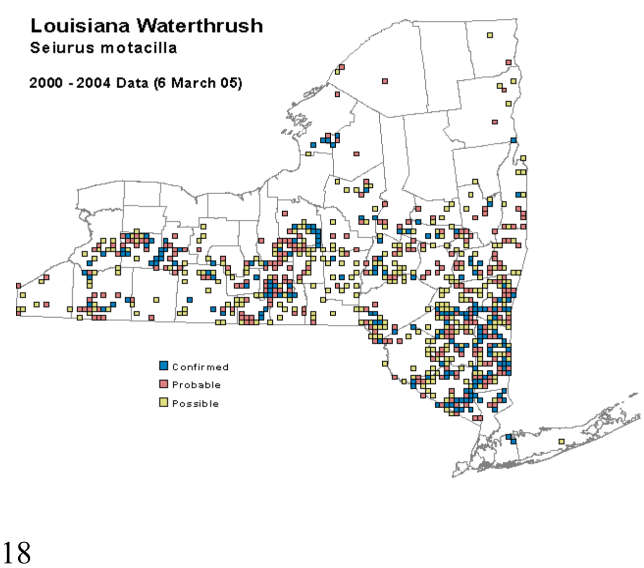


Figure 9. Breeding distribution of the Louisiana Waterthrush based on Breeding Bird Atlas for NY (NYDEC 2006).

5.5 Mercury exposure in songbirds by site and foraging guild

A total of 11 separate locations were sampled for songbirds (Appendix II). The blood Hg levels by site provide comparisons for inter-species relationships. Particularly important were the multiple neighboring sites sampled at varying elevations in the Hunter and Plateau Mountain area (Figure 10). Larger sample sizes from each of these locations will provide insight and statistical comparisons into inter-species comparisons at multiple elevations.

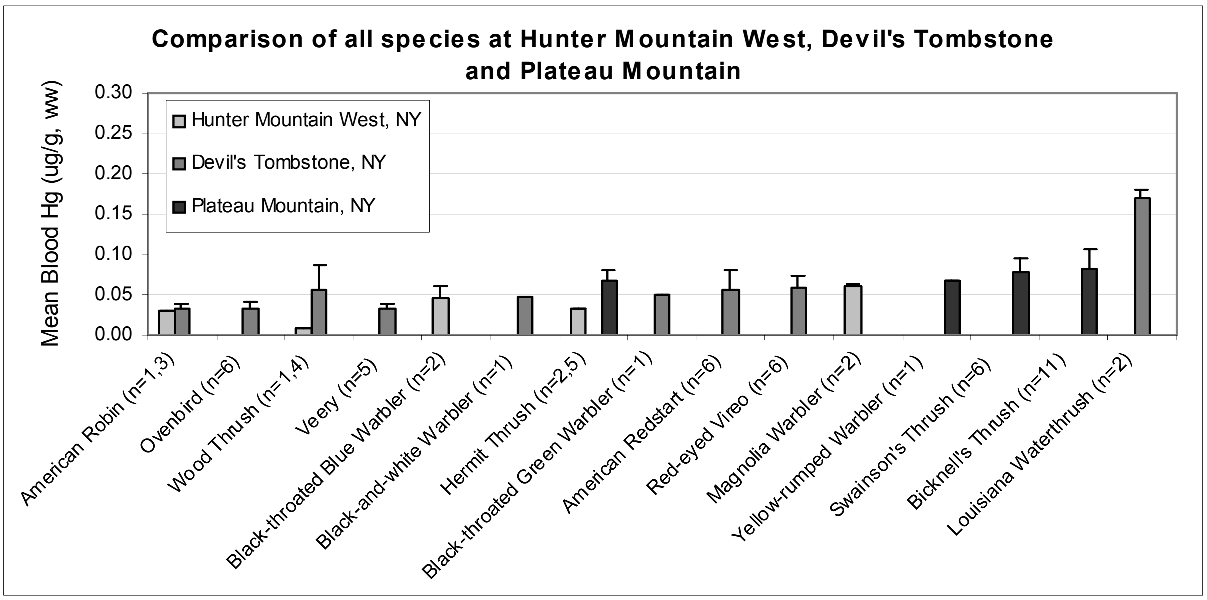


Figure 10. Comparison of Hg body burdens in species from the Hunter and Plateau Mountain area, 2005.

Generally larger bodied songbirds of both ground and canopy foraging species had the highest Hg levels (Figure 11). This is likely because larger birds tend to feed on larger prey items that tend to have higher methlymercury levels. Small sample size preclude conclusions, but larger songbirds are likely at greatest risk to MeHg availability.

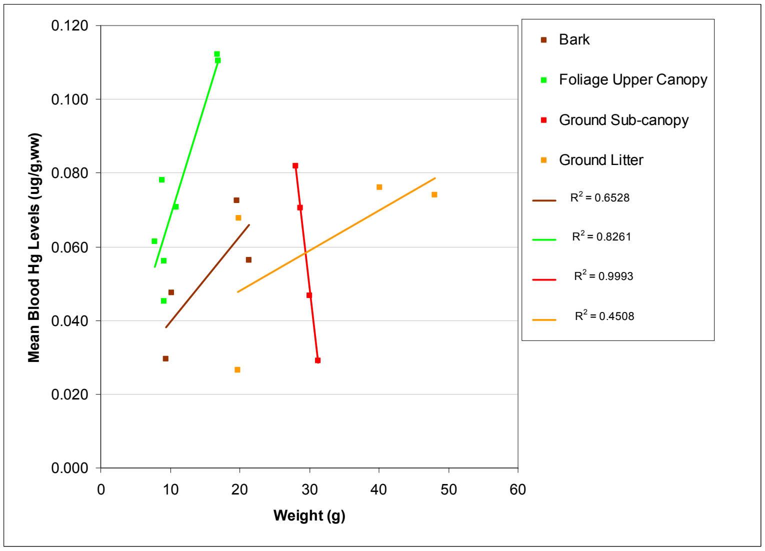
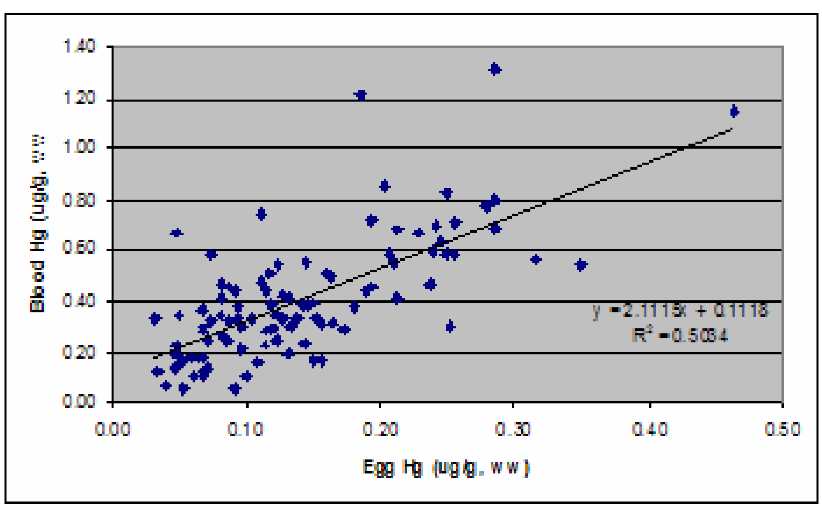


Figure 11. Comparison of Hg body burdens in species from grouped into six foraging guilds .

5.6 Mercury thresholds for songbirds

There are few datasets available that provide a level of concern for methlymercury accumulation and exposure to avian insectivores. Baron et al. (1999) estimated the dose of methlymercury to Northern Rough-winged Swallows (*Stelgidopteryx serripennis*) that was considered a lowest observed adverse effect level (LOAEL) as 0.25 ug/g, ww. Recent additional work on swallows, specifically the Tree Swallow (*Tachycineta bicolor*), by scientists at the U.S. Geological Survey's Patuxent Wildlife Research Center provides more relevant information for this pilot assessment. Through formal Hg dosing experiments of Tree Swallow eggs based on protocols established for the CALFED-Bay Delta Mercury Project (Heinz 2003), Hg levels that posed a cause of concern were developed by Gary Heinz (pers. com.). Using an endpoint of embryo survival at 90% within the hatching date, Heinz found a significant negative impact in embryo survival at egg Hg levels of 0.80 ug/g (ww). Egg Hg levels of 0.40 ug/g (ww) were not significantly different than the reference condition (p=0.19); although larger samples sizes may indicate a cause of concern at this Hg levels. Eggs were not dosed at the 0.60 ug/g (ww) level. The CALFED study is determining the relative sensitivities of methlymercury effects on eggs of over 30 species. Because the LOAEL for the Mallard is 0.80 ug/g (ww) (Heinz and Hoffman 2005) and swallow eggs are considered to be more sensitive to the negative impacts of methlymercury in eggs than mallards, a value between 0.40 to <0.80 ug/g (ww) should be used for a cause of concern for Tree Swallows.

The use of eggs as a sampling tissue for the NFHR pilot assessment was not feasible. Blood Hg levels were used instead. Based on an unpublished dataset from BRI, a regression model provides a relevant tool for predicting blood Hg levels from egg Hg levels. Based on 99 paired Hg levels from eggs and blood collected from the same female, approximately 50% of the variability can be predicted



using a model of: Blood Hg = 2.1115 (Egg Hg) + 0.1118 (Figure 12).

Figure 12. Model of egg Hg levels a predicted blood Hg levels[4].

Based on evaluations by Heinz (pers. com.), the level of concern for negative impacts of methlymercury on eggs for all songbirds (based on the Tree Swallow and Common Grackle) is between 0.40 and 0.60 ug/g (ww). Using the BRI predictive model, blood Hg levels for this range are between 0.96 and 1.38 ug/g (ww) (Figure 13). Pending further data, blood Hg levels below 0.96 ug/g (ww) are proposed here as no or low risk, levels between 0.96 and 1.38 ug/g (ww) are likely at risk, and blood Hg levels >1.38 ug/g (ww) are individual birds at risk to injury from methlymercury toxicity to reproductive success.

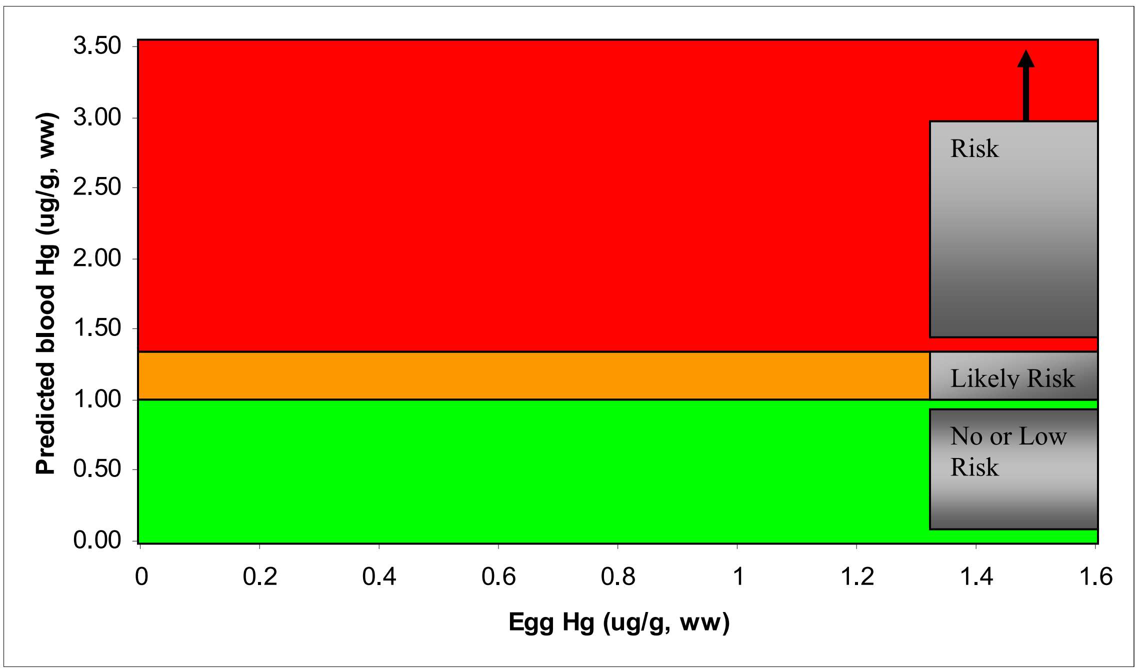


Figure 13. Model of egg Hg levels and predicted blood Hg levels.

As predicted, none of the birds sampled in 2005 exceeded the LOAEL for Hg of 0.96 ug/g, ww of in the blood. The highest level recorded was well below the LOAEL and was 0.24 ug/g, ww in the blood of a Louisiana Waterthrush in Allegany State Park. While MeHg levels are not at the LOAEL, they are elevated. If elevated MeHg levels are found in birds associated with areas low in available Ca, could that trigger physiological, behavioral and potentially even reproductive impacts?

5.7 Relationship of mercury and calcium availability in acidified habitats

In acidified environments, negative effects on songbird fitness and breeding success have been related to a deficiency in calcium availability. Typically, there is an inverse relationship

[4] Based on unpublished data by BRI for the Tree Swallow.

between soil exchangeable calcium and increasing soil pH. Calcium is generally a limited nutrient in terrestrial foodwebs, but increased provisions of calcium are needed for eggshell production and for proper growth of hatchlings. Therefore, areas with low soil pH, have low levels of soil exchangeable calcium, which results in smaller individuals of calcium-rich invertebrates, lower densities, and therefore inefficient transfer of calcium to individual songbirds. Experimental manipulations that supplement available dietary calcium indicate that hatchling size and growth rates (Tilgar et al. 2004) are enhanced and indicate reproductive performance by songbirds in acidified environments may be problematic (Dawson and Bidwell 2005). How different species within the same area respond to calcium deficiencies varies (Mand and Tilgar 2003) and therefore requires high resolution investigations that carefully select indicator species.

Terrestrially acidified environments not only reduce calcium availability, but they also enhance aluminum (Graveland 1998) and methlymercury availability (Scheuhammer 1987). Mercury methylation in terrestrial systems is a relatively new realization by those studying mercury cycling in forested habitats and forest songbirds (Rimmer et al. 2005, Evers et al. 2005). Because soil pH and methlymercurly relationships in relevant biota are likely strong, particularly in soils that favor methylation such as those with (a) low oxygen (usually saturated soils), (b) high sulfur load, and (c) high dissolved organic carbon. Preliminary data collected from the IES site may provide the insight needed to directly connect acidification of terrestrial habitats with reduced calcium availability and enhanced methlymercury availability.

At the IES site, we collected soil samples that represented organic and mineral layers, their pH, and total Hg and Ca levels. At those same sites, blood Hg levels were determined for the Wood Thrush and Veery. We found a significant inverse relationship between soil pH and Hg in the organic layer and a tendency for soil calcium levels to increase as soil pH increased (Figure 12a, b). Therefore, as topsoil became more acidic total Hg increased and Ca decreased.

a. b.

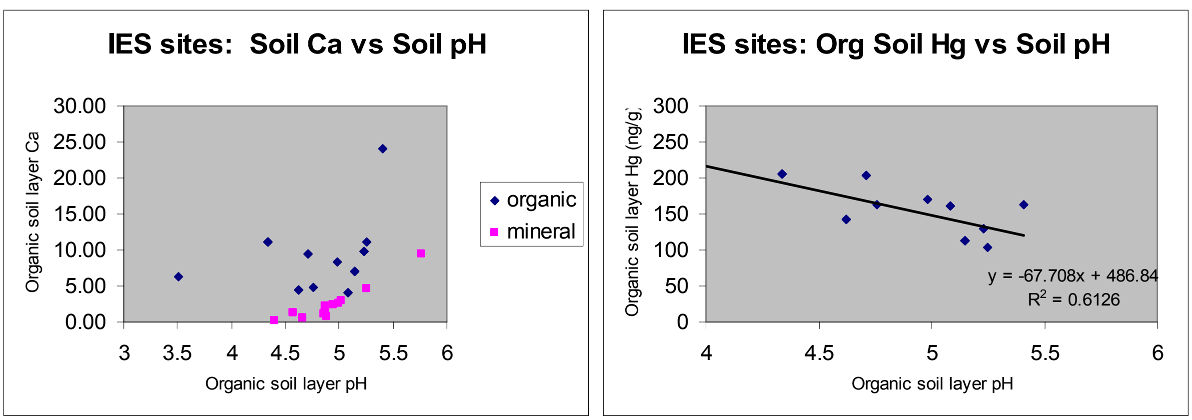


Figure 12. Relationship of pH with (a) Ca and (b) Hg levels in the organic soil layer.

The response detected in forest floor songbirds generally corresponded with these findings. Wood Thrush blood Hg levels increased with organic soil Hg levels (Figure 13a) and had an inverse relationship with organic soil exchangeable Ca levels (Figure 13b). Similar analysis with associated Veery individuals did not exhibit trends found in the Wood Thrush (Figure 13a, b).

a. b.

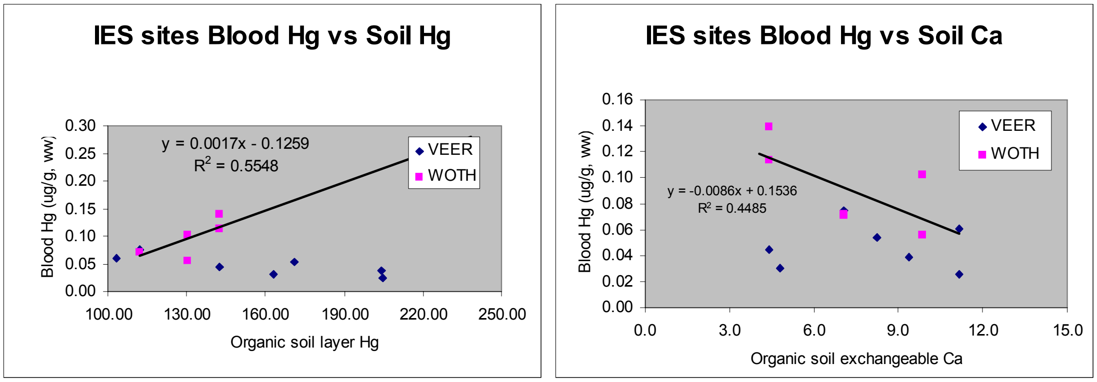


Figure 13. Relationship of organic soil layer for (a) Hg and (b) exchangeable Ca.

A preliminary comparison of how blood Hg levels of the Wood Thrush and Veery compare with soil pH are illuminating. One species, the Wood Thrush, exhibits the hypothesized relationship of higher blood Hg levels in more acidified soils, while the Veery's relationship of blood Hg levels and organic soil pH are counter to our hypothesis. (Figure 14). The effects of calcium deficiency on birds can be species- and even population-specific (Mand and Tilgar 2003) and subtle differences in foodweb pathways for methlymercury biomagnification and transfer can also create multiple-fold differences in blood Hg exposure in sibling species within the same areas (Shriver et al. In Press). Because the Wood Thrush feeds primarily on the forest floor by moving leaf litter to locate prey items (Holmes and Robinson 1988), the pathway of methlymercury through its prey is likely connected with the organic soil. This analysis indicates that the Wood Thrush is a valuable choice as an indicator species when linking abiotic and biotic compartments of Hg with Ca.

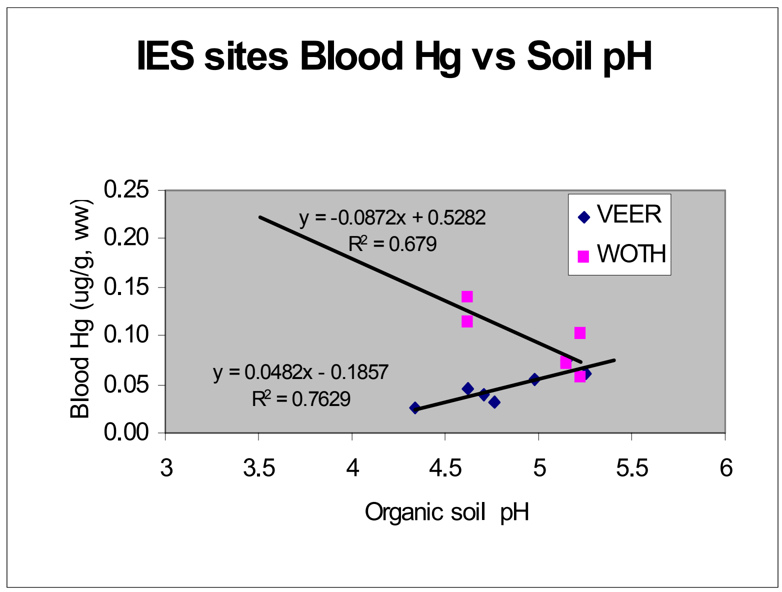


Figure 14. The relationships between thrush blood Hg levels and organic soil pH.

5.8 Spatial relationships among sites for Hg

The spatial relationship of MeHg availability as measured through a standard thrush blood Hg unit provides an avenue for assessing habitat sensitivity and potential proximity to Hg emission sources (Figure 15). Because sample sizes within sites and the number of distinct sites and their juxtaposition are severely limiting this spatial analysis should be strictly considered as an example of future potential findings.

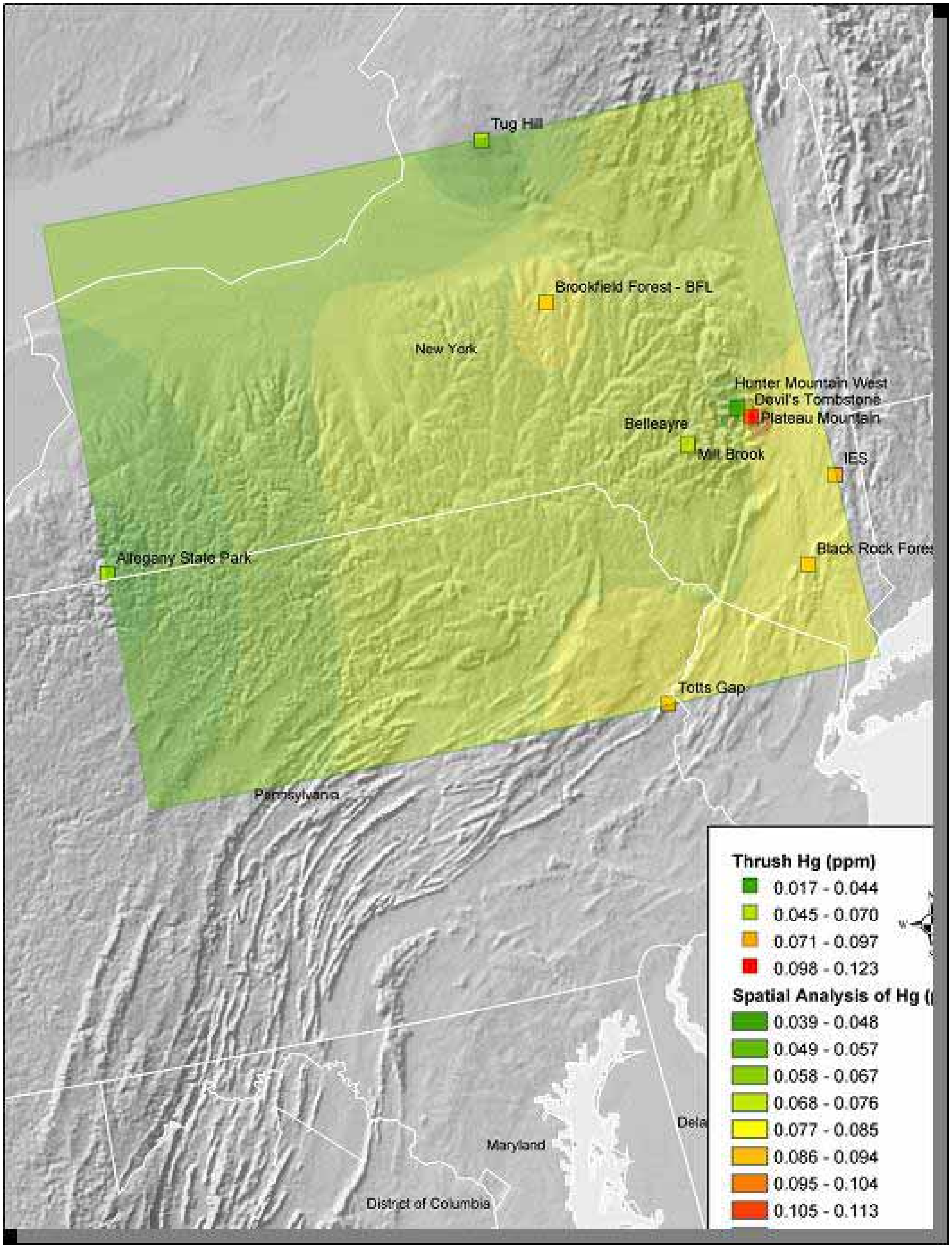


Figure 15. The spatial relationships for blood Hg levels standardized for a Wood Thrush.

6.0 Policy Implications

The reduction of pollutant emissions is particularly important in northeastern North America. Industrial areas in the Ohio River valley are likely sources of sulfur and Hg deposition in New England and New York. Keeler et al. (2005) used back trajectories of air masses to directly link Hg deposition in western Vermont with sources in the Ohio River Valley and neighboring areas. This likely explains the dichotomy for why significant efforts in New England and New York to reduce Hg emissions do not yet reflect regionwide declines – current Hg deposition in many areas of the Northeast are still dictated by neighboring states.

Such regional connectivity does not supercede the ability for local sources of Hg to have significant local impacts. Even though the premise of the U.S. Environmental Protection Agency's rule-making for the Clean Air Mercury Rule (CAMR) or "Cap-and-Trade" policy is that utility-attributable hotspots would not occur after implementation of CAMR mercury trading program (USEPA 2005), there is growing evidence that basic premise may not be completely accurate.

Recent findings indicate a growing body of evidence that atmospheric deposition and biological Hg hotspots can be created by local emission sources; five such studies include: (1) Steubenville, Ohio where a U.S. Environmental Protection Agency funded project demonstrated that nearly 70% of the Hg collected at a monitoring site originated from a neighboring coal-burning facility (Landis et al. 2005), (2) northeastern Massachusetts where the Massachusetts Department of Environmental Protection reported a 32% decline in yellow perch during a seven year decline in nearby Hg emissions from municipal and hospital incinerators (Hutcheson 2003), (3) southern Florida where fish and wading bird Hg concentrations declined 60-70% per efforts directed by the state of Florida and University of Florida (Frederick et al. 2005), (4) Cresson, Pennsylvania where researchers from Pennsylvania State University and the Pennsylvania Department of Environmental Protection demonstrated that Hg levels were 47% higher in areas closer to power plants than distant ones such as in Wellsboro, Pennsylvania, and (5) nine southeastern New Hampshire lakes where Hg levels declined over 50% in the blood of the Common Loon between 2001 and 2004 (Evers et al. In Review). In New Hampshire, this decline in MeHg availability correlated with the removal of 6,600 pounds of Hg from upwind incinerator emission sources located within 200 km of the study area.

If these examples are not the exception, but the rule, then local emission sources can cause local impacts and atmospheric deposition and biological Hg hotspots are likely widespread, especially in the eastern U.S. The recent identification and characterization of biological Hg hotspots in the Northeast by Evers et al. (*In Review*) further demonstrates that they exist and are present for multiple reasons that include local emission sources as well as landscape biogeochemical cycling. The contentious nature of both atmospheric and biological Hg hotspots was recently highlighted by a 15 May 2006 report by the Acting Inspector General for the U.S. Environmental Protection Agency (USEPA 2006). Within the report, the Inspector General questioned the U.S. Environmental Protection Agency's premise for their mercury rule that emissions from power plants after emissions trading will not lead to local hotspots of Hg deposition. In response, the U.S. Environmental Protection Agency Inspector General's office recommended the development and implementation of a mercury monitoring plan.

The influence of both local and regional Hg sources on associated ecosystems therefore needs careful consideration – particularly in context with the new U.S. Environmental Protection Agency's "Cap-and-Trade" rule. A cost-benefit analysis with new information on the existence of biological Hg hotspots that are controlled by local and likely regional Hg sources may diverge from the federal analysis[5]. Until such an analysis is conducted, the trading of Hg emissions should take into account (1) current Hg emission levels and (2) nearby habitat sensitivity.

Based partly on new evidence by the New York State Energy Research and Development Authority (NYSERDA 2006), New York just proposed one of the most stringent Hg emission reduction standards for coal-burning facilities in the country (on 26 May 2006). The proposed rule would reduce Hg emissions from electricity-generating stations by 50% by 2010 and would require a 90% reduction by 2015. Under the current federal rule, power plants need to reduce their Hg emissions by 50% by 2018 and sometime after 2020 will reduce emissions by a total of 70% (40 CFR Part 60, Appendix B; 70 Fed. Reg. 28,606). The New York ruling increases the overall reduction of Hg and has a more aggressive timeline.

The rapid identification of sensitive habitats and the species of greatest risk in New York and nearby states and provinces is paramount for avoiding increased impacts from regional Hg emission sources during near-term trading of emission pollutants. Because Hg emissions in one part of the world have the ability to pollute distant parts, eventually the solution will need to be an international one. However, as long as biological Hg hotspots can be traced to local emission sources, local solutions are possible[6].

Photos of a net lane (left), Louisiana Waterthrush (upper right), Red-eyed Vireo (lower right).

[5] In addition, the USEPA (2005) did not include ecological impacts in their cost-benefit analysis, even with scientific precedent for the importance of ecological impacts on socioeconomic interests (Bockstael et al. 2000).
[6] Technologies are rapidly being developed to reduce Hg emissions from coal-fired generation facilities in an efficient and economic way (Srivastava et al. 2006).

7.0 Conclusions

There are compelling reasons to link existing knowledge bases of relevant pollutants with impact to breeding songbirds in eastern forests. Much is already known about the effects of acidic deposition on northeastern landscapes and the depletion of available Ca in soil. Only recently has the additional stressor of increased MeHg availability been implicated with the acidification process. The distribution of Hg and the availability of MeHg are now well documented in the Northeast. This pattern was accomplished from a four-year study funded by the USDA Forest Service. BRI and their collaborators compiled and synthesized most of the publicly available mercury data in the Northeast into a series of 21 papers in a special issue of Ecotoxicology (Evers and Clair 2005). From this comprehensive review on how Hg is distributed across the landscape there are three findings that partly serve as a basis for this current investigation: (1) new findings indicate MeHg availability is more prevalent in terrestrial birds than previously considered (Evers et al. 2005), (2) birds in montane terrestrial habitats are especially at risk (Rimmer et al. 2005), which is likely related to atmospheric deposition of wet and dry Hg that is higher than lower elevation habitats (VanArsdale et al. 2005), and (3) there is a significant relationship between wet and dry Hg deposition models based on Miller et al. (2005) and Bicknell's thrush blood Hg levels (Rimmer et al. 2005).

With our sampling efforts of forest songbirds in 2005 we found blood Hg levels that were elevated, but not at levels that cause impact. Patterns of blood Hg levels indicate that body size, elevation, and geographic location are important variables to measure. Because of the rapid and near-complete loss of breeding populations of the Wood Thrush in the Adirondack Mountains and prominent declines in other areas of eastern New York, including the Catskill Mountains, we feel that the hypothesis of elevated Hg levels and deficient Ca levels in the its breeding range remains compelling. Other species, such as the Louisiana Waterthrush and Rusty Blackbird exhibit similar population trends in New York and appear to bioaccumulate greater amounts of MeHg than the Wood Thrush.

As there are yet no emission controls on electric utilities, the major source of atmospheric Hg in the U.S., results from this investigation may provide important information to policy makers on the pervasiveness of Hg in the Northeast and how synergy with other stressors such as acidic deposition could have broad-scale impacts to bird populations and ecosystem health. If our efforts here link emission sources from the Ohio River Valley with biological Hg hotspots in New York, the premise of the U.S. Environmental Protection Agency's "Cap-and-Trade" ruling is further challenged. The trading of Hg among coal-fired boilers could result in increased Hg emissions to (1) some areas that are highly sensitive to Hg and S deposition, such as montane and bog habitats in the Adirondack Mountains and new areas that currently have lower relative emissions. All point sources in New England are under 500 pounds per year (Figure 16).

Because BRI and colleagues, including those from the Hubbard Brook Research Foundation, are actively linking Hg scientific findings with national policy through Hg briefings to Congress and other means, the jointly funded research by The Nature Conservancy (2005 and 2006) and NYSERDA (2006) could ultimately contribute to a framework for new national legislation to regulate Hg emissions and eventually standardized monitoring efforts. Should the decline of Wood Thrushes and other songbirds truly signal a widespread and major disruption in how forests function in New York, New England and surrounding areas then this effort becomes very timely and may help stave off further silencing of northern forests.

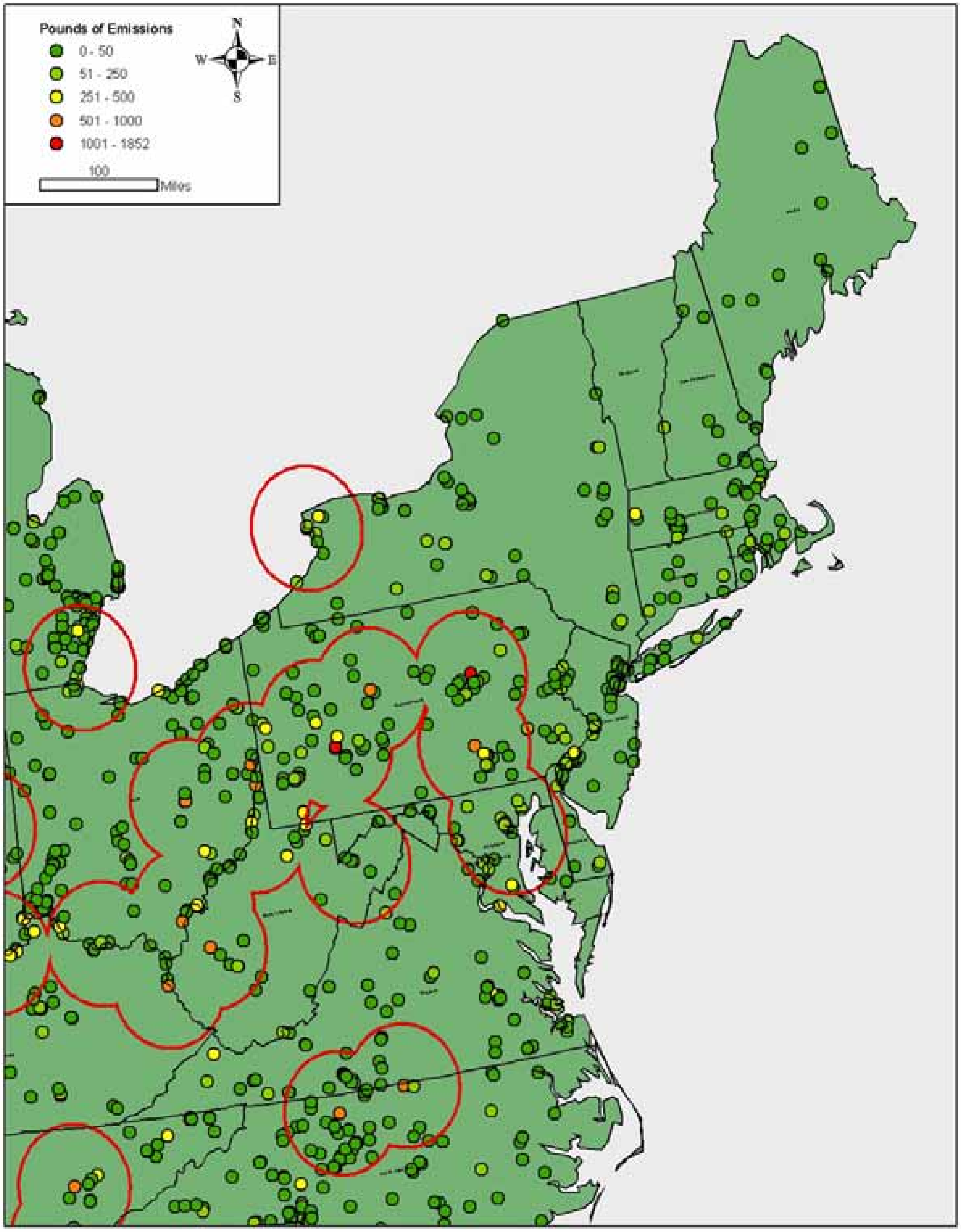


Figure 16. Mercury emission point sources in eastern U.S with sources of >500 pounds associated with a 50 mile radius red circle.

8.0 Recommendations for 2006.

1. Continue development of Hg exposure profile to (see Appendix III for map and listing of 2006 sampling stations):
    a. Identify potential biological Hg hotspots;
    b. Determine regional spatial gradient of MeHg availability;
    c. Search for areas and habitats that might exceed the 0.96 ug/g, ww impact level of Hg in the blood (i.e., bog areas).

2. Include an analysis of Hg and Ca in soil, prey items and birds to:
    a. Quantify the relationship of Hg and Ca in birds for different geographic areas;
    b. Quantify the relationship of Hg and Ca among soil, prey, and bird compartments;
    c. Use relationships to develop a predictive model for identifying problem areas and extrapolating such findings across the region.

3. Add a field sampling component that measures bird response to pollutant stressors using nationally standardized protocols, such as:
    a. Birds of Forested Landscapes to determine presence and density of singing males of target species;
    b. Monitoring Avian Productivity and Survivorship (MAPS) to determine productivity and survivorship of target species.

4. Present findings at forums that include scientific and policy oriented outlets, including:
    a. Scientific conferences and journals;
    b. National policy arenas, such as the U.S. Senate's Environment and Public Works Committee.

5. Explore abilities to add this and similar Hg monitoring efforts to the national Hg monitoring plan.

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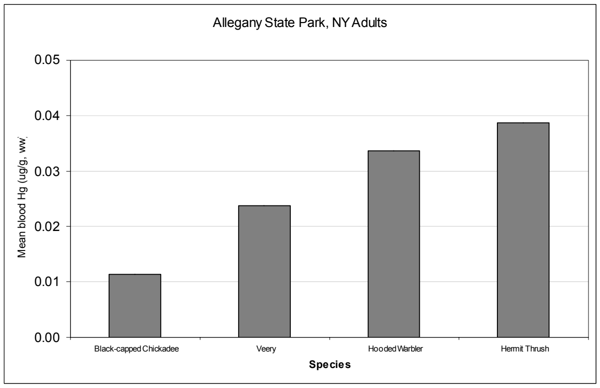
Appendix I. Samp
ling effort for soil, invertebrates, and birds in New York and Pennsylvania, 2005.

Location / Species	Sample Size	Invertebrates*	Soil	Location / Species	Sample Size	Invertebrates*	Soil
Allegany State Park, NY		1 sp, 2 c, 2 m	2	**IES**		none	0
Hermit Thrush	1			Wood Thrush	8		
Veery	4			Veery	1		
Louisiana Waterthrush	3			**Millbrook, NY**		none	0
Other songbirds	6			Hermit Thrush	2		
Belleayre, NY		2 sl, 4 ca	4	Wood Thrush	4		
Swainson's Thrush	1			Other Songbirds	5		
Black Rock Forest, NY		1 sp, 2 so, 2 m, 2 c	2	**Plateau Mountain, NY**		3 c, 4 ca, 2 sl, 3 b, 2 bl	4
Wood Thrush	2			Bicknell's Thrush	11		
Other songbirds	13			Hermit Thrush	5		
Brookfield Forest, NY		3 sp	2	Swainson's Thrush	9		
Veery	2			Other Songbirds	1		
Wood Thrush	2			**Shawangunk, NY**		3 sp, 3 c, 1 m, 1 gh	2
Other Songbirds	3			Hermit Thrush	1		
Devil's Tombstone, NY		4 sp, 1 m, 1 sl, 2 c, 2 cr	2	Other Songbirds	7		
American Robin	5			**Tott's Gap, PA**		1 sp, 1 c, 1 b	2
Veery	6			Wood Thrush	10		
Wood Thrush	6			Other Songbirds	12		
Louisiana Waterthrush	2			**Tug Hill, NY**		1 sp, 2 c, 1 m, 1 k	2
Other songbirds	21			Hermit Thrush	5		
Hunter Mountain West, NY		3 sp, 1 c	1	Swainson's Thrush	1		
American Robin	1			Other Songbirds	8		
Hermit Thrush	3			* b: beetle, bl: beetle larvae, c: centipede, ca: caterpillar, cr: cricket, gh: grasshopper, k: katydid, m: millipede, sl: slug, sn: snail, so: sowbug, sp: spider			
Wood Thrush	3						
Other Songbirds	4						

Appendix IIa.



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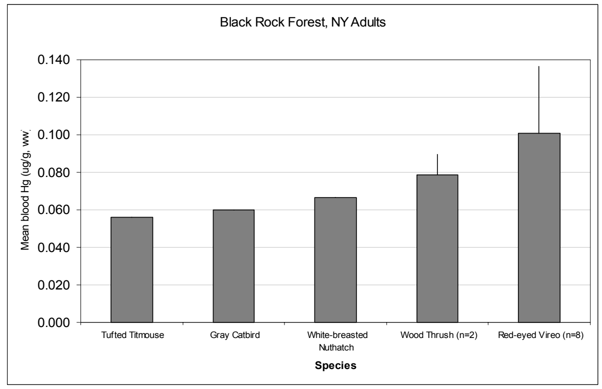

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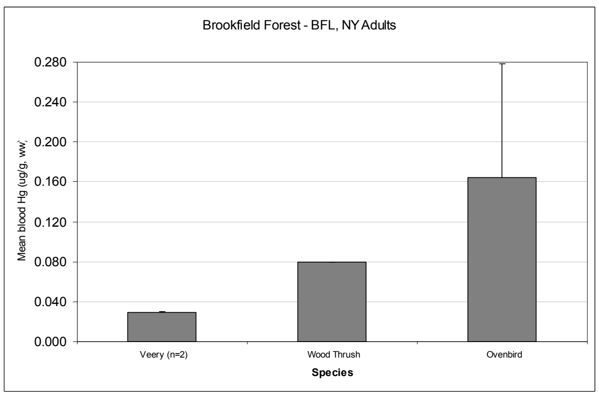

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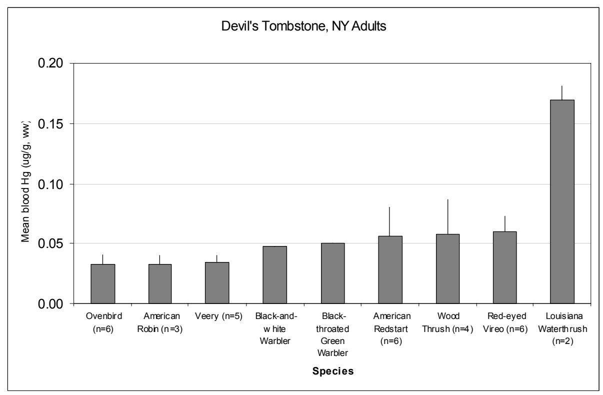

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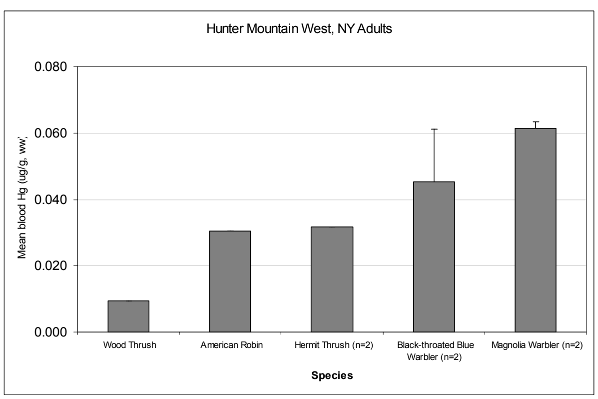

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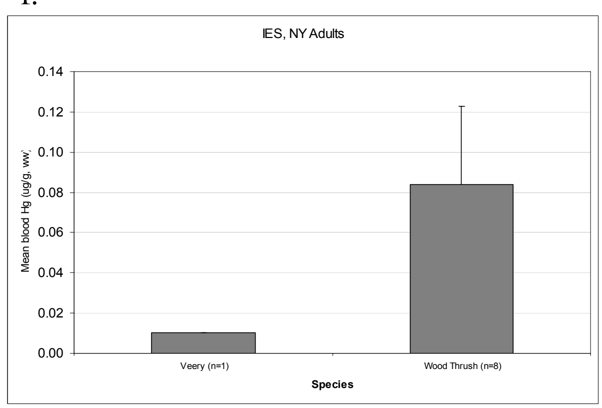
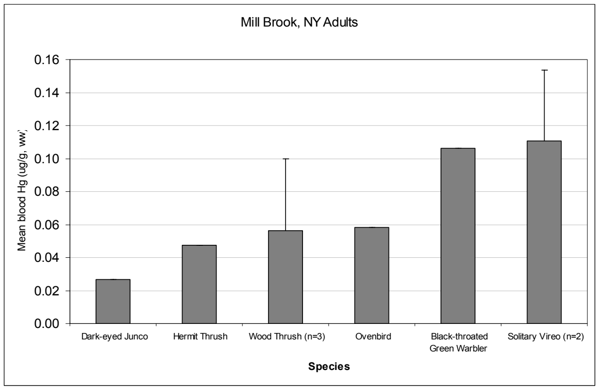


Appendix II, cont'd.

g.



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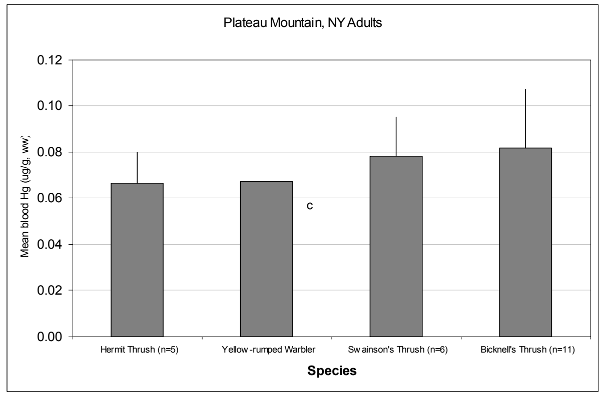

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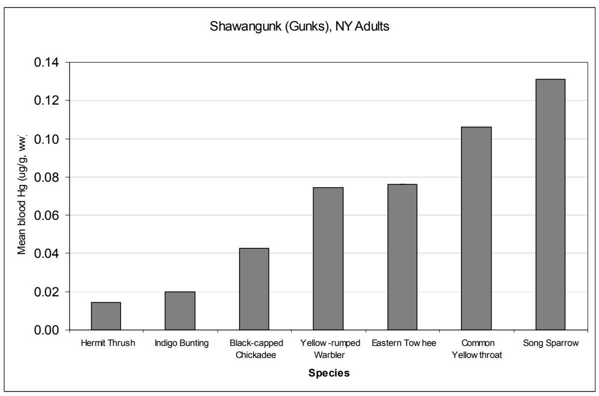

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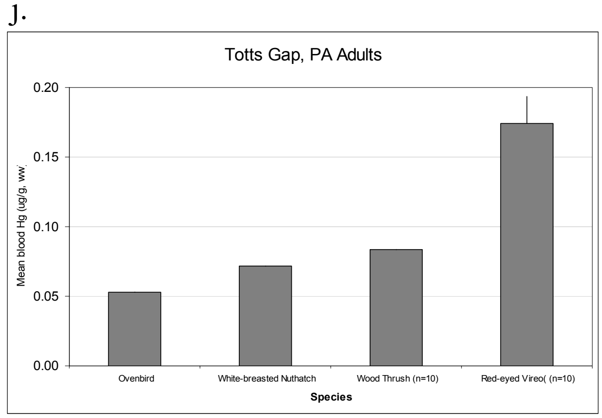

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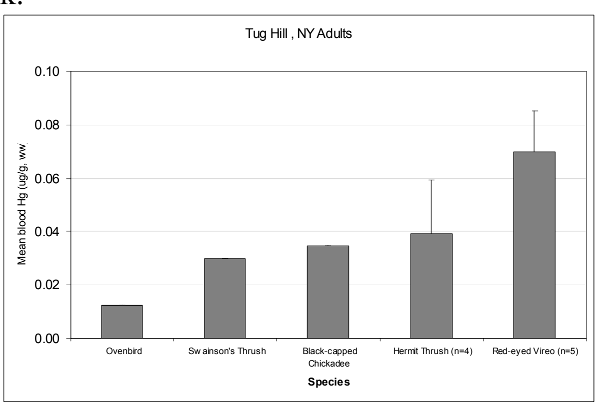
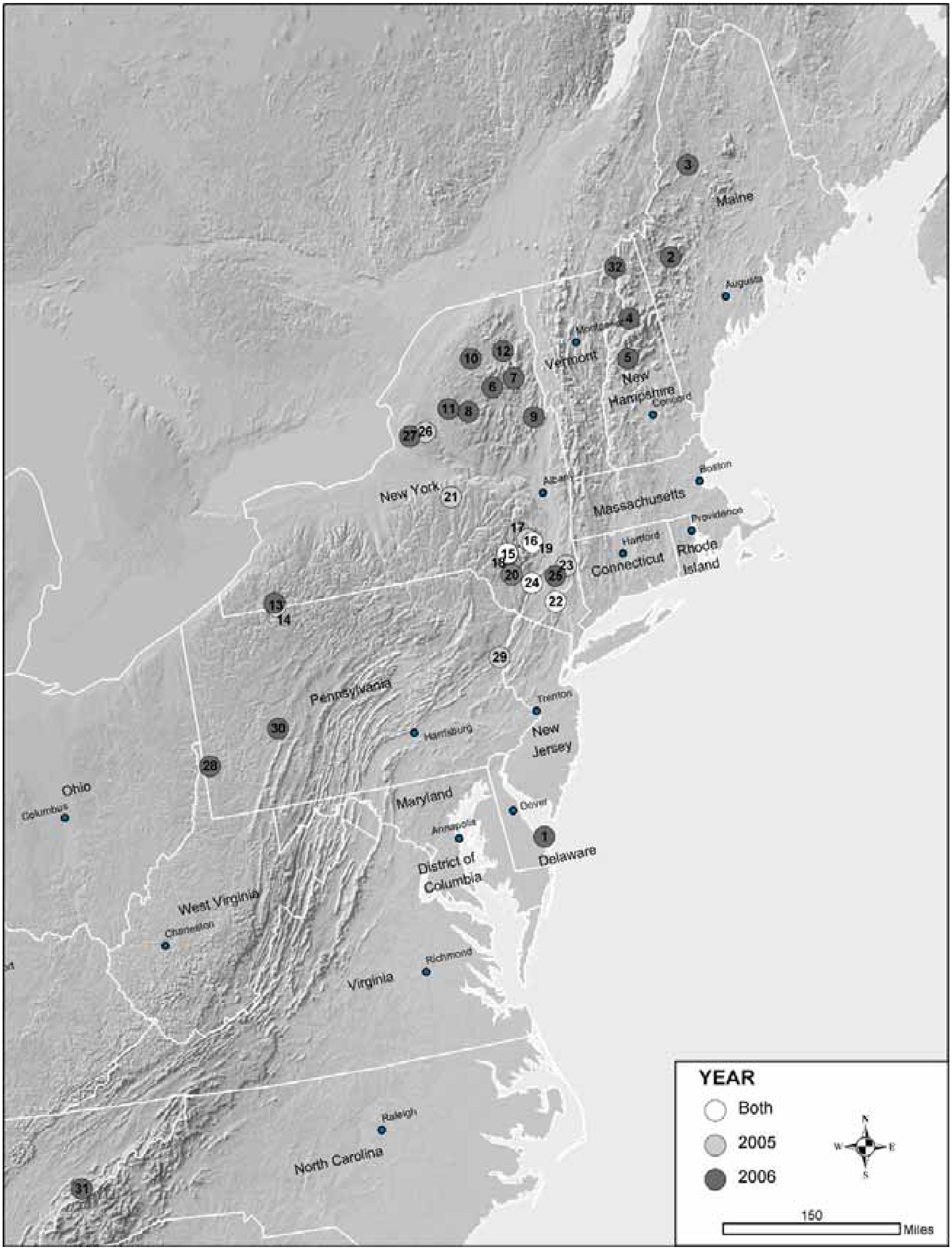


Appendix III. Probable locations of sampling stations in 2006.



Appendix III, cont'd. Probable locations of sampling stations in 2006.

Map Number	State	Region	Site	Latitude	Longitude	Sampling 2005	TNC Sampling 2006	NYSERDA Sampling 2006	BRI Sampling 2006	Target Species 2006 1=Thrush; 2=Rusty Blackbird; 3=Bat	Approx. Dates of Sampling
1	DE	northern DE	Univ. Delaware	38.785700	-75.101600				x	1	1 May-31 Jul
2	ME	western ME	Bigelow/Saddleback Mtns.	44.936700	-70.503100				x	1	1 Jul-1 Aug
3	ME	western ME	Seboomook Lake area	45.910600	-69.733700				x	2	1 Jun-12 Aug
4	NH	cental NH	Pondicherry NWR	44.377900	-71.525900				x	2	1 Jun-12 Aug
5	NH	central NH	Hubbard Brook Reserch For.	43.934500	-71.729600				x	1	2 Aug-5 Aug
6	NY	Adirondack Mtns	Arbutus Lake	43.988100	-74.241300			x		1,3	19 Jul-21 Jul[1] ; 14 Jun-15 Ju
7	NY	Adirondack Mtns	Elk Lake	44.031200	-73.829900		x			1	21 Jul-23 Jul
8	NY	Adirondack Mtns	Ferd's Bog	43.774400	-74.761500			x		2,3	17 Jul-19 Jul[2] ; 12 Jun-13 Ju
9	NY	Adirondack Mtns	Lake George - Dome Island	43.541500	-73.638700		x			1	24 Jul-26 Jul
10	NY	Adirondack Mtns	Spring Pond Bog	44.366300	-74.506700				x	2	8 Aug-10 Aug
11	NY	Adirondack Mtns	Sunday Pond	43.858400	-75.103800			x		1,3	6 Aug-8 Aug[1] ; 16 Jun-17 Ju
12	NY	Adirondack Mtns	Whiteface Mountain	44.365900	-73.902600			x		1	17 Jul-30 Jul
13	NY	Allegheny Plateau	Allegany State Park - north	42.029000	-78.813080	x	x			1	3 Jul-5 Jul
14	NY	Allegheny Plateau	Allegany State Park - south	42.057100	-78.828700		x			1	30 Jun-2 Jul
15	NY	Catskill Mtns.	Belleayre	42.067500	-74.645200	x				n/a	
16	NY	Catskill Mtns.	Devil's Tombstone	42.155400	-74.204300	x	x			1	19 Jun-21 Jun
17	NY	Catskill Mtns.	Hunter Mtn. - west	42.187400	-74.250200	x				n/a	
18	NY	Catskill Mtns.	Mill Brook	42.076840	-74.650060	x	x			1	10 Jun-12 Jun
19	NY	Catskill Mtns.	Plateau Mountain	42.137900	-74.174300	x	x			1	19 Jun-30 Jul
20	NY	Catskill Mtns.	Neversink Reservoir	41.830700	74.657500			x		1,3	14 Jun-16 Jun[1] ; 10 Jun-11 J
21	NY	central NY	Brookfield Forest - BFL	42.856200	-75.400100	x				n/a	
22	NY	Lower Hudson R. Valley	Black Rock Forest	41.408300	-74.021500	x	x			1,3	5 Jun-7 Jun[1] ; 6 Jun-7 Jun[3]
23	NY	Lower Hudson R. Valley	Institute of Ecosystem Studies	41.785100	-73.694000	x			x	1	15 May-15 Aug
24	NY	Lower Hudson R. Valley	Shawangunk Mountains	41.681200	-74.348200	x	x			1,3	8 Jun-10 Jun[1] ; 8 Jun-9 Jun[3]
25	NY	Lower Hudson R. Valley	Mohawk Valley	41.700400	-73.921000		x			1	11 Jun-13 Jun
26	NY	Tug Hill	Tug Hill - south	43.655840	-75.598980	x				n/a	
27	NY	Tug Hill	Tug Hill - west	43.644000	-75.888800		x			1	13 Jun-15 Jun
28	PA	southwestern PA	Powdermill Nature Reserve	40.329000	-80.409200				x	1	26 Jun-28 Jun
29	PA	eastern PA	Totts Gap	40.925660	-75.175160	x				n/a	
30	PA	mid Appalachian Mtns.	To be determined	40.621500	-79.152500				x	1	22 Jun-24 Jun
31	TN	s. Appalachian Mtns.	Great Smokey Mtn NP	35.689200	-83.526900				x	1	15 May-15 Aug
32	VT	northeastern VT	Northeast Kingdom	44.996200	-71.538400				x	2	15 May-15 Aug
		Total				12 sites	11 sites	5 sites	11 sites		

Appendix IV.

Common Name	**Latin Name**
Red-eyed Vireo	*Vireo olivaceus*
Blue-headed Vireo	*Vireo solitarius*
Black-capped Chickadee	*Poecile atricapilla*
Tufted Titmouse	*Baeolophus bicolor*
White-breasted Nuthatch	*Sitta carolinensis*
Swainson's Thrush	*Catharus ustulatus*
Veery	*Catharus fuscescens*
Bicknell's Thrush	*Catharus bicknelli*
Hermit Thrush	*Catharus guttatus*
Wood Thrush	*Hylocichla mustelina*
American Robin	*Turdus migratorius*
Gray Catbird	*Dumetella carolinensis*
Magnolia Warbler	*Dendroica magnolia*
Black-throated Blue Warbler	*Dendroica caerulescens*
Black-throated Green Warbler	*Dendroica virens*
Yellow-rumped Warbler	*Dendroica coronata*
Black-and-white Warbler	*Mniotilta varia*
American Redstart	*Setophaga ruticilla*
Common Yellowthroat	*Geothlypis trichas*
Louisiana Waterthrush	*Seiurus motacilla*
Ovenbird	*Seiurus aurocapillus*
Hooded Warbler	*Wilsonia citrina*
Indigo Bunting	*Passerina cyanea*
Eastern Towhee	*Pipilo erythrophthalmus*
Song Sparrow	*Melospiza melodia*
Dark-eyed Junco	*Junco hyemalis*