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MERCURY CONCENTRATIONS IN TROPICAL RESIDENT AND MIGRANT SONGBIRDS ON HISPANIOLA

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ABSTRACT

Despite growing concerns over mercury (Hg) exposure to humans and wildlife on a global scale, little is known about Hg bioaccumulation in the New World tropics. From 2005 to 2011, we monitored Hg concentrations in blood of nine avian species occupying a geographic range of tropical wet broadleaf sites on the island of Hispaniola, including eight passerines (two Nearctic-Neotropical migrant and six resident species) and one top order predatory accipiter. Invertivorous songbirds were further differentiated by foraging guild, with six species of ground-foragers and two species of foliage-gleaners. Blood Hg concentrations were orders of magnitude higher in birds sampled in central and southern cloud forest sites (1000 – 1800 m elevation) than in northern and northeastern rainforest sites (50 – 500 m elevation), with migratory and resident species both showing 2 – 20 X greater blood Hg concentrations in cloud forests than in rainforests. Within cloud forest sites, ground-foraging species had higher Hg concentrations than foliage-gleaning species. Top order predatory sharp-shinned hawks (*Accipiter striatus*) had the highest blood Hg concentrations among all species, suggesting that Hg biomagnification is occurring in terrestrial forests of Hispaniola. Two migrant songbird species overwintering on the island had higher blood Hg concentrations than have been recorded on their North American breeding grounds. Future studies should seek to elucidate sources of variation in atmospheric Hg deposition on Hispaniola and to quantify the dynamics of Hg cycling in tropical forest ecosystems, which may differ in important ways from patterns documented in temperate forest ecosystems.

KEYWORDS – Bicknell’s Thrush, Bioaccumulation, Biomagnification, Hispaniola, Mercury, Neotropical migrant, Tropical ecotoxicology

INTRODUCTION

Mercury (Hg) deposition, bioaccumulation and toxicity to wildlife and humans have been extensively studied in temperate regions of North America, Europe and Asia, yet little is known about Hg dynamics and trophic transfer in tropical ecosystems (Burger and Gochfeld 1997, Lacher and Goldstein 1997, Uryu et al. 2001). Although major sources of atmospheric Hg such as coal-burning power plants, incinerators, and concentrated large-scale industrial activity are not widespread in Latin America and the Caribbean, these areas may still be vulnerable to Hg deposition from global atmospheric transport (Montagnini et al. 1984, Lindberg et al. 2007) and highly localized sources such as cement factories (Fukuzaki et al. 1986), metal smelters (Pacyna and Pacyna 2002) and gold-mining operations (Tarras-Wahlberg et al. 2001). Despite increased awareness of Hg toxicity to humans (Mergler et al. 2007, Ashe 2012) and wildlife (Wolfe et al. 1998), and calls from the United Nations Environmental Program to better understand its global transport and local impacts (UNEP 2009), few data exist to identify and monitor regional patterns of Hg accumulation in the Neotropics (Lacher and Goldstein 1997, Evers 2008).

During the boreal winter, the avifauna of the Neotropics is composed of both resident and Nearctic-Neotropical migrant species. Blood samples taken from this diverse assemblage have the potential to reveal landscape-wide patterns of Hg deposition and trophic transfer (Rimmer et al. 2005, Shriver et al. 2006, Edmonds et al. 2010, Winder and Emslie 2011), and to help identify "hotspots" where elevated Hg concentrations threaten the health of human and wildlife populations (Evers et al. 2007). To date, there has been little to no monitoring of bioaccumulation in resident and endemic songbirds of the Neotropics and very little information exists on Hg concentrations in Nearctic-Neotropical migrant songbirds during the winter period. Although several studies have assessed Hg concentrations in migrant songbirds during their temperate breeding season (Rimmer et al. 2005, Shriver et al. 2006, Brasso and Cristol 2008, Jackson et al. 2011), it is important to monitor these species throughout their full life cycle in order to properly interpret time- and site-specific bioindicator values (Burger and Gochfeld 2001, Rimmer et al. 2009).

From 2005 to 2011, we collected blood samples for analysis of Hg concentrations from resident and migrant songbirds on Hispaniola, the Caribbean island politically divided between the Dominican Republic and Haiti. To our knowledge, this study provides the first documentation of Hg concentrations in migrant songbirds wintering in the tropics, and our assessment of Hg concentrations in resident species is among the first ecotoxicological studies conducted in the Caribbean region as a whole. We sampled across a range of sites and forest types, concentrating on low- to mid-elevation rainforest (50 – 500 m elevation) and high-elevation cloud forest (1000 – 1800 m elevation) in five distinct ecological regions of the island. We particularly focused on Bicknell's thrush (*Catharus bicknelli*), a Nearctic-Neotropical migrant of high conservation concern. The basic overwinter ecology and habitat preferences of this species have been studied extensively on Hispaniola (Townsend et al. 2010, Townsend et al. 2011) and we sought to compare winter Bicknell's thrush Hg concentrations with those previously reported from the breeding range (Rimmer et al. 2005, Rimmer et al. 2009) to understand Hg cycling throughout this species' annual cycle. Our primary goals in the present study were to 1) establish baseline Hg concentrations for eight species of migrant and resident songbirds occurring at sites across Hispaniola; 2) compare differences in Hg concentrations among resident and migrant species, foraging guilds and sites; and 3) compare winter Hg concentrations for Bicknell's thrush with known concentrations from the species' North American breeding grounds.

STUDY SITE AND METHODS

Field Methods – During the boreal winters of 2005-2011, we collected blood samples from avian species at a wide range of wet forest sites on Hispaniola as part of on-going ecological studies of the island's resident and migrant avifauna (Fig. 1; for detailed site descriptions see (Townsend et al. 2010, Townsend et al. 2011). Sampling was opportunistic at most sites, but intensive at two long-term focal sites, one in mid-elevation (350 – 500 m) rainforest of the Cordillera Septentrional situated along the northeastern coast of the island (hereafter "focal rainforest site"), and the other in high-elevation (>1200 m) cloud forest of the Sierra de Bahoruco located in the south-central area of the island (hereafter "focal cloud forest site"). Birds were captured in 6- and 12-m 36-mm mesh mist nets, both passively and by luring individuals via playback of conspecific vocalizations. Blood was collected from each bird (30 – 50 ul) in heparinized capillary tubes via brachial venipuncture using sterile 27-gauge hypodermic needles and maintained in sealed capillary tubes stored in a vacutainer. Blood was stored in a portable freezer in the field then maintained frozen in laboratory freezers until analysis.

Laboratory Methods – Blood was expressed from capillary tubes into nickel boats for total Hg analysis in a Milestone DMA 80 according to USEPA method 7473. In the DMA 80, samples were heated to 800^{o} C to vaporize Hg content. The vaporized Hg was then carried in a flow of oxygen gas to an amalgamator where a gas trap captured all Hg species present. The continuous flow of oxygen carried all other combusted molecules out of the amalgamated trap. Heating of the amalgamator then desorbed Hg from the trap and carried it to the spectrophotometer, where a Hg vapor lamp in a quartz cuvette irradiated all Hg present and transmitted results to a system controller where weight of sample and response relative to a calibration curve were calculated to produce a Hg concentration for the sample.

Quality assurance samples with each batch of ten blood samples included a method blank, an instrument blank, a duplicate, and reference to international standards including a continuing calibration verification sample (Mussel; SRM 2976, National Institute of Standards and Technology, Gathersburg, MD, USA) and a quality control sample (Seronorm; SRM 966 Toxic Levels in Bovine Blood Level 2, National Institute of Standards and Technology, Gathersburg, MD, USA). Mean percent recoveries of total Hg for SRM 2976 were 108.7 ± 1.2% (hereafter, mean ± 1 standard error [SE] of the mean; n = 44), and for SRM 966 were 106.6 ± 1.9% (n = 20). Mean relative percent difference between duplicate samples was 5.1% ± 1.1 (n = 38).

Statistical Analysis – For Bicknell's thrush, ovenbird (*Seirus aurocapilla*) and red-legged thrush (*Turdus plumbeus*) – three species that occurred at both the rainforest and cloud forest focal sites – we assess differences in Hg concentrations between these habitats by creating separate ANOVAs for each species with site and year as the predictor variables. At the cloud forest site, where we sampled from two distinct foraging guilds, we analyzed differences in Hg concentrations using ANOVA with species, foraging guild and year as predictor variables. Bicknell's thrush was the only species for which we were able to reliably determine age and sex. For the island-wide sample of Bicknell's thrush, we assessed the effect of sex, age and site on Hg concentrations in this species using ANOVA with site, age, sex, and the age X sex interaction as predictor variables. All data were log-transformed to meet the assumptions of the normal distribution. All blood Hg concentrations are reported as wet weight (ww) parts per million (mg/kg; ppm) ± 1 SE.

RESULTS

We sampled 365 individuals of nine species, including eight passerines (two migrants and six residents) and one resident accipiter, at 13 sites across the island of Hispaniola (Fig. 1a, Table 1). Three species were sampled from both the focal rainforest site and the focal cloud forest site: the resident red-legged thrush and the migrants ovenbird and Bicknell's thrush. All had significantly higher blood Hg concentrations at the cloud forest site than at the rainforest site (red-legged thrush $F = 66.17$, $P < 0.0001$; ovenbird $F = 78.01$, $P < 0.0001$; Bicknell's thrush $F = 587.86$, $P < 0.0001$; Fig. 2).

Within-site comparisons – At the rainforest site, blood Hg concentrations in red-legged thrushes, Bicknell's thrushes and ovenbirds were low (Fig. 2), although concentrations were significantly different between species ($F = 55.57$, $P < 0.0001$). Ovenbirds had greater mean blood Hg concentrations than the other two species and red-legged thrushes had greater concentrations than Bicknell's thrushes (Tukey's HSD). Year of sampling was not a significant predictor of blood Hg concentrations ($F = 0.17$, $P = 0.69$). At the cloud forest site, congeneric red-legged thrushes and La Selle thrushes (*Turdus swalesi*), both residents, had the highest Hg of all sampled species (Fig. 2).

Comparison of foraging guilds – At the cloud forest site (but not at the rainforest site) we captured birds from two distinct foraging guilds. Bicknell's thrush, ovenbird, LaSelle thrush, red-legged thrush, and western chat-tanager (*Calyptophilus tertius*), all ground-foraging species, had greater Hg concentrations than green-tailed ground warbler (*Microlegia palustris*) and white-winged warbler (*Xenoligea montana*), both foliage-gleaners ($F = 100.05$, $P < 0.0001$; Fig. 2). Year of sampling was not a significant predictor of blood Hg concentration at this site ($F = 0.28$, $P = 0.61$). Blood Hg concentrations in sharp-shinned hawks captured in cloud forest habitat were an order of magnitude higher than for most songbirds, with a mean concentration of 1.14 ppm ± 0.65 (SD) among five captures. One individual captured in rainforest habitat had a blood concentration of 0.46 ppm, less than half the mean concentration of cloud forest hawks.

Bicknell's thrush – We obtained more samples from Bicknell's thrush (n = 168) than from any other species. Sex ($F = 0.02$, $P = 0.9$) and age ($F = 2.47$, $P = 0.118$) were not significant predictors of blood Hg concentrations, but geographic location showed important effects. Bicknell's thrushes had significantly higher blood Hg concentrations in cloud forest sites, which primarily occur in central and southern areas, than in rainforest, gallery forest and mixed wet forest sites, which primarily occur in northern regions of the island ($F = 51.82$, $P < 0.0001$; Table 1, Fig. 1b). Birds wintering at cloud forest sites had higher blood Hg concentrations than did individuals breeding at sites in the Catskill Mountains of New York (Townsend 2011) and Green Mountains of Vermont (Rimmer et al. 2005); birds wintering at rainforest sites, however, had lower concentrations than breeding birds (Table 2).

DISCUSSION

This study is among the first published accounts of Hg bioaccumulation in forest-dwelling songbirds of the Neotropics (Rimmer et al. 2005, Evers 2008). Due to the general paucity of ecotoxicological data from tropical areas (Lacher and Goldstein 1997), our findings provide novel and valuable information to identify patterns of Hg bioaccumulation on Hispaniola. We identified a generally increasing pattern in avian blood Hg concentrations moving from low- and mid-elevation rainforest sites in the north and northeast of the island to high-elevation cloud forest sites in central and south-central regions (Fig 1b). Two focal sites for long-term studies were situated along this gradient, and for species occurring at both sites, concentrations were 2 – 20 X greater at the cloud forest than at the rainforest site.

We propose several potentially overlapping explanations for the large differences in Hg bioaccumulation between these sites; each requires further investigation. First, it seems likely that atmospheric Hg inputs vary considerably between lower elevation rainforest and high-elevation cloud forest sites. In general, Hg enters terrestrial forests via multiple pathways involving both wet (rainfall, throughfall, cloud drip) and dry (adsorption to leaf surfaces) atmospheric deposition (Weathers et al. 1995, Rea et al. 2001). Once deposited, residence time of Hg in forests is dependent on rates of litter-fall decomposition, potential for evasion, soil bacterial and fungal composition, and soil temperature and pH (Schroeder et al. 1989, Schwesig et al. 1999, Demers et al. 2007). At our sites in the Dominican Republic, sources of precipitation vary considerably. Northeastern rainforest sites receive moisture primarily in the form of heavy seasonal rainfall resulting from exposure to northeast trade winds, whereas southern cloud forest sites primarily receive convective cloud water precipitation, which probably originates from the Caribbean Sea. The implications for Hg inputs of these different precipitation regimes are difficult to identify in the absence of atmospheric monitoring, but our documentation of extreme differences in Hg concentrations suggests a strong need for such monitoring. It is possible that the pool of available atmospheric Hg for these forests is composed of globally-transported Hg ions combined with Hg released locally from cement factories and metal smelters (Fukuzaki et al. 1986, UNEP 2009). The higher elevations of our cloud forest sites relative to rainforest sites could also lead to more concentrated Hg deposition as a result of orographic effects and nearly year-round cloud precipitation, which frequently is Hg-enriched in comparison to rainfall (Lovett 1984, Weathers et al. 1995, Lawson et al. 2003). The relatively higher convective cloud heights in the tropics might also contribute to increased scavenging of oxidized Hg in the upper free troposphere, leading to greater deposition via cloud and fog drip (Lovett 1984, Weathers et al. 1995).

Dietary differences among birds at the two sites might also influence patterns of Hg bioaccumulation. Mercury exposure in songbirds results from dietary intake during the previous days or weeks, and thus reflects temporally immediate inputs from wintering sites (Hill et al. 2008, French et al. 2010). We previously identified site-specific differences in Bicknell's thrush diet, with heavy consumption of soft-bodied fruit at the focal rainforest site and reliance on leaf litter arthropods at the focal cloud forest site (Townsend et al. 2010). In terrestrial forests, the invertivore food web is a pathway of Hg biomagnification (Rimmer et al. 2009) and an invertebrate-heavy diet could, therefore, be expected to lead to greater Hg bioaccumulation than a primarily plant-based diet (Leady and Gottgens 2001). Both ovenbird and red-legged thrush, the other two species occurring at both rainforest and cloud forest sites, have flexible, omnivorous diets that can vary depending on site-specific resources, similar to Bicknell's thrush (Brown and Sherry 2006, Latta 2006). The differences in diet of birds between rainforest and cloud forest sites could be a contributing factor to the large site-based differences in avian blood Hg concentrations. For cloud forest sites, it is possible that the combination of greater atmospheric Hg inputs and an invertebrate-dominated diet accounts in large part for the elevated Hg concentrations in songbirds occupying this habitat.

Diet also appears to affect Hg concentration among birds of different foraging guilds. At the focal cloud forest site, white-winged warbler and green-tailed ground warbler, both small-bodied foliage-gleaners (Latta 2006), had significantly lower Hg concentrations than the predominantly ground-foraging Bicknell's thrush, ovenbird, red-legged thrush, western chat-tanager, and LaSelle thrush (Fig. 2). It is likely that ground-foraging species encounter greater numbers of predatory spiders and other higher trophic level arthropods than do foliage-gleaning birds that primarily come in contact with phytophagous insects (Rimmer et al. 2009). The higher trophic level arthropods consumed by ground-foragers are likely to contain higher concentrations of Hg, leading to greater biomagnification in avian blood samples, as has been shown in invertivore food webs of temperate forests (Cristol et al. 2008, Rimmer et al. 2009). The high Hg concentrations in predatory sharp-shinned hawks (mean 1.4 ppm) at the focal cloud forest site provide further evidence of biomagnification in this terrestrial food web. A single sharp-shinned hawk sampled at a rainforest site showed less than half the blood Hg concentration of individuals sampled at the cloud forest site, further supporting the system-wide differences in Hg bioaccumulation between these sites.

Our findings also highlight variations in blood Hg concentrations throughout the annual cycle of two migrant species. Blood Hg concentrations in wintering ovenbird and Bicknell's thrush exceeded the mean concentrations documented in these species on their breeding grounds (Table 2). This contrasts with findings from other studies that have sampled migrant birds on both their breeding and wintering grounds and generally found lower values during the winter period (Edmonds et al. 2010, Cristol et al. 2011). On the Bicknell's thrush breeding grounds, studies of seasonal patterns in blood Hg concentrations have identified early season peaks in Hg concentration as migrating birds arrived from wintering areas, followed by steady summer-long declines (Rimmer et al. 2005, Rimmer et al. 2009, Townsend 2011). It is possible that early breeding season concentrations reflect winter Hg burdens, and are not strictly related to breeding grounds Hg uptake *per se*. It is also possible that females returning from wintering sites with particularly elevated Hg concentrations could transfer these winter-accumulated toxins to their offspring hatched in relatively uncontaminated sites, a biological "vectoring" of Hg between sites separated by > 1000 km. Much further work is needed in this regard, but our data from this and previous studies (Rimmer et al. 2005, Rimmer et al. 2009, Townsend 2011) provide a starting point to understand Hg cycling throughout the annual cycle of a migratory songbird and to consider how Hg concentrations might adversely affect Bicknell's thrush at different times of year.

Data to assess blood Hg concentrations that could lead to adverse effects on free-living songbirds are sparse, but new information is rapidly emerging. Known effects among free-living songbirds include compromised immunocompetence (Hawley et al. 2009) and reductions in fecundity (Brasso and Cristol 2008). Avian reproduction is considered a particularly sensitive endpoint for Hg toxicity, and recent modeling work with a free-living invertivorous songbird, Carolina wren (*Thryothorus ludovicianus*), identified 0.7 ppm as a lower limit for adverse breeding effects (Jackson et al. 2011). Blood Hg concentrations of four individuals analyzed in this study (one Bicknell's thrush, two red-legged thrush, and one La Selle thrush) exceeded this threshold, and all of these were sampled at high elevation cloud forest sites. Further studies should measure the extent to which nestlings of species breeding on Hispaniola are exposed to a high-Hg diet and seek to quantify any potential fitness impacts.

SUMMARY AND CONCLUSIONS

In summary, tropical areas are generally under-represented in Hg monitoring programs, and this study provides a starting point for assessing the region-wide accumulation of Hg in the Greater Antilles. We used a suite of resident and migrant songbirds as bioindicators to reveal the presence of Hg in Hispaniolan tropical broadleaf forests remote from any known point sources of contamination. Mercury bioaccumulation and biomagnification varied with geography and feeding guild, suggesting the importance of local weather events to Hg deposition and of food web dynamics to subsequent trophic bioaccumulation. Two migratory songbird species occurring in high elevation cloud forest habitat had blood Hg concentrations that were higher than those recorded on their North American breeding grounds. Sources of bioavailable Hg in Hispaniolan tropical forests have yet to be identified and will require further investigations into local and regional point sources, atmospheric Hg pools, weather patterns, and cycling of Hg through the unique decomposition processes of tropical forests. Such data would help to inform United Nations' plans to reduce sources and levels of Hg exposure on a global scale (UNEP 2009), and they could catalyze further Hg contamination monitoring and remediation efforts throughout the New World tropics.

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FIGURE LEGENDS

Figure 1. a) Locations on the island of Hispaniola where avian species were sampled to determine blood Hg concentrations and b) geometric means of blood Hg concentrations for the migrants Bicknell's thrush (*black bars*) and ovenbird (*gray bars*), and the resident Red-legged thrush (*white bars*). Error bars are ± 1 SE. Each number represents a sampling location described in Table 1.

Figure 2. Geometric means of blood Hg concentrations for invertivorous songbird species occupying cloud forest and rainforest on Hispaniola. Error bars are ± 1 SE.

TABLE LEGENDS

Table 1. Location of sampling sites on the island of Hispaniola and mean blood Hg concentrations (ppm) for eight songbird species and one species of accipiter. BITH = Bicknell's thrush, OVEN = ovenbird, RLTH = red-legged thrush, LATH = LaSelle's thrush, WCHT = western chat-tanager, ECHT = eastern chat-tanager, GTGW = green-tailed ground warbler, WWWA = white-winged warbler, SSHA = sharp-shinned hawk.

Table 2. Mean blood Hg concentrations (ppm, wet weight) for two Nearctic-Neotropical migratory songbird species at wintering sites in the Dominican Republic and breeding sites in northeastern North America. Wintering sites include high-elevation cloud forest in the central and southern regions of the Dominican Republic and low- and mid-elevation rainforest in the north. Breeding sites include spruce-fir montane forest of New York and Vermont, USA for Bicknell's Thrush and mixed-deciduous forest of Pennsylvania and New York, USA for Ovenbird.

Table 1. Tukey's pair-wise comparison of Bicknell's thrush (*Catharus bicknelli*) blood Hg concentrations ($F = 96.9$; $P < 0.0001$) from five wintering regions in the Dominican Republic and one breeding region in the Catskill Mountains, New York, USA.

Regional comparison	Difference between least-square means	Magnitude of difference between geometric means
Central cloud forest > gallery forest	1.55	4.6x
Central cloud forest > northern rainforest	1.26	3.4x
Central cloud forest > mixed wet forest S. Martin Garcia	0.91	2.5x
Central cloud forest > Catskill Mountains, New York	0.36	1.4x
Southern cloud forest > gallery forest	1.52	4.6x
Southern cloud forest > northern rainforest	1.24	3.5x
Southern cloud forest > mixed wet forest S. Martin Garcia	0.36	2.5x
Southern cloud forest > Catskill Mountains, New York	0.33	1.4x
Catskill Mountains, New York > gallery forest	1.19	3.4x

Catskill Mountains, New York > northern rainforest	2.07	1.8x
Catskill Mountains, New York > mixed wet forest S. Martin Garcia	1.27	1.4x

Table 2. Mean blood Hg concentrations (ppm, wet weight) for two Nearctic-Neotropical migratory songbird species at wintering sites in the Dominican Republic and breeding sites in northeastern North America. Wintering sites include high-elevation cloud forest in the central and southern regions of the Dominican Republic, while breeding sites are spruce-fir montane forest and mixed-deciduous forest.

	Blood Hg concentration (sample size)		
Species	Winter cloud forest	Winter rainforest	Summer temperate
Bicknell's Thrush	0.245 ± 0.015 (132)	0.013 ± 0.001 (36)	0.107 ± 0.005 (77)*
Ovenbird	0.179 ± 0.016 (40)	0.063 ± 0.006 (41)	0.050 ± 0.050 (27)**

*from Townsend (2011)
**from Evers and Duron (2009)

Figure 1. Locations on the island of Hispaniola where avian species were sampled to determine blood Hg concentrations. Each number represents a sampling location which is more fully described in Table S1. * = focal study site.

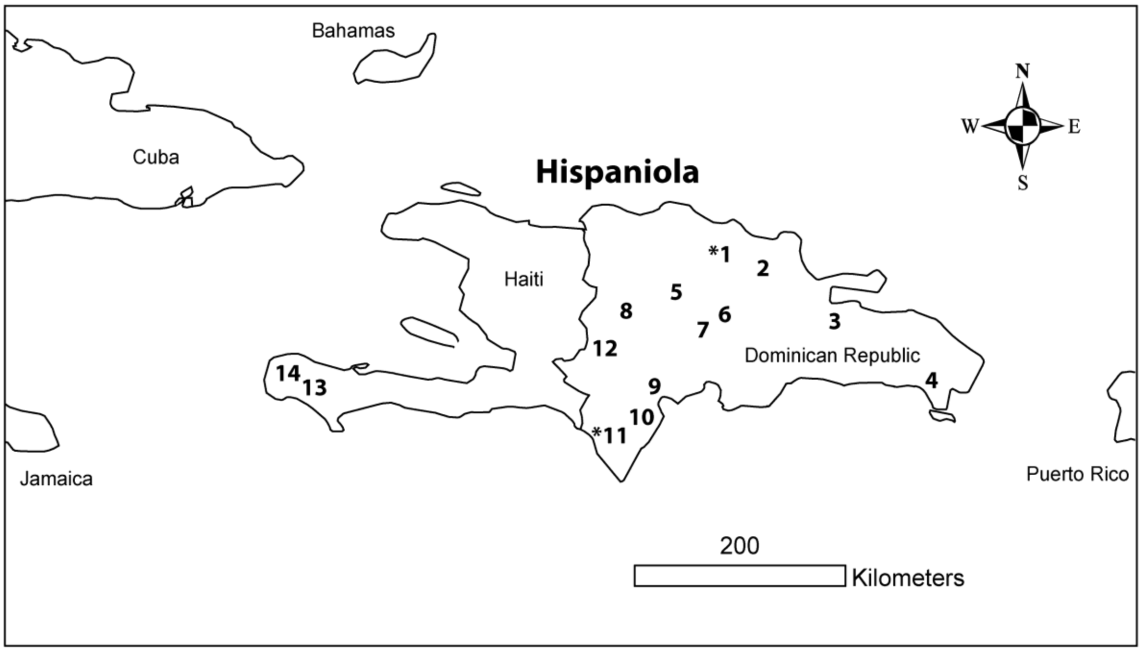

Figure 2. Log-transformed blood Hg concentrations for three songbird species that occurred in both cloud forest and rainforest sites in the Dominican Republic. Red-legged thrush is a resident species. Ovenbird and Bicknell's thrush are migrant species. Boxes bound the upper and lower quartiles, bars spanning the boxes represent the median, dashes represent the mean, and range bars display the maximum and minimum values.

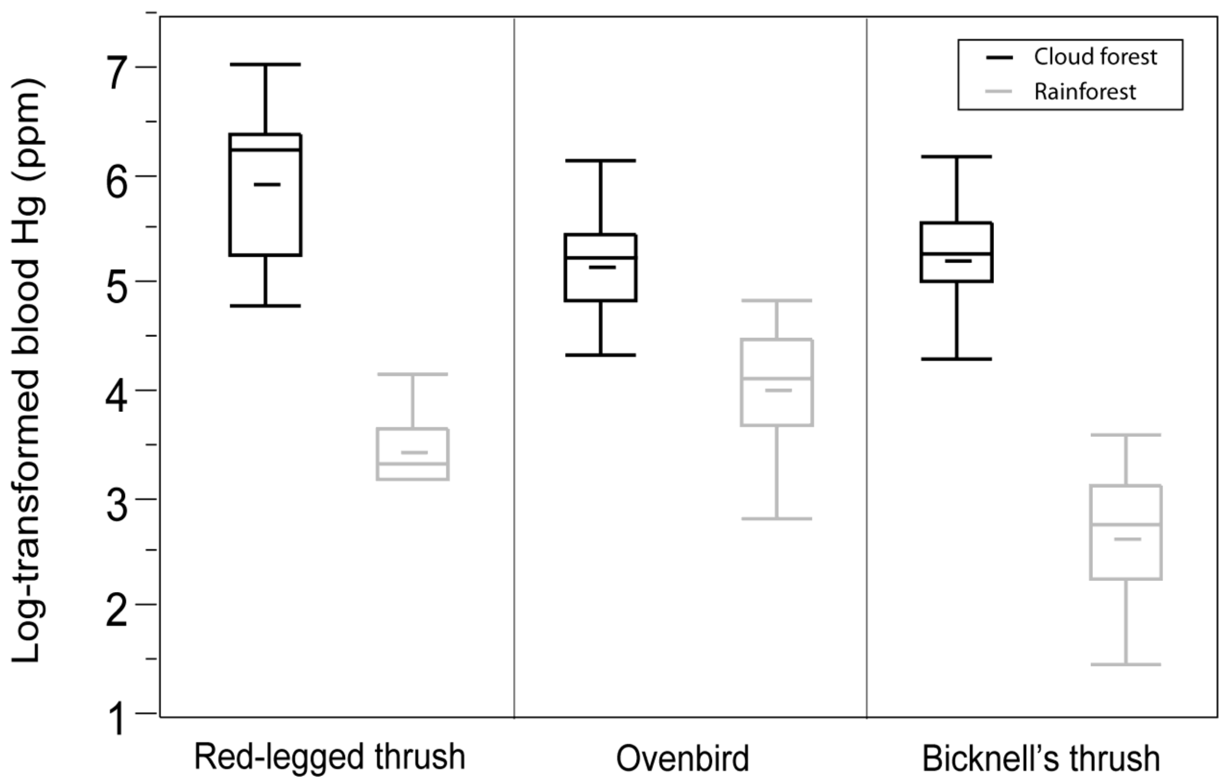

Figure 3. Mean and range of blood Hg concentrations for invertivorous songbird species on Hispaniola. The dashed line at 0.2 ppm represents background values in forest songbirds of temperate forests and the line at 0.7 ppm delineates a lower adverse effect limit for breeding effects in songbirds. Numbers above the dashed threshold lines and to the right of a species' range bar represent the number of individuals exceeding each threshold level. BITH = Bicknell's thrush, OVEN = ovenbird, LATH = LaSelle's thrush, RLTH = red-legged thrush, WCHT = western chat-tanager, GTGW = green-tailed ground warbler, WWWA = white-winged warbler.

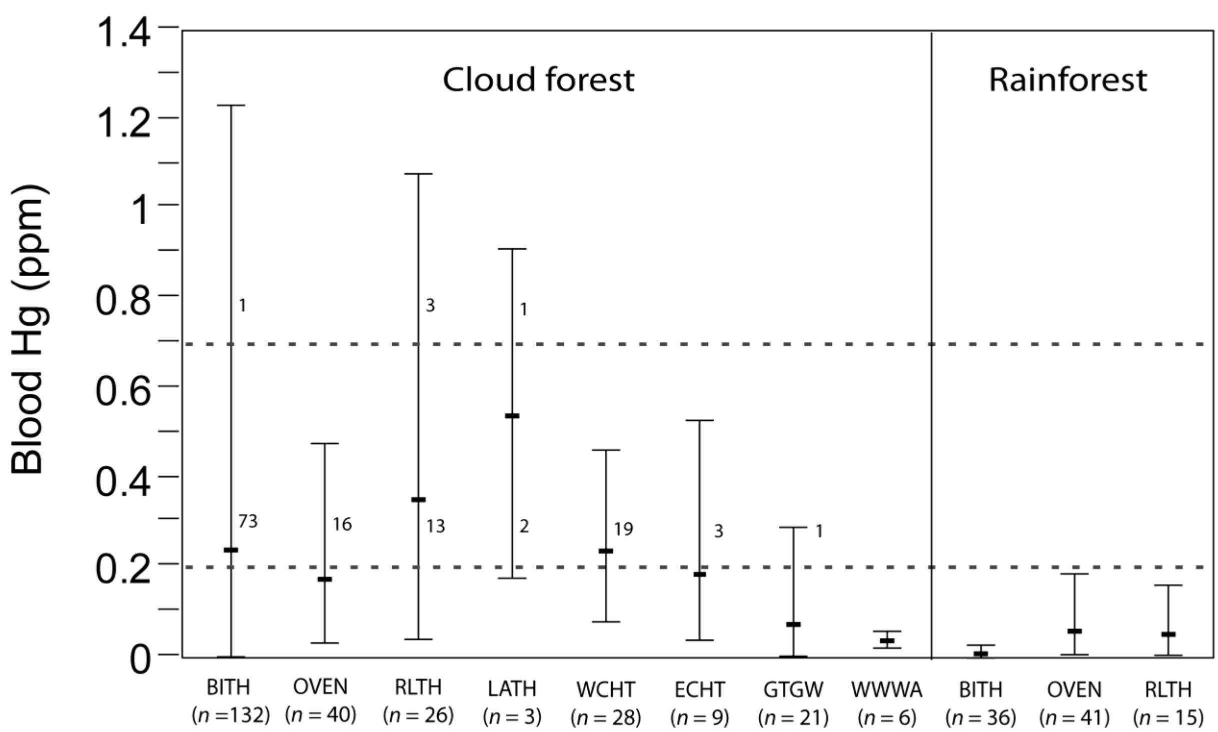

Figure 4. Log-transformed blood Hg concentrations for seven species of invertivorous songbirds occurring at a cloud forest site in the Sierra de Bahoruco, Dominican Republic, five of which are ground-foragers and two of which are foliage-gleaners. Bicknell's thrush and ovenbird are migrant species, whereas the others are resident species. Boxes show the upper and lower quartiles, bars spanning the boxes represent the median, dashes represent the mean, and range bars display the maximum and minimum values.

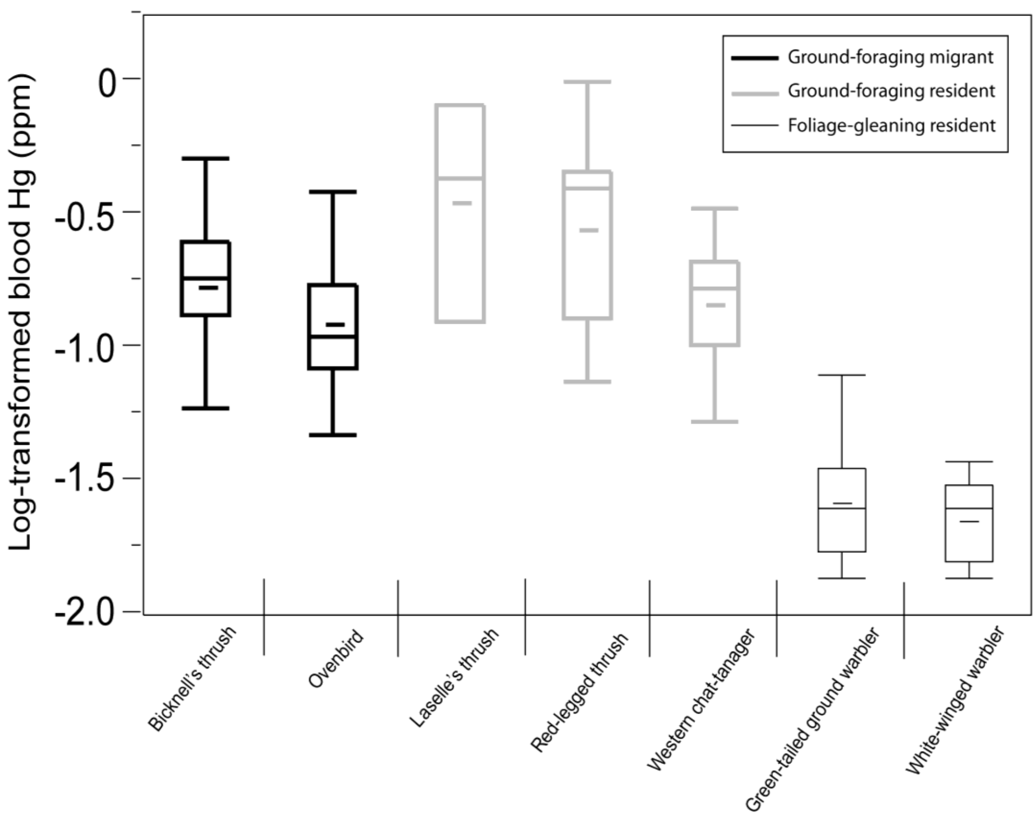

Table S1 (Appendix 1). Location of sampling sites on the island of Hispaniola and mean blood Hg concentrations (ppm). BITH = Bicknell’s thrush, OVEN = ovenbird, RLTH = red-legged thrush, LATH = LaSelle’s thrush, WCHT = western chat-tanager, ECHT = eastern chat-tanager, GTGW = green-tailed ground warbler, WWWA = white-winged warbler, SSHA = sharp-shinned hawk.

Map #	Site	Region	Habitat	Blood Hg concentrations by species								
				BITH	OVEN	RLTH	LATH	WCHT	ECHT	GTGW	WWWA	SSHA
1	Canela	North	Rain-forest	0.014 ± 0.001 (29)	0.064 ± 0.006 (25)	0.032 ± 0.006 (6)						
2	Guaconejo	North	Rain-forest	0.009 ± 0.001 (2)								
3	Bosque Humedo	Northeast	Rain-forest	0.012 ± 0.002 (2)	0.072 ± 0.014 (13)	0.090 ± 0.022 (7)						
4	Parque Nacional del Este	Southeast	Semi-humid scrub		0.122 ± 0.059 (7)							
5	Cienega	Central	Gallery forest	0.006 ± 0.001 (3)	0.018 ± 0.004 (3)	0.011 ± 0.001 (2)				0.008 (1)		0.459 (1)
6	Ebano Verde	Central	Cloud forest	0.438 ± 0.118	0.343 (1)				0.534 (1)	0.07 (1)		

				(4)								
7	Valle Nuevo	Central	Cloud forest	0.314 ± 0.076 (3)					0.308 (1)	0.085 ± 0.013 (3)		
8	Valvacoa	Central	Cloud forest	0.092 ± 0.007 (3)						0.029 (1)		
8	Rio Limpio	Central		0.023 (1)		0.133 ± 0.054 (3)						
9	SMG	South	Mixed wet forest	0.045 ± 0.018 (10)	0.186 (1)				0.212 (1)	0.043 (1)		
10	Cachote	South	Cloud forest	0.026 ± 0.011 (5)	0.053 ± 0.009 (6)	0.047 (1)			0.127 ± 0.027 (6)			
11	Pueblo Viejo	South	Cloud Forest	0.268 ± 0.012 (101)	0.199 ± 0.017 (30)	0.453 ± 0.069 (17)	0.544 ± 0.082 (3)	0.226 ± 0.018 (25)		0.050 ± 0.009 (10)	0.043 ± 0.005 (6)	1.144 ± 0.021 (4)
12	Las Nueces	South		0.519 ± 0.360 (3)	0.298 (1)	0.530 (1)				0.187 ± 0.056 (4)		
13	Rok Bwa	Southwest	Cloud forest	0.036 (1)	0.064 (1)	0.078 ± 0.026 (3)		0.384 ± 0.054 (3)				
14	Pic Formon	Southwest	Cloud forest	0.094 (1)		0.372 (1)						