The Movement of Aquatic Mercury Through Terrestrial Food Webs

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Mercury is a persistent contaminant that biomagnifies up the food web, causing mortality, reproductive failure, and other health effects in predatory wildlife and humans (*1*, *2*). From 1930 to 1950, industrial mercuric sulfate entered the South River, a tributary of the Shenandoah River in Virginia (United States) (*3*). To determine whether this mercury contamination had moved into the adjacent terrestrial food web, we analyzed total mercury concentrations in blood from adults of 13 terrestrial-feeding bird species breeding within 50 m of the river (*4*). We compared these to breeding adults of the same species at uncontaminated reference sites (Fig. 1A). Twelve species had significantly higher mercury than that found in individuals from reference sites (Fig. 1B and table S1). We simultaneously sampled adults of five bird species with direct dietary connections to the aquatic mercury; their mercury concentrations were also significantly elevated relative to reference birds (Fig. 1B and table S1). With the exception of a duck species, all aquatic birds had blood mercury ranging from 2 to 4 parts per million (ppm) (wet weight), about the level of adverse effects (*5*). Two terrestrial songbirds species, a wren and a vireo, had the highest blood mercury levels of any species, and a majority of terrestrial-feeding birds were in the same range as aquatic-feeding species.

We simultaneously sampled feathers of three nonmigratory terrestrial species that had molted locally about a year earlier. Whereas blood mercury reflects recent dietary intake, feathers indicate cumulative exposure; mercury can only enter feathers while they are growing and connected to the blood supply. Wrens (*Thyrothorus ludovicianus*) averaged 8.76 ± 6.46 (SD) ppm (n = 6), compared with 5.63 ± 2.12 ppm for owls (n = 5) and 2.38 ± 1.31 ppm for woodpeckers (n = 10), all about twice the level of blood mercury.

We collected prey delivered to nestlings of three songbird species at all of the contaminated study sites. None of the diet items was aquatic in origin. The most prevalent items in all three bird species' diets were members of the orders Araneae (spiders), Lepidoptera (moths or caterpillars), and Orthopterae (grasshoppers). Together these comprised >80% of the biomass (fresh weight) delivered to nestlings (Fig. 1C). All three terrestrial birds ate diets of ~20 to 30% spider biomass. Average total mercury concentration in spiders (n = 101) was 1.24 ± 1.47 ppm dry weight, compared with only 0.38 ± 2.08 ppm for lepidopterans (n = 137) and 0.31 ± 1.22 ppm for orthopterans (n = 50). Invertebrates collected similarly on reference sites contained negligible mercury (spiders, 0.05 ± 0.03 ppm, n = 25; lepidopterans, 0.02 ± 0.64 ppm, n = 20; orthopterans, all below detection limit, n = 6).

Much of the mercury in the spiders was in the form of highly bioavailable methylmercury (49 ± 21%, n = 30), whereas invertebrates lower in the food web had less methylmercury (lepidopterans 24 ± 20%, n = 22; orthopterans 38 ± 24%, n = 35), consistent with other reports (*6*). The spiders at our study site had higher total mercury than fish collected from kingfishers at the site (contaminated fish 0.73 ± 1.76 ppm dry weight, n = 21; reference fish, 0.15 ± 0.09 ppm, n = 18), consistent with our observation that some terrestrial songbirds had higher mercury levels than fish-eating kingfishers.

These results show that any risk from mercury faced by the river's aquatic birds exists for birds in adjacent terrestrial habitats as well. By preying on predatory invertebrates such as spiders, songbirds increased the length of their food chains, increasing the opportunity for biomagnification. To assess the potential risk of aquatic mercury moving into terrestrial food webs, it is imperative to determine whether the methylmercury we observed in predatory invertebrates was transported directly to the terrestrial food web by emergent aquatic insects or had been deposited on the floodplain during historical floods.

References and Notes

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Supporting Online Material

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Materials and Methods
Table S1
References

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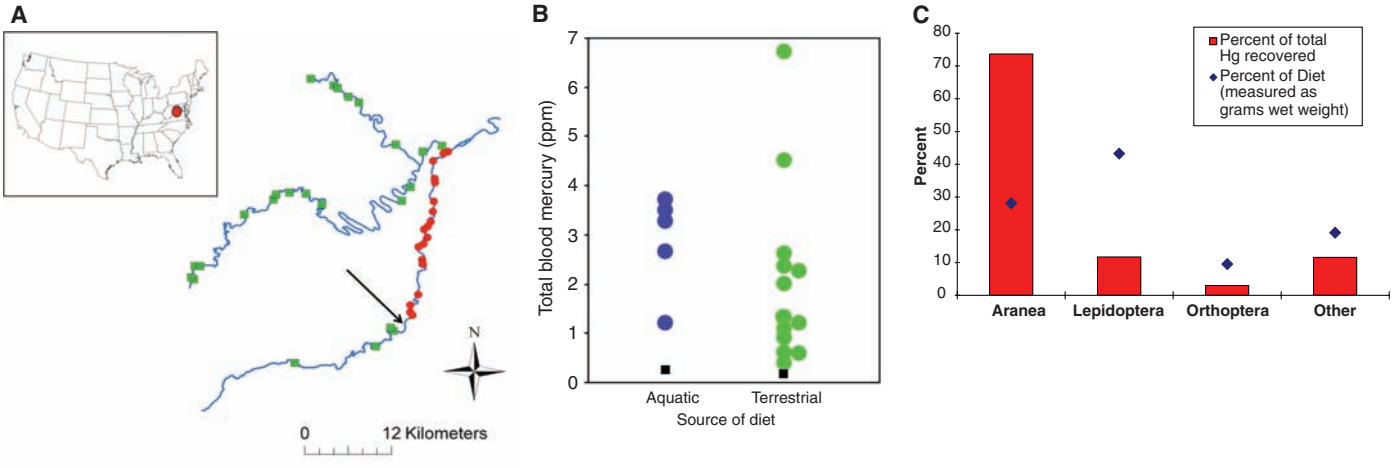

Fig. 1. (**A**) Map of study sites in which red circles indicate contaminated collection sites and green squares indicate uncontaminated sites. Arrow indicates mercury source. (**B**) Mean blood mercury for bird species primarily feeding on aquatic (blue) or terrestrial (green) organisms. Black squares are average mercury levels for same species at reference sites. (**C**) Percentage of diet composed of each prey type (blue diamonds) and mercury intake (red bars) for two wren species.