

HG-CONTAMINATED TERRESTRIAL SPIDERS POSE A POTENTIAL RISK TO
SONGBIRDS AT CADDO LAKE (TEXAS/LOUISIANA, USA)GRETCHEN L. GANN,[†] CLEVELAND H. POWELL,[‡] MATTHEW M. CHUMCHAL,^{*†} and RAY W. DRENNER[†][†]Biology Department, Texas Christian University, Fort Worth, Texas, USA[‡]School of Geology, Energy and the Environment, Texas Christian University, Fort Worth, Texas, USA

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Abstract: Methylmercury (MeHg) is an environmental contaminant that can have adverse effects on wildlife. Because MeHg is produced by bacteria in aquatic ecosystems, studies of MeHg contamination of food webs historically have focused on aquatic organisms. However, recent studies have shown that terrestrial organisms such as songbirds can be contaminated with MeHg by feeding on MeHg-contaminated spiders. In the present study, the authors examined the risk that MeHg-contaminated terrestrial long-jawed orb weaver spiders (*Tetragnatha* sp.) pose to songbirds at Caddo Lake (Texas/Louisiana, USA). Methylmercury concentrations in spiders were significantly different in river, wetland, and open-water habitats. The authors calculated spider-based wildlife values (the minimum spider MeHg concentrations causing physiologically significant doses in consumers) to assess exposure risks for arachnivorous birds. Methylmercury concentrations in spiders exceeded wildlife values for Carolina chickadee (*Poecile carolinensis*) nestlings, with the highest risk in the river habitat. The present study indicates that MeHg concentrations in terrestrial spiders vary with habitat and can pose a threat to small-bodied nestling birds that consume large amounts of spiders at Caddo Lake. This MeHg threat to songbirds may not be unique to Caddo Lake and may extend throughout the southeastern United States. *Environ Toxicol Chem* 2015;34:303–306.
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INTRODUCTION

Methylmercury (MeHg) is an environmental contaminant that can have adverse effects on wildlife [1]. Most mercury (Hg) in the environment originates from anthropogenic sources that release Hg into the atmosphere [2], but Hg can also be discharged directly into water bodies from industrial sources [3]. Inorganic Hg deposited from the atmosphere or discharged from industrial sources into aquatic systems is converted to MeHg by bacteria [2]. Methylmercury enters the food chain and biomagnifies, reaching high concentrations in predators [4]. Because inorganic Hg is converted to MeHg primarily in aquatic ecosystems, studies of MeHg contamination of food webs historically have focused on aquatic organisms. However, recent studies have found that terrestrial organisms such as songbirds can be contaminated with MeHg [5–8]. At the South River (VA, USA), a site contaminated by industrial discharge into the river, Cristol et al. [6] found that songbirds could be exposed to MeHg by feeding on MeHg-contaminated spiders. No studies have investigated whether MeHg-contaminated spiders pose a risk to arachnivorous birds at sites polluted with atmospheric Hg.

In the present study, we examined the risk that MeHg-contaminated terrestrial spiders pose to songbirds at Caddo Lake (TX and LA, USA). Caddo Lake is a large river–wetland–lake complex [9] that is contaminated with Hg from the atmosphere [10]. Because MeHg contamination of the food chain in Caddo Lake varies spatially, with highest and lowest levels in the wetland and open-water habitats, respectively [11,12], we hypothesized that MeHg contamination of terrestrial spiders and the risk they pose to birds would vary between

habitats. To test this hypothesis, we collected long-jawed orb weaver spiders (*Tetragnatha* sp.) from different habitats of Caddo Lake and determined if the MeHg concentrations in these spiders were high enough to pose a risk to songbirds. Long-jawed orb weaver spiders are predators that can become contaminated with high concentrations of MeHg by feeding on small-bodied emergent aquatic insects such as chironomids [13,14]. Several investigators have proposed using the long-jawed orb weaver spider as an indicator species for monitoring sites polluted with biomagnifying contaminants (e.g., polychlorinated biphenyls, MeHg) [13,15,16].

METHODS

Study site

Caddo Lake and its associated wetlands are located on the border of Texas and Louisiana and cover 10 850 hectares [9]. The western portion of the lake is a relatively shallow forested wetland dominated by bald cypress (*Taxodium distichum*) and water elm (*Planera aquatica*) [17], and it receives riverine inflows from Big Cypress Bayou. The eastern portion of the lake is primarily open-water habitat [18]. Forested wetlands with diverse habitat types (e.g., river, wetland, and open-water habitats) such as Caddo Lake occur throughout the southeastern United States [19].

Elevated concentrations of Hg have been found in aquatic invertebrates, fish, snakes, and piscivorous birds from Caddo Lake [11,12,20–24]. Mercury contamination in Caddo Lake is of particular concern because the lake supports a high level of biodiversity, including rare and threatened species [9], which may be negatively impacted by MeHg exposure [23].

Spider collection

Spiders were collected from 56 sites ($n = 17, 22,$ and 17 sites from river, wetland, and open-water habitats, respectively) from

All Supplemental Data may be found in the online version of this article.

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20 May to 19 June 2013 (Supplemental Data, Figure S1). Individual spiders were collected from trees, emergent aquatic vegetation, and docks with nets and by hand and immediately preserved in 95% nondenatured ethanol. We collected 14.0 ± 6.9 (average \pm standard deviation) spiders at each sampling site. Prior to Hg analysis, spiders were dried at 60 °C for 48 h and homogenized to a fine powder using a ball-mill grinder.

Hg analysis

We determined total Hg concentrations in composite samples of spiders from each site using a Milestone Direct Hg Analyzer, which uses thermal decomposition, gold amalgamation, and atomic absorption spectroscopy [25]. Quality assurance included reference (National Research Council of Canada Institute for National Measurement Standards) and duplicate samples. Reference samples (DORM-2) were analyzed approximately every 10 samples, and the average percentage of recovery was $101 \pm 1.48\%$ (range, 99.3–104%; $n = 27$). Duplicate samples were analyzed approximately every 20 samples, and the average relative percent difference was $1.68 \pm 1.55\%$ (range, 0.07–5.95%; $n = 18$). The limit of detection was 0.39 ng of Hg (i.e., 13 ng/g based on a typical sample weight of 0.03 g). All samples were above the limit of detection.

We estimated MeHg concentrations in spiders from total Hg. Using data collected in conjunction with a previous study [13], we determined that 70.8% of total Hg (inorganic Hg + MeHg) in long-jawed orb weaver spiders was MeHg (Supplemental Data). In the present study, total Hg was converted to MeHg by multiplying total Hg by 0.708.

In the present study, MeHg data are presented on a wet weight basis. Total Hg concentrations were initially determined on dried spider tissue. Using a supplemental sample of long-jawed orb weaver spiders, we determined that water accounts for 69.4% of the body weight of spiders (Supplemental Data). Therefore, we estimated wet weight MeHg concentrations by dividing dry weight MeHg concentrations by a conversion factor of 3.27 to account for weight change as a result of water loss.

Method for calculating spider-based avian wildlife values for MeHg and risk to songbirds

Spider-based avian wildlife values were calculated to assess the exposure risk for arachnivorous birds at Caddo Lake using methods modified from the US Environmental Protection Agency (USEPA) [26], Lazorchak et al. [27], and Walters et al. [15] (Supplemental Data). Spider-based avian wildlife values reflect the minimum MeHg concentrations in spiders, consumed by birds in normal proportions of total diet, required to create physiologically significant doses [15,26]. A lower wildlife value is associated with a higher sensitivity of birds to consumption of MeHg-contaminated spiders [15].

Wildlife values were developed for 1-d-old and 12-d-old Carolina chickadees (*Poecile carolinensis*) and adult Carolina wrens (*Thryothorus ludovicianus*), eastern bluebirds (*Sialia sialis*), and American robins (*Turdus migratorius*). We used these 4 species of birds because they are year-round residents of the Caddo Lake region [28], and Walters et al. [15] presented life-history data that we could use to compute their wildlife values (Supplemental Data, Table S1). These species could be considered surrogates for other small passerine birds with similar levels of spider consumption and ingestion rates.

Following the approach of Walters et al. [15], we compared avian wildlife values with spider MeHg concentrations to assess

the relative risk to birds consuming spiders. In the present study, long-jawed orb weaver spiders were used as a proxy for all spider taxa consumed by birds. During the present study we observed 2 species of songbirds feeding on long-jawed orb weaver spiders, and other studies have documented that long-jawed orb weavers are consumed by birds [29–31]. We assessed risk to birds by calculating a risk quotient as spider concentration/avian wildlife value. The risk quotient represents the proportional difference between dietary concentrations and those expected to cause adverse effects in birds [15]. Spider MeHg concentrations exceed avian wildlife values when the risk quotient is >1 . Risk quotients were calculated at each sampling site and averaged for river, wetland, and open-water habitats for each bird species.

There are a number of sources of uncertainty in this screening-level risk analysis. For example, we did not consider bird movement between habitats or foraging outside of the areas surrounding Caddo Lake. In addition, birds may consume a variety of spider taxa, with different concentrations of MeHg from those in long-jawed orb weavers. Finally, birds may consume emergent aquatic insects, which would also be contaminated with MeHg; and this source of dietary MeHg was not considered in the present risk analysis.

Statistical analysis

To determine if spider MeHg concentrations differed among habitats, we used a one-way analysis of variance (ANOVA), followed by a Tukey post hoc test. Following guidelines of the USEPA [32], we used a modified *t* test to determine if the average MeHg concentration of spiders within a habitat was significantly greater than the calculated wildlife value for each bird species (i.e., if the risk quotient was significantly >1).

RESULTS AND DISCUSSION

Site-specific MeHg concentrations in spiders ranged from 19.4 ng/g wet weight to 256 ng/g wet weight, with a longitudinal trend of decreasing MeHg concentrations from west to east across Caddo Lake (Figure 1). Methylmercury concentrations in spiders were significantly different among habitats, with highest to lowest concentrations found in the river (150 ± 47 ng/g), wetland (115 ± 37 ng/g), and open-water (63 ± 22 ng/g) habitats, respectively (ANOVA, $F_{2,53} = 24.1$, $p < 0.001$; Tukey, $p < 0.05$ for all habitat comparisons; Figure 1).

Wildlife values for MeHg in songbirds, expressed as nanograms of MeHg per gram of spider tissue per day, were 34.6 ng/g/d (12-d-old Carolina chickadee), 52.0 ng/g/d (1-d-old Carolina chickadee), 175 ng/g/d (Carolina wren), 281 ng/g/d (eastern bluebird), and 433 ng/g/d (American robin). Carolina chickadee nestlings were the most sensitive to MeHg-contaminated spiders because they are small-bodied and have high consumption rates of spiders (Supplemental Data, Table S1). Conversely, Carolina wrens, eastern bluebirds, and American robins were less sensitive to MeHg-contaminated spiders because they are large-bodied and/or have low consumption rates of spiders (Supplemental Data, Table S1).

For each bird species, the risk quotient was greatest in the river, followed by the wetland and open-water habitats (Figure 2). Only 12-d-old and 1-d-old Carolina chickadees had risk quotients that exceeded 1, indicating that they are at risk from consuming spiders at Caddo Lake. The 12-d-old and 1-d-old Carolina chickadees were at risk in all 3 habitats (Figure 2). Average risk quotients of Carolina chickadees across habitats ranged from 1.22 to 4.34, indicating that spider consumption at

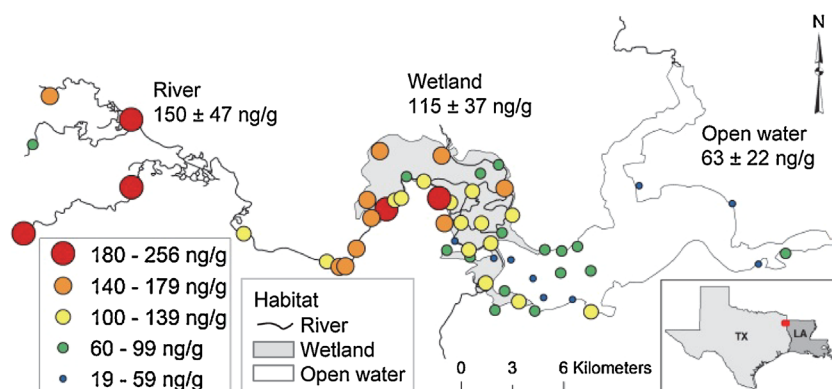


Figure 1. Site-specific concentrations of methylmercury (wet) in long-jawed orb weaver spiders at Caddo Lake. Average (\pm standard deviation) concentrations of methylmercury in spiders from each of the 3 habitats are presented.

Caddo Lake would result in Hg exposures ranging from 122% to 434% of wildlife values.

The present study is one of the first to find that MeHg accumulation in terrestrial spiders poses a potential risk to arachnivoracious songbirds, like nestling Carolina chickadees, at a site contaminated with Hg from the atmosphere. We also found that MeHg in spiders and bird risk varied across Caddo Lake, with the highest concentrations of MeHg in spiders and the greatest risk to birds in the river habitat. Our risk-analysis approach is a critical first step for identifying at-risk populations of sensitive species and life stages [15] and suggests that MeHg poses a risk to songbirds at Caddo Lake.

It is likely that this MeHg threat to songbirds is not unique to Caddo Lake and that it may extend throughout the southeastern United States. Long-jawed orb weaver spiders [33] and arachnivoracious songbirds [28] are found throughout the southeastern United States. In addition, the environmental factors that led to MeHg contamination of Caddo Lake's food chain, such as high levels of atmospheric Hg deposition [34] and forested-wetland habitats [35], are common throughout the southeastern United States. Evaluating spider MeHg concentrations within a risk framework, as in the present study, may be a cost-effective way to identify water bodies with high levels of

Hg contamination and populations of songbirds at risk [15] in the southeastern United States.

In general, the assessment of MeHg's threat to songbirds is just beginning to be understood [36]. Successful bird conservation strategies are dependent on a comprehensive understanding of the threats to populations [36]. An increasing body of literature suggests that elevated amounts of MeHg in the diet can pose a risk to songbirds (e.g., Jackson et al. [37] and Varian-Ramos et al. [38]). The present study suggests that songbirds that consume long-jawed orb weaver spiders at sites contaminated with Hg from the atmosphere will be exposed to aquatic MeHg pollution and that nestling arachnivoracious songbirds are most at risk. Given that songbirds are critical components of ecosystems [39] and are economically important because of birding [40], MeHg accumulation in these species may have a negative effect on the ecology and economy of this region.

SUPPLEMENTAL DATA

Table S1.

Figure S1. (158 KB DOC).

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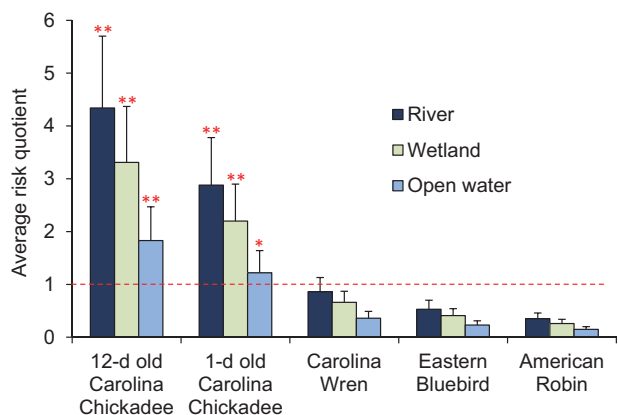


Figure 2. Average (\pm standard deviation) risk quotients for river, wetland, and open-water habitats for 5 birds. A risk quotient of 1 (indicated by dashed red line) indicates the point at which methylmercury concentrations in spiders are equivalent to the avian wildlife value. A risk quotient significantly >1 (indicated by asterisks) indicates that birds are at risk from consuming methylmercury-contaminated spiders (t test: $*p < 0.025$; $**p < 0.001$).

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