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Short communication

Maternally transferred mercury in wild largemouth bass, *Micropterus salmoides*

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ABSTRACT

Maternal transfer of mercury in fish represents a potential route of elimination for adult females and a risk to developing embryos. To better quantify maternal transfer, we measured Hg in female largemouth bass (*Micropterus salmoides*) muscle and eggs from six waterbodies. Mercury in eggs from two waterbodies exceeded a US federal screening level (0.3 μg g^{-1}) and was likely high enough to cause adverse reproductive effects. We found a curvilinear relationship between female and egg Hg. Fish with <0.37 μg g^{-1} Hg had low levels of Hg in eggs; those with Hg >0.37 μg g^{-1} showed a direct relationship between egg and muscle Hg (Log_{10} egg Hg = −1.03 + 1.18 * $\log_{10}$ muscle tissue Hg + 2.15 * ($\log_{10}$ muscle tissue Hg + 0.35)^2). We also report higher maternal transfer (0.2–13.2%) and higher ratios of egg to muscle tissue Hg (4–52%) and egg to whole body Hg concentrations (7–116%) than previously observed for teleost fish.

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1. Introduction

Maternal transfer of Hg has been examined in birds and mammals (Helander et al., 1982; Mergler et al., 2007; Scheuhammer et al., 2007) but is relatively unstudied in fish (Latif et al., 2001; Niimi, 1983). Much of the current knowledge on maternal transfer in fish focuses on fathead minnows, *Pimephales promelas*, a small short-lived species often used in laboratory experiments and walleye, *Sander vitreus*, a common apex predator. In the case of fathead minnows, it has been reported that a small quantity of Hg is transferred from mother to eggs during oogenesis, and maternal diet has been implicated as an important source of that Hg (Hammerschmidt and Sandheinrich, 2005). Similarly, previous research on walleye, among a few other species, has suggested that just a fraction of the total body burden (<3%) of female Hg is transferred to eggs and eliminated during spawning (Hammerschmidt and Sandheinrich, 2005; Niimi, 1983). Maternal transfer as a route of Hg elimination has also been examined by comparing egg Hg concentrations to those in either the total body (excluding the eggs) or the muscle tissue (Drevnick et al., 2006; Johnston et al., 2001; Latif et al., 2001), where Hg is primarily stored and accumulated in fish (e.g., Giblin and Massaro, 1973; Has-Schon et al., 2006). High ratios would indicate that Hg is concentrating in egg tissue. Whether using muscle or total body concentrations to compare to egg concentrations, previous studies have indicated that this ratio is relatively low as well (0.2–2.1% egg to whole body Hg and 1.3–12% egg to muscle tissue Hg, Johnston et al., 2001; 2–11% egg to muscle tissue Hg, Latif et al., 2001). It remains unclear, however, whether these patterns are consistent for other species and waterbodies.

From a natural resource management perspective, understanding maternally transferred Hg is important because fishery agencies often use large, fecund broodfish that are potentially high in Hg for propagation and stocking purposes. If broodfish have high Hg body burdens, and Hg is transferred to eggs, this could result in unsuccessful fertilizations, impaired embryos and juveniles and, eventually, stocked fish that have difficulty reproducing (Crump and Trudeau, 2009; Matta et al., 2001; Wiener and Spry, 1996; Weis, 2009). For instance, Fjeld et al. (1998) found that fish exposed to mercury in the first 10 days of development exhibited reduced feeding efficiencies and limited ability to compete with other fish for food 3 years later. Matta et al. (2001), using lower and more environmentally relevant concentrations of Hg, found reduced fertilization success of fathead minnow eggs and altered sex ratios of offspring. Further, for individuals and wildlife that consume more than just the fillet, it is important to understand Hg levels in fish eggs and fish total body burdens to better map Hg cycling and bioaccumulation pathways in food webs.

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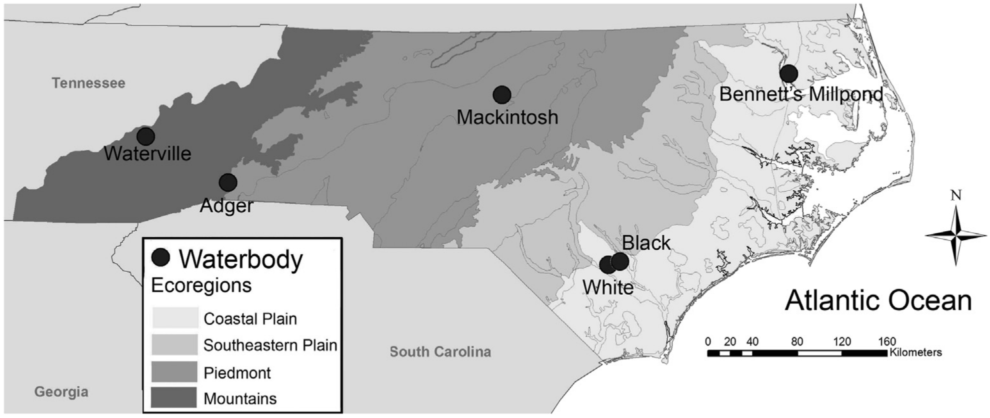

Fig. 1. Location of study sites in North Carolina, USA. Waterbodies represented a range of fish tissue Hg concentrations based on previous data (Sackett et al., 2009, 2013).

The aims of this study were to (1) determine if Hg concentrations in largemouth bass *Micropterus salmoides* eggs were correlated with maternal fish tissue Hg as an indication of maternal transfer, (2) determine the general range of Hg concentrations in wild-caught bass eggs and (3) determine the relative importance of maternal transfer as a route of Hg elimination for bass with various levels of Hg contamination.

2. Materials and methods

We sampled six waterbodies in North Carolina, USA (Fig. 1) with a known range of Hg contamination in fish (Sackett et al., 2009, 2013) and collected by electrofishing 32 gravid female largemouth bass ranging in size from 350 to 555 mm total length (TL; Table 1). Collections were made from March 15th to April 12th, 2010, just prior to bass spawning (eggs were fully developed and readily spilled from dissected ovaries). Largemouth bass are an appropriate species to study because they are widely distributed, often consumed by humans and wildlife, have existing fish consumption advisories for Hg, and wild broodfish are used for propagation and stocking in waters throughout North Carolina and the United States. Bass are common apex predators that feed primarily on fish and are often considered a high Hg species (e.g., Olsen, 1996; Sackett et al., 2009).

Collected fish were measured (TL to the nearest mm), placed in sealable food-grade storage bags, and held frozen (−20 °C) until processing. In the laboratory, fish were thawed, weighed (to the nearest g), and processed for Hg analysis using a trace metal-free dissection technique (USEPA, 2000; Sackett et al., 2010). In addition, eggs were removed after the fillet following the same trace metal-free dissection technique to ensure there was no cross-contamination with maternal tissue. Because previous studies have indicated that MeHg constitutes the majority of Hg in fish muscle tissue (95–99%; Bloom, 1992) and eggs (85–96%; Hammerschmidt et al., 1999), we analyzed total Hg, which is much more cost effective than analyzing MeHg. Total Hg was measured using USEPA method 7473 (USEPA, 2007; Sackett et al., 2013). All blanks, spikes and certified reference materials (CRMs) were within acceptable limits; recoveries of CRM ranged from 90% to 114%, with an overall mean recovery of 99.2 ± 6.7% standard deviation. We converted Hg concentrations to wet weight using the percent moisture calculated for each sample. For age determination, otoliths were dissected and aged in cross-section by two independent readers. Any otoliths for which the first two readers disagreed were aged by a third reader to reach consensus.

As a measure of maternal transfer, $\log_{10}$ transformed egg Hg was regressed using standard least squares on $\log_{10}$ transformed fish muscle tissue Hg with both linear and non-linear (degree 2 polynomial fit) approaches. Data were log transformed to meet assumptions of normality and equal variance. We used an equation developed by Bevelhimer et al. (1997) with largemouth and spotted bass *Micropterus punctulatis* ($R^2 = 0.99$) to estimate the concentration of Hg in the whole body of each bass based on fillet concentrations: concentration in the whole body = exp (−0.84 + 0.74 * ln (concentration in the fillet)). This relationship was established in the same general region as our study (southeastern United States) and was likely a good estimate of whole body concentrations for our fish. Others have also found estimating whole body concentration using muscle tissue very reliable in various species and locations (Peterson et al., 2005). Egg Hg concentrations were multiplied by egg weight, and whole body concentrations were multiplied by whole body weight (excluding egg weight) to estimate body and egg burdens of Hg in each fish. Egg and body burdens were summed to determine total Hg body burden. Egg Hg burdens were then divided by total Hg body burdens to examine maternal transfer and Hg elimination from spawning. In addition, ratios of egg Hg concentrations to muscle Hg and whole body concentrations of Hg were estimated for comparison to values from other studies (Drevnick et al., 2006; Johnston et al., 2001; Latif et al., 2001).

3. Results and discussion

The range of fish muscle tissue Hg in collected female bass was 0.19–1.61 μg g^{-1}. Egg concentrations of Hg ranged from 0.01 to 0.47 μg g^{-1} and five females had egg concentrations that exceeded the USEPA fish tissue Hg screening level (0.3 μg g^{-1}; USEPA, 2000). Although some have suggested that Hg levels in fish eggs are consistently low (e.g., Niimi, 1983), we found that largemouth bass egg concentrations are a function of maternal muscle tissue concentrations, and can reach levels high enough to exceed a human consumption advisory for muscle tissue (Table 1; Fig. 2). Whereas few people consume an entire fish (including eggs), egg consumption is much more common among piscivorous wildlife. As such, the notion that largemouth bass eggs can have high Hg concentrations, particularly in more contaminated waterbodies (Table 1; Fig. 2; Sackett et al., 2009, 2013), is an important component of assessing and managing Hg movement through food webs.

Previous studies have noted that Hg concentrations in fish eggs were linked to adverse reproductive effects at concentrations less

Table 1
Sample size (*N*), size and age range, and concentration of Hg (mean and standard error, SE) in muscle tissue and eggs of female largemouth bass collected from six waterbodies in North Carolina, USA. TL = total length. Parenthetical values represent dry weight Hg.

Site	*N*	TL range (mm, TL)	Age range (years)	Fish tissue Hg (μg g^{-1})		Egg Hg (μg g^{-1})	
				Mean	SE	Mean	SE
Bennett's Millpond	8	350–520	1–6	0.29 (1.32)	0.04 (0.16)	0.03 (0.10)	0.00 (0.01)
Waterville	7	411–548	4–12	0.38 (1.90)	0.06 (0.32)	0.04 (0.12)	0.01 (0.04)
Adger	8	367–555	4–10	0.48 (2.30)	0.07 (0.36)	0.04 (0.14)	0.01 (0.03)
Mackintosh	2	447–522	4–8	0.59 (2.71)	0.19[a] (0.14)[a]	0.05 (0.17)	0.04[a] (0.05)[a]
White	5	362–540	2–11	0.79 (3.76)	0.13 (0.63)	0.25 (0.75)	0.08 (0.21)
Black	2	445–482	4	1.54 (7.10)	0.13[a] (0.19)[a]	0.37 (1.01)	0.05[a] (0.05)[a]

[a] For sites where only two samples were collected, values indicate range rather than SE.