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Toxicological significance of mercury in yellow perch in the Laurentian Great Lakes region

James G. Wiener[a,*], Mark B. Sandheinrich[a], Satyendra P. Bhavsar[b], Joseph R. Bohr[c], David C. Evers[d], Bruce A. Monson[e], Candy S. Schrank[f]

[a] University of Wisconsin-La Crosse, River Studies Center, 1725 State Street, La Crosse, WI 54601, USA
[b] Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch, 125 Resources Road, Toronto, Ontario M9P 3V6, Canada
[c] Michigan Department of Natural Resources and Environment, Water Resources Division, P.O. Box 30273, Lansing, MI 48909, USA
[d] Biodiversity Research Institute, 19 Flaggy Meadow Road, Gorham, ME 04038, USA
[e] Minnesota Pollution Control Agency, 520 Lafayette Road North, St. Paul, MN 55155-4194, USA
[f] Wisconsin Department of Natural Resources, Fisheries Management (FH/4), 101 South Webster Street, Madison, WI 53707-7921, USA

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ABSTRACT

We assessed the risks of mercury in yellow perch, a species important in the trophic transfer of methylmercury, in the Great Lakes region. Mean concentrations in whole perch from 45 (6.5%) of 691 waters equaled or exceeded 0.20 μg/g w.w., a threshold for adverse effects in fish. In whole perch within the size range eaten by common loons (<100 g), mean concentrations exceeded a dietary threshold (0.16 μg/g w.w.) for significant reproductive effects on loons in 19 (7.3%) of 260 waters. Mean concentrations in fillets of perch with length ≥ 15.0 cm, the minimum size retained by anglers, exceeded the USEPA criterion (0.3 μg/g w.w.) in 26 (6.4%) of 404 U.S. waters and exceeded the Ontario guideline (0.26 μg/g w.w.) in 35 (20%) of 179 Ontario waters. Mercury levels in yellow perch in some waters within this region pose risks to perch, to common loons, and to mercury-sensitive human populations.

1. Introduction

The yellow perch (*Perca flavescens*) is widely distributed and abundant in many lentic waters of the Great Lakes region, occurring across much of the north-central and northeastern United States and eastern Canada (Scott and Crossman, 1973; Becker, 1983). This species is regionally important in the transfer of methylmercury to upper trophic levels of lacustrine food webs because of its importance in the diet of piscivorous fish and wildlife, including walleye (*Sander vitreus*; Colby et al., 1979), northern pike (*Esox lucius*; Soupir et al., 2000), and common loons (*Gavia immer*; Barr, 1996). Moreover, yellow perch are widely sought by anglers and retained for consumption (Cook and Younk, 1998; Awad, 2006), providing a pathway for human exposure to methylmercury.

Yellow perch have been used as biosentinels of methylmercury concentrations in aquatic food webs (Kamman et al., 2004; Wiener et al., 2007; Wyn et al., 2010). Concentrations of total mercury in small yellow perch are strongly and positively correlated with concentrations in co-existing piscivorous fish, including walleye, black bass (*Micropterus* spp.), and northern pike (Suns et al., 1987; Cope et al., 1990). Nearly all of the mercury in yellow perch is methylmercury, which on average accounts for 99% of total mercury in their axial muscle tissue (Grieb et al., 1990; Bloom, 1992) and 95% or more of total mercury in whole yellow perch (Hammerschmidt et al., 1999; Drysdale et al., 2005; Van Walleghem et al., 2007). Statistical analyses have shown strong relations between the total-mercury concentration in yellow perch and ecosystem characteristics (e.g., lake chemistry, wetland influence) or perturbations (e.g., water-level fluctuations, lake acidification, mercury loadings) that are known to influence the microbial production of methylmercury and its concentration in aquatic food webs (Suns and Hitchin, 1990; Simonin et al., 1994; Frost et al., 1999; Drysdale et al., 2005; Sorensen et al., 2005; Wiener et al., 2003, 2006; Harris et al., 2007; Orihel et al., 2007; Dittman and Driscoll, 2009; Gabriel et al., 2009). Yellow perch are acid tolerant and inhabit lakes across a broad range in pH (Wiener et al., 1984; Nierzwicki-Bauer et al., 2010).

We compiled and analyzed data on mercury in yellow perch from lentic waters in the Laurentian Great Lakes region, as part of

* Corresponding author.
E-mail addresses: jwiener@uwlax.edu (J.G. Wiener), msandheinrich@uwlax.edu (M.B. Sandheinrich), satyendra.bhavsar@ontario.ca (S.P. Bhavsar), bohrj@michigan.gov (J.R. Bohr), david.evers@briloon.org (D.C. Evers), Bruce.Monson@state.mn.us (B.A. Monson), candy.schrank@wisconsin.gov (C.S. Schrank).

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a bi-national synthesis of regional mercury data (Evers et al., 2011a; Wiener et al., 2011). Our overall goal was to assess the potential toxicological significance of methylmercury in yellow perch. Our principal objectives in this study were (1) to assess the potential for toxicological effects of methylmercury exposure on the health and reproduction of yellow perch in the Great Lakes region, (2) to compare mercury concentrations in yellow perch to dietary concentrations associated with reduced reproduction of common loons *Gavia immer*, an avian piscivore that forages selectively on yellow perch, and (3) to compare concentrations of mercury in axial muscle and fillets of yellow perch to criteria established to protect the health of humans who eat wild fish.

2. Methods

2.1. Compilation of regional monitoring data

To compile regional monitoring data on mercury in yellow perch, we examined fish-contaminant databases produced by the monitoring and surveillance programs of six state agencies (Illinois Environmental Protection Agency, Indiana Department of Environmental Management, Michigan Department of Environmental Quality, Minnesota Pollution Control Agency, Ohio Environmental Protection Agency, Wisconsin Department of Natural Resources), one provincial agency (Ontario Ministry of the Environment), and one tribal commission (Great Lakes Indian Fish and Wildlife Commission) in the Laurentian Great Lakes region. General descriptions and metadata for most of these databases are available on-line through the MercNet monitoring inventory (http://mercnet.briloon.org/).

The combined data from state, provincial, and tribal monitoring programs were used to develop a regional monitoring database on total mercury in yellow perch. We limited this database to yellow perch that had been analyzed individually or as multi-fish composite samples of skin-on fillet, axial muscle (i.e., skin-off fillet), or whole fish. Data from analyses of other sample matrices were not retained. Records for yellow perch that had been analyzed individually included records for skin-on fillet ($n = 582$ fish from U.S. waters; $n = 5$ from Ontario), axial muscle ($n = 32$ from U.S.; $n = 4569$ from Ontario), or whole fish ($n = 1229$ from U.S.; $n = 23$ from Ontario). For composite samples, the database contained records for skin-on fillet (309 composite samples from U.S. waters), axial muscle (20 composites from U.S.), and whole fish (407 composites from U.S., 387 from Ontario).

The regional monitoring database was limited to fish sampled in 1990 or later. Water bodies represented in the database included the Great Lakes, inland lakes, and reservoirs. Data for fish from streams, rivers, and canals were not included. For this study, we define "inland lakes" as natural lakes and reservoirs (not including the Great Lakes) within the region.

To obtain an estimate of total mercury concentration in both whole fish and fillet of each fish in the database, we used an equation derived from analyses of 21 yellow perch from lakes in Kejimkujik National Park in Nova Scotia, Canada (from p. 5 of Supporting Information for Wyn et al., 2010),

$$\mathrm{Hg}_w = 0.60 \times \mathrm{Hg}_m, \quad (1)$$

where Hg_w is the concentration of total mercury in the whole fish in μg/g (wet weight), Hg_m is the concentration of total mercury in axial muscle in μg/g (wet weight), and the regression equation had a coefficient of determination (r^2) of 0.942 ($p < 0.001$).

All fish lengths were converted to centimeters, and all total mercury concentrations were converted to μg/g wet weight. Observations for fish lacking data on body length were deleted.

For individually analyzed fish, the final regional monitoring database contained observations from mercury determinations on 6440 yellow perch, with records for 4328 fish from inland lakes and reservoirs and 2112 fish from the Laurentian Great Lakes. Data on body weight were available for nearly all (99%) of these fish. Estimates of fish age were available for only 4% of the individually analyzed yellow perch in the regional monitoring database, but data on age were not essential for our study objectives.

The complete regional monitoring database contained data from five states (Indiana, Michigan, Minnesota, Ohio, Wisconsin) and the province of Ontario (Fig. 1). The state fish-contaminant database from the Illinois Environmental Protection Agency did not contain data on mercury in yellow perch. All mercury data on yellow perch in the statewide databases from Indiana and Ohio were from analysis of composite samples containing multiple fish. All records for mercury in yellow perch in the database for Ohio were for composite samples from Lake Erie; there was no data for yellow perch from inland waters in Ohio.

All statistical analyses of regional monitoring data and regional investigations data were conducted with SAS® software version 9.1.3 (SAS Institute Inc., Cary, NC). A Type I error of 0.05 was used to judge the significance of all statistical tests.

2.2. Risks of methylmercury exposure to yellow perch

To assess the potential for direct effects of methylmercury exposure on yellow perch, we compared concentrations in yellow perch to threshold concentrations

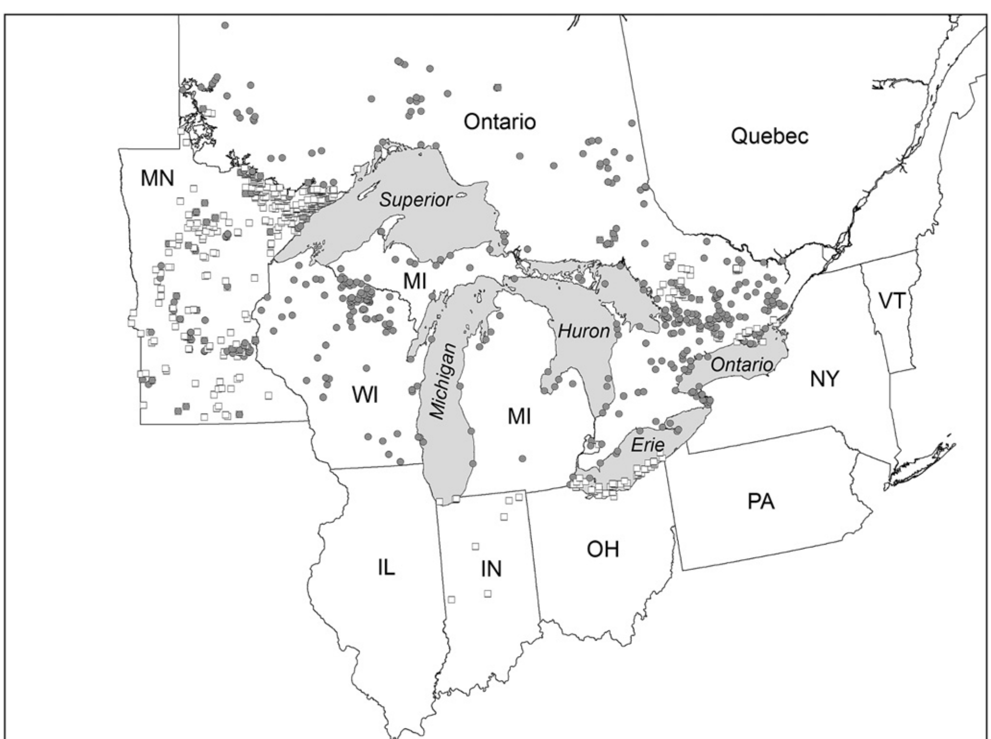

Fig. 1. Geographic distribution of water bodies represented in the regional monitoring database on mercury in yellow perch. Circles show locations with records for samples of individually analyzed fish, and squares show locations with records for multi-fish composite samples.