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Lake variability: Key factors controlling mercury concentrations in New York State fish

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Lake water chemistry variables, dams, and wetlands play major roles in determining fish mercury concentrations.

Abstract

A 4 year study surveyed 131 lakes across New York State beginning in 2003 to improve our understanding of mercury and gather information from previously untested waters. Our study focused on largemouth and smallmouth bass, walleye and yellow perch, common piscivorous fish shown to accumulate high mercury concentrations and species important to local fisheries. Fish from Adirondack and Catskill Forest Preserve lakes generally had higher mercury concentrations than those from lakes in other areas of the state. Variability between nearby individual lakes was observed, and could be due to differences in water chemistry, lake productivity or the abundance of wetlands in the watershed. We found the following factors impact mercury bioaccumulation: fish length, lake pH, specific conductivity, chlorophyll *a*, mercury concentration in the water, presence of an outlet dam and amount of contiguous wetlands.

Keywords: Mercury; Fish; Water chemistry; Bioaccumulation; Adirondack Mountains; Catskill Mountains; New York State

1. Introduction

During the last century, atmospheric deposition has caused an increase in mercury (Hg) in freshwater ecosystems in the northeastern United States. In many lakes of this region, mercury levels are high enough to threaten ecosystem health and pose health risks to humans who eat fish from these waters (Kamman et al., 2005; Evers, 2005). In New York State many lakes and ponds now have fish consumption advisories (NYSDOH, 2006). Still there are questions regarding why certain lakes and fish have higher mercury concentrations than others.

A project was developed to gain a clearer picture of mercury in the aquatic environment. Although the New York State Department of Environmental Conservation (NYSDEC) has been monitoring fish for mercury concentrations for over 30 years, many lakes remain untested. Two of the primary objectives of this synoptic survey were to: (1) collect fish and water samples statewide from previously unsurveyed waters; and (2) evaluate the relationship between fish mercury concentrations and various lake chemistry and watershed variables.

2. Methods

2.1. Lake selection and field collections

Fish and water samples were collected from 131 New York State lakes to provide a representative sample of the diverse hydrological characteristics of the state (Fig. 1). The distribution of study lakes was primarily determined by the abundance of lakes within various areas of the state. For example, about 50% of New York lakes are located in the northeastern part of the state (Greeson and Williams, 1970); therefore, about 50% of our study lakes were selected from that region. The following criteria were used to select study lakes: (1) lakes open to public fishing; (2) at least one and preferably more of the target fish species present; (3) untested state park lakes were a priority because of high public use; and (4) to ensure a diverse selection of waters, a range of different lake sizes. Although the lakes were not randomly selected, they included a wide range of lake types from all regions of the state.

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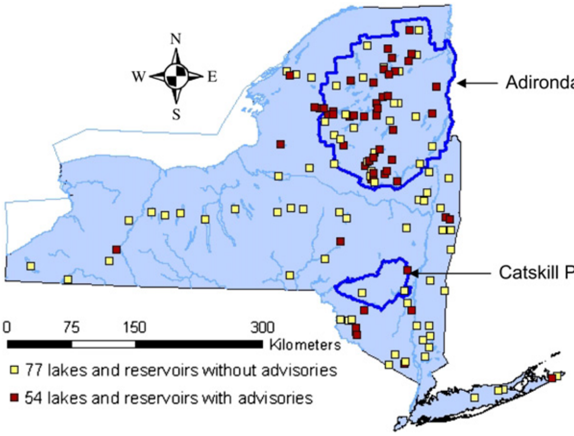

Fig. 1. Map of New York State showing locations of study lakes and resulting fish consumption advisories (NYSDOH, 2006).

Target fish were largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), and yellow perch (*Perca flavescens*), because these are common, widely distributed, piscivorous species that may accumulate high mercury concentrations (Simonin et al., 1994; Loukmas and Skinner, 2005; Kamman et al., 2005). Fish were sampled primarily during spring and summer, 2003–2005, by a variety of means including electrofishing, gill netting, trap netting, and angling. Legal edible sizes of fish were targeted, with an objective of 30 fish (10 each of yellow perch, bass, and walleye) for collection from each lake. Fish were weighed, measured, individually bagged and kept frozen until processing for mercury analysis.

Surface water samples were collected during the month of July in 2003, 2004 or 2005 from the deepest point in each lake for chemical analysis. One sample per lake was placed on ice and transported to the Adirondack Lakes Survey Corporation (ALSC, Ray Brook, NY) laboratory for analysis. Field parameters measured included temperature, dissolved oxygen, Secchi depth, and other physical characteristics. Two additional water samples per lake were collected using "clean-hands" procedures for analysis of total and methyl mercury. These samples were kept on ice and shipped to Frontier Geosciences, Inc. (Seattle, WA) within 24 h. Chlorophyll *a* was measured from a separate integrated water sample collected from a column of water from the surface to two times the Secchi depth. These samples were filtered in the field on a 25 mm glass-microfiber filter. The volume of water filtered was based on Secchi depth. Filters were wrapped in aluminum foil, placed in a plastic bag, placed on ice and frozen within 24 h. Samples were later shipped on ice to Upstate Freshwater Institute (Syracuse, NY), for analysis.

2.2. Water chemistry analysis and tissue preparation

The ALSC laboratory analyzed water samples for: lab pH; air-equilibrated (AE) pH; sulfate; nitrate; ammonium; calcium; chloride; magnesium; potassium; sodium; silica; fluoride; total dissolved aluminum; dissolved organic carbon (DOC); acid-neutralizing capacity (ANC); color; specific conductance; total, organic, and inorganic monomeric aluminum. USEPA protocols were used for sample analysis (Table 1) and quality control (USEPA, 1987, 1991). Frontier Geosciences also used USEPA-approved protocols for analysis of total (USEPA, 2002) and methyl mercury (USEPA, 2001). Quality control for these samples consisted of calibration and check standards, reference materials, blanks, and sample duplicates. All water chemistry QC results were within acceptable limits. For water Hg analysis, mean values for QC parameters were as follows: calibration standards (percent recovery: THg, 93.4 ± 4.9; MeHg, 98.7 ± 6.8), matrix spikes (percent recovery: THg, 86.6 ± 12.4; MeHg, 95.4 ± 6.7), reference materials (percent recovery: THg, 97.2; MeHg, 103.4 ± 7.9), blanks (THg, 0.05 ± 0.04 ng/L; MeHg, 0.01 ± 0.01 ng/L), and duplicates (relative percent difference (RPD): THg, 9.2 ± 6.7; MeHg, 6.5 ± 6.2).

Fish were processed by partially thawing the sample, removing scales and then removing a skin-on and rib bone-in fillet that extended from the gill cover to the caudal fin (i.e., standard fillet). The fillet was then homogenized, and aliquots were placed in cleaned, labeled glass jars and refrozen. Frozen samples were shipped with dry ice to CEBAM Analytical. Inc. (Seattle, WA) by overnight delivery. Typically about 95% of the mercury in fish is methyl mercury (Bloom, 1992), so total mercury was analyzed using a modified USEPA method 1631 (USEPA, 2002). Quality control samples for mercury were analyzed at a rate of one duplicate for every 16 samples, one matrix spike every 19 samples, one method blank every 22 samples, and one certified reference material every 41 samples. Mean values for sample duplicates (RPD = 3.7 ± 3.1), matrix spikes (percent recovery = 99.1 ± 4.8), method blanks (<0.5 ng/g ww), and certified reference materials (percent recovery = 96.2 ± 3.2) were all within acceptable limits. All mercury data are presented as wet weight concentrations.

Wetlands coverage data were available for many of our study lakes (FWS, 2004; APA, 2001, 2002). Contiguous wetlands (those touching the lakeshore) were determined for 84 lakes, and watershed wetlands (those located throughout the lake's watershed) were measured for 38 lakes. Physical lake characteristics were obtained from 129 lakes.

2.3. Statistical analyses

We used Statistix®8 (Analytical Software, 2003) for both parametric and non-parametric analyses of data. In addition, we used the SAS System for Windows Version 7 (SAS Institute, 1998) to conduct multivariate, stepwise regression, cluster analysis and Pearson correlation coefficient determinations of the full dataset. Most water chemistry parameters were log-transformed to make the relationships linear with the fish mercury concentration. Separate SAS runs were conducted for individual fish species using all the water chemistry data, and then additional runs were conducted using the limited data for lakes with watershed and contiguous wetland measurements. Two methods were used to evaluate the relationship between fish mercury concentrations and lake variables. In the first Standard Size Method, a single mercury concentration for each species was calculated for each lake based on standardized lengths. Standard lengths were calculated using the overall average lengths for each fish species in the full dataset. We then plotted for each individual lake the species-specific regression lines of mercury concentration against length. From each regression line we determined the predicted mercury concentration at the standard length for each fish species in the lakes where at least three individuals were collected. We used this predicted mercury concentration even in the few cases where the regression relationship was not significant, because this standardized value was the best estimate of fish mercury concentration comparable across multiple lakes.

In the second All Data Method, all of the individual fish mercury concentrations along with the fish length and weight data were used. This method was biased toward lakes with a greater number of fish samples. In both methods the various water chemistry and physical/watershed variables were evaluated to determine the relationship to fish mercury concentration.

3. Results

3.1. Water chemistry

New York State has a wide variety of lake types ranging from sand-bottom ponds and organic tea-colored bog waters to rocky reservoirs and deep glacial lakes. As a result the water chemistry of our study lakes ranged widely. Sample size, median, mean, SD, and range values of numerous water chemistry parameters are presented in Table 1. Study lakes ranged in pH from 4.97 to 8.49, calcium from 1 to 68 mg/L, SO_4 from 2.1 to 41.6 mg/L, DOC from 0.4 to 12.3 mg/L, and chlorophyll *a* from 0.4 to 46.2 μg/L.

To further evaluate and separate the lake chemical and physical data, we compared the data for lakes within the