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Revised fish aging techniques improve fish contaminant trend analyses in the face of changing Great Lakes food webs

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ABSTRACT

Incorporation of fish age into the assessment of status and trends for persistent, bioaccumulative and toxic chemicals in the Great Lakes has become an important step for the U.S. EPA's Great Lakes Fish Monitoring and Surveillance Program (GLFMSP). A slowing in the rate of decline for total PCBs in Lake Huron beginning in 2000, led the Program to complete a retrospective analysis to assess how chemical contamination may be influenced by fish age. Analytical results suggest that fish age is an important variable when assessing contaminant trends and that the Program needed to revise its compositing scheme to group fish according to age, rather than by length, prior to homogenization and chemical analysis. An Interlaboratory comparison study of multiple age structures was performed to identify the most appropriate age estimation structure for the Program. The lake trout (*Salvelinus namaycush*) maxillae was selected, over the otolith, as the most precise, accurate, and rapidly assessed structure for the Program when compared between laboratories and against the known age from the coded wire tag (CWT). Age-normalization practices can now be implemented when assessing contaminant concentrations and trends for the GLFMSP.

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Introduction

Changes in Great Lakes food webs have had several serious repercussions on the health of Great Lakes fish over the past 20 years, including changes in bioaccumulation potential of contaminants in top predator species such as lake trout (*Salvelinus namaycush*) and walleye (*Sander vitreus*) (Zhou et al., 2017a, 2017b; Pagano et al., 2018). Food web structures have been stressed by nutrient availability, presence of invasive species, declines in prey availability, increases in predator density, density dependent growth and increases in predator-prey ratios and overall predation pressures (Tsehaye et al., 2014; He et al. 2015 and 2016; USGS, 2016; Lake Michigan Lake Trout Working Group Report, 2016). Each of those stress factors could result in slower growing fish which might contribute to higher chemical concentrations of persistent and bioaccumulative compounds. For example, in Lakes Huron and Michigan, there are signs of increasing oligotrophication in open waters (Barbiero et al., 2012; Barbiero et al. (this issue); and Bunnell et al., 2014). Additionally, changes in invertebrate communities have the potential to impact the size and composition of prey fish communities due to resource availability and exploitative competition and ultimately top predator species, like lake trout (*Salvelinus namaycush*), Chinook salmon (*Oncorhynchus tshawytscha*), and walleye (*Sander vitreus*) (He et al., 2016 and Barbiero et al., 2012).

The U.S. EPA Great Lakes National Program Office (GLNPO) Great Lakes Fish Monitoring and Surveillance Program (GLFMSP) has been monitoring chemical concentrations of whole body top predator fish species in the Great Lakes since the 1970s (*GLFMSP Quality Management Plan (QMP)*, 2012) (Carlson et al., 2010; Carlson and Swackhamer, 2006; Chang et al., 2012; De Vault et al., 1996; McGoldrick and Murphy, 2016). The target species is lake trout in Lakes Superior, Huron, Michigan, and Ontario and walleye in Lake Erie. In 2013, after several years of collection and comparison of lake trout and walleye (2008–2011), lake trout replaced walleye as the target species in the eastern basin of Lake Erie. Historically, lake trout in the size range of 600–700 mm were targeted with an assumption that they represented fish between the ages of six and eight years old (Elrod et al., 1996; Madenjian et al., 1998). Similarly, walleye in the size range of 400–500 mm were targeted with an assumed age of four and six years old based on broad assumptions regarding age/size relationships

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(GLFMSP QMP, 2012). The GLFMSP composite scheme identified that fish were to be grouped, based on length, into 10 composites of five fish each, homogenized, and then analyzed for contaminant concentrations. Beginning in 2003, fish age was assessed post homogenization from saved structures using various methods (otolith, scale, fin clip, and/or coded wire tags (CWTs)) and recorded for future use. Fish age was not assessed for the GLFMSP prior to 2003.

As part of routine assessments of status and trends of persistent, bioaccumulative, and toxic chemicals, the GLFMSP identified an increase in both the annual mean total PCB concentrations and the range in concentration of the ten fish composites from the Port Austin (Odd Year) site in Lake Huron (Fig. 1) in the early 2000's, resulting in a slowing in the rate of decline of the total PCB concentration trend (Fig. 2, Total PCB Concentration piecewise trend dotted line). An apparent increase was observed in both the average age and the range of ages of composites at the Port Austin site beginning in approximately 2003 (Fig. 2, Age Trend linear dashed line). While the long term trend for total PCBs at the Port Austin site in Lake Huron continued to decline (Fig. 2, Total PCB Concentration linear trend solid line), the combination of increasing mean age of composites and the total PCB concentration trend indicated the need to investigate the source of the change and led to a retrospective review of age for GLFMSP samples in all lakes. Results of the review indicated that fish in the target size range were exceeding the target age range at some stations (Fig. 3–e).

The GLFMSP considered the number of documented environmental stresses in the Great Lakes that may impact fish growth and age and determined that older, and potentially more contaminated, fish can confound the long term trend assessments for the GLFMSP. Additionally, age was assessed post compositing which likely resulted in a high variability of contaminant concentrations within individual composites, making it difficult to estimate the total variability around the site mean and indicating the need to consider age in interpreting chemical results. Age contaminant relations were developed and documented by the GLFMSP and other sources which has resulted in age-normalizing when calculating contaminant concentrations (Zhou et al., 2017a, 2017b; Fernando et al., 2017; Zhou et al., 2017a, 2017b; Omara et al., 2015; Pagano et al., 2018; Sackett et al., 2013; Doetzel, 2007). To our knowledge, the application of maxillary age enumeration to age-normalize whole fish samples for contaminant concentration analysis and trends is a novel practice.

To normalize ages, a revision of the compositing scheme was needed in order to age fish quickly prior to homogenization, to better interpret data, and control for the effect of age on chemical analysis. The coordinated efforts of two laboratories contributed to a multi-year inter-laboratory comparison between the use of otoliths and maxillae for assigning lake trout ages prior to fish sample homogenization. Aquatec Biological Sciences, Inc. (Aquatec), the current homogenization laboratory supporting the GLFMSP (2011–present), and the Michigan Department of Natural Resources (MDNR), a long term sample collection partner of GLFMSP and experienced in the use of maxillae to estimate lake trout ages (Wellenkamp et al., 2015), participated in the inter-laboratory study.

Lake trout used in the study included those from all sampling locations in Lakes Superior, Michigan, Huron and Ontario during the 2013–2016 field seasons and the 2013 and 2015 collection from the eastern basin of Lake Erie. An additional 10 lake trout were also collected from the eastern basin of Lake Erie in 2014. This study was designed to 1) assess the influence of age versus size in compositing practices and 2) determine the most appropriate fish structure for the GLFMSP to use for fish age estimation prior to homogenization by

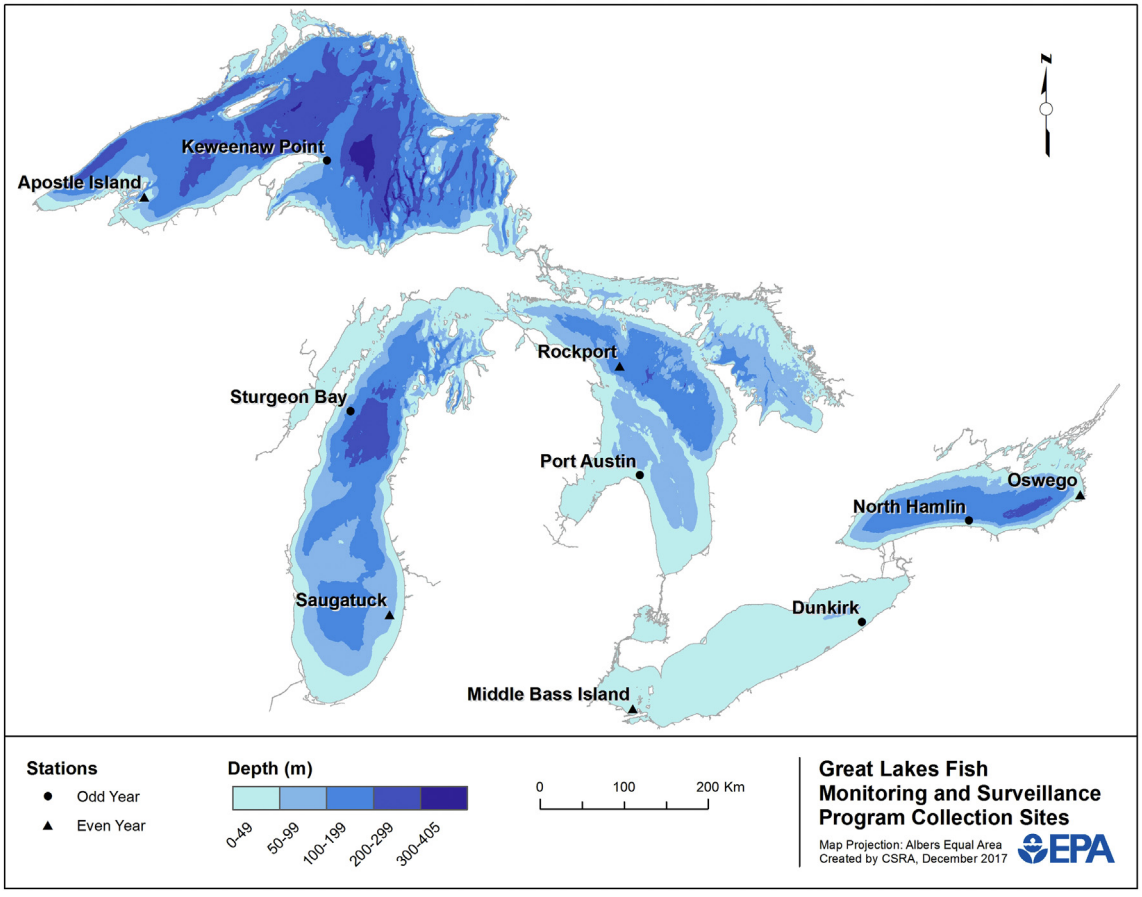

Fig. 1. Great Lakes Fish Monitoring and Surveillance Program collection locations. Sites indicated with a circle are sampled in odd years and sites indicated with a triangle are sampled in even years.

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