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Lipids and fatty acids of *Mysis diluviana* in lakes Michigan and Huron, 2008

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ABSTRACT

The opossum shrimp (*Mysis diluviana*) is a vital component of Great Lakes food webs. Baseline data on the nutritional condition of *Mysis* populations are necessary to evaluate potential impacts of recent, dramatic changes in the lower food webs of lakes Michigan and Huron. Information on lipid and fatty acid content can reveal patterns of health and physiological condition of mysids, including inferences on availability and quality of food. We sampled *Mysis* populations in the two lakes in spring and late summer/early fall 2008 and analyzed total lipid content and fatty acid profiles to describe *Mysis* nutritional condition. On average, adult *Mysis* in Lake Huron had lower total lipids and elevated concentrations of the fatty acid docosahexaenoic acid compared with Lake Michigan, although differences were not always significant. Results suggest that Lake Huron *Mysis* could have been starving during spring 2008.

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Introduction

In recent years, pelagic food webs in lakes Michigan and Huron have undergone rapid, drastic changes. Non-native species introductions have altered phytoplankton, zooplankton, benthos, and fish communities in Lake Michigan (Madenjian et al., 2002). Populations of the important benthic amphipod *Diporeia* have declined dramatically across broad regions of the Great Lakes (Nalepa et al., 2007, 2009). Nutrient cycling has been altered, likely as a result of quagga mussel (*Dreissena rostriformis bugensis*) filtering, and chlorophyll *a* and silica dynamics suggest that primary production in both lakes has declined drastically in the last several years (Barbiero et al., 2009a; Evans et al., 2011; Fahnenstiel et al., 2010a,b; Hecky et al., 2004; Kerfoot et al., 2010; Mida et al., 2010). Populations of Lake Huron forage fish, especially alewife (*Alosa pseudoharengus*), have collapsed in recent years (Riley et al., 2008). Declining condition of salmonines in Lake Huron has required reductions in stocking and resulted in the loss of an important recreational fishery (MDNR, 2005) and subsequent economic losses to the region.

Following these changes, importance of other prey species in the lower food web has increased. One such species is the opossum shrimp, *Mysis diluviana* (formerly *Mysis relicta*, Audzijonyte and Väinölä, 2005; hereafter *Mysis*), a historically important prey item

for numerous species of benthic and pelagic fishes (Crowder et al., 1981; Crowder and Crawford, 1984; Kitchell et al., 2000; Kraft and Kitchell, 1986; Wojcik et al., 1986). The relative importance of *Mysis* in diets of some fishes has increased because of recent lower food web changes (Hondorp et al., 2005; O'Brien et al., 2009; Pothoven et al., 2001).

Despite its demonstrated importance in Great Lakes food webs, *Mysis* has been poorly studied in Lake Huron, and recent studies in Lake Michigan are limited spatially (Pothoven et al., 2010). Little work has examined physiological condition of *Mysis* populations in any of the Great Lakes. Here we present results of analyses of total lipids (TLs) and fatty acid (FA) composition of *Mysis* from lakes Michigan and Huron in spring and late summer 2008.

Total lipid content can indicate when invertebrates are food-limited or near minimum levels necessary for reproduction (Cavaletto et al., 1996; Hill et al., 1992). Fatty acid profiles can provide more detail, because they represent diet of an organism integrated over a longer period than the snapshot provided by direct diet analysis (Napolitano, 1999). Furthermore, several FAs, known as essential fatty acids (EFAs), are of particular importance to fish (Arts, 1999) and their proportions in *Mysis* respond in a predictable manner to starvation (Schlechtriem et al., 2008).

Here we focus on one of these EFAs, docosahexaenoic acid (22:6n-3, DHA), because starving *Mysis* contain elevated levels of this fatty acid (Schlechtriem et al., 2008). Storage lipids (primarily triglycerides) are depleted during starvation and membrane lipids tend to remain stable, so membrane lipids will compose an increased percentage of total lipids under starvation (Schlechtriem et al., 2008). Because membrane lipids are rich in DHA, it follows that starving *Mysis* will have increased proportions of DHA.

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Methods

We collected *Mysis* samples from Lake Huron in spring and summer 2008 during U.S. Environmental Protection Agency (U.S. EPA) monitoring cruises aboard the R/V Lake Guardian (Fig. 1, Table 1). Spring cruises occurred in April during isothermal conditions, and summer cruises were in late summer when the water column was fully stratified. *Mysis* vertical tows were taken only at night, at least 1 h after sunset and no later than 1 h before sunrise. As a result, in 2008 no station that was sampled for *Mysis* in spring was sampled again in summer.

Prior to arrival at a *Mysis* station, all external ship lights were extinguished and technicians used flashlights with red lenses on deck to avoid mimicking sunlight, which would cause *Mysis* to descend in the water column. Tows were taken with a 1-m × 1-m square net, which extended 2 m to a cod-end container. The top two-thirds of the net were made of 1-mm, bar-mesh Nitex, and the bottom one-third of 250- μ m Nitex. The mouth of the net was sent to 2–4 m above bottom, depending on wave conditions. It was raised to the surface at a speed of 0.5 m · s⁻¹ and washed down thoroughly; collected *Mysis* were anesthetized immediately with carbonated water. Individual *Mysis* were then blotted dry and sorted into two categories according to maturity level: adults (defined as greater than 10 mm in length, Pothoven et al., 2004) and juveniles. Sorted *Mysis* were placed in individual sterile plastic vials and immediately frozen in liquid

Table 1

Characteristics of stations at which *Mysis* were sampled in lakes Michigan and Huron, spring and late summer/early fall 2008. Agency abbreviations: USGS = United States Geological Survey, Great Lakes Science Center, EPA = U.S. Environmental Protection Agency, Great Lakes National Program Office. ID numbers coordinate with Fig. 1.

| Lake | ID | Station name/serial | Agency | Date sampled | Station depth (m) |
|----------|----|---------------------|--------|--------------|-------------------|
| Michigan | 1 | MI11 | EPA | 15-Apr-2008 | 122 |
| | 2 | 105 | USGS | 8-Aug-2008 | 90 |
| | 3 | MIFE | EPA | 15-Apr-2008 | 64 |
| | 4 | 108 | USGS | 28-Aug-2008 | 115 |
| | 5 | 90 | USGS | 21-Aug-2008 | 105 |
| | 6 | 82 | USGS | 20-Aug-2008 | 80 |
| | 7 | 88 | USGS | 20-Aug-2008 | 130 |
| | 8 | 78 | USGS | 17-Aug-2008 | 150 |
| | 9 | 74 | USGS | 16-Aug-2008 | 150 |
| | 10 | MI41M | EPA | 18-Apr-2008 | 258 |
| Huron | 11 | 70 | USGS | 15-Aug-2008 | 210 |
| | 12 | 111 | USGS | 20-Sep-2008 | 82 |
| | 13 | 154 | USGS | 26-Sep-2008 | 114 |
| | 14 | 165 | USGS | 29-Sep-2008 | 82 |
| | 15 | HUFE | EPA | 5-Aug-2008 | 111 |
| | 16 | 148 | USGS | 25-Sep-2008 | 66 |
| | 17 | 157 | USGS | 26-Sep-2008 | 108 |
| | 18 | 120 | USGS | 21-Sep-2008 | 74 |
| | 19 | 161 | USGS | 27-Sep-2008 | 96 |
| | 20 | HU37 | EPA | 20-Apr-2008 | 70 |
| | 21 | 141 | USGS | 23-Sep-2008 | 77 |
| | 22 | HU27 | EPA | 8-Aug-2008 | 53 |
| | 23 | HU45M | EPA | 6-Aug-2008 | 95 |

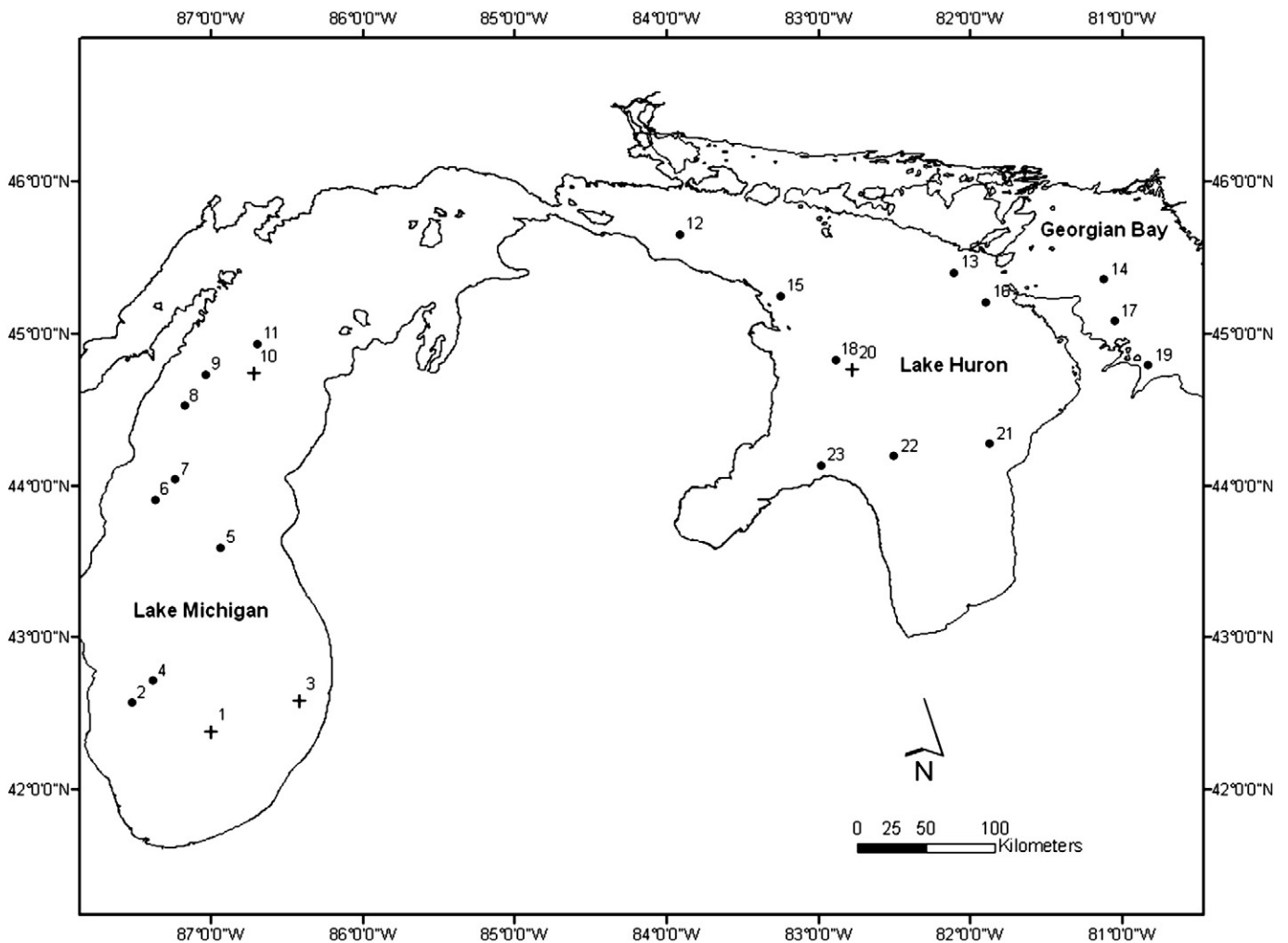


Fig. 1. Map showing station locations in lakes Michigan and Huron. Cross symbols represent stations sampled in spring 2008; circle symbols represent stations sampled in summer 2008. See Table 1 for station names and characteristics, including sampling agency.

nitrogen to prevent lipid degradation before samples arrived at the laboratory for analysis.

Mysis samples for lipid analysis were also collected from lakes Michigan and Huron, and Lake Huron's embayment Georgian Bay, during United States Geological Survey (USGS) acoustic surveys in late summer and early fall 2008 aboard the R/V Sturgeon (Fig. 1, Table 1). Tows were performed as described above; however, samples were stored onboard the ship in a -80°C freezer prior to transfer to the laboratory.

Lipid and fatty acid analyses were conducted at the USGS Great Lakes Science Center, Ann Arbor, MI. Samples of *Mysis* were held at -80°C until processing. Total lipids were extracted according to Folch et al. (1957), using chloroform–methanol (2:1 v:v) containing 0.025% butylated hydroxytoluene as an antioxidant. Solvents were evaporated under nitrogen gas and percent lipid was determined gravimetrically. A minimum wet weight of 0.10 g of tissue was necessary for accurate extraction, so generally three to five adult mysids from a particular sampling station were pooled into a single sample. In this paper, only data from samples containing adult mysids are presented.

Fatty acids were converted to fatty acid methyl esters (FAMES) with boron trifluoride–methanol as described in Metcalfe and Schmitz (1961). Thirty-five separate FAMES, including C19:0 as an internal standard, were quantified by a gas chromatograph–mass spectrometer (GC/MS) using an Agilent GC/MS system (HP 6890 GC and HP 5973 MS) with a Supelco® Omegawax™ 320 column and helium as the carrier gas. Injector temperature was 250°C . Oven temperature programming was per Rinchar et al. (2007). Mass spectrometer source temperature was 230°C . Positive identification of FAMES was made by comparing retention times and spectra of FAMES in samples with standards (Nu-Chek-Prep, Inc. and Supelco®); and with known spectrographic patterns of FAMES as determined by William W. Christie at the Scottish Crop Research Institute (and MRS Lipid Analysis Unit), Invergowrie, Dundee (DD2 5DA), Scotland (www.lipidlibrary.co.uk). Individual FAs are reported as percentage of total FAs detected.

Total lipids were measured as percentage of *Mysis* wet lab weight (%WW). We converted some TL values to percentage of dry weight (%DW) for purposes of comparison with values in the literature using the equation developed for *Mysis* by Chipps (1997):

$$\text{DW} = \left(\frac{\text{WW}}{1.14} \right)^{1.37}$$

where DW = dry weight and WW = wet weight. Due to low sample sizes, data on *Mysis* TLs and FAs were averaged within each lake, and statistical analysis of spring data was not possible. In cases where mean summer values of TLs or FAs were compared between the two lakes, a non-parametric Mann–Whitney *U* test with a significance level of $\alpha = 0.05$ was used. All statistical analyses were performed using Predictive Analytics SoftWare (PASW) Statistics 17.0 software (SPSS Inc. 2009, Chicago, IL).

Results and discussion

In spring 2008, mean total lipid as percentage of wet weight (%TL) in adult *Mysis* from Lake Michigan was 6.9% (17.8% converted to dry weight, DW; $N = 5$), and the Lake Huron value was 5.0% (13.9% DW; $N = 1$) (Table 2). Mysids from both lakes had higher %TL in summer than in spring. Percent TL of adult mysids in Lake Michigan sampled in summer 2008 was 9.3% (25.0% DW), significantly higher than the Lake Huron mean of 5.8% (14.8% DW) (Mann–Whitney $U = 31.0$, $p = 0.046$).

In Lake Huron, mean %DHA of adult *Mysis* was higher than in Lake Michigan in both spring and summer 2008 (Table 2). In spring, the Lake Michigan mean was 12.0% compared with the Lake Huron mean of 27.0%. Percent DHA decreased in both lakes from spring to summer,

Table 2

Spring and summer mean total lipids (as percent wet lab weight (%WW) and percent dry weight (%DW) converted using Chipps' (1997) equation and fatty acids (FAs) (as % of total FAs detected) for adult *Mysis* in lakes Michigan and Huron, 2008. Sample size (N) represents number of composite samples of multiple animals. Standard errors are in parentheses. nd = not detected. Three-letter abbreviations are given for the essential fatty acids of interest in this paper.

| | Spring | | Summer | |
|------------------------|---------------|------------|---------------|-------------|
| | Lake Michigan | Lake Huron | Lake Michigan | Lake Huron |
| Sample size | $N = 5$ | $N = 1$ | $N = 14$ | $N = 26$ |
| Stations sampled | 3 | 1 | 8 | 11 |
| Total lipids (%WW) | 6.9 (1.6) | 5.0 | 9.3 (0.7) | 5.8 (0.4) |
| Total lipids (%DW) | 17.8 (8.0) | 13.9 | 25.0 (2.0) | 14.8 (0.8) |
| FAs | | | | |
| <i>Saturated</i> | | | | |
| 12:0 | 0.2 (0.02) | 5.0 | 0.3 (0.01) | 0.3 (0.01) |
| 14:0 | 3.0 (0.7) | 1.0 | 4.9 (0.2) | 4.2 (0.2) |
| 15:0 | 0.4 (0.04) | 0.2 | 0.5 (0.03) | 0.4 (0.01) |
| 16:0 | 15.5 (0.5) | 14.9 | 15.3 (0.3) | 15.8 (0.2) |
| 17:0 | nd | nd | nd | nd |
| 18:0 | 1.3 (0.1) | 1.6 | 1.2 (0.04) | 1.3 (0.04) |
| 23:0 | nd | nd | nd | nd |
| Σ Saturated | 20.3 (1.1) | 17.8 | 22.2 (0.4) | 22.0 (0.3) |
| <i>Monounsaturated</i> | | | | |
| 14:1 | nd | nd | nd | nd |
| 16:1 <i>n</i> -9 | nd | nd | nd | nd |
| 16:1 <i>n</i> -7 | 11.4 (3.7) | 0.8 | 12.4 (1.1) | 8.2 (0.6) |
| 17:1 | nd | nd | nd | nd |
| 18:1 <i>n</i> -9 | 14.1 (1.7) | 13.0 | 14.1 (0.3) | 15.4 (0.5) |
| 18:1 <i>n</i> -7 | 4.1 (0.3) | 3.9 | 4.4 (0.1) | 4.3 (0.1) |
| 20:1 | 0.2 (0.1) | nd | 0.3 (0.1) | 0.1 (0.03) |
| 20:1 <i>n</i> -9 | 1.0 (0.1) | 1.0 | 1.2 (0.04) | 1.3 (0.1) |
| 22:1 | nd | nd | nd | nd |
| 22:1 <i>n</i> -9 | nd | nd | nd | nd |
| Σ Monounsaturated | 30.8 (2.5) | 18.6 | 32.2 (0.9) | 29.3 (0.6) |
| <i>Polyunsaturated</i> | | | | |
| 18:2 <i>n</i> -6 (LIN) | 7.6 (3.8) | 3.2 | 5.0 (0.3) | 5.9 (0.6) |
| 18:2-11,14 | 0.1 (0.03) | nd | 0.01 (0.01) | 0.1 (0.04) |
| 18:3 <i>n</i> -3 (ALA) | 0.4 (0.4) | nd | 3.1 (0.4) | 0.9 (0.3) |
| 18:4 <i>n</i> -3 | 2.8 (0.8) | nd | 3.8 (0.1) | 2.6 (0.2) |
| 20:2 <i>n</i> -6 | 1.0 (0.1) | 1.5 | 1.1 (0.04) | 0.9 (0.03) |
| 20:3 <i>n</i> -6 | nd | nd | 0.01 (0.01) | 0.01 (0.01) |
| 20:4 <i>n</i> -6 (ARA) | 3.3 (0.6) | 6.0 | 3.4 (0.3) | 5.0 (0.3) |
| 20:3 <i>n</i> -3 | 0.7 (0.1) | nd | 0.8 (0.04) | 0.3 (0.04) |
| 20:4 <i>n</i> -3 | 1.3 (0.2) | nd | 1.4 (0.1) | 0.9 (0.1) |
| 20:5 <i>n</i> -3 (EPA) | 18.3 (1.5) | 24.0 | 15.2 (0.3) | 18.1 (0.5) |
| 22:4 <i>n</i> -6 | nd | nd | 0.03 (0.02) | nd |
| 22:5 <i>n</i> -6 | 1.2 (0.2) | 2.0 | 1.7 (0.1) | 1.7 (0.1) |
| 22:5 <i>n</i> -3 | 0.3 (0.1) | nd | 0.5 (0.1) | 0.3 (0.1) |
| 22:6 <i>n</i> -3 (DHA) | 12.0 (2.0) | 27.0 | 9.6 (0.4) | 12.0 (0.6) |
| Σ Polyunsaturated | 48.9 (3.5) | 63.6 | 45.7 (1.0) | 48.6 (0.7) |

with a Lake Michigan mean of 9.6% and a Lake Huron mean of 12.0% in summer (Table 2). The difference in summer mean %DHA between lakes was not significant (Mann–Whitney $U = 93.0$, $p = 0.062$).

There appear to be differences in the proportions of several other EFAs, including linoleic acid methyl ester (18:2*n*-6) (LIN), α -linolenic acid (18:3*n*-3) (ALA), arachidonic acid methyl ester (20:4*n*-6) (ARA), and eicosapentaenoic acid (20:5*n*-3) (EPA) (Table 2). The proportion of the monounsaturated fatty acid 16:1*n*-7 was 11.4% in Lake Michigan *Mysis* in spring, but only 0.8% in Lake Huron. During summer in Lake Michigan, percentage of 16:1*n*-7 was 12.4%, significantly higher than the Lake Huron mean of 8.2% (Mann–Whitney $U = 73.0$, $p < 0.001$).

Differences in %TL and fatty acids lend insight into diet and nutritional condition of *Mysis* in the two lakes. Although sample sizes were small, patterns in %TL and %DHA values suggest that *Mysis* in Lake Huron could have been starving during spring 2008. Adult *Mysis* collected from Lake Ontario in April and exposed to 6 weeks of fasting had TLs below 14% of dry weight (Schlechtriem et al., 2008), while

Mysis from our Lake Huron station in spring 2008 had a mean %TL of 13.9% DW (5.0% WW). Although relying on Chipps' (1997) equation to convert from wet to dry weight complicates comparisons, %DHA is not a weight-based measurement and is thus directly comparable. Schleichriem et al.'s (2008) starved mysids consistently had %DHA above 25%; our Lake Huron spring measurement was 27%.

In Lake Michigan in spring, mean %TL was above the Schleichriem et al. (2008) starvation threshold of 14% and mean %DHA was well below the starvation threshold of 25%. Thus, there is no indication that *Mysis* in Lake Michigan were seriously food-limited. Lake Michigan spring *Mysis* appear to be in similar physiological condition as populations in the 1980s. Our measured lipid content is lower than the 27% reported for Lake Michigan in April 1984 (Gardner et al., 1985); however, the Gardner et al. (1985) value is relative to ash-free dry weight (AFDW) and thus is expected to be higher.

Total lipids in adult *Mysis* from both lakes increased from spring to summer, a pattern commonly observed in *Mysis* populations (Adare and Lasenby, 1994; Gardner et al., 1985) that likely reflects seasonal changes in availability of high-quality food. However, mean %TL of adult mysids in Lake Huron did not increase as much as in Lake Michigan, and the Lake Huron summer mean was close to the 14% starvation threshold at 14.8% DW. This suggests that Lake Huron *Mysis* might have been in worse condition than Lake Michigan *Mysis* even in summer. As observed in spring, mean %TL of *Mysis* in Lake Michigan in summer 2008 was lower than the mean reported for summer 1984 (Gardner et al., 1985), but values from the 1980s are likely skewed high because they were measured relative to AFDW. Mean %DHA decreased in both lakes from spring to summer, with a large drop in Lake Huron from 27.0% to 12.0%.

If Lake Huron *Mysis* populations were experiencing food limitation in spring 2008, there are several possible causes: intraspecific competition, interspecific competition, and limited food availability. If intraspecific competition among *Mysis* were important, we would expect to see degraded *Mysis* nutritional condition where abundance was higher. Based on a linear regression between *Mysis* %TL and abundance from samples from the same stations (Mida, 2010), higher *Mysis* densities do not appear correlated with lower condition; thus, intraspecific competition was unlikely.

Interspecific competition with other large zooplankton species could also contribute to food limitation in *Mysis*. Diets of both *Limnocalanus macrurus* and *Bythotrephes longimanus* overlap with that of *Mysis* (Branstrator and Lehman, 1991; Lehman, 1991; Warren, 1985) and these species have recently increased in abundance (Barbiero et al., 2009a, 2009b). Additionally, Bunnell et al. (2011) found that in May–October 2007, *Bythotrephes* consumed more zooplankton than did fish or *Mysis* in northern Lake Huron. Diet overlap with this non-native planktivore could result in competition for zooplankton resources. However, vertical distributions of *Bythotrephes* and *Mysis* in the water column do not overlap to a large degree, which may limit competition between the two species (Foster and Sprules, 2009).

The third possible explanation for decreased physiological condition in *Mysis* is a decline in the availability of phytoplankton and zooplankton due to oligotrophication of open-water regions of the Great Lakes. Abrupt and dramatic declines in offshore primary production in the past 5 to 10 years, evidenced by increasing Secchi depths, declines in chlorophyll *a* concentrations, decreases in seasonal silica depletion, and reductions in phytoplankton biomass, have occurred in both Lake Michigan (Barbiero et al., 2009b; Evans et al., 2011; Fahnenstiel et al., 2010a; Kerfoot et al., 2010; Mida et al., 2010) and Lake Huron (Barbiero et al., 2009b; Evans et al., 2011) and are likely due to dreissenid mussel filtering (Fahnenstiel et al., 2010a,b). Reductions in phytoplankton biomass were especially dramatic for diatoms that typically bloom early in the spring and once dominated the spring phytoplankton community (Barbiero and Tuchman, 2001). This production peak has recently all but disappeared in southern

Lake Michigan, and sparse remaining production has shifted to occur later in spring (Fahnenstiel et al., 2010a). Recovery of some zooplankton species from food limitation is highly dependent on the type of algae available during the restoration period; thus, zooplankton populations tend to synchronize peak population densities with densities of high-quality, lipid-rich foods (Arts, 1999). If *Mysis* experience a deficiency of quality food in winter (Schleichriem et al., 2008) they may rely on the spring diatom bloom as an important food source (Gardner et al., 1985), and changes in timing and magnitude of phytoplankton productivity in the spring could be prolonging overwinter starvation.

In addition to declines in the availability of phytoplankton, reductions in zooplankton biomass could be affecting *Mysis*. Populations of the cladoceran *Daphnia*, a preferred food of *Mysis* (Balcer et al., 1984; Bowers and Vanderploeg, 1982), have decreased in both lakes in the past decade (Barbiero et al., 2009a,b). These changes in zooplankton populations are likely a consequence of the aforementioned reductions in primary production (Barbiero et al., 2011).

Differences in other fatty acids provided additional information related to the question of whether Lake Huron *Mysis* were starving in spring 2008 and whether they were nutritionally impaired compared with Lake Michigan *Mysis* during both seasons. Lake Huron mysids had higher %ARA than Lake Michigan mysids in both spring and summer; Schleichriem et al. (2008) found that ARA was consistently conserved during fasting, similar to DHA. In addition, Napolitano (1999) suggested that 16:1n-7 may be a marker for a diatom-based diet. The low proportion of 16:1n-7 in *Mysis* from Lake Huron in spring 2008, especially compared with the large proportion of that fatty acid observed in Lake Michigan *Mysis*, may indicate reduced diatom availability in Lake Huron. However, the influence of diet on fatty acid profiles has not been clearly established for freshwater invertebrates (Arts, 1999), so it is difficult to determine whether the patterns observed in this study resulted from between-lake differences in diet composition.

It must be noted that *Mysis* at different life stages and sizes can differ in lipid content and FA profiles (Adare and Lasenby, 1994). Though we attempted to separate juvenile from adult mysids for this study, we did not measure the length of the animals before analysis, so we were unable to determine the exact effect of life stage on the observed differences in TLs and FA profiles. Indeed, *Mysis* samples taken during the U.S. EPA survey showed differences in mean length between the two lakes, and *Mysis* in Lake Michigan on average tended to be larger than Lake Huron mysids (Mida, 2010). Total lipids of *Mysis* also vary seasonally (Adare and Lasenby, 1994; Gardner et al., 1985); thus, because some of our Lake Huron summer samples were collected in September, and all Lake Michigan samples were from August, between-lake comparisons could be affected by seasonal differences. Total lipids and %DHA of Lake Huron mysids, however, did not change significantly from August (N=9) to September (N=17) (%TL: Mann-Whitney U=50.0, p=0.164; %DHA: Mann-Whitney U=89.0, p=0.525). Thus, we feel confident that between-lake differences in %TL and %DHA in summer were not due to differences in sampling month.

Conclusions

Our results suggest that nutritional condition of *Mysis* in Lake Huron in spring 2008 differed from that of Lake Michigan, and that *Mysis* in Lake Huron could have been starving. Recent declines in primary production in lakes Michigan and Huron and changes in lower food webs are potential drivers of these spatial and temporal differences in lipids and fatty acid profiles. However, small sample sizes and limited spatial distribution make it difficult to conclude this with certainty. In addition, it is important to note that *Mysis* used by Chipps et al. (1997) originated from Lake Pend Oreille, ID. Our use of

this conversion equation results in only an estimate of dry weight for Great Lakes mysids.

To reach more definitive conclusions, it is important that populations of *Mysis*, and other components of the lower food web such as zooplankton, be sampled simultaneously both seasonally and annually to monitor coincident changes through time. Lipid and fatty acid analyses may be particularly useful in identifying populations that are experiencing starvation, but the number of samples needs to be increased and sampling must be conducted more frequently to understand dynamics of *Mysis* physiological condition across space and time. To understand overwintering effects, *Mysis* should be sampled from the same stations in fall and the following spring to investigate changes in the same local community of animals. These analyses also should be combined with other condition indices, such as RNA:DNA ratios. In conclusion, these data serve as a stimulus to encourage the investigation of whether *Mysis* in these lakes could be facing chronic starvation in the near future.

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