Stable Isotope Analysis of Food Webs Supporting Fisheries in the Muskegon River Watershed and Nearshore Lake Michigan

Katharine Marko[1,2], Edward Rutherford[3], Brian Eadie[3] and Margaret Lansing[3]

[1]University of Michigan, Ann Arbor, MI, [2]US EPA, [3]NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI

Goal

Great Lakes food webs have changed dramatically with invasive species introductions, reductions in nutrient inputs, human population growth, and consequent degradation of watershed and near shore environments. The dependence of fisheries on nearshore and watershed habitats is poorly known. Stable isotope analysis is useful for identifying habitat dependency (using Carbon) and trophic interactions (using Nitrogen).

The Muskegon River watershed is the 2nd largest tributary to Lake Michigan and supports large populations of key fisheries species (Chinook salmon, walleye, trout, bass, pike, suckers), as well as lake sturgeon.

We used carbon (δC^{13}) and nitrogen (δN^{15}) stable isotopes and diet analysis to quantify habitat dependence of key fisheries species on habitats in the Muskegon River watershed and near shore Lake Michigan.

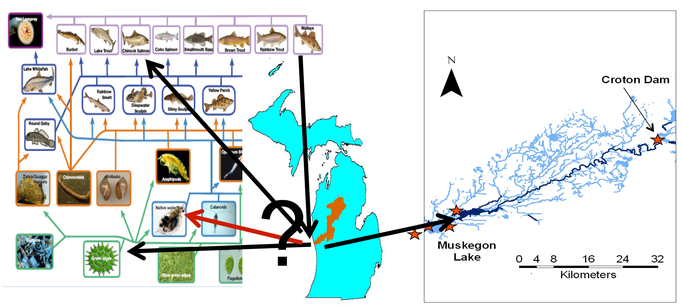


Figure 1. Lower Muskegon River and Muskegon Lake (right). Lake Michigan food web and Muskegon River watershed in Michigan's lower peninsula (left). Stars indicate sampling locations for nutrients.

Methods

- We measured flow and nutrients monthly at five locations throughout the watershed and nearshore Lake Michigan from May through October, 2003, and sampled sediments in May and September.
- We sampled biota monthly at 4 sites from May to October, and at 14 sites within multiple habitats in May and October.
- We measured isotope signatures of sediment fractions, particulate organic matter (POM), zooplankton, and lipid-extracted tissues of macroinvertebrates and fish. We also examined fish diets.

Results

Nutrients –Table below shows annual particulate organic carbon (POC) and total phosphorus (TP) loads flowing into and out of Muskegon Lake (ML) and into Lake Michigan in 2003. The difference is retained in Muskegon Lake, a prime nursery area for key fisheries species and their prey. Also shown are nutrient loads flowing into Muskegon Lake in 1994 and 1995.

	POC (kgC/y)	TP (KgP/y)
1994 into ML	1.2 e 6	6.4 e 4
1995 into ML	1.4 e 6	4.3 e 4
2003 into ML	1.3 e 6	3.7 e 4
2003 out of ML	0.5 e 6	2.4 e 4
2003 Retained in ML	0.8 e 6	1.3 e 4

Sediments – Carbon and nitrogen isotope signatures for lightest surface sediment fractions (<63 µm) indicate retention and processing of organic matter in Muskegon Lake. Lake Michigan carbon signature is enriched with respect to Muskegon Lake, and depleted in nitrogen.

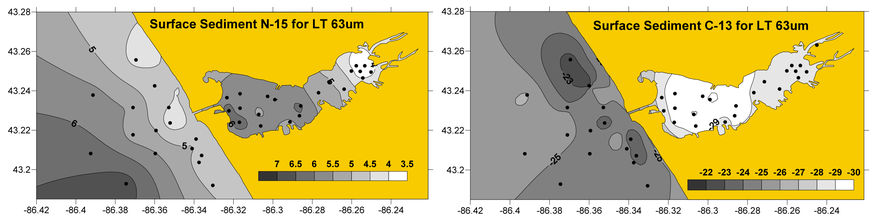
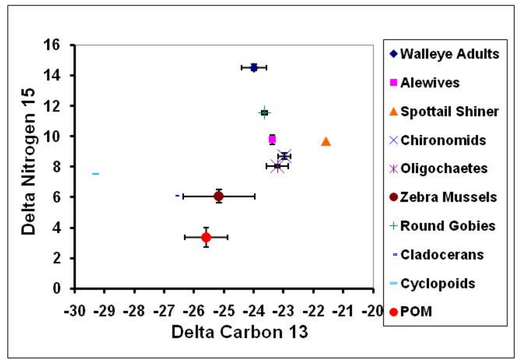


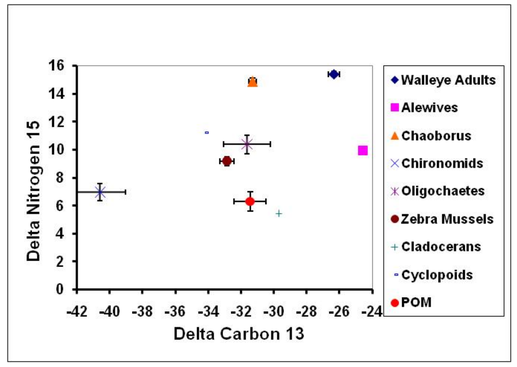
Figure 2. δN^{15} and δC^{13} isotope signatures in Muskegon Lake and nearshore Lake Michigan during September, 2003. Coordinates of latitude and longitude are on vertical and hortizontal axes, respectively.

Food Webs -

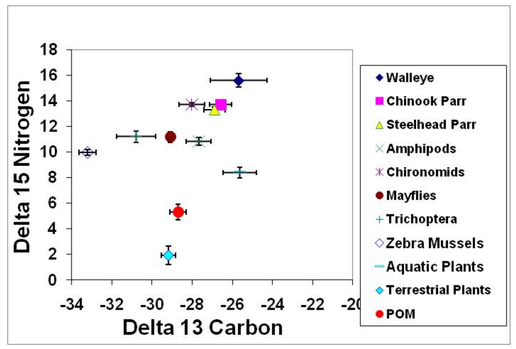
Nearshore Lake Michigan food web, Summer 2003. Shown are average (+ 1 s.e.) δC^{13} and δN^{15} isotope signatures of species groups. The lake carbon signature is enriched with respect to Muskegon Lake or Muskegon River. Assuming an increase of 3.4% in nitrogen per trophic level, walleyes are feeding on alewives and round gobies.



Muskegon Lake food web, Summer 2003. Extensive processing of organic matter and methanogenesis by bacteria deplete the carbon signature of the lower food web, making it distinct from Lake Michigan or Muskegon River. Walleyes and their alewife prey show enriched carbon signatures, indicating recent arrival from Lake Michigan. Depleted zooplankton carbon signatures may result from not extracting lipids before analysis



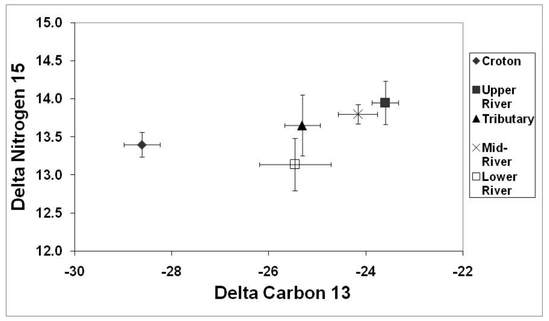
Upper Muskegon River food web, Spring/Summer 2003. Walleyes feed on chinook and steelhead parr, which prey on macroinvertebrates, which in turn use aquatic and terrestrial plants as particulate organic matter sources (POM). As in Muskegon Lake, depleted carbon signatures for zebra mussels may result from methanogenesis by bacteria in the impoundment above Croton dam.



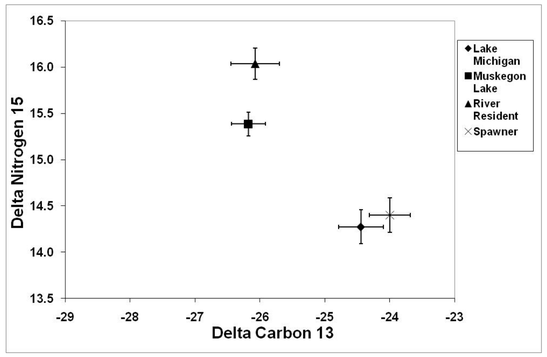
Funding - University of Michigan and Great Lakes Fisheries Trust.

Fisheries species isotopic variation is habitat-dependent -

Isotope signatures of Chinook salmon parr varied among river habitats during parr out-migration, Spring 2003 and 2004. Site variation reflected signatures of parr's prey: zooplankton from upstream impoundment (Croton dam), and macroinvertebrates from creek and other river habitats.



Walleye isotope signatures varied among river and lake habitats. Most spawning walleyes collected in upper Muskegon River immigrated from Lake Michigan and had consumed alewives, while walleyes resident in lower Muskegon River and Muskegon Lake reflected isotope signatures of salmonid parr and alewife prey, respectively, in these areas.



Conclusions

Stable isotope analysis defined carbon sources of food webs supporting key sport fishes in watershed and nearshore Great Lakes habitats. Nutrients, sediment, and organic matter from Muskegon River are retained in Muskegon Lake, and largely do not contribute directly to food web and fisheries of nearshore Lake Michigan.

Users

Managers and scientists may use this information to conserve habitats and predict impacts of invasive species such as Asian carp.

Status

Marko, K.M. 2008. Tracing the Flow of Organic Matter from the Muskegon River Estuary System to Nearshore Lake Michigan: a Stable Isotope Analysis. Masters thesis, University of Michigan, Ann Arbor.