Approaches to understanding the fate of mercury in aquatic ecosystems

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Photo credit: M. Clayden
What am I going to talk about?

• Why do fish vary in their mercury levels?
• What happens to mercury in aquatic food webs?
  – Mercury hotspot – Nova Scotia
  – Arctic lakes
  – Global trends in mercury
• The future – climate change, Minamata Convention
Sources of mercury

http://www.backyardnature.net/q/mercury.htm

Methylmercury (MeHg) in aquatic ecosystems

Diet and environment matter

Global concerns about human and wildlife exposure

Higher in systems
- With low pH
- Higher water organic carbon
- Lower nutrients

Accumulates in body, neurotoxic and impairs reproduction in fish and fish-eating wildlife and humans (Hammerschmidt et al. 2001; Burgess & Meyer 2008)
Inputs drive methylmercury in prey and fish

Orihel et al. 2007 ES&T

**Graphs**

1. **B. Amphipoda**
   - Linear regression equation: $Y = -0.81 + 0.81X$
   - $F = 19$, $p = 0.002$
   - $R^2 = 0.71$

2. **E. Age 1 Fish**
   - Linear regression equation: $Y = -0.33 + 0.91X$
   - $F = 297$, $p < 0.00001$
   - $R^2 = 0.97$
Why does mercury vary?

• Inputs (point sources)
• Water quality (pH, nutrients, etc.)
• Physical characteristics (size, wetlands, depth)
• Biology (diet, age/size, growth)

Vermont Agency of Natural Resources
Mercury in aquatic food webs

- Using nitrogen isotopes ($\delta^{15}N$) to measure trophic position
- Log [MeHg] and $\delta^{15}N$ positively related
- Slope of regression is average biomagnification
Kejimkujik National Park and National Historic Site (Keji)

Biological “mercury hotspot”
Some lake food webs concentrate mercury more than others

- Studied 11 lakes
- Slopes varied
- Why?

- Big Dam West: $0.16, R^2 = 0.85, p < 0.001$
- North Cranberry: $0.19, R^2 = 0.90, p < 0.001$
- Beaverskin: $0.23, R^2 = 0.92, p < 0.001$
Higher mercury transfer in food webs of lakes with:
- Lower N, P, organic carbon, Fe, Al, Ca
- Why?

What is happening in Arctic lakes?

Arctic charr in Nunavut

• Important cultural and economic value
• Source of contaminants to consumers
• Susceptible to climate change
• Anadromous (sea-run) and lacustrine (lake-dwelling) populations
Coastal Arctic lakes with lake trout (three with anadromous Arctic charr)
Heidi’s fun in the field

Watching for bears is important

Gill netting at Nauyuk Lake
Fish community affects mercury in lake trout

Life history also affects mercury in fish

- Like charr, lake trout also migrate to the sea (otoliths, isotopes)
- Lake trout that migrate have lower mercury
- Charr have lower mercury than trout

What drives mercury in food webs globally?

69 studies
205 food webs

Biomagnification of Mercury in Aquatic Food Webs: A Worldwide Meta-Analysis

Legend
- MeHg slope
- THg slope

Latitude explains some variability:

- cold T°:
  - ↓ somatic growth dilution
  - ↓ excretion rate = ↑ accumulation

Converted slopes (increase / trophic level):
What about international mercury pollution?

- Hg pollution is a global concern due to long range transport
- Emissions decreasing in N. America, increasing in Asia
- Artisinal gold mining now largest source
- Most (~70%) of Hg in atmosphere from outside N. America (Selin and Jacob, 2008)

Minamata Convention came into force in August, 2017 (yahoo)

- Will it help reduce Hg in fishes?
- How long will it take?
- How will climate change affect its success?
How will mercury be affected by climate change?

• Higher temperature and precipitation could increase
  • Methylation of HgII to MeHg
  • Availability of MeHg to base of food web
  • Primary production

• Also changes in biology and ecology
  • Distributions of species
  • Habitat use (e.g. access to ocean)
  • Diets
  • Growth/condition /metabolism of food web organisms

• Overall impact difficult to predict, will depend on local climate changes and environment

http://http-server.carleton.ca
Temporal trends of mercury in fish and wildlife in Canada - Canadian Mercury Science Assessment led by Environment Canada
Summary

• 50+ years of Hg studies, but lots of unknowns for GWF
• Mercury remains critical issue for human, wildlife and fish health
• Inputs, ecosystem and ecological characteristics important drivers
• Minamata Convention fantastic, should decrease exposure

• Monitoring is critical for understanding risks and environmental change
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Links for GWF

Global Change Drivers

- Invasive species
- Climate change
  - Land use change
  - Hydrologic alteration

Mechanisms underlying Bioaccumulation

- Primary productivity
- Habitat use
- Bioenergetics
- Food web structure

MeHg Bioaccumulation and Biomagnification

Eagles-Smith, C. et al. 2018 Ambio