Reservoir management to minimize mercury in fish: lessons from a hydropower storage basin

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Jody Kubitz, Ph.D.
Deer Lake is a Great Lakes Area of Concern (AOC)
Deer Lake AOC is connected to Coastal Lake Superior
Image of Deer Lake reservoir
New flooding increases mercury methylation

- A 'standard' (24-inch) northern pike from Deer Lake
- MDCH guideline for "no consumption"
- FDA action level
- MDCH guideline for unrestricted consumption

Sediments exposed

Sediments flooded

Year fish captured

Mercury concentration (mg/kg)
3 critical requirements for mercury methylation

Anaerobic (sulfate-reducing) bacteria

\[ \text{Hg}^{+2} \quad \text{Hg}^{+2} \quad \text{SO}_4^{-2} \]
Objective was to minimize net mercury methylation

- Sediment - Maintain a “full” reservoir condition to minimize sediment-based nutrients (sulfate) for mercury-methylating bacteria

- Water Column - Release cold water through the valve before oxygen is consumed (anaerobic)
  - Higher oxygen content minimizes the growth of methylating bacteria
  - Higher oxygen content maximizes the growth of de-methylating bacteria
Sediment - maintain stable sulfides & “starve” SRB

Anaerobic (sulfate-reducing) bacteria

Hg$^{+2}$

FeS
H$_2$S
Water - maintain aerobic conditions & SRB cannot compete for carbon
Make Blue Large and Green Small
Move O/A Boundary to Sediment/Water Interface

O/A Boundary

Sediments

deposition
evasion
demethylation
bioaccumulation
methylation
sedimentation
Northern pike say that source control + SRB starvation work quite well
Water Column Management: bottom water release
Valve closed: 3,400 mg methyl mercury per year
Valve open: 2,000 mg methyl mercury per year

136 acre-feet

427 acre-feet
Yellow perch say that bottom water discharge works quite well
What does Deer Lake tell us that applies elsewhere?

- Flooded soils and wetlands typically generate and export methyl mercury

- Aquatic habitat management can control mercury methylation
  - Microbial habitat (aerobic vs anaerobic)
  - Sulfur cycling (sulfate vs sulfide)
  - Carbon, Nitrogen and Phosphorus loading matter

- If mercury is an issue in sediments and/or fish
  - Recommend a stable water level (run-of-river)
  - Recommend bottom- water discharge

- Reservoirs, if properly managed, are methyl mercury sinks
  - Deer Lake keeps 80% of the mercury from its watershed out of the coastal zone of Lake Superior
What is the sustainability message?

- United Nations Brundtland Commission (June 1987) defined Sustainable Development as
  “…meets the needs of the present without compromising the ability of future generations to meet their own needs”

- Global Reporting Initiative (GRI)
  - International framework for reporting environmental, social and economic performance (triple bottom line)
  - Developed in response to the EXXON Valdez oil spill in 1989 by Ceres, an association for investors
  - Assumes if we manage for sustainable performance, disasters will be avoided
  - United Nations Environment Programme (UNEP) joined forces with Ceres in 1990
  - GRI spun off as an independent organization in 2001
  - Third generation guidelines (g3) released in 2007
The GRI g3 has six indicator protocols

- Economic & Financial
- Environmental
- Social
- Labor Practices & Human Rights
- Communication & Public Relations
- Product Service & Responsibility
## Economic & Financial Performance Comparison

<table>
<thead>
<tr>
<th>Managed Reservoir</th>
<th>Drained &amp; Dredged</th>
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<tbody>
<tr>
<td>• $50,160,000 property value</td>
<td>• $10,505,500 property value</td>
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<tr>
<td>• $37,000 annual fishery value</td>
<td>• $1,040 annual fishery value</td>
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<tr>
<td>• Full-time mining jobs maintained</td>
<td>• Full-time mining jobs lost</td>
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<tr>
<td></td>
<td>• Part-time construction jobs gained</td>
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Deer Lake at normal pool
Deer Lake drawn down
Environmental Performance Comparison

- Managed Reservoir
  - 1,010 acre lake
  - Methyl mercury budget
    - ~9 g input
    - ~2 g in-lake
    - ~2 g to Lake Superior
  - 1,516 acres land protected
    - 34,000 feet shoreline
    - 4.5 river miles
  - 1,645 gallons diesel
  - 10,225 miles driven
  - 16,615 kg CO₂

- Drained & Dredged
  - 90 acre lake
  - Mercury budget (est)
    - ~9 g input
    - ≥2 g in basin
    - ≥ 11 g to Lake Superior
  - No land conservation
    - 4 river miles restored
  - 901,204 gallons diesel
  - 7,389,144 miles driven
  - 9,102,160 kg CO₂
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<th>Social Performance Comparison</th>
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<tr>
<td><strong>Managed Reservoir</strong></td>
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<tr>
<td>- Human health protected</td>
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<tr>
<td>- ≤14 miles from population center to excellent walleye fishery</td>
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<tr>
<td>- Trout stream protected</td>
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<td>- 40 personal vehicle trips of traffic over 30 years</td>
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<tr>
<td><strong>Drained &amp; Dredged</strong></td>
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<tr>
<td>- Human health protected</td>
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<tr>
<td>- 53 miles from population center to excellent walleye fishery</td>
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<tr>
<td>- Trout stream vulnerable</td>
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<td>- 29,320 semi-truck trips of traffic over 8 years</td>
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Summary

- Reservoirs can be managed to control methyl mercury in fish
  - Microbial communities can be managed by manipulating habitat
  - Nutrients are also important
  - Sediment, wetland and water column habitats need to be considered in a comprehensive plan

- Recommendations for methyl mercury management
  - Stable pool preferred over fluctuating water level
  - Run-of-river hydraulic regimens are preferred
  - Bottom water release is generally preferred

- The GRI g3 is a useful sustainability assessment tool
  - Flexible self-reporting method
  - Gaining acceptance in the private sector, used to communicate p
  - Useful for comparing options and communications
Thank You

Jody.kubitz@cardno.com