Spatial and Temporal Dynamics of Microcystins and their Relation to Other Water Quality Variables in Upper Klamath Lake, Oregon

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Background: Upper Klamath Lake (UKL)

- Large (232 km²), shallow (2.8 m, average)
- Hypereutrophic
- Seasonal blooms of *Aphanizomenon flos-aquae* (AFA; > 90 %)
- Endangered Lost River and shortnose suckers

http://or.water.usgs.gov/klamath/
Background: Microcystins in UKL

- Toxigenic M. aeruginosa detected in A. flos-aquae dietary supplements by Gilroy et al., 2000; Saker et al. 2007.
- Pathological effects on juvenile suckers investigated by USGS, 2007-present, as seen by VanderKooi et al., 2010.
- Microscopic gut analysis, 2008, showing M. aeruginosa ingested during benthic feeding by B. Rosen, USGS, unpublished data.
Sample Collection 2007-2011

- All years: Water column
- 2009: Sediment cores and sediment traps
- 2010: Chironomid larvae
- 2011: qPCR (MDN, MDT)

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<th>Year</th>
<th>MDN</th>
<th>WMR</th>
<th>EPT</th>
<th>MDT</th>
<th>MDL</th>
<th>RPT</th>
<th>HDB</th>
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Dissolved, 2008-2011

Large Particulate Fraction, 2007-2011
Sediment Surface, Traps 2009

![Graphs showing Microcystins concentrations over time]
Spatial Variation 2009, 2011

Based on 2-year median values

EXPLANATION

Dissolved microcystins
- Low
- Moderate
- High

Large particulate microcystins
- Low
- Moderate
- High
- **Cyanobacteria, 16S rRNA**
- **M. aeruginosa, 16S rRNA**
- **Microcystin production, mcyE**
Total Microcystins vs. Chlorophyll $a$, Total and Dissolved Nutrients, 2009
A. flos-aquae vs. M. aeruginosa

- Microcystin occurrence and toxigenic M. aeruginosa associated with the second A. flos-aquae-dominated bloom
- N\textsubscript{2} fixation in A. flos-aquae, not M. aeruginosa
- Hypothesis: Toxigenic M. aeruginosa growth stimulated by DIN during A. flos-aquae-dominated bloom decline, but dependent on DIP to regulate A. flos-aquae growth and decline
- Impact of nutrient reduction (management) on microcystin occurrence
Summary

- High inter-annual variability; large particulate microcystin concentrations highest in 2007 and 2009
- Concentrations highest at MDT (trench)
- Toxin concentrations increase after recovery of first lakewide bloom, with increasing chlorophyll a, TN and TP
- Relation between *A. flos-aquae* and *M. aeruginosa* based on nutrient dynamics
  - *M. aeruginosa* dependent on *A. flos-aquae* to supply DIN directly, DIP indirectly through bloom cycle