**Interactive Effects of Climate Change, Wetlands, and Dissolved Organic Matter on UV Damage to Aquatic Foodwebs**

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**Overarching Goal**

Provide a better understanding of how land use, climate, and UVR affect foodweb structure in streams and rivers through their complex interactions with DOM, landscape characteristics, and climate.

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**Five Main Objectives**

1. Relate DOM concentration and chemical characteristics to discharge, landscape characteristics, and stream geomorphology.

2. Determine how in-stream processing of DOM through biodegradation and photodegradation varies spatially within the watershed.

3. Determine how various climate change scenarios will affect discharge and, thus, DOM concentration at a variety of spatial scales.

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**Objectives, Cont.**

4. Determine interactions among UVR intensity and DOM concentration and chemistry.

5. Determine the response of stream foodwebs to the interactions among UVR intensity and DOM concentration and type.

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**Stream UVR-DOM Study (SUDS)**

![Diagram of Stream UVR-DOM Study (SUDS)]

- Wetland area, type, spatial distribution
- Warmer, drier climate
- Hydrograph
- DOM concentration, total flux, and chemical characteristics
- Photodegradation and photoaggregation
- Upland land use, ecosystem type, soils, slope, etc.
- UV-B and light penetration in water column
- Microbial growth on and transformation of DOM
Objectives

1. Relate DOM concentration and chemical characteristics to discharge, landscape characteristics, and stream geomorphology.

Study Sites

Ontonagon watershed
-3600 km² watershed
-drains into Lake Superior
-streams 1st to 6th order
-60 sampling sites in Sept. 2002
-35 sites sampled ~ 2 months for 2 years

Characteristics of Ontonagon sub-watersheds

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of area in wetland</td>
<td>18.7</td>
<td>0.02</td>
<td>48.1</td>
</tr>
<tr>
<td>% of area in lake</td>
<td>4.06</td>
<td>0</td>
<td>22.6</td>
</tr>
<tr>
<td>% of area in agriculture</td>
<td>4.93</td>
<td>0.05</td>
<td>62.8</td>
</tr>
<tr>
<td>watershed area (km²)</td>
<td>14.5</td>
<td>0.25</td>
<td>345</td>
</tr>
<tr>
<td>total stream length (km)</td>
<td>108</td>
<td>1.35</td>
<td>2628</td>
</tr>
<tr>
<td>drainage density (km km⁻²)</td>
<td>7.43</td>
<td>1.39</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Why the wide range in DOC among these streams?

- landscape features:
  - % lake
  - % developed
  - % evergreen
  - % agriculture
  - % wetland
- stream geomorphology:
  - log stream length
  - log watershed area
  - log watershed perimeter
  - log drainage density
  - log maximum slope
  - log mean slope
  - log standard deviation slope

Sept. 2002 Sampling

n = 65
mean = 13.4
range = 3.5-34.0
**Multiple factor regression [DOC]**

\[ y = 1.7881x + 1.6 \]

\[ r^2 = 0.1825 \]

**Predictor Variables**

- 5% lake (-)
- % developed
- % evergreen
- % agriculture
- 4% wetland (+)
- log stream length
- log watershed area (-)
- log watershed perimeter
- log maximum slope
- log mean slope (+)
- log standard deviation slope

**DOC Molecular Weight**

\[ y = 60.709x + 1234.8 \]

\[ R^2 = 0.6952 \]

\[ y = 16.067x + 1284.7 \]

\[ R^2 = 0.5612 \]

**May + August 2003 DOM Data**

**Average [DOC] from Combined May and August 2003**

<table>
<thead>
<tr>
<th>No Lakes</th>
<th>Lake Outflows</th>
</tr>
</thead>
<tbody>
<tr>
<td>285.0</td>
<td>420.0</td>
</tr>
<tr>
<td>297.2</td>
<td>379.5</td>
</tr>
<tr>
<td>314.8</td>
<td>417.0</td>
</tr>
<tr>
<td>334.2</td>
<td>379.5</td>
</tr>
</tbody>
</table>

**Absorbance at 280 nm divided by the moles C per liter**

<table>
<thead>
<tr>
<th>No Lakes</th>
<th>Lake Outflows</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>3.9</td>
</tr>
<tr>
<td>3.8</td>
<td>4.1</td>
</tr>
<tr>
<td>4.0</td>
<td>4.3</td>
</tr>
<tr>
<td>4.2</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Ongoing Landscape DOM Projects

- Expand GIS database by adding surficial geology, soil type, and soil C:N ratio. Compare different wetland databases and determine if wetland type is an important variable.
- Examine how landscape relationships with DOM concentration and chemistry vary with seasonally with ~ bimonthly sampling of stream survey.

Ongoing Landscape DOM Projects, Cont.

- Explore how DOM concentration and chemistry vary longitudinally in streams with and without lake outlets.

Objectives

2. Determine how in-stream processing of DOM through biodegradation and photodegradation varies spatially within the watershed.

Results to Date

- Biodegradation of high molecular-weight DOM is faster, and the low-molecular weight fraction is preferentially degraded.
- Biodegradation rates of DOM are dependent on microbial community structure.

Ongoing DOM Experiments

- Examine short- and long-term photodegradation and biodegradation rates of DOM from six different stream sources.
- With and without nutrient addition.
- How important is prior photodegradation in biodegradation?

Objectives

3. Determine how various climate change scenarios will affect discharge and, thus, DOM concentration at a variety of spatial scales.
Factor analysis has been used at the scale of the conterminous U.S., the Great Lakes region, and the Upper Great Lakes region to determine landscape and climatic correlates of annual and seasonal discharge in streams and rivers.

We will gather as many [DOC] vs. discharge data as can be found for the Upper Great Lakes. Various climate change scenarios will be applied to these models to predict effects on DOM concentrations and UVR penetration into the water column.

Mechanistic hydrological model for the Ontonagon Watershed?

Objectives

4. Determine interactions among UVR intensity and DOM concentration and chemistry.

The "Kd" tells you how fast light disappears in the water

\[ k_d = - \ln \left( \frac{I_d}{I_0} \right) / \text{depth} \]

Big \( k_d \) \( \Rightarrow \) Little light

Small \( k_d \) \( \Rightarrow \) Lots of light

\[ K_d = 7.27 \times \text{DOC} + 4.85 \]

\[ r^2 = 0.51 \]

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \]

DOC (mg C/L)

\[ 0 \quad 30 \quad 60 \quad 90 \quad 120 \quad 150 \]

Kd UVB (m-1)

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \]

DOC (mg C/L)

\[ 0 \quad 30 \quad 60 \quad 90 \quad 120 \quad 150 \]

Kd UVB (m-1)

Graneli et al. (1996) - temperate lakes

Peterson et al. (2002) - 'early season' wetlands

Grauel et al. (1996) - 'early season' wetlands

In this study, streams
**Stream UVB Model**

![Graph showing the relationship between DOC (mg C/L) and UVB (µW cm⁻²) with different tree cover percentages.]

**Ongoing UVR Landscape Research**
- Mapping UVR penetration within the entire Ontonagon Watershed.
- Quantifying UVR dose spatially within a number of streams with “dosimetry” strips.

**Objectives**

5. Determine the response of stream foodwebs to the interactions among UVR intensity and DOM concentration and type.

**Controlled experiments to examine the interactive effects of UVR and DOM on stream food web structure**

**Experiment:**
Change UV flux onto periphyton by altering DOM concentration and through the use of plastic UV screens

<table>
<thead>
<tr>
<th>plus DOC</th>
<th>w/ plastic</th>
<th>no plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>no UVB</td>
<td>low UVB</td>
<td>high DOC</td>
</tr>
<tr>
<td>high DOC</td>
<td>high DOC</td>
<td>low UVB</td>
</tr>
</tbody>
</table>

4 replicates per treatment combination

**Total Solar Dose**

![Graph showing the total solar dose with and without plastic.]

% reduction from surface

No DOC was present under the plastic

No plastic

No DOC Plu DOC
Ongoing Foodweb Experiments:
How does light intensity interact with UVR to affect periphyton growth?

<table>
<thead>
<tr>
<th></th>
<th>+ shading (-90%)</th>
<th>no shading</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- UVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- UVB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ongoing Foodweb Experiments:
How do nutrients and DOM molecular weight interact to affect foodwebs?

<table>
<thead>
<tr>
<th></th>
<th>+ N, +P</th>
<th>- N, - P</th>
</tr>
</thead>
<tbody>
<tr>
<td>no DOM (ground water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ HMW DOM (~ 8 mg/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ LMW DOM (~ 8 mg/L)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

UVR excluded in all treatments
Periphyton; last week snails, mayflies, caddisflies, chironomids, amphipods