What is the role of fluvial phytoplankton in Lower Columbia River food webs?

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Lower Columbia River Estuary Partnership

www.stccmop.org
Stream food web

Macneale et al. 2010
The River Continuum Concept

Vannote et al. 1980
The River Continuum Concept
### Historic Columbia River

**Columbia River Estuary**
**Historic Habitat Types - 1880**

- **Tidal marsh**
- **Sand flats**
- **Tidal swamp**
- **Shallow water habitat**

*Map courtesy of Russell, 2009*
Modern Day Columbia River

Shared use:
- Endangered Species
- Hydropower management
- Land use, irrigation, agriculture

Additional stressors:
- Urbanization (e.g. contaminants)
- Changing climate

Role of dams in river ecological function

Grand Coulee Dam

http://www.usbr.gov
‘Greening’ of the Columbia River

Sullivan et al. 2001
A sensors approach for quantifying river ‘greening’
A sensors approach for quantifying river ‘greening’
A sensors approach for quantifying river ‘greening’
A sensors approach for quantifying river ‘greening’

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDOM</td>
<td>23.11</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>6.68 μg/L</td>
</tr>
<tr>
<td>Conductivity</td>
<td>0.0090 S/m</td>
</tr>
<tr>
<td>Depth</td>
<td>3.822 m</td>
</tr>
<tr>
<td>Dissolved O₂</td>
<td>9.23 ml/l</td>
</tr>
<tr>
<td>Nitrate</td>
<td>29.7 μM</td>
</tr>
<tr>
<td>O₂ Saturation</td>
<td>8.90 ml/l</td>
</tr>
<tr>
<td>O₂ % Saturation</td>
<td>103.7 %</td>
</tr>
<tr>
<td>Salinity</td>
<td>0.07 PSU</td>
</tr>
<tr>
<td>Temperature</td>
<td>5.10 °C</td>
</tr>
<tr>
<td>Turbidity</td>
<td>4.90 NTU</td>
</tr>
<tr>
<td>Battery Voltage</td>
<td>12.8 V</td>
</tr>
</tbody>
</table>
High turbidity associated with episodic storm events

Chlorophyll a biomass characteristic of temperate latitude phytoplankton blooms

Nitrate highest during winter, decreases correlated with chl a
Using dissolved $O_2$ to calculate metabolic rates

1) Net Primary Production
2) Respiration Rate
3) Gross Primary Production
4) Net Ecosystem Metabolism
Using dissolved O$_2$ to calculate metabolic rates

1) Net Primary Production
2) Respiration Rate
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Calculating oxygen flux

1) Biological Oxygen Change per hour:

\[ BDO_t = (DO_t - DO_{t-1}) \times h - F_{O2} \]

2) Oxygen Flux by air-water diffusion:

\[ F_{O2} = -vO_2 \times (O_{2\text{meas}} - O_{2\text{sat}}) \]

3) Piston velocity estimates:

\[ k_{flow} = U \left( \frac{v}{D} \right)^{-\frac{1}{2}} \left( \frac{Uh}{v} \right)^{-\frac{1}{2}} = \sqrt{\frac{UD}{h}} \]

\[ k_{wind} = 0.31 \times u_{10}^2 \left( \frac{Sc}{660} \right)^{-0.5} \]

O'Connor DJ and WE Dobbins (1958)
Wanninkhof R. (1992)
Productivity > respiration during summer

Spring Freshet depressed metabolic rates

NEM has distinct seasonal cycles
Lower Columbia River food web components

Johnson et al., 2003
Lower Columbia River food web components

Johnson et al., 2003
How might the landscape affect phytoplankton biomass?
Asterionella formosa

Cell count comparison: mainstem vs. side channels

Cells/mL

- Birnie Slough
- Beaver Army Terminal

Main stem

6-Apr  11-Apr  16-Apr  21-Apr  26-Apr  1-May  6-May  11-May  16-May  21-May  26-May  31-May
Aulacoseira granulata

Cells/mL

- Birnie Slough
- Beaver Army Terminal

Main stem

6-Apr 11-Apr 16-Apr 21-Apr 26-Apr 1-May 6-May 11-May 16-May 21-May 26-May 31-May
Zooplankton percent abundance at Whites Island (Birnie Slough)

- **April**: Rotifers (black) are dominant, followed by Copepods (red), Cladocerans (green), and Annelids & polychaetes (yellow).
- **May**: Rotifers (black) are still dominant, followed by Copepods (red), Cladocerans (green), and Annelids & polychaetes (yellow).
- **June**: Rotifers (black) remain dominant, followed by Copepods (red), Cladocerans (green), and Annelids & polychaetes (yellow).
- **July**: Rotifers (black) continue to be dominant, followed by Copepods (red), Cladocerans (green), and Annelids & polychaetes (yellow).

The bar chart shows the percent abundance of each zooplankton group for April, May, June, and July. Rotifers have the highest abundance, followed by Copepods, Cladocerans, and Annelids & polychaetes.
Fine Particulate Organic Matter deposition in streams

- Water velocity, $u$
- Scaling factor ($u$*water depth)
- Discharge ($Q$)
- Cross-sectional area of channel ($A$)
- Relative storage zone ($A_s/A$)
- Transient storage zone coefficient ($\alpha$)

Minshall et al., 2000
Questions

- What is the importance of deposited material (FPOM) in shallow streams, and how does it change with main channel river flow and tidal exchange?

- How do depositional patterns differ in tidal vs. non-tidal streams?

- What contribution to benthic food webs does the deposition of fluvial phytoplankton make?
How has the reduction in tidal channels and streams influenced deposition rates of organic matter?

*Thomas (1983)*
Summary & management implications

- Net ecosystem metabolism calculated using in situ sensors provides a continuous picture of ecosystem function, which can be routinely monitored.

- River flow influences plankton composition and abundance.

- Stream environments may be important depositional environments where fluvial phytoplankton might accumulate and feed benthic deposit feeders.
Acknowledgments

USGS
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Florian Moeller
Melissa Gilbert

Bonneville Power Administration, U.S. Army Corps of Engineers
5. Comparison of the present estuarine boundaries with those of 1870, illustrating the loss of estuarine surface area due primarily to diking (modified from Thomas, 1983).
Lower Columbia River Estuary

Garono & Robinson, 2003
How does ‘greening’ alter river export flux?

210 KM  140 KM  70 KM

Brown River

106 CO₂ + 16 N + 1 P

1° Production
Respiration

Organic Matter + 150 O₂

50%

48%

2%

Brown River

Green River

INPUT

DOM
Nutrients
POM

CMOP
How does ‘greening’ alter estuarine flux?

- **Plume and Coastal Ocean**
- **Columbia River Estuary (saltwater)**
- **Brown River**
- **Green River**

ETM

**Legend:**
- DOM
- Nutrients
- POM
• How does ‘greening’ alter river fluxes to the coastal margin?

- Nutrients: PP converts a relatively small proportion of inorganic nutrients to organic matter during spring and summer. Therefore very little change to coastal zone flux and not enough to account for summer declines in nutrients

- POC is altered significantly in all seasons, with important implications for salt water estuary organic matter supply
<table>
<thead>
<tr>
<th>Season</th>
<th>DOC (µmol L⁻¹)</th>
<th>Salt water estuary</th>
<th>% Change</th>
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<tbody>
<tr>
<td>Winter</td>
<td>113</td>
<td>108</td>
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<tr>
<td>Spring</td>
<td>129</td>
<td>133</td>
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<tr>
<td>Summer</td>
<td>189</td>
<td>191</td>
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<tr>
<td>Fall</td>
<td>138</td>
<td>133</td>
<td>-4</td>
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<table>
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<th>Nitrate (µmol L⁻¹)</th>
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<td>32</td>
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<td>Fall</td>
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<td>23</td>
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<table>
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<tr>
<th>Season</th>
<th>POC (µmol L⁻¹)</th>
<th>Salt water estuary</th>
<th>% Change</th>
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<tbody>
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<td>Summer</td>
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<tr>
<td>Fall</td>
<td>18</td>
<td>13</td>
<td>-29</td>
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</tbody>
</table>
Organic Carbon: Comparison of estimates

Organic Carbon

Chl POC (C:Chl = 30)
PP (d⁻¹)
POC

Org C (µmol L⁻¹)

Jul-09 Jan-10 Jul-10 Jan-11

CMOP
NSF