First Year Findings from James River CHLa Study

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Dissolved O\textsubscript{2} standards are commonly used as the basis for establishing target nutrient loads (via water quality models linking nutrients, algae and hypoxia).

- Are DO-based standards sufficiently protective of eutrophication effects on living resources and human health?
- How do we establish nutrient targets where hypoxia does not occur (e.g., well-mixed estuaries)?

Managing Eutrophication (in context of CWA)

Impairments to Designated Uses from Algal Blooms

<table>
<thead>
<tr>
<th>Designated Uses</th>
<th>Impairments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimmable</td>
<td>Transparency &amp; Aesthetics, also algal toxins (e.g., Microcystin)</td>
</tr>
<tr>
<td>Drinkable</td>
<td>Taste &amp; Odor compounds, algal toxins</td>
</tr>
<tr>
<td>Fishable</td>
<td>Hypoxia, transparency, algal toxins</td>
</tr>
</tbody>
</table>

How to develop algae-based water quality standards (metrics & rationale)?

Strategy & Roadmap

Existing criteria

- Balanced Communities
- Historical Data Approach
- Water Quality Approach
- HAB Approach

Alternative CHLa criteria

- Review DEQ methodology used to derive existing standard
- Review data & methodology
- Dissolved O\textsubscript{2} & clarity
- Data arising from this project

Do criteria derived from multiple methods agree?

- yes
- no

Propose alternative methodology

- Existing criteria robust
- Combine or select
2012 Findings

- Magnitude, Duration and Composition of Algal Blooms
- Conditions Favoring Bloom Development
- Deleterious Effects of Algal Blooms

Magnitude, Duration and Composition of Blooms

<table>
<thead>
<tr>
<th>Segment</th>
<th>2012 Bloom Events</th>
</tr>
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<tbody>
<tr>
<td>Tidal-fresh</td>
<td>Summer lasting 26 weeks (May thru Oct) with CHLa &gt; 20 µg/L - comprised of diatoms (76%), chlorophytes (16%) and cyanobacteria (6%)</td>
</tr>
<tr>
<td>Mesohaline</td>
<td>Spring lasting 5 weeks (Feb &amp; Mar) by the non-HAB dinoflagellate <em>Heterocapsa triqueta</em> with CHLa &gt;40 µg/L covering 18% of area.</td>
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<tr>
<td>Polyhaline</td>
<td>Summer lasting 13 weeks (June thru Sept) of <em>Cochlodinium polykrikoides</em> with CHLa &gt;40 µg/L covering 60% of area.</td>
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Algal Blooms in the Lower James

CHLa concentrations in the saline waters of the James River Estuary during the Spring *Heterocapsa* bloom (left) and the Summer *Cochlodinium* bloom (right).

Rain events result in localized nutrient inputs which can trigger blooms; these are not adequately captured by watershed and estuarine monitoring programs.

An intensive monitoring and mapping program was conducted in 2011 and 2012 to identify the causal factors initiating and sustaining algal blooms.

In both years blooms initiated in the Lafayette River, a sub-tributary of the lower James River, and extended into the Elizabeth and lower James River through August.
Algal Blooms in Lower James

- Samples were obtained during bloom events to assess adverse health impacts via laboratory toxicity assays using whole cells or lysates.
- Bioassays with Artemia were conducted using samples collected during the Codioldinium bloom.
- Artemia mortality was directly related to Codioldinium cell concentrations and CHLa levels in the samples.

Algal Blooms in the tidal-fresh James

- The natural geomorphometry of the channel and proximal nutrient inputs foster persistent algal blooms that exceed current CHLa standards.

Phytoplankton Nutrient Limitation

<table>
<thead>
<tr>
<th></th>
<th>1992-93*</th>
<th>2012**</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. experiments</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Nutrient limitation detected</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Dissolved inorganic N (mg/L)</td>
<td>0.45</td>
<td>0.25</td>
</tr>
<tr>
<td>Phosphate (mg/L)</td>
<td>0.022</td>
<td>0.013</td>
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Algal bioassay experiments provide evidence for increasing severity of nutrient limitation associated with reductions in point source nutrient inputs to the tidal-fresh James. Data from Fisher et al. 1999* and Wood & Bukaveckas (Estuaries & Coasts, in review)**.

Cyanobacteria blooms in tidal-fresh James

Wood et al. Environmental Science & Technology (in review)
Microcystin in tidal fresh James 2012

- 104 of 105 water samples (May-October); max = 1 µg/L.
- 11 of 60 sediment samples (peak in August).
- 254 of 379 (67%) fish and shellfish.
  - Highest incidence of MC in blue crabs (viscera = 100%; muscle = 64%).
  - Blue crab tissues exceeded WHO safety guidelines in August.

Microcystin in the Food Web of the James

- Autochthonous contributions to diet predict MC accumulation in tissues.

Microcystin in the Food Web - Why are some taxa more vulnerable than others?

- Toxin effects on ecosystem services - filtration rate of wedge clams drops from 28% / d to 10% / d.

Wood et al. Environmental Science & Technology (in review)
What have we learned?

- Tidal Fresh:
  - Reductions in point source inputs correspond to lower nutrient concentrations and greater severity of nutrient limitation.
  - Ubiquitous presence of Microcystin in James River Estuary - implications for human health (blue crab consumption), living resources (crabs, pelagic fishes) and ecosystem services (benthic filter-feeders).

- Lower James:
  - An expanded monitoring effort in 2012 provided enhanced spatial and temporal resolution to characterize the magnitude, duration and composition of algal blooms.
  - Bloom initiation was linked to local rainfall events and subsequent transport of algae from shallow tributaries of the James.

Three Key Data Needs

<table>
<thead>
<tr>
<th>External Drivers</th>
<th>System Response</th>
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<tbody>
<tr>
<td>Watershed Runoff</td>
<td>Hydrodynamics</td>
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<tr>
<td></td>
<td>CHLa</td>
</tr>
<tr>
<td></td>
<td>A. Linking nutrient loads to algal uptake</td>
</tr>
<tr>
<td></td>
<td>B. Linking HABs to CHLa</td>
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<tr>
<td></td>
<td>C. Linking HABs to effects on living resources</td>
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Learn more at: http://wp.vcu.edu/jamesriver/

Photo: VCU Rice Center