Benthic Taxa Sensitivity Analyses
Response along an urban gradient (2004-2015)

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Key Points

• Fairfax County has a rich monitoring data set, that includes a large number of sites with high levels of watershed imperviousness

• Taxa sensitivity and tolerance values are needed as part of the development and evaluation of:
  – Fairfax County’s BIBI
  – Biological Condition Gradient
  – Urban streams standard

• Underlying geology affects stream chemistry, habitat and changes benthic community structure

• Taxa tolerance values can/should be adjusted to local conditions for a local BIBI
Stream Biological Monitoring Program

Fairfax County Stream Protection Strategy (SPS)

- Established by BOS in 1998 to assess WQ/stream/watershed conditions Countywide
- Evaluated chemical, biological, habitat and geomorphic conditions at 124 sites in 1999

- 40 sites selected annually.
- Sampled for:
  - Benthic Macroinvertebrates (spring)
  - Fish and habitat (summer)
  - Bacteria (quarterly)
  - Water quality (every visit)
  - 12-16 reference sites

Annual Stream Quality Index (SQI)

Fairfax County Stream Quality Index 2014 (40 sites)

- Very Poor: 5%
- Poor: 27.5%
- Fair: 27.5%
- Good: 15%
- Excellent: 25%

Stream Biological Monitoring Program
USGS Partnership: Stream Gaging Study

- Initiated in 2007 with the USGS VA Water Science Center (Richmond)
  - Generate long-term monitoring data to describe:
    - Current water-quality conditions
    - Trends in water-quality, nutrient and sediment loads and yields
    - Started with 14 sites, expanded to 20 sites in 2012
Typical Year of Fairfax Co. Benthic Monitoring (2015)

- Probabilistic [40]
- USGS (trend) [20]
- Reference (trend) [18]
- Restorations and special projects [8]
- QA/QC [4]

- ~ 90 sites annually
Level IV Ecoregions – Benthic Monitoring 2015

- Northern Piedmont (64)
  - 64a Triassic Lowlands
  - 64b Diabase and Conglomerate Uplands
  - 64c Piedmont Uplands

- Piedmont (45)
  - 45e Northern Inner Piedmont

- Southeastern Plains (65)
  - 65e Chesapeake Rolling Coastal Plain
Fairfax Co. Data for this Study

- **644 benthic samples (2004-2015)**
  - Evaluated unique taxa occurring 20+ times (n=80)
- **Drainage areas**
  - 2ft elevation DTM, created a DEM in 2009
  - Storm Sewer network & outfalls burned to DEM in 2010
  - Each monitoring reach was delineated using a tool developed for Ffx Co.
  - Additional data from adjoining jurisdictions were appended
- **2009 Planimetric layer (fly-over) for impervious areas**
  - Resolution is <1m instead of 30m with NLCD
  - Went live in 2013 (4 years for QA/QC)
- **Median annual specific conductance** – 620 samples (491 sites)
  - Mean number of measurements/year ~5
Sensitivity Analyses

• How to evaluate taxa sensitivity and tolerance values as part of the evaluation and re-development of a new BIBI?

• Cumulative Distribution Function (CDF) [from Utz et al. 2009]
  – Process for linking sensitivity of benthic taxa to a particular stressor
  – Requires much data (20-25 occurrences of a taxa)

• Can create other metrics, based upon a CDF stressor gradient
  – $T_{95}$ = the point at which 95% probability you will no longer find the taxa
    • Essentially a measure of extirpation

• Taxa sensitivity comparable to other CDFs & Tolerance Values (TVs)
Positive Response to Stressor (% Imp. Area)

Cheumatopsyche

Cumulative Abundance

Percent Watershed Impervious Surface Area

- **Cheumatopsyche Abundance**
- **Expected (all taxa)**
- **Cheumatopsyche P:A**
Negative Response to Stressor (% Imp. Area)

Cumulative Abundance

Percent Watershed Impervious Surface Area

- Amphinemura P:A
- Amphinemura Abundance
- Expected (all taxa)
Negative Response to Stressor (Specific Conductance)

Cumulative Abundance

Median Annual Specific Conductance

Amphinemura

95th percentile, T95
Taxa Richness vs Stressor (% Imp Area), 80 taxa

Potential Taxa Remaining in Response to Watershed Impervious Surface Area

- 2% Imp Area
- 7% Imp Area

Remaining Taxa vs Percent Watershed Impervious Surface Area

75th Percentile of Sites
95th Percentile of Sites
95th Percentile of Abundance
34% of common taxa (20+) effectively lost by 7% watershed imperviousness

### Impervious Area 0→2%

**Mean TV = 1.9**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>IA75th Sites</th>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexatoma</td>
<td>1.37</td>
<td>1.5</td>
</tr>
<tr>
<td>Haploperla</td>
<td>1.46</td>
<td>1.6</td>
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<tr>
<td>Lepidostoma</td>
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<td>Ephemerella</td>
<td>1.67</td>
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<td>Serratella</td>
<td>1.73</td>
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<tr>
<td>Acroneuria</td>
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<td>2.5</td>
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<tr>
<td>Heterocloeon</td>
<td>1.91</td>
<td>TBD</td>
</tr>
<tr>
<td>Isonychia</td>
<td>1.91</td>
<td>2.5</td>
</tr>
<tr>
<td>Wormaldia</td>
<td>2.00</td>
<td>1.8</td>
</tr>
</tbody>
</table>

### Impervious Area 2→7%

**Mean TV = 2.9**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>IA75th Sites</th>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydatophylax</td>
<td>2.63</td>
<td>3.4</td>
</tr>
<tr>
<td>Leuctra</td>
<td>3.67</td>
<td>0.4</td>
</tr>
<tr>
<td>Cordulegaster</td>
<td>5.32</td>
<td>2.4</td>
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<tr>
<td>Stegopterna</td>
<td>5.42</td>
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<tr>
<td>Eccoptura</td>
<td>5.51</td>
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<tr>
<td>Paraleptophlebia</td>
<td>5.51</td>
<td>2.0</td>
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<tr>
<td>Isoperla</td>
<td>6.02</td>
<td>2.4</td>
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<td>Psephenus</td>
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<td>3.1</td>
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<td>Bezzia</td>
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<td>3.3</td>
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<tr>
<td>Nigronia</td>
<td>6.12</td>
<td>1.4</td>
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<td>Paranemoura</td>
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<td>Rhyacophila</td>
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<td>2.1</td>
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<td>Limnophila</td>
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<td>4.8</td>
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<tr>
<td>Ameletus</td>
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<td>Hydroptila</td>
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<td>Prosimulium</td>
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<td>2.4</td>
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<tr>
<td>Pycnopsyche</td>
<td>6.84</td>
<td>3.1</td>
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</tbody>
</table>
Sensitivity: Specific Conductance & % Imp Area

\[ y = 13.104x + 69.602 \]

\[ R^2 = 0.7376 \]

### Taxa Sensitivity: Comparison of Impervious Area and Specific Conductance

- **Antocha**
- **Argia**
- **Calopteryx**
- **Cheumatopsyche**
- **Corbicula**
- **Enallagma**
- **Hemerdromia**
- **Hydropsyche**
- **Peltodytes**
- **Amphinemura**

**95th Percentile of Abundance (T95)**

**Linear (95th Percentile of Abundance (T95))**
Extirpation Thresholds ($T_{95}$) vs. Tolerance Values (TVs)

Fairfax County $T_{95}$s vs Tolerance Values

- Linear (T5-Specific Conductance): $y = 4.13x + 5.52$, $R^2 = 0.51$
- Linear (T5-Impervious Area): $y = 64.04x + 99.43$, $R^2 = 0.52$
Triassic Basin (64a & b) mean specific conductance is **225.5 µS/cm³@25°C** higher than Piedmont (64c & 45e).

(159 to 292, 95%CI, p < 0.0005)
### Tolerance of taxa at Spec Cond 225

<table>
<thead>
<tr>
<th>Taxa lost (Genus)</th>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepidostoma</td>
<td>0.0</td>
</tr>
<tr>
<td>Cambarus</td>
<td>0.4</td>
</tr>
<tr>
<td>Leuctra</td>
<td>0.4</td>
</tr>
<tr>
<td>Eccoptura</td>
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<tr>
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<td>2.5</td>
</tr>
<tr>
<td>Ameletus</td>
<td>2.6</td>
</tr>
<tr>
<td>Ceratopogon</td>
<td>2.7</td>
</tr>
<tr>
<td>Oulimnius</td>
<td>2.7</td>
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<tr>
<td>Serratella</td>
<td>2.8</td>
</tr>
<tr>
<td>Paranemoura</td>
<td>2.9</td>
</tr>
<tr>
<td>Shipsa</td>
<td>2.9</td>
</tr>
<tr>
<td>Amphinemura</td>
<td>3.0</td>
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**Mean TVs:**
- **Taxa Lost:** 2.1 (n=22)
- **Taxa Retained:** 5.5 (n=51) p<0.0005
Conclusions & Next Steps

• CDFs are an effective approach at evaluating taxa sensitivity
  – Supports indicator species analyses
  – Supports IBI re-development

• The Triassic Basin has a much higher base level of dissolved ions (Specific Conductance)
  – There are thresholds at which sensitive taxa are unexpectedly absent

Next Steps

• Explore difference among Ecoregions (Triassic)
• Test other possible stressors (Habitat, land use, or other factors?)
• Use ordination or regression to determine likely taxa TVs
• Apply new TVs to evaluate/re-redevelop BIBI, BCG, or USS
For additional information, please contact

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www.fairfaxcounty.gov/dpwes
Physiochemical: pH & Specific Conductance

EXPLANATION
Specific conductance, in microsiemens per centimeter at 25°C:
- 23 to 100
- 101 to 200
- 201 to 300
- 301 to 400
- 401 to 500
- 501 to 750
- 751 to 1,000
- 1,001 to 2,500
- 2,501 to 5,000
- 5,001 to 7,500
- 7,501 to 13,000

Dead Run

Difficult Run

Radlick Branch

South Fork Little Difficult Run
Extirpation Thresholds ($T_{95}$) vs. Tolerance Values (TVs)

Comparison of $T_{95}$s with Tolerance Values

- FairfFax-MBSS2 TVs
- MD(Utz)-MBSS2 TVs

Linear (Fairfax-MBSS2 TVs): $y = 0.13x + 0.96$, $R^2 = 0.48$

Linear (MD(Utz)-MBSS2 TVs): $y = 0.12x + 2.10$, $R^2 = 0.45$