Riverscape patterns of fish and habitat in the Chehalis River

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September 22, 2015
Key questions addressed

• Where are the important summer rearing areas for juvenile salmonids?
• How are summer habitat and temperature characteristics associated with fish species composition?
Riverscape methodology

- Fish count by snorkeling, 200 m reaches

- Habitat metrics
  - Maximum depth
  - Average depth
  - Wetted and bankfull width
  - Substrate (Wolman 1954)

- Temperature measured in study area via loggers

- Pool count
- Pool forming structure
- Channel type (Montgomery and Buffington 1997)
Fish species

- Age 0 salmon (Chinook and coho)
- Age 0 trout (O. mykiss, O. clarkii)
- Age 1+ trout
- Redside shiner
- Dace (speckled and longnose)
- Northern pikeminnow
- Largescale suckers
- Mountain whitefish
- Exotic species*
Temperature metrics — there are lots! (Arismendi et al. 2013)

- Mean daily minimum
- Mean daily maximum
- Mean daily range
- Mean daily duration greater than 18°C (Madej et al 2006)
Analysis – two multivariate approaches

- Spatial organization of fish, habitat, and temperature metrics independently
  - PCA to describe the variation in species composition
  - Chord transformation for species counts (Legendre & Gallagher 2001)
  - PCA to describe variation in habitat and temperature
  - River gradient: PCA versus river kilometer

- Fish species composition explained by habitat & temperature metrics
  - Partial RDA to describe reach-scale contributions to species composition while controlling for river kilometer
  - Variance partitioning (Borcard et al. 1992; Peres-Neto et al. 2006)
Analysis – first approach

• Spatial organization of fish, habitat, and temperature metrics independently
  – PCA to describe the variation in fish species composition
  – Chord transformation for species counts (Legendre & Gallagher 2001)
  – PCA to describe variation in habitat and temperature
  – River gradient: PCA versus river kilometer
Spatial organization of fish species

Principal components versus river kilometer

Fish assemblages described by PC1 are related to river km
Spatial organization of fish species
Principal components versus river kilometer

Trout.0
Salmon.0

Shiner
Dace

Trout.0
2013

Principal Component 1 (53%)

Shiner
Dace

Prinicipal Component 1 (70%)

2014
Both years, we observed a transition from juvenile salmonid zone (upper) to Cyprinid zone (lower) throughout study area.
General Habitat Characteristics

Channel Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool-Riffle</td>
<td>150</td>
</tr>
<tr>
<td>Plane</td>
<td>0</td>
</tr>
<tr>
<td>Bed</td>
<td>0</td>
</tr>
<tr>
<td>Forced</td>
<td>0</td>
</tr>
<tr>
<td>Pool-Riffle</td>
<td>0</td>
</tr>
<tr>
<td>Step-Pool</td>
<td>0</td>
</tr>
<tr>
<td>Cascade</td>
<td>0</td>
</tr>
<tr>
<td>Canyon</td>
<td>0</td>
</tr>
</tbody>
</table>

Pool Forming Structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinuosity</td>
<td>150</td>
</tr>
<tr>
<td>Bedrock</td>
<td>20</td>
</tr>
<tr>
<td>Boulder</td>
<td>0</td>
</tr>
<tr>
<td>Wood</td>
<td>0</td>
</tr>
<tr>
<td>Bridge</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
</tbody>
</table>
Spatial organization of habitat & temperature

Principal components versus river kilometer

↓ pool freq.
↓ horiz. complex
↑ wet width/BFW
fine substrate

↑ pool freq.
↑ horiz. complex
↓ wet width/BFW
coarse substrate
Spatial organization of habitat & temperature

Principal components versus river kilometer

- Pool frequency: ↓
- Horizontal complexity: ↓
- Wet width/BFW: ↑
- Fine substrate: ↑
- Coarse substrate: ↓

- Minimum temperature: ↓
- Duration > 18°C: ↓

Habitat

Temperature
“River gradient” is the combined gradient in fish, habitat, and temperature

Temperature (mean daily)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>18.7°C</td>
</tr>
<tr>
<td>Max</td>
<td>22.8°C</td>
</tr>
<tr>
<td>Range</td>
<td>4.1°C</td>
</tr>
<tr>
<td>Dur. &gt; 18°C</td>
<td>0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>16.2°C</td>
</tr>
<tr>
<td>Max</td>
<td>20.3°C</td>
</tr>
<tr>
<td>Range</td>
<td>4.1°C</td>
</tr>
<tr>
<td>Dur. &gt; 18°C</td>
<td>0.44</td>
</tr>
</tbody>
</table>
Analysis – second approach

• Fish species composition explained by habitat & temperature metrics
  – Partial RDA to ask whether habitat and temperature metrics explain species composition when controlling for river kilometer (i.e., river gradient accounted for).
  – Variance partitioning method to quantify variation explained by each variable individually and together (Borcard et al. 1992; Peres-Neto et al. 2006)
Species explained by habitat & temperature

Partial Redundancy Analysis

Permutation test: $p = 0.001$
Once river km was accounted for, the combination of habitat and temperature metrics explained additional variation in fish species composition.
Species explained by habitat & temperature

Variance Partitioning

Habitat  Temperature

River kilometer

12.3 %  2 %  7.3 %
52.4 %  0.3 %  3.6 %
0 %

Numbers are adj R² values
Residual Adj R²= 0.229
Summary: River km, habitat, temperature

• “River gradient” explains majority of overall variation (52.4%) in species composition but a smaller portion is explained by habitat (12.3%) and temperature (7.3%) characteristics alone.

<table>
<thead>
<tr>
<th>AGE-0 TROUT</th>
<th>SHINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>Coarse substrate</td>
</tr>
<tr>
<td></td>
<td>Fine substrate</td>
</tr>
<tr>
<td>High long. complexity</td>
<td>Low long. complexity</td>
</tr>
<tr>
<td>Temperature</td>
<td>Low minimum</td>
</tr>
<tr>
<td></td>
<td>High minimum</td>
</tr>
<tr>
<td></td>
<td>Low maximum</td>
</tr>
<tr>
<td></td>
<td>High maximum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AGE-0 SALMON</th>
<th>DACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>High pool freq</td>
</tr>
<tr>
<td></td>
<td>Low pool freq</td>
</tr>
<tr>
<td>Temperature</td>
<td>Low maximum</td>
</tr>
<tr>
<td></td>
<td>High maximum</td>
</tr>
<tr>
<td></td>
<td>Low temp range</td>
</tr>
<tr>
<td></td>
<td>High temp range</td>
</tr>
</tbody>
</table>
Discussion

• “River gradient” being observed here is consistent with “River continuum”
• A portion of fish species composition is not explained by any of the variables examined at summer low flows
Discussion

• “River gradient” being observed here is consistent with “River continuum”
• A portion of fish species composition is not explained by any of the variables examined at summer low flows
• Fish composition can be explained by an interaction of habitat, temperature, and river km
  – Cautious to say any one factor makes a reach suitable for juvenile salmonids
Restoration implications for summer rearing habitat

• Multiple characteristics of the river appear to provide suitable summer rearing areas for juvenile salmonids
• Are we focusing on improving habitat where salmonids currently are distributed?
• Are we attempting to expand habitat into area’s that salmonids are not currently occupying?
Acknowledgements

• Fish Ecology and Life Cycle Monitoring Unit: Thomas Buehrens, Kale Bentley, Patrick Hanratty, Trevor Johnson, Jamie Lamperth

• Funding: Washington State legislature

• Field work
  – WDFW technicians: Richard Visser II, Matthew Hobin, Amy Edwards, Noelia Ragland, Riley Freeman, Brianna Murphy, Eric Walther

• Helpful comments:
  – George Pess and Martin Liermann (NOAA)
  – Christian Torgersen (USGS)
Thank you!
Discussion

• “River gradient” likely result of geomorphology, watershed size, historical land use combined.
• Transition in summer fish assemblages (if observed in other sub-basins) suggests suitable summer rearing areas for salmonids are a small subset of 5000 km$^2$ basin.
• Fish assemblage can be explained by both river gradient and reach-scale characteristics.
  • Age-0 trout vs. shiner, age-0 salmon vs. dace
• A portion of fish species assemblages is not explained by any of the variables examined at summer low flows
  • Factors at other temporal or spatial scales
Riverscape survey

- Elk Creek (157.9 km)
- Upper Chehalis River (175.5 km)
- West Fork Chehalis River (193.3 km)

Temperature loggers:

- Crim Creek
- East Fork Chehalis River

Riverscape survey 2014

Kilometers and Miles Scale:

- 0 0.75 1.5 3 4.5 6 (Miles)
- 0 1.25 2.5 5 7.5 10 (Kilometers)
Spatial organization of fish species

K-Means clusters versus river kilometer
Summary: Spatial Organization

- “River gradient” is the combined gradient in fish, habitat, and temperature

<table>
<thead>
<tr>
<th></th>
<th>UPSTREAM</th>
<th>DOWNSTREAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>Juvenile salmonid</td>
<td>Cyprinid</td>
</tr>
<tr>
<td>Habitat</td>
<td>Coarse substrate</td>
<td>Fine substrate</td>
</tr>
<tr>
<td>High pool freq</td>
<td>Low pool freq</td>
<td></td>
</tr>
<tr>
<td>Narrow wet width</td>
<td>Wide wet width</td>
<td></td>
</tr>
<tr>
<td>High horizontal complexity</td>
<td></td>
<td>Low horizontal complexity</td>
</tr>
<tr>
<td>Temperature</td>
<td>Low minimum</td>
<td>High minimum</td>
</tr>
<tr>
<td>Low duration &gt; 18C</td>
<td>High duration &gt; 18C</td>
<td></td>
</tr>
</tbody>
</table>
Riverscape – a spatially continuous approach (Fausch et al. 2002)
Channel complexity metrics
Channel complexity metrics

- Horizontal (cross section)
  - Wetted width : Bankfull width
Channel complexity metrics

• Horizontal (cross section)
  – Wetted width : Bankfull width

• Vertical (cross section)
  – Average wetted width : Maximum depth
Channel complexity metrics

• Horizontal (cross section)
  – Wetted width : Bankfull width

• Vertical (cross section)
  – Average wetted width : Maximum depth

• Longitudinal
  – Average depth : Maximum depth
Spatial organization of fish species
Principal components versus river kilometer

Trout
Salmon
Shiner
Dace

Principal Component 1 (53%)

River kilometer

2013