Assessing the Relations between Aquatic Habitat Indicators and Forest Harvesting at Both Watershed and Reach Scales

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Introduction

- Using criterion and indicators is an important approach to support sustainable forest and watershed management.
- Many identified aquatic habitat indicators have not been well tested in relation to forest disturbance.
- The majority of the studies was on stream-reach scales, and only a few on watershed scales.
Objectives

- Evaluate and identify the variables which can effectively quantify cumulative forest logging disturbances
- Assess the relations between the forest disturbance quantifiers and aquatic habitat indicators at watershed and reach levels
British Columbia Context

- **Key Industry Sectors**
  - Forestry
  - Fishery
  - Tourism
  - Water Development
  - Others

- Key industries depend on management of interactions between forests, water and fish habitat
Biogeoclimatic zones
BC
Fish and Fish Habitat
Adams River, BC
General Research Approaches

- Experimental methods
- Computer simulations
- Sampling and statistical tests
Study Area

- South and central interiors of British Columbia, including Bowron, Willow, Horsefly River Watersheds and Okanagan Valley.
The following criteria were used for selection of sites:

- Headwater mountain streams, mainly second to third orders
- Low gradient (3 – 10%) for being sensitive to disturbance
- Disturbed mainly by forest logging activity with varying intensities (i.e., pristine / undisturbed, moderately harvested and intensively logged) with no or minimal agricultural or urban activities
- In total, 43 sites were sampled
Data Collection

- A representative reach with a total length of 120 m was selected for each site sampled;
- The reach was divided evenly into six sections at 20 m intervals;
- For each reach the following habitat indicators were measured:
  - Bankfull width and depth, wetted width and depth, stream gradient, left and right bank slopes
  - Substrate size, embedment
  - Pool dimension and frequency
  - In-stream wood
  - Riparian disturbance
  - Others: macro-invertebrates (to be reported late this year)
Watershed V.S. Reach scales
Forest Disturbance Quantifiers: watershed scale

- Historical Clear-cut Area
- Equivalent Clear-cut Area (ECA)
  - Use the assumed hydrological recovery rate for different tree height to multiply the historical clear-cut area to get the equivalent clear-cut area, which offsets the subsequent tree recovery process
- All are cumulative
An example: hydrological recovery (%) according to age (year) and height (m) of main tree species (Spruce)

<table>
<thead>
<tr>
<th>Average height of the main canopy (m)</th>
<th>Corresponding age (years)</th>
<th>Hydrological recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;3</td>
<td>0-21</td>
<td>0</td>
</tr>
<tr>
<td>3-&lt;5</td>
<td>22-27</td>
<td>25</td>
</tr>
<tr>
<td>5-&lt;7</td>
<td>28-33</td>
<td>50</td>
</tr>
<tr>
<td>7-&lt;9</td>
<td>33-38</td>
<td>75</td>
</tr>
<tr>
<td>9+</td>
<td>&gt;39</td>
<td>90</td>
</tr>
</tbody>
</table>
Forest Riparian Disturbance: Reach Scale

- Samples were grouped based on the year when riparian was logged:
  - Group 3: logged \( \geq 30 \) years ago (11 samples)
  - Group 2: logged 5 – 29 years ago (28 samples)
  - Group 1: old, intact (control) (4 samples)
Assessing Forest Disturbance Quantifiers

Percent ECA & historical clear-cut area show no significant correlation to watershed area and elevations, therefore, both percent ECA and historical clear-cut area can effectively quantify forest harvest disturbance.

<table>
<thead>
<tr>
<th>Watershed physical characteristics</th>
<th>percent ECA</th>
<th>percent historical clear-cut area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
<td>$p$-value</td>
</tr>
<tr>
<td>watershed area</td>
<td>0.3093</td>
<td>0.1093</td>
</tr>
<tr>
<td>elevation(min)</td>
<td>-0.0654</td>
<td>0.7410</td>
</tr>
<tr>
<td>elevation(max)</td>
<td>0.4074</td>
<td>0.0314</td>
</tr>
<tr>
<td>elevation(mean)</td>
<td>0.2272</td>
<td>0.2450</td>
</tr>
</tbody>
</table>
Use percent ECA, four significant indicators were found, including relative width, relative roughness, pool frequency, and per piece LWD (in-stream wood) volume, since they are not significantly influenced by watershed area and elevations.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Correlation Coefficient (r)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative width</td>
<td>-0.5902</td>
<td>0.0009</td>
</tr>
<tr>
<td>Relative roughness</td>
<td>-0.5379</td>
<td>0.0032</td>
</tr>
<tr>
<td>Pool frequency</td>
<td>-0.5533</td>
<td>0.0023</td>
</tr>
<tr>
<td>LWD volume (m³)/Piece</td>
<td>0.5576</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

**Relative width:** ratio of $D$ to bankfull width) ($D$ is the $b$ axis diameter of the largest substrate particle; **Relative roughness:** ratio of $D$ to bankfull depth
Results at Watershed Scale (2)

- Use percent historical clear-cut area, three significant indicators were found, including relative width, pool frequency, and per piece LWD volume, which are valid indicators, since they are not significantly influenced by watershed area and elevations.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Correlation Coefficient ($r$)</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative width</td>
<td>-0.4884</td>
<td>0.0084</td>
</tr>
<tr>
<td>Pool frequency</td>
<td>-0.4875</td>
<td>0.0085</td>
</tr>
<tr>
<td>LWD volume ($m^3$)/Piece</td>
<td>0.5235</td>
<td>0.0043</td>
</tr>
</tbody>
</table>
Quantitative Model for Predicting Indicators Using Percent ECA

Linear regressions of the three valid significant aquatic habitat indicators, relative width (A), pool frequency (B) and per piece LWD volume (C) on percent ECA.
Quantitative Model for Predicting Indicators Using Percent Historical Clear-cut Area

Linear regressions of the three valid significant aquatic habitat indicators, relative width (A), pool frequency (B) and per piece LWD volume (C) on percent historical clear-cut area.
Results at Reach Scale

Only relative width and relative roughness were significantly different among the groups.
Conclusions

- Percent ECA and percent clear-cut area can effectively quantify the cumulative forest logging disturbance by limiting the influence from watershed area and elevations.

- Relative width, pool frequency and per piece LWD volume are significantly correlated to forest harvesting disturbance at watershed scale, while relative width and relative roughness were significantly related to riparian disturbance at reach scale.

- Sensitivity of aquatic habitat indicators to forest disturbance is scale specific.
Questions and Comments??