Geographic Variation in Puget Sound Tidal Channel Geometry
Developing a Tool for Restoration Planning, Design, and Monitoring

This work funded by the WDFW ESRP

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Skagit River System Cooperative
Allometry of marsh islands and channel geometry.

Landscapes are fractal, i.e., scaling relationships exist between different landscape elements, e.g., marsh islands and tidal channels.

Note: scaling relationships are power functions that can be linearized by log transformation,

\[ P = cA^b \rightarrow \log(P) = \log(c) + b \log(A) \]

Benefit: Prediction of a suite of useful channel geometries not typical of hydraulic geometry.
**Goal:** Develop predictive models for habitat restoration design and planning

<table>
<thead>
<tr>
<th>Deltas</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lummi</td>
<td>5</td>
</tr>
<tr>
<td>Nooksack Delta</td>
<td>9</td>
</tr>
<tr>
<td>Skagit Delta NF</td>
<td>27</td>
</tr>
<tr>
<td>Skagit Delta SF</td>
<td>48</td>
</tr>
<tr>
<td>Stillaguamish</td>
<td>6</td>
</tr>
<tr>
<td>Snohomish Delta</td>
<td>9</td>
</tr>
<tr>
<td>Nisqually</td>
<td>10</td>
</tr>
<tr>
<td>Quilcene Delta</td>
<td>4</td>
</tr>
<tr>
<td>Dosewallips Delta</td>
<td>8</td>
</tr>
<tr>
<td>Duckabush Delta</td>
<td>5</td>
</tr>
<tr>
<td>Hama-Hama Delta</td>
<td>7</td>
</tr>
<tr>
<td>Dewatto Delta</td>
<td>2</td>
</tr>
<tr>
<td>Tahuya Delta</td>
<td>2</td>
</tr>
<tr>
<td>Skokomish Delta</td>
<td>6</td>
</tr>
<tr>
<td>Union River Delta</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lagoons</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iverson</td>
<td>1</td>
</tr>
<tr>
<td>North Bluff</td>
<td>1</td>
</tr>
<tr>
<td>Race</td>
<td>1</td>
</tr>
<tr>
<td>Oak Harbor</td>
<td>2</td>
</tr>
<tr>
<td>Seabeck</td>
<td>2</td>
</tr>
<tr>
<td>Thorndyke</td>
<td>3</td>
</tr>
<tr>
<td>Dabob</td>
<td>6</td>
</tr>
<tr>
<td>Point Julia</td>
<td>1</td>
</tr>
<tr>
<td>Hama-Hama</td>
<td>2</td>
</tr>
</tbody>
</table>
2. Puget Sound Results
Similar scaling functions between marsh island area and a suite of channel planform metric for tidal marshes throughout Puget Sound.

\[ y = 1.6451x^{0.66} \]
Non-linear cumulative effects are evident for total channel length, total channel surface area, and the surface area of the largest channel draining a marsh island (i.e., allometric exponents > 1.0)
\[ y = 73.4x^{1.28} \]
3. Examining regression intercepts
Wave Height

Tide Range

Finlayson 2006
Stepwise multiple regression of ANCOVA elevations (y-intercepts) with wave height (Finlayson 2006), drainage basin area (Czuba et al. 2011), and tide range (NOAA).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Predictor</th>
<th>P-value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel count</td>
<td>Tide range, wave height</td>
<td>&lt; 0.0007</td>
<td>0.77</td>
</tr>
<tr>
<td>Total channel area</td>
<td>Wave height, tide range</td>
<td>&lt;0.002</td>
<td>0.72</td>
</tr>
<tr>
<td>Total channel length</td>
<td>Wave height, tide range</td>
<td>&lt;0.0005</td>
<td>0.79</td>
</tr>
<tr>
<td>Total magnitude</td>
<td>Wave height, tide range</td>
<td>&lt;0.002</td>
<td>0.84</td>
</tr>
<tr>
<td>Area of largest channel</td>
<td>Wave height</td>
<td>&lt;0.004</td>
<td>0.56</td>
</tr>
<tr>
<td>Length of largest channel</td>
<td>Wave height, tide range</td>
<td>&lt;0.002</td>
<td>0.72</td>
</tr>
<tr>
<td>Magnitude of largest channel</td>
<td>Wave height, tide range</td>
<td>&lt;0.004</td>
<td>0.82</td>
</tr>
<tr>
<td>Tributary count of largest channel</td>
<td>Wave height, tide range</td>
<td>&lt;0.003</td>
<td>0.71</td>
</tr>
</tbody>
</table>

TIDE +, WAVE -
4a. Application to Restoration Design and Planning
### Smith Island Conceptual Design vs. Model Predictions

<table>
<thead>
<tr>
<th></th>
<th>Predicted (95%/80% CL)</th>
<th>Planned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Count</td>
<td>46 (14%/22)</td>
<td>8</td>
</tr>
<tr>
<td>Total Length</td>
<td>47,172 (11,095%/18,566)</td>
<td>14,021</td>
</tr>
<tr>
<td>Largest chan. L</td>
<td>14,034 (3,231%/5,448)</td>
<td>9,060</td>
</tr>
<tr>
<td>Largest chan. Tribs</td>
<td>41 (10%/17)</td>
<td>23</td>
</tr>
<tr>
<td>Total Area</td>
<td>13.0 (56.0%/33.3)</td>
<td>14.1</td>
</tr>
<tr>
<td>Largest chan. A</td>
<td>4.9 (29.1%/15.5)</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Thanks to Bob Aldrich
Snohomish Co. Public Works Dept.
Non-linear cumulative effects have significant implications for restoration planning, e.g., “splitting the baby” negotiations, SLOSS decisions, mitigation for loss.

E.g.,

<table>
<thead>
<tr>
<th>Site size</th>
<th>Total Channel Area</th>
<th>Total Channel Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ha</td>
<td>5.81 ha</td>
<td>24,173 m</td>
</tr>
<tr>
<td>50 ha</td>
<td>2.03 ha</td>
<td>10,093 m</td>
</tr>
<tr>
<td>65 ha</td>
<td>2.03 ha</td>
<td>14,080 m</td>
</tr>
<tr>
<td>75 ha</td>
<td>3.78 ha</td>
<td></td>
</tr>
</tbody>
</table>
4b. Application to Restoration in the Columbia River Estuary!
ANCOVA

$F_{2,89} \text{ (slopes)} = 3.17; \ p < 0.05$

Russian – White’s

$y = 2.25x^{0.47}$

$R^2 = 0.70$

Skagit Delta

$y = 1.65x^{0.66}$

$R^2 = 0.75$

Young’s Bay

$y = 1.11x^{0.71}$

$R^2 = 0.72$
\[ y = -3.07 \ln(x) + 28.68 \]
\[ R^2 = 0.240 \]
\[ p < 0.002 \]

![Graph showing the relationship between residual and distance upriver with an equation and correlation coefficient provided.]

\[ y = 2.34x^{0.46} \]
\[ R^2 = 0.71 \]

Emergent vegetation, mostly Russian Island complex

Dense forest/shrub, mostly upriver
Summary

1. Landform allometry is a useful tool for restoration planning, design, and monitoring – many reference sites possible.

2. Tidal channel geometry is affected by marsh area, tide range, and wave energy.

3. Allometry of channel count for Columbia River marshes is affected by distance upriver (≈ tide range) and forest/shrub cover.

4. Non-linear cumulative effects exist: bigger marsh area is better.

5. Restoration practitioners tend to underestimate the number of tidal channels a site should have, which may affect site accessibility.