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Effects of Shoreline Armoring on Physical Beach Characteristics in the Salish Sea, WA

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Introduction

To assess the effects of shoreline armoring on beach morphology, we compared physical beach characteristics of both the backshore and foreshore from adjacent sections of armored and unarmored shoreline at a variety of locations representing three shore types in the Salish Sea. Beach width, slope, and arm or bluff toe elevation was extracted from high-resolution lidar data at 10 meter intervals alongshore, which offers a significantly more robust dataset than previous work. Findings from this research aim to provide insights about nearshore morphodynamics in the region, which can aid in optimizing armor removal restoration efforts.

Methods

Eighteen reaches were identified, each a minimum of 500 meters in length and represented one of three shore types: bluff-backed, accretionary, or transition zone, with approximately equal parts armored and natural shoreline. The table below summarizes conditions for the reaches included. Note, due to the small sample size and high variability, transition zone reaches were excluded from some analyses.

<table>
<thead>
<tr>
<th>Shore Type</th>
<th>Armored</th>
<th>Accretionary</th>
<th>Transition Zone</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluff-backed</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Natural</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>11</td>
<td>4</td>
<td>3</td>
<td>18</td>
</tr>
</tbody>
</table>

The diagram to the right shows the general workflow used in this study. Data collection and processing was completed using ArcGIS Pro and Excel, and analysis was largely completed in R. All beach parameters were measured in both the foreshore and backshore zones as defined in the figure below.

Results

In the foreshore, average width and slope were similar between armored and unarmored sections. In the backshore, average width was lower in armored sections than natural sections by all measures, and slope was slightly higher in armored sections. Toe elevation was lower by all measures in armored sections compared to natural sections. The plots below display the ranges of beach parameters.

Ranges varied by shore type. Backshore width was lower in armored sections of bluffed-backed reaches and accretionary reaches. Backshore width was less variable and toe elevations more variable in armored sections of transition zones, however this pattern may be due to the small number of transition zone reaches included. Toe elevation of armored sections was slightly lower on accretionary beaches and significantly lower on bluffed-backed beaches. Ranges of backshore width and toe elevation by shore type are shown in the plots below.

Comparison of Armored and Unarmored Beach Metrics

Paired t-tests of the average beach width and slope in armored and natural sections of each reach were run to determine if significant differences were present. The results for the paired t-tests are summarized in the table to the right. At a 95% confidence interval, backshore width and toe elevation were significantly lower in armored sections compared to their adjacent natural sections. When tested within shore types, backshore width and toe elevation were significant at a 95% confidence interval, however there was no significance in either measure along accretionary reaches.

Preliminary Conclusions

- Bluffed-backed reaches had strong significant differences in toe elevations and backshore width between armored (lower and narrower) and natural sections (higher and wider), but there was no significance in accretionary reaches. Armor removal restoration efforts may be most effective along bluffed-backed shorelines where the armor toe is lower than the adjacent bluff toe.
- Foreshore beach slope may not be a good measure of beach slope, and therefore beach slope may not be a good measure of restoration success.
- Toe elevation and backshore width are correlated in accretionary reaches and transition zones. In these shore types, armor removal should focus on locations where the armor toe is significantly lower on the beach than adjacent natural shorelines.

Discussion and Next Steps

Beach parameters varied significantly between individual reaches. This is likely due to external factors not accounted for in this research such as wave exposure and sediment size. The high number of transects included here allows for further testing on a site-specific scale that may result in additional criteria for prioritizing and monitoring armor removal efforts in the Salish Sea.