A Tale of Two Rivers - Evaluating Restoration Methods with Bayesian Networks in the South River (VA) and Puyallup River (WA)


Western Washington University, Bellingham WA, USA
The Question-How to evaluate the effects of a management alternative?

It is possible to use risk assessment as a tool and restoration probability can be estimated.

A tale of two rivers on opposite coasts and two types of ecological restoration schemes..
The Question-How to evaluate the effects of a management alternative?

Cause-effect networks based on the relative risk model for ecological risk assessment.

Bayesian networks as the mathematical structure.

Incorporates both the deterministic and stochastic nature of ecological structures.
Cause-effect networks based on the relative risk model for ecological risk assessment.

Bayesian networks are Directed Acyclic Graphs (DAGs) that represent relationships between variables. 

*Source* — *Stressor* — *Habitat* — *Effect* — *Impact*

In other words cause-effect pathways.
Bayesian Networks (BNs)-short introduction

The nodes are random variables

The links are the pathways of influence
Bayesian Networks (BNs) - short introduction

Parent Nodes

Child Node
Bayesian Networks (BNs)-short introduction

Parent Node

This is the CPT for the Child Node
The relationships in the CPT can be determined in a number of ways:

- Simulation models for populations or communities
- Field results
- Exposure-response data
- Expert Elicitation

Bayesian Networks (BNs)-short introduction
Conceptual model from the RRM

Turned into a Bayesian network
Cause effect pathways with management nodes included
A tale of two rivers on opposite coasts and two types of ecological restoration schemes.

We will use two examples, the Puyallup River in Washington and the South River in Virginia.

Puyallup River work has been published (Hines and Landis 2014)-summary.
Endpoint- Prespawn Mortality (PSM)  
*Oncorhynchus kisutch* (Coho or Silver salmon)

- Coho are listed as species of concern under Endangered Species Act.

- Only observed in coho salmon in lowland urban watersheds (Fiest et al. 2011).

- Observed as high as >90% PSM in returning populations (Spromberg and Scholz 2012)
Management alternative - Low Impact Development (Green Infrastructure)
It is possible to use risk assessment as a tool and restoration probability can be estimated.

Even with LID incorporated, the issue is that very little LID can be applied to date.
It is possible to use risk assessment as a tool and restoration probability can be estimated.

Shift the risk distribution from that seen in Region 6 to that of regions 2 and 1.

Risk regions 3, 5, and 6 have as much as 49%, 70%, and 67% impervious surface. Region 2 had the lowest risk to PSM and had 6% impervious surface.
South River in Virginia-New Stuff
South River-Diverse with multiple uses
South River RCRA Historical site for Hg pollution

**Annual mercury loading sources**

1. Channel margin (banks) ~83%
2. Runoff ~15%
3. Point Sources ~3%

Total loading: 189.4 kilograms/year

Other stressors include other contaminants, suspended solids, and temperature.
Endpoints

Biotic Endpoints

Belted Kingfisher
Carolina Wren
Smallmouth Bass
White Sucker

Water quality endpoints

Water quality standards
Fishing river use
Swimming river use
Boating river use
Management Alternatives

Bank Stabilization

Best Management Practices (BMPs)
Management options

– Bank Stabilization
Pilot study, Expert elicitation bank stabilization—Anchor Environmental- Expert elicitation—Belted Kingfisher (Dr. Dan Cristol)

– Ag BMP
Benthic Impairment Total Maximum Daily Load (TMDL) for South River, Cullum et al 2006-Sheffield et al 1997
South River BN for the Smallmouth bass endpoint.
Distributions of risk to smallmouth and Belted Kingfish

Different kinds of risk distributions.
Results: Bank Stabilization-Region 6
Smallmouth Bass

<table>
<thead>
<tr>
<th></th>
<th>Smallmouth Bass</th>
</tr>
</thead>
<tbody>
<tr>
<td>zero</td>
<td>25.3</td>
</tr>
<tr>
<td>low</td>
<td>17.6</td>
</tr>
<tr>
<td>med</td>
<td>24.0</td>
</tr>
<tr>
<td>high</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>3.3 ± 2.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Smallmouth Bass</th>
</tr>
</thead>
<tbody>
<tr>
<td>zero</td>
<td>35.6</td>
</tr>
<tr>
<td>low</td>
<td>15.8</td>
</tr>
<tr>
<td>med</td>
<td>21.0</td>
</tr>
<tr>
<td>high</td>
<td>27.6</td>
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<tr>
<td></td>
<td>2.81 ± 2.5</td>
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</table>
Results: Bank Stabilization Risk Region 2

Nests avoided

<table>
<thead>
<tr>
<th>Kingfisher</th>
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<tbody>
<tr>
<td>zero</td>
<td>26.6</td>
<td></td>
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<tr>
<td>low</td>
<td>29.3</td>
<td></td>
</tr>
<tr>
<td>med</td>
<td>32.5</td>
<td></td>
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<tr>
<td>high</td>
<td>11.7</td>
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<tr>
<td></td>
<td>2.58 ± 2</td>
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</table>

Nests destroyed

<table>
<thead>
<tr>
<th>Kingfisher</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>zero</td>
<td>0</td>
</tr>
<tr>
<td>low</td>
<td>0</td>
</tr>
<tr>
<td>med</td>
<td>0</td>
</tr>
<tr>
<td>high</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>6 ± 0</td>
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</table>
Results: Ag-BMPs

- Risk distribution shape did not change for any endpoints

<table>
<thead>
<tr>
<th>Sexual River Use</th>
<th>Zero</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
</tr>
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<tbody>
<tr>
<td>Zero</td>
<td>1.73</td>
<td>13.2</td>
<td>44.7</td>
<td>40.4</td>
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<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Med</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td>4.48</td>
<td>13.2</td>
<td>44.7</td>
<td>40.4</td>
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</table>

<table>
<thead>
<tr>
<th>Swimming River Use</th>
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<th>Med</th>
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<tr>
<td>Zero</td>
<td>1.77</td>
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<tr>
<td>Med</td>
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</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4.46</td>
<td>13.4</td>
<td>45.0</td>
<td>39.8</td>
</tr>
</tbody>
</table>

4.48 ± 1.5

4.46 ± 1.5
Results: Management Options

- Bank management reduce the risk for smallmouth bass---but may increase risk to Kingfisher.

- Ag-BMP no difference in risk but also no regrets.
Results: Management Options

• Bank management reduce the risk for smallmouth bass---but may increase risk to Kingfisher.

• Ag-BMP no difference in risk but also no regrets.
Summary

• It is possible to use risk as a metric to evaluate current conditions and the plausibility of management options.

• Can estimate increases in risk due to management options to other endpoints.
Summary

• Some management methods may not alter the risk (enhance restoration) in certain scenarios.

• There are numbers involved attached to distributions.
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