A Bayesian Network to Prioritize Restoration of Aquatic Connectivity, Western Oregon

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Abstract

There are numerous road culverts that impede passage of fish in the Pacific Northwest and no consistent procedure for prioritization. Priorities are essential because the cost of restoration is large. For example, the GAO estimates the cost of fish passage restoration to be at least $375 million for just public lands in Oregon and Washington. The state of Oregon has invested over $28 million alone in the past decade to restore passage.

Using Netica software, a decision support tool was developed in the form of a Bayesian Network (BN) to assist prioritization of fish passage restoration. The BN incorporates empirical evidence and expert opinion to depict factors affecting the decision to replace a barrier. Major factors in the BN include potential habitat quality, likelihood of fish using habitats above a barrier, degree of passage impairment, and cost. The BN combines these considerations to inform a decision to replace a culvert or not.

We are adapting this generalized model to the specific case of ESA listed winter-run steelhead trout (*Oncorhynchus mykiss*) in the Santiam Basin Oregon. Lessons learned from this case application will be applied to prioritizing fish passage restoration in the Santiam Basin, and to refining the BN for more widespread application.

Decision context for fish passage restoration:

We assumed the decision to replace a culvert is based primarily on:

1) Degree of Passage Impairment
   - Life stages influenced (juvenile vs. adult)
   - Conditional or unconditional impairment
2) Biological Benefit
   - Quality of habitat accessed and probability of use
3) Cost of Replacement

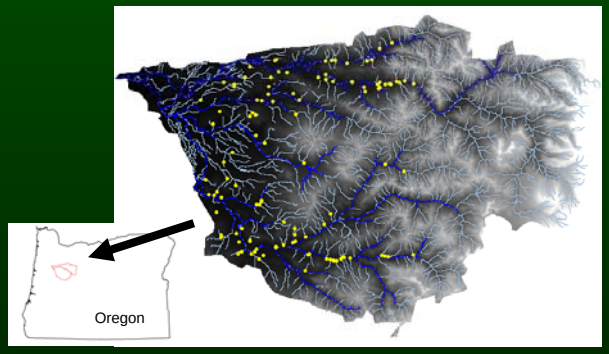

Fig. 1: Santiam basin and potential barriers on private lands

Study Area:

- Santiam River Basin: ~1,800 sq mi. primarily forested headwaters and agriculture in lower reaches
- A Willamette River tributary that originates in the Western Cascades Mtns
- North Santiam: 4th field basin, ~70% public / ~30% private ownership
- South Santiam: 4th field basin, ~40% public / ~60% private ownership
- Historically had large runs of winter steelhead, now listed as threatened
- Barrier replacement top restoration priority for the basin

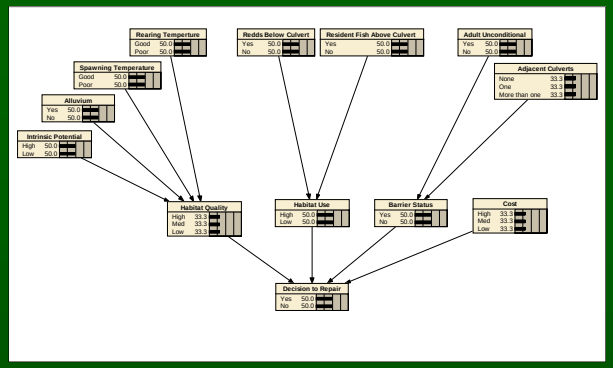

Fig. 2: Model Structure

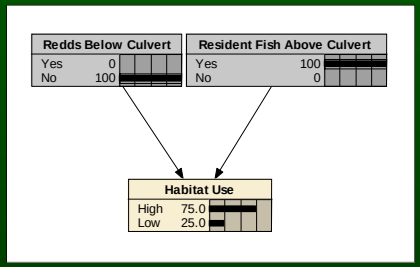

Fig. 3: Probability of Habitat Use and parent nodes

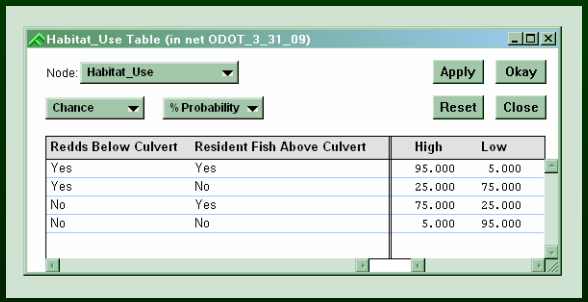

Fig. 4: Conditional Probability Table for Habitat Use Node. Values based on expert opinion.

Anatomy of the Bayesian Network

- Netica software used as modeling shell.
- Nodes (variables) have discrete states depicting possible domains.
- Conditional Probability Table depict relationships between nodes, with values populated from expert opinion or case data.
- State values within nodes depicted as probabilities. E.g., The final node has two states, yet is represented as probability (e.g. 80% yes, 20% no).

Nodes:

Habitat Quality = Intrinsic Potential + Alluvium + Spawning Temperature + Rearing Temperature

Intrinsic Potential: Ability of stream reach to rear steelhead[1]
Alluvium: Redd abundance can be predicted with alluvium[2]
Spawning Temperature: OR DEQ spawning stream criteria
Rearing Temperature: OR DEQ cold core water habitat criteria

Habitat Use = Redds below culvert + resident fish above culvert

Redds Below Culvert: Measure of probability fish will use habitat upstream if passage restored
Resident Fish Above Culvert: Current use of habitat, another assumed indicator of probability of steelhead

Barrier Status = conditional barrier + barrier location

Conditional Barrier: Depicts barrier to upstream migrating Adults
Adjacent Culverts: Culvert in relation to other culverts

Decision to Replace = Habitat quality + habitat use + barrier status + cost

Cost: Estimated cost of replacement

Implications

- This model can assist prioritization of restoration investments
- Complete or partial data may be used to assess multiple information scenarios (sensitivity analysis) and evaluate information needs (e.g. info is costly , how much do we need?), see Peterson et al. 2008[3]
- Transparent approach for justifying priorities.
- BN can be modified for other species and locales.
- The final decision is up to the land manager.

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[1]Burnett et al. 2007, Ecol. Appl.
[2]Steel et al. 2004, CJFAS
[3]Peterson et al. 2008, CJFAS

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