Mesohabitat Scale Hydrodynamic Modeling: Influence on Habitat Suitability Indices

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Abstract

Two-dimensional (2D) hydrodynamic numerical models are commonly used to model flow depth and depth-averaged velocity in rivers and streams used to evaluate habitat suitability (HSI)[1] for many applications including fish passage[2], river restoration[3], life cycle models, and carrying capacity models. Previous studies have described myriad benefits of 2D models for habitat suitability analysis[4]. This study investigates the impact of using principles of salmonid habitat to guide development of the hydrodynamic model for habitat suitability analysis. Habitat features that are relevant to spawning and rearing life stages have physical characteristics[5] that can be integrated in model development through cell size and depth-varied roughness. Increasing resolution of depth and velocity simulation within complex hydraulic areas, such as around large wood, edge habitat, hyporheic flow zones, riffle crests, side channel, and off channel habitat can improve suitability predictions.

Introduction

Hypothesis: Incorporating characteristics of salmonid habitat in hydrodynamic model development will improve resolution of habitat suitability in ecologically relevant areas.

Mesohabitat Scale Characteristics[5]

Spawning	Rearing
Chinook: • Riffles, riffle crests, lateral bars, shallow glides, tail-outs • Proximity to cover and pools **Steelhead**: • Complex riffles, variable • Proximity to cover and pools	**Chinook**: • Pools, shallow and slow water edge habitat • Proximity to cover, substrate as cover **Steelhead**: • Shallow and slow edge habitat, pocketwater • Proximity to cover, substrate as cover

Varies with season, age class, region, and time of day

Hydrodynamic Modeling Considerations

Cell Size

- Decreasing cell size tends to increase peak velocity and improve edge habitat resolution
- Ability to accurately capture riffle crest hydraulic properties

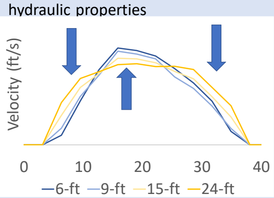

Figure 1. Cross section of velocity sensitivity to cell size.

Impacts to habitat suitability:

- Improve resolution of channel margin rearing habitat velocity
- Resolve riffle crest height, pool depth, and velocity distribution for spawning

Depth-Varied Roughness

- Frictional resistance of water passing over channel features increases with substrate size
- Decreases with relative submergence

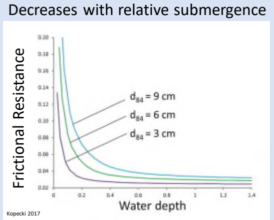

Figure 2. Frictional resistance relative to submergence.

Impacts to habitat suitability:

- Improve riffle velocity resolution
- Simulate increased resistance during low spawning flows
- Reduced velocity where substrate is used for cover

Methods

Two-dimensional hydrodynamic models were created for two case study reaches, the Hanford Reach of the Columbia River and the Upper Grande Ronde River, using the United States Bureau of Reclamation's (USBR's) SRH-2D Version 3.2 computer program[6]. Average flow conditions for the relevant species and life stage were run under steady-station conditions. Pre- and post-processing for this model was completed using SMS Version[7] 13.2.13. Depth and velocity rasters were extracted for each species/life stage.

Grande Ronde River | Hanford Reach Columbia River

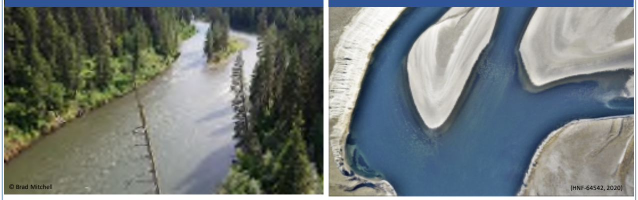

Figure 3. Overhead photos of the case study rivers; Grande Ronde (left) and Hanford Reach of the Columbia River (right).

Hydraulic habitat suitability was evaluated using the using the Habitat Suitability Index Modeler Tool[8]. This RShiny tool allows for rapid and flexible habitat suitability computations over large spatial domains. Weighted Usable Area (WUA) and Suitability Index (SI) was calculated for each species/life stage relevant combination using the methodology summarized in (Figure 4) using previously derived habitat suitability[9].

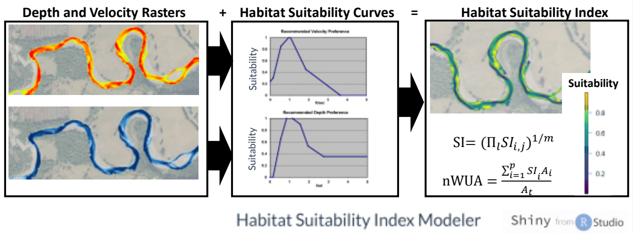

Figure 4. Graphical representation of habitat suitability calculations.

Results

It was hypothesized that decreasing cell size allows for increased model resolution of bank conditions, riffle gradient, and edge habitat (Figure 1).

- Both spawning and rearing suitability index increased with decreasing cell size
- Sensitivity to cell size is a function of curve shape and morphology

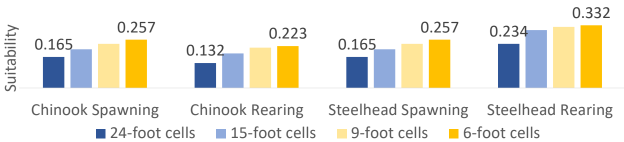

Figure 5. Spawning and Rearing suitability index sensitivity to hydrodynamic model cell size for the Upper Grande Ronde River.

Results

Spawning and rearing flows were simulated with three different frictional resistance (or roughness) conditions. A single roughness value in the main channel, a single depth-varied roughness value[10] based on reach-wide substrate characteristics, and a spatially distributed depth-varied roughness value representing the variety of substrate compositions observed within the reach.

- Spawning suitability decreased for both species, possibly representing a misapplication of reach-scale substrate size within riffles
- Rearing suitability increased for both species, indicating the influence of substrate in rearing

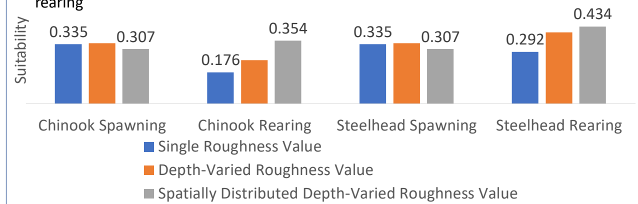

Figure 5. Spawning and rearing suitability index sensitivity to roughness values for the Upper Grande Ronde River.

Results

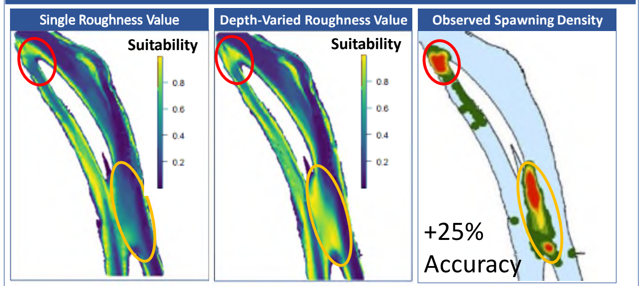

Figure 5. Comparison of spawning habitat suitability in the Hanford Reach using a single roughness value (left) and depth-varied roughness (middle) compared to observed redd densities (right) showing a 25% increase in Mann-U Whitney accuracy.

Conclusions

- Small changes in hydraulic parameters can have a significant influence on suitability
- Mesoscale habitat suitability modeling is important in representing spatially coincident habitat characteristics to resolve nuance within larger habitat units
- Decreasing cell size can improve channel margin habitat resolution, side and off channel areas, and riffle crests
- Incorporating depth-varied roughness can improve resolution of spawning habitat associated with riffles as well as rearing habitat along channel margins
- There are additional factors outside of hydraulic properties that may drive suitability
- Validation and bioverification are informative methods of assessing accuracy

Conclusion: Incorporating characteristics of salmonid habitat in hydrodynamic model development will improve habitat suitability in ecologically significant areas.

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