MODELING THE INFLUENCE OF CHANNEL MORPHOLOGY ON SPATIAL PATTERNS IN ENERGETIC PROFITABILITY OF FORAGING HABITAT FOR DRIFT-FEEDING TROUT

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Channel morphology strongly influences the properties and spatial patterns of the flow field, which in turn defines hydraulic habitat that fish utilize for foraging, movement, spawning and refuge. In this research, we have examined how channel morphology and the associated hydraulic conditions influence the distribution and energetic profitability of foraging habitat for drift-feeding salmonids. To this end, we have linked hydrodynamic and bioenergetic models and applied them to study habitat for Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*) in four reaches of a small, mountain stream in British Columbia with distinct morphologies. The model was applied for two flow scenarios, approximately 10% and 50% of the bankfull discharge. Using model output, we have investigated spatial patterns of net energy intake for three body size classes of trout within and between the study reaches.

1 INTRODUCTION

Channel morphology constitutes a critical element of physical habitat for freshwater fish. The shape and roughness of channel bed and banks dictate the properties and spatial patterns of the flow field and, consequently, control hydraulic habitat utilized by fish for foraging, movement, spawning and refuge. The composition and arrangement of this heterogeneous habitat strongly influences individual fitness and population dynamics [1, 2].

Much of current understanding of the quality and distribution of fish habitat in streams has been based on correlation between habitat attributes and fish presence or abundance. Recently, mechanistic approaches to habitat analysis, such as bioenergetics modeling, have become increasingly popular and provide an excellent tool to generate new insights into fish-habitat relationships [3]. However, thus far, little effort has been directed towards a systematic evaluation of how differences in channel morphology may influence spatial patterns of fish habitat at a range of different scales. The objective of this research was to address this question, focusing specifically on salmonids and small gravel-bed streams which they often inhabit.

2 METHODS

To achieve our goal we linked a 2D hydrodynamic model with a bioenegetic model for drift-feeding trout and applied them in four reaches of a small stream in British Columbia. The study reaches form a sequence of distinct morphologies ranging from cobble-bed rapid (plane-bed) to gravel-bed pool-riffle, and are inhabited by a population of resident Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*). The model was run for two flow scenarios, approximately 10% and 50% of the bankfull discharge. The lower discharge represented baseflow conditions experienced by fish in the study stream during spring and early summer. The higher discharge was an approximation of the maximum flows which fish in this stream are likely to experience during that season.

FaSTMECH, the hydrodynamic model used in this study, is a widely applied depth-averaged code with channel-fitted coordinate system [4]. The model was parameterized using field data that included bed topography, discharge, and water surface elevations at the downstream boundary. Other input parameters included lateral eddy viscosity (LEV), which was estimated from shear velocity and flow depth, and bed roughness. Bed roughness parameter was calculated as a function of flow depth and roughness length, the value of which was estimated from linear regression fitted to spatially averaged velocity profiles.

The output of the hydrodynamic model served as input into the bioenergetics model, in which net energy intake (NEI) was calculated as the difference between gross energy intake and swimming cost. The foraging sub-model, based on the framework developed by Hughes and Dill [5], was first utilized to estimate fish capture area. Gross energy intake was then calculated using Holling's disc equation [6] as a function of the rate of drift passing through that capture area and the energy content per prey item. The swimming cost was estimated from a routine swimming model of Boisclair and Tang [7], which considers unsteady swimming e.g. during maneuvers.

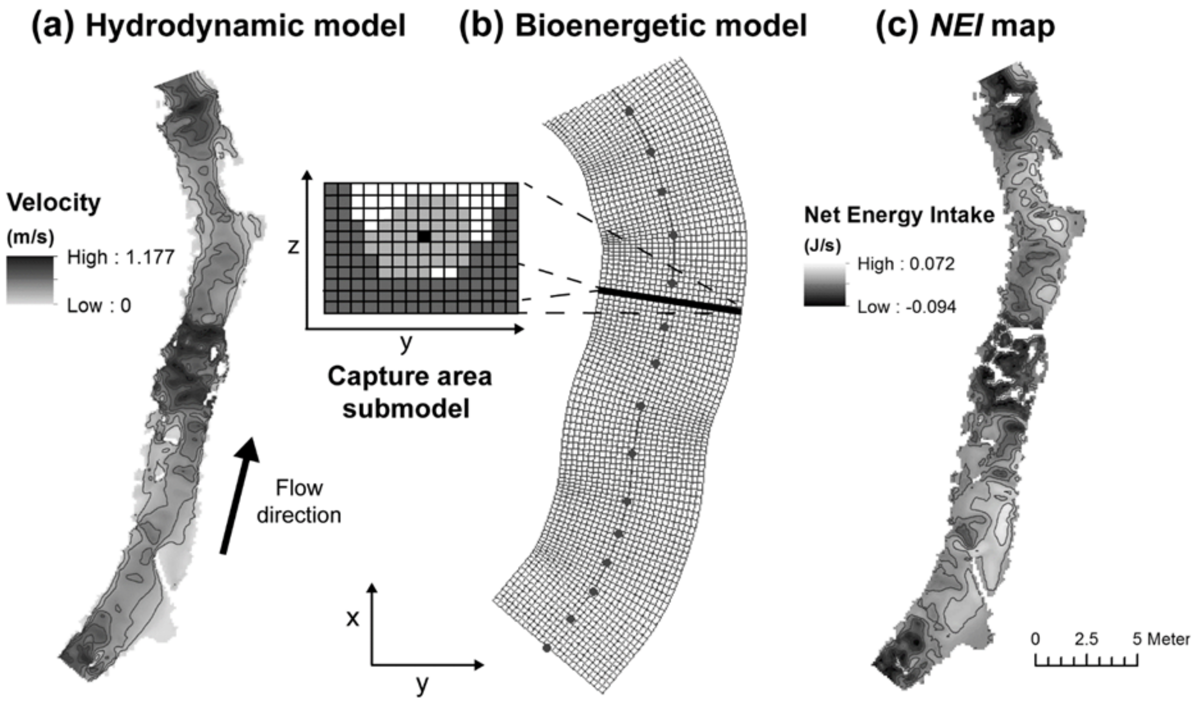

Figure 1. Hydrodynamic and bioenergetic models employed to investigate foraging habitat for Cutthroat Trout: (a) a map of velocity simulated using FaSTMECH; (b) a computational grid for the bioenergetic model; a cross-sectional representation of flow field was used to model prey capture area (light grey color) for each potential feeding location within the wetted channel. Note that cell size is exaggerated for the clarity of presentation; (c) a map of the modeled net energy intake.

3 RESULTS

The results of the integrated model suggested that the spatial patterns of net energy intake in the study reaches were complex and depended on channel morphology, flow discharge, and fish body size.

At the within-reach scale, the spatial pattern of modeled NEI during low flow had clear longitudinal and lateral structure. The longitudinal component was associated with pools, which were typically sites of highest predicted net energy intake, and riffles. Even in the Rapid reach, vertical flow expansions in scour holes were associated with higher NEI. The cross-stream structure differed for the three modeled body size classes. Although the results varied somewhat for different reaches, energetically optimal habitat for smaller fish was often predicted closer to the banks in comparison with the best feeding positions for larger individuals. The spatial pattern of NEI changed dramatically when the model was applied for flow equivalent to 50% bankfull flow. Under these conditions, only the near-bank zones, especially hydraulically sheltered areas such as separation eddies, provided energetically profitable habitat (NEI > 0), regardless of fish body size.

Aggregation of the above results enabled between-reach scale comparison. The results indicate that during low flows the reaches with well-developed pool-riffle morphology provided on average better foraging habitat in comparison with reaches with simple, plane-beds. However, this pattern no longer held during the higher flow. Under such conditions, the morphologically simpler reaches had generally higher average NEI. We believe the latter finding was a result of higher bank roughness in these reaches (associated with bank projections and large wood).

4 CONCLUSIONS

The results of the integrated hydrodynamic and bioenergetic models suggest that morphology in the study reaches indeed influenced availability, distribution, and quality of foraging habitat for drift-feeding trout but that influence was modified by discharge. We believe that these findings may be broadly representative of conditions in other coarse-bed streams with similar characteristics.

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