EEMS Demonstration Model Description

DM_River_Fish_Habitat_Analysis

1 Objective

This demonstration model uses EFDC+ Explorer (EE) and EFDC+ to simulate three-dimensional river hydrodynamics in the Habitat River reach, and to apply the Habitat Analysis post-processing feature of EE to assess the suitability of the simulated hydraulic conditions for two freshwater fish species: **muskellunge** (*Esox masquinongy*) and **burbot** (*Lota lota*).
The model is designed to demonstrate two capabilities in a single workflow. First, the hydrodynamic simulation provides spatially resolved fields of water depth and depth-averaged velocity across a complex, meandering river reach with wetting and drying. Second, the EE Habitat Analysis tool applies the Instream Flow Incremental Methodology (IFIM) to translate those hydraulic outputs into Habitat Suitability Curves (HSC) and Habitat Suitability Indices (HSI) for each species and life stage, enabling direct assessment of how simulated flow conditions meet species-specific habitat requirements.

2 Model Description

The model configuration is summarized in Table 1 and the model domain is shown in Figure 1. The domain represents a meandering river reach with a bottom elevation ranging from approximately 231 m to 243 m, reflecting a montane or boreal river setting consistent with the Coriolis parameter ($f = 1.22 \times 10^{-4}$ s^{-1}, latitude ≈57° N). The reach includes mid-channel islands and braided sections visible as holes with no active cells in Figure 1. Wetting and drying is activated to simulate the emergence and inundation of shallow bars and benches as flow varies over the simulation period, which is critical for accurate habitat area estimates.

Table 1 Model configuration summary

Run Period (Julian time)	Horizontal Cells	Vertical Layers	Activated Modules
210-217	5,898 cells	• 4 layers (standard sigma)	• Hydrodynamics

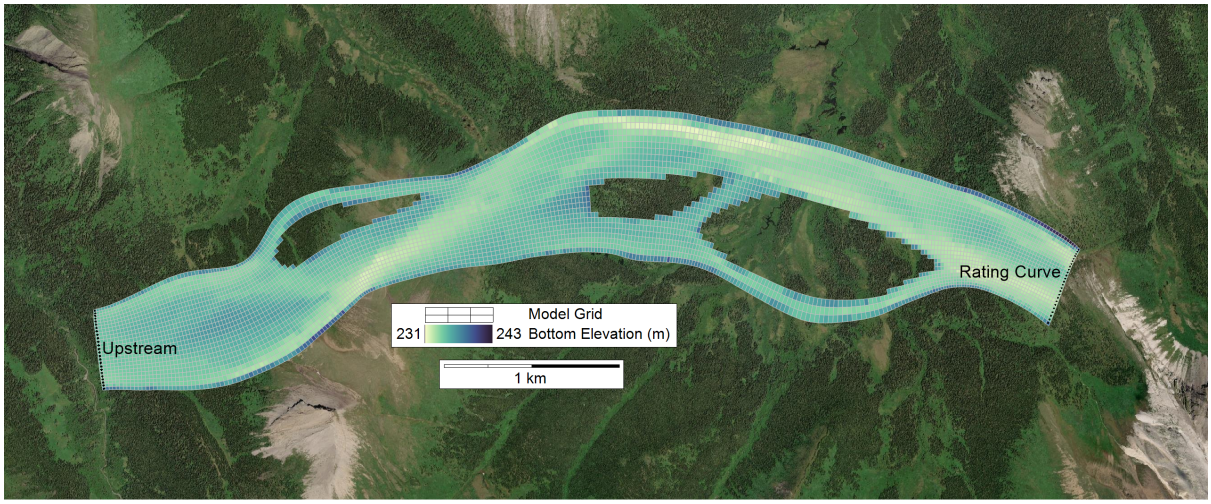


Figure 1 Model domain

2.1 Hydrodynamic Configuration

Flow is driven by a time-varying upstream inflow distributed across 25 boundary cells at J = 3 (left bank to right bank of the upstream cross-section), each assigned a width-weighted fraction of the total discharge from `US_Flow.dat`. The downstream boundary condition uses a rating curve applied at 25 cells at J = 282, derived from `DS_Rating_Curve.dat`. This stage–discharge relationship allows the water surface elevation at the downstream end to respond dynamically to changes in flow, avoiding an unrealistic fixed-stage boundary.
Turbulence is represented using the General Ocean Turbulence Model (GOTM) closure scheme, providing depth-resolved vertical mixing appropriate for the 4-layer sigma grid. Dynamic time-stepping is activated with a base timestep of 0.1 s and a maximum of 4 s, which accommodates the fast flow velocities and shallow depths characteristic of gravel-bed river reaches.

2.2 Habitat Analysis Configuration

The IFIM-based Habitat Analysis in EE uses the simulated depth and velocity fields to compute, at each model cell and timestep, a composite Habitat Suitability Index for each species–life stage combination. The analysis is configured for two species:

- **Muskellunge** (*Esox masquinongy*): a large predatory fish requiring relatively deep, low-velocity pools with woody debris or macrophyte cover. Habitat suitability curves for muskellunge are defined by preferences for water depth and near-bed velocity by life stage (adult, juvenile, spawning).
- **Burbot** (*Lota lota*): a cold-water benthic species associated with deep, fast-flowing reaches with coarse substrate. Burbot exhibit strong depth and velocity preferences that differ markedly from muskellunge, making the two species a useful contrasting pair for demonstrating the Habitat Analysis tool.

The HSC and HSI outputs are provided in the supplementary files `HabitatRiver_Model_Example_(2024_09_13).pdf` and `HabitatAnalysisData.xlsx` in the Data/Habitat folder.

3 Folder Structure

The model package contains the following components:

- **Model**: The complete EFDC+ model project directory, loadable directly in EFDC+ Explorer for pre- and post-processing, including the Habitat Analysis configuration.
- **Data**: Contains all input and supplementary files, organized into three subfolders:
  - *Bathymetry*: `Bottom_Elevation.dat`
  - *Boundaries*: `US_Flow.dat` (upstream flow time series) and `DS_Rating_Curve.dat` (downstream stage–discharge relationship)
  - *Habitat*: `HabitatRiver_Model_Example_(2024_09_13).pdf` and `HabitatAnalysisData.xlsx` (HSC definitions and computed HSI outputs)

4 Model Results

Figures 2–4c show results at Julian day 211, one day into the simulation. The water surface elevation (WSE) map establishes the hydraulic context, and the four HSC maps demonstrate how the same flow conditions produce markedly different habitat suitability patterns depending on species and life stage.

Water Surface Elevation

Figure 2 shows the simulated water surface elevation across the reach at day 211. WSE decreases from ≈235.4 m at the upstream end to ≈233.2 m at the downstream end, reflecting the longitudinal slope of the river. This WSE field, combined with the bathymetry, directly controls the water depth available to each species.

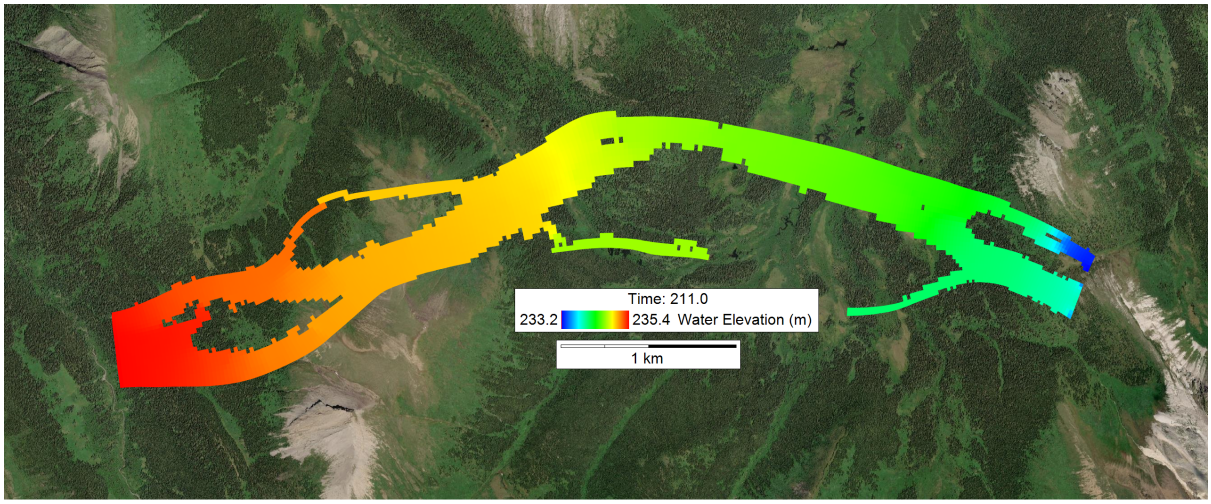


Figure 2 Water surface elevation (m) at Julian day 211

Burbot Adult

Figure 3 shows the HSC index for Burbot Adult at day 211. High suitability is concentrated in the main thalweg throughout the reach, with lower values on the shallow marginal bars and secondary channels. The spatial footprint of suitable habitat is relatively narrow and confined to the deeper channel centerline, consistent with the burbot adult preference for deep, fast-flowing habitat with coarse substrate.

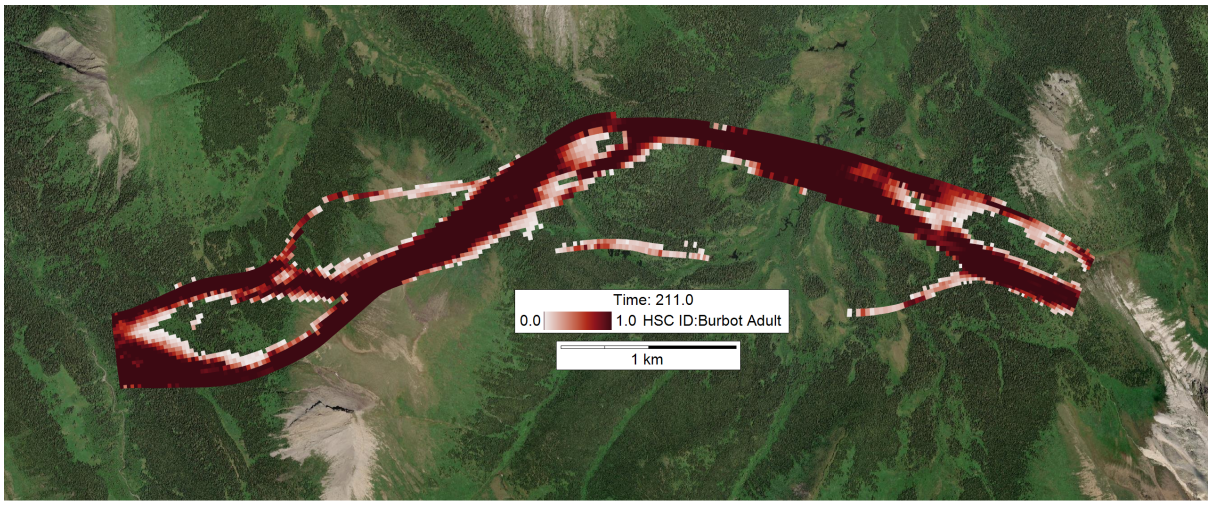
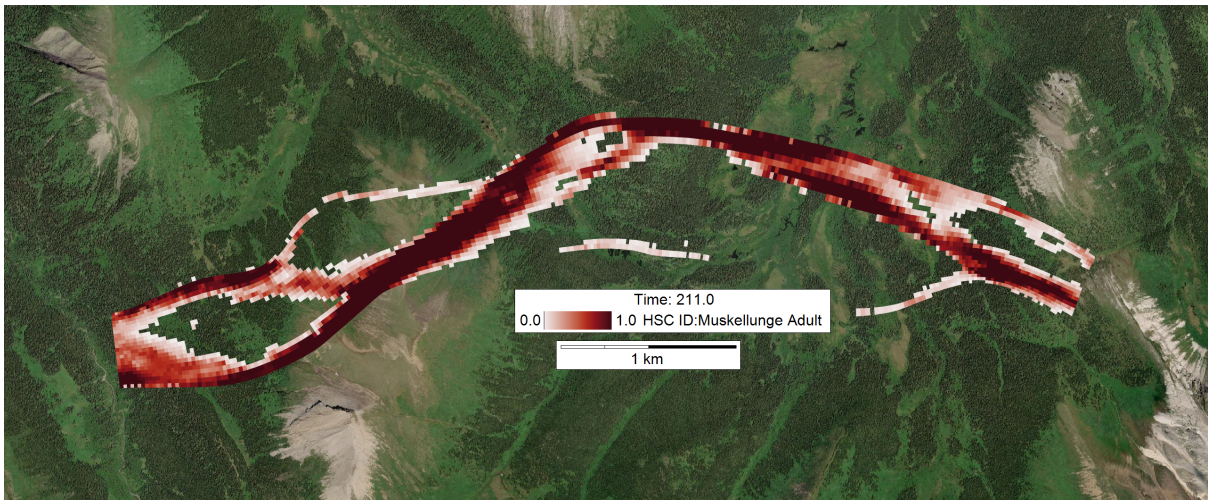


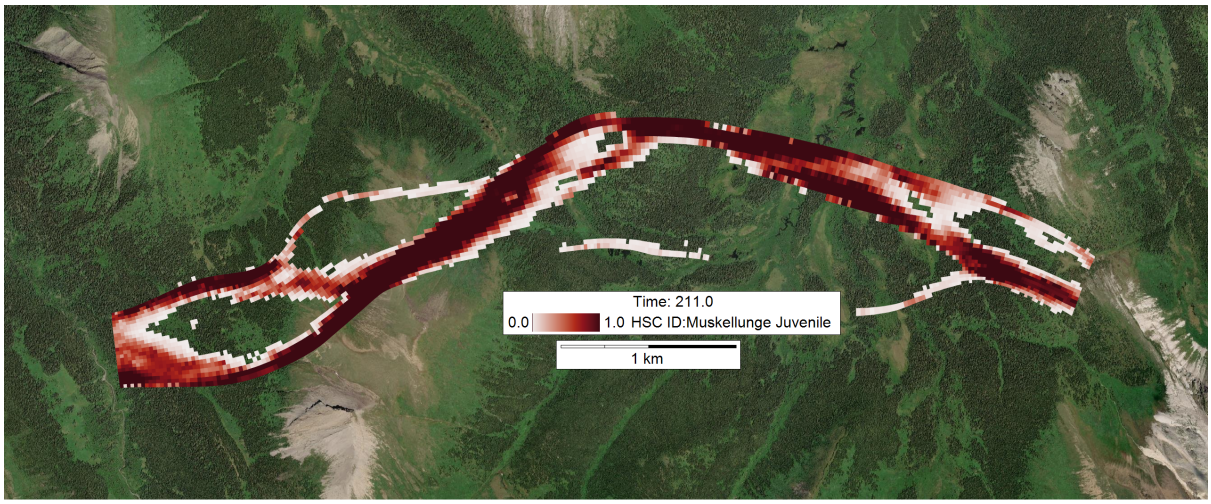
Figure 3 HSC index for Burbot Adult (water depth) at Julian day 211

Muskellunge by Life Stage

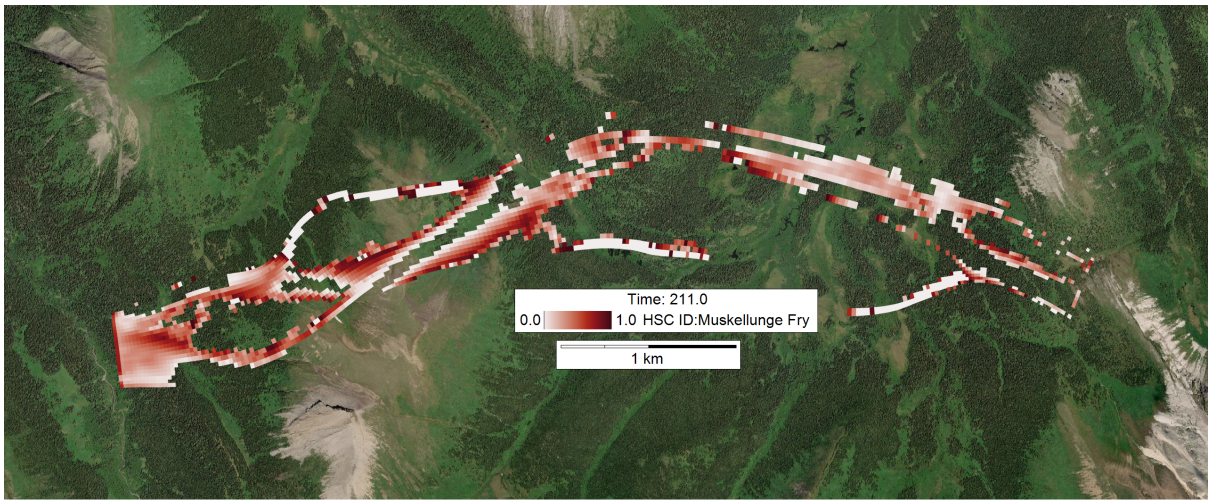
Figures 4a–4c show the HSC index for muskellunge across three life stages: Adult, Juvenile, and Fry. Comparing across the three panels reveals how habitat requirements shift substantially through the life cycle.



(a) Muskellunge Adult



(b) Muskellunge Juvenile



(c) Muskellunge Fry

Figure 4 HSC index for muskellunge by life stage (water depth, HSC scale 0–1.0) at Julian day 211.

The **Adult** stage (Figure 4a) shows a broad band of high suitability extending across much of the wetted channel width, including the outer bends and deeper areas of the braided section. The spatial pattern is similar to Burbot Adult but with a wider suitable footprint, suggesting

muskellunge adults use a broader range of depths and velocities than burbot adults under these flow conditions.
The **Juvenile** stage (Figure 4b) shows a pattern nearly identical to the adult, with high HSC values across the main channel. The similarity between adult and juvenile patterns suggests that the depth and velocity thresholds defining suitable habitat do not differ strongly between these two life stages at this flow level, though subtle differences in HSC magnitude are visible at the channel margins.
The **Fry** stage (Figure 4c) is distinctly different from both the adult and juvenile patterns. Suitable habitat is much more fragmented and is preferentially located along the shallow channel margins and the upstream braided section, rather than in the thalweg. This reflects the muskellunge fry preference for very shallow, slow-moving water near bank cover. The total area of high-suitability fry habitat is visibly smaller and more spatially restricted than for adults or juveniles.

5 Notes

5.1 Disclaimer

This model is provided to demonstrate that EFDC+ Explorer and EFDC+ can be used to build and analyze this type of models. The simulation results are consistent with expected behavior; however, the model should not be considered a final or validated product. Users are encouraged to review, modify, and refine model parameters to obtain results appropriate for their specific application.

5.2 EEMS Demo Mode

In Demo mode, the model is validated against a set of predefined signatures, including grid size, domain area, center coordinates, transport count, and module configuration. While certain parameter values may be adjusted, the grid cannot be modified, transports cannot be added, and the prescribed module setup cannot be altered. Any deviation from these conditions results in the model no longer being considered a valid demo model.

5.3 Support

For technical support, additional documentation, or to obtain the latest version of EFDC+ Explorer, please visit: `www.eemodelingsystem.com`