Instream Physical Habitat Modeling Methodology: Overview and Case studies

Ravi Nalamothu, P.E., HSW Engineering, Inc. (rnalamothu@hsweng.com)

The water management districts in Florida are required by s. 373.042, F.S. to establish minimum flow and levels (MFLs) for a priority list of water bodies that is updated each year. These MFLs are established for water bodies to prevent "significant harm" to the water resources or ecology because of withdrawals for beneficial use, and can be an effective water resource management tool. Protection of the resource from significant harm is a benefit to the variety of existing users of the resource as well as the ecological systems supported by the water bodies. This article presents an overview of a modeling technique and an associated tool typically used to protect the instream habitat from significant harm.

Flow is generally considered the "master variable" of riverine systems, because it is always a determinant of water quality, biology, physical habitat, and energy transfer (Poff et al. 1997, Annear et al. 2004). Maintaining natural flow variability benefits native aquatic species that have adapted to such variability and inhibits invasive species from flourishing (Poff et al. 1997). Many studies have shown that altering the flow regime can significantly impact biota, including fish, mussels and aquatic insects (McManamay et al. 2013).

Instream Flow Incremental Methodology (IFIM) was developed in the 1970s by the U.S Fish and Wildlife Service and is a widely-used method to determine the instream-flow needs for fish and wildlife. IFIM integrates concepts of water-supply planning, analytical hydraulic engineering models, and empirically derived habitat-versus-flow relationships. Physical habitat simulation models are a major component of IFIM and incorporate hydrology, stream morphology, and habitat preferences to determine the relationship between streamflow and available habitat. Physical habitat modeling is designed to calculate an index of the amount of habitat available for different life stages of aquatic organisms at different flow levels. Area Weighted Suitability (AWS), also known as Weighted Usable Area (WUA), is the index used to measure the available habitat. Software has been developed, such as SEFA and PHABSIM, to perform physical habitat modeling.

Physical habitat models are coupled models that use cross-section geometry, stage-discharge data, and water velocity profiles, similar to hydraulic models such as HEC-RAS, coupled with a species-specific habitat suitability models to characterize the amount of aquatic habitat that occurs at different flows. The physical habitat model simulates a relationship between streamflow and physical habitat for various life stages of a species of fish or other aquatic organisms. This relationship is used to determine incremental flow reduction associated with an incremental reduction in AWS.

Habitat Suitability Curves

Hydraulic and morphological variables, such as water depth, velocity, and bottom substrate are the main factors presumed to influence the distribution and abundance of aquatic species habitat in aquatic ecosystems. The velocity, depth, and habitat preference criteria (bottom substrate) for

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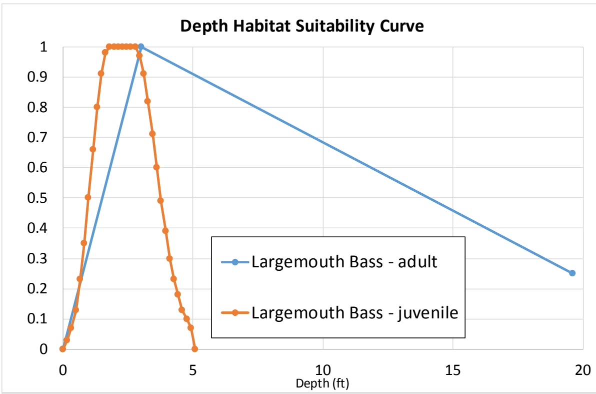
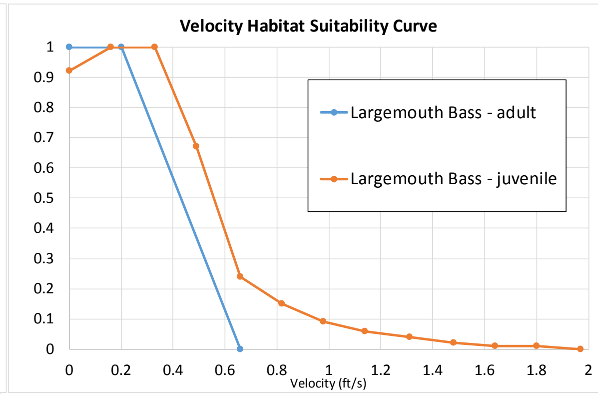
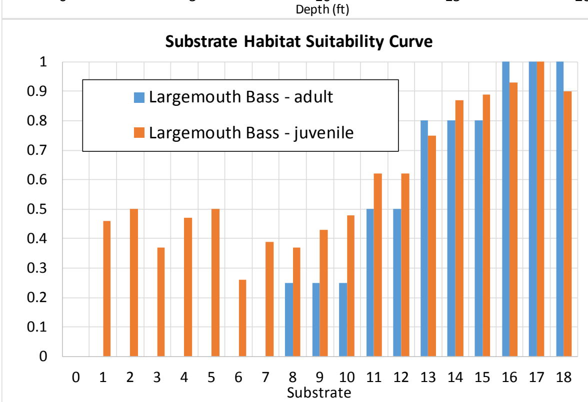
each species and life stage are utilized in the calculation of the AWS. For example, the preference criteria of Largemouth Bass for adult and juvenile life stages are presented below.

Largemouth Bass – Optimal current velocities for adult are less than 0.65 feet per second (ft/s) and habitat requirements of juveniles are similar to those of adults. Juveniles prefer water depths of five feet or less, whereas adults prefer 20 feet or less. Optimal substrate requirements include streams with some form of cover.





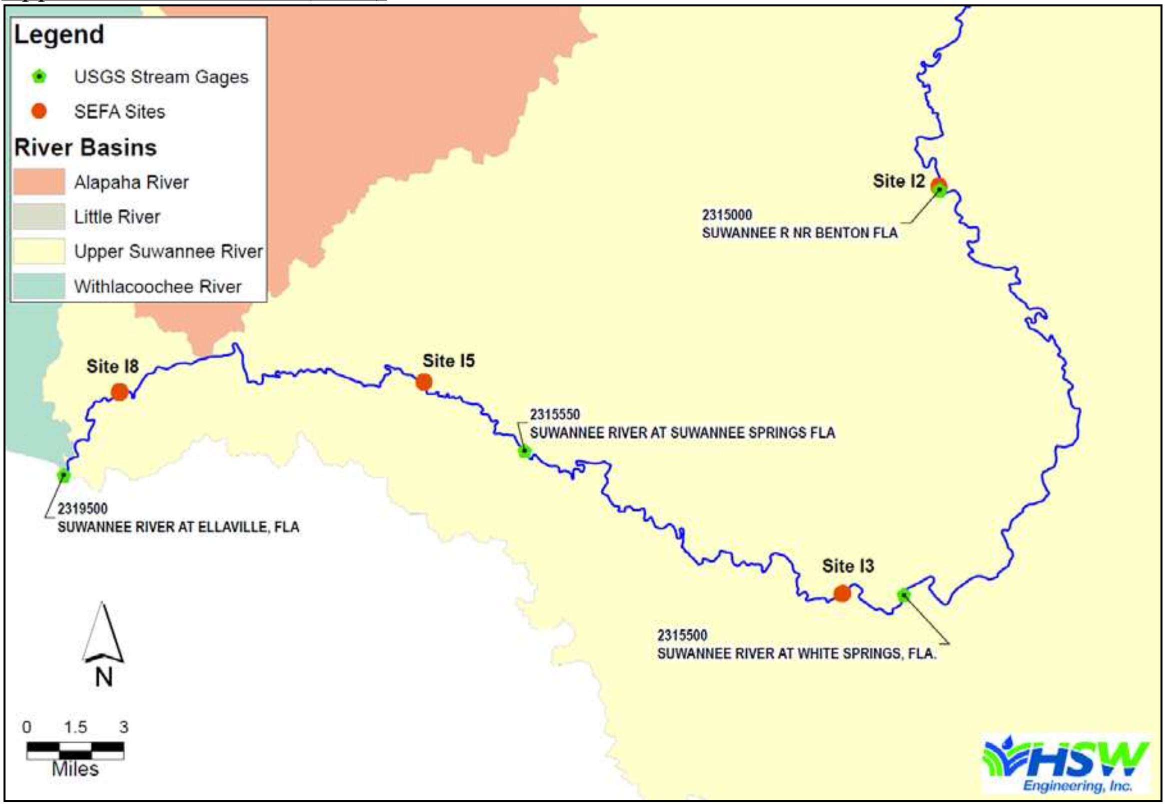


Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debri	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

<u>Case Studies</u>

System for Environmental Flow Analysis (SEFA), a Windows-based physical habitat simulation program, was used to evaluate the effects of flow reduction scenarios on available riverine habitat in the Upper Suwannee River and Aucilla River in north Florida. SEFA uses a time series of discharge to calculate a time series of AWS for select species and life-stages. The AWS time series can then be further processed using other software, for example to characterize AWS frequency distributions.

Upper Suwannee River (USR)



Field data (depth, velocity and substrate characteristics) were collected at four locations within the USR (I2, I3, I5, and I8) and under three flow conditions to calibrate the SEFA models. The four locations are characteristic of the heterogeneity of the USR with pool-riffle sequences, even and uneven bottom geometry, and sand and/or rock bottom; and the flow conditions represented the velocity preferences of the various species. The three most upstream sites (I2, I3, and I5) typify the USR and the fourth site (I8) is a known spawning site for the Gulf sturgeon (*Acipenser oxyrinchus desotoi*), a federally and State listed threatened species.

Instream monitoring site I8 looking from right bank during low flow across the exposed Gulf sturgeon spawning site at Indian Shoal
[Undated photo courtesy of M. Randall (USGS) on March 14, 2016]

Four different SEFA models were developed using the data collected at the four sites during three site visits under different flow conditions. The three sets of stage and flow measurements were used to establish log-log rating relationships for each transect in the SEFA program. Fortytwo habitat suitability curves of various species and life stages were incorporated into the four SEFA models, and a 62-year period of daily AWS was calculated for each species and life stage. Largemouth bass-fry at Site I5 is the most restrictive species and life stage, with a 14% reduction in flow resulting in a 15% reduction in average AWS. Site I8 is the second most restrictive site, with a 15% flow reduction associated with a 15% reduction in average AWS.

Aucilla River

The study area encompasses a 0.2-mile reach on the Aucilla River located about 11 miles downstream of US Highway 27 near Lamont, FL. Data along seven transects within the study reach were collected during three different flow conditions, and recorded data were used in the hydraulic, instream habitat, and time series routines of the model. Flow reduction scenarios were analyzed for a 64-year period of daily discharge until a 15% reduction in baseline AWS was calculated.

The average AWS for adult channel catfish, a shallow/fast habitat guild, and total *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies), referred to as EPT, were somewhat sensitive to flow reductions, with the shallow/fast habitat guild being most sensitive. A flow reduction of 35.7% resulted in a 15% reduction in the baseline shallow/fast guild AWS metric. The average AWS for adult channel catfish and EPT-Total were even less sensitive than the shallow/fast guild, with relative flow reductions of 49.7% and 46.1%, respectively, associated with a 15% reduction in the baseline AWS change criterion. The large allowable flow reduction implies that habitat is not very sensitive to flow and was not a driver in setting MFLs.

Summary

Physical habitat modeling is an effective tool used to predict the changes in physical habitat associated with flow alterations. The model simulates the flow dependent characteristics of physical habitat considering selected biological responses of target species and life stages. In Florida, where withdrawals could create significant harm to the water resources, the predictive capabilities provided by physical habitat modeling tools (SEFA, PHABSIM) are beneficial for protection of instream habitat and other fisheries issues in stream management projects.

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About the authors: Ravi Nalamothu, P.E. is a Senior Environmental Engineer with HSW Engineering, Inc. He has over 12 years of experience, specializing in minimum flows and levels assessments for rivers, estuaries, and springs.