MESO OR MICRO: A COMPARATIVE ANALYSIS OF TWO HABITAT MODELLING APPROACHES

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The study reviews the two habitat models CASiMiR (microscale) and MesoHABSIM (mesoscale) regarding the aspects scale, data collection, model set-up, handling habitat preferences, result presentation and application. Both models were applied at a river stretch at the upper Inn River in Austria, which provided a basis for closer comparison and analysis of the strengths, weaknesses, opportunities, and threats (SWOT) of both models. These analyses allowed the identification of the main methodological aspects influencing the habitat assessment within both models.

1 INTRODUCTION

Habitat models are important tools in river management and can address instream habitat on several scales, mostly the microhabitat or the mesohabitat scale. Microhabitat models include the explicit numerical simulation of the spatial variation of the hydraulic features within the river [1]. The habitat conditions are therefore analyzed on each numerical cell, which's dimensions mostly correlate with microhabitats. Mesohabitat models, on the other hand, analyze the habitat on a coarser scale and mostly do not include the hydrodynamic simulation of hydraulic features, but focus on the observation and manual characterization of the different hydromorphologic patterns at different discharge rates [2]. In general, literature comparing different habitat models is scarce, which makes it difficult for users to select an adequate method for their specific research questions [3;5]. Lamouroux et al. (2017) point out that, with focus on e-flow assessment, a microhabitat models requires an intensive and detailed data collection while, on the other hand, mesohabitat approaches based on mesohabitat mapping are affected by subjectivity [1]. Within this study, the microhabitat model CASiMiR (Computer Aided Simulation Model for Instream flow Requirement [5]) and the mesohabitat model MesoHABSIM (Mesoscale HABitat SIMulation, [2]), were compared and applied at a river stretch of the upper Inn River, in Tyrol, western Austria to demonstrate inherent differences. The approaches and methodologies of the two models were analyzed and compared to answer the following question: What are the methodological differences between the models? How does the model methodology affect the results?

2 MATERIAL AND METHODS

2.1 Study Area

The river stretch analyzed within this study is around 1.7 km long and is located in Tyrol, western Austria. Here, the catchment area is 2277 km². The river stretch is located within the residual flow stretch of the hydropeaking diversion hydropower plant GKI currently build at the border between Switzerland and Austria [6] and was therefore subject of several research studies and environmental impact assessments [e.g. 7 and 8]. In addition, this particular river stretch was artificially restored in the last decade to provide more natural habitat conditions by widening the river bed, reconnecting sidearms and forming of gravel bars and islands. The target species in this study is the brown trout (*Salmo trutta fario*). Brown trout and its spawning behavior are well studied and therefore their habitat requirements are well known. The species prefers spawning sites with loose gravel, water depths of 10 to 75 cm and flow velocities of 15 to 75 cm/s [9].

2.2 Habitat Models

The CASiMiR model, representing the microscale approach, is based on hydrodynamic models, where the simulation results of each numerical model cell are evaluated according to the defined habitat preferences which are expressed using Fuzzy rules [5]. MesoHABSIM is a mesohabitat model which is based on the delineation of hydromorphological units (HMU) at different flow conditions [2]. The characteristics of both models are shown and compared in Table 1 (light blue lines) for the aspect of scale, data collection, model set-up, habitat preferences, result presentation and application. The CASiMiR model for the presented study is based on a 2D-hydrodynamic model that was setup using a combination of cross section data for underwater areas and photogrammetric evaluation of drone images (structure-from-motion). Dominant bottom substratum as one of the key habitat parameters was mapped on the basis of field observation and aerial pictures. Hydrodynamic calculations were performed for 7 different flow rates in the range between 5 and 100 m³/s. Instead of the conventional data collection of MesoHABSIM, the data available from the microscale model (hydrodynamic model, orthophotos and substrate mapping) were used to set up the MesoHABSIM model at the upper Inn River (“MesoHABSIM Desktop”). For each flow condition, all data were visualized within a GIS environment, which allowed the manual detection of hydraulic and morphological patterns and therefore the identification and delineation of the different hydromorphological units (HMUs) and their cover parameters. For each HMU, 10 random samples (evaluation points) of depth, velocity and substrate were selected from CASiMiR model simulations. The HMUs were mapped this way for three flow conditions (15.8 m³/s, 32.9 m³/s and 90 m³/s).

2.3 Comparison and SWOT Analysis

The objective of this comparison was not to identify which habitat modelling approach achieved better results but to identify the aspects influencing model results in order to guide potential users and to make sure the results are interpreted correctly. The results of the two models were compared using the HMU suitability classification of MesoHABSIM and the distribution of SI values within these HMUs. The model results of both models were analyzed closely with the goal to identify the aspects influencing the suitability assessment of these particular HMUs. In order to help potential user to understand the aspects influencing model results, we summarized these aspects using the so-called SWOT method (strength, weakness, opportunity, threats) for each model separately (Table 1).

3 RESULTS AND DISCUSSION

Figure 1 shows exemplarily the location and boundaries of two HMUs (ID 23224 and 23227) together with the associated suitability index (SI) and the simulated flow velocities and water depths. HMU 23224 was classified similarly in both models as both models predicted a high habitat quality. As the SI-values are mostly higher than 0.6, the CASiMiR model shows high suitability for the entire region. Within MesoHABSIM, the HMU was identified as a “glide”, including enough cover-structures and was therefore classified as an “optimal” habitat. It can be seen that MesoHABSIM, with its coarser view (~mesoscale), recognizes this region as connected area with similar properties and therefore similar habitat quality and delineates this region from the rest of the riverbed.

MesoHABSIM does not assess each numerical element within the HMU (in contrast to CASiMiR) but uses the selected evaluation points (blue dots in Fig.1), which turns out to be sufficient for this HMU, as the hydraulic values are quite constant. This coarser view needs less resources in the data collection and has less requirements to the hydraulic data in terms of accuracy and resolution, which makes the model faster and easier to be set-up. CASiMiR predicts for HMU 23227 a high number of cells with low SI values (<0.4) due to the water depth and velocity simulated. Within MesoHABSIM, however, this mesohabitat was again classified as „optimal". As the values of the selected 10 evaluation points are integrated into the mesoscale in MesoHABSIM by calculation distributions of predetermined classes, suitability is determined by defining required portions of the evaluation points (so-called cut-off values) which need to fall within suitable classes. The cut-off values were set to 30%, and for the HMU 23227 more than 30% of the chosen 10 evaluation points of the parameter depth within the HMU fell into the suitable range (Fig.1). The entire habitat parameter "depth" was therefore classified as suitable as well as the other 3 parameters substrate, cover and HMU type (velocities values were too high). The entire HMU was set to be "optimal" because of the requirement that 4 of 5 parameters need be fulfilled for this status. The use of such cut-off values is a precondition of the meso-approach as evaluation points needs to be summarized and interpreted at the mesoscale, possibly influencing the habitat quality. Additional aspects of both models, classified as strengths, weaknesses, opportunities and threats are given in Table 1.

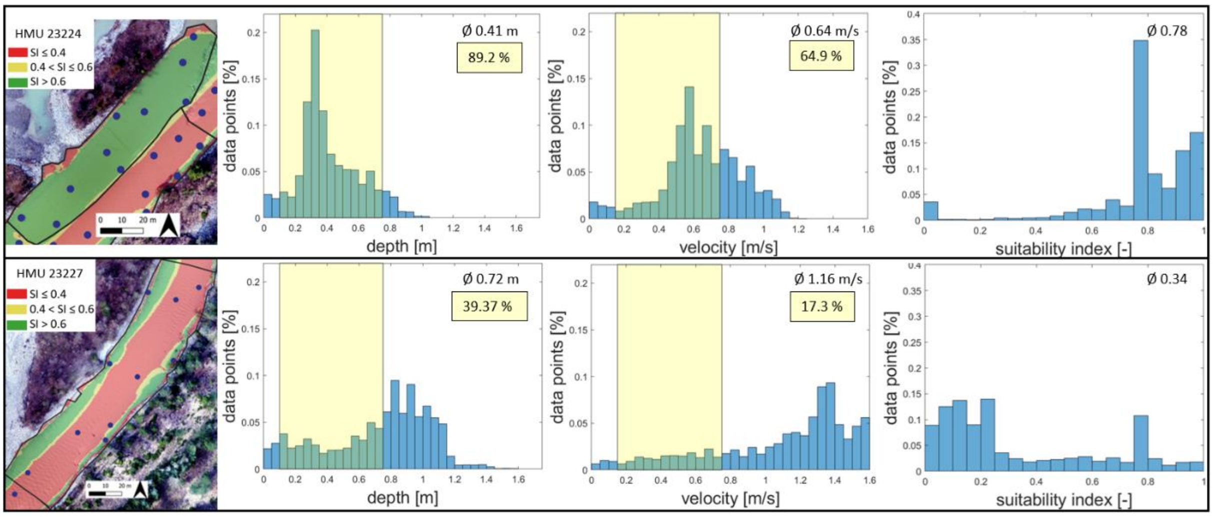

Figure 1. Location and boundaries of identified HMU 23224 and 23227 with colored SI-values obtained from CASiMiR (dark dots within the HMUs are evaluation points of the MesoHABSIM model) together with depth, velocity and SI values (distribution and mean values Ø) and portion of measurement points, which fall into the suitable ranges for depth and velocity for spawning brown trout (marked bright yellow)

Table 1. Composition of the main aspects of MesoHABSIM and CASiMiR and the identified SWOT for each method (S: strength, W: weakness, O: opportunity, T: threat)

MesoHABSIM					CASiMiR			
Mesoscale, hydromorphologic units (HMU)				Scale	Microscale, numerical elements of the hydraulic model			
S: hydromorphic units correlate with mesohabitats, hydromorphologic patterns can be recognized	W: no detailed, spatially specific hydraulic information	O: can account for organisms' mobility	T: not designed for spatially specific, detailed planning of engineering measures		S: high resolution of habitat parameters possible	W: scale linked to numerical model but not to biology	O: size of elements can be selected by the user	T: selecting element size without considering biologic meaning: important hydraulic patches might be lost
Portable GIS devices: Delineation and classification of HMUs, documenting cover types; Point measurements / evaluation: depth, velocity, substrate				Data collection	Topographic, tachymetric survey of river bathymetry; Substrate mapping Waterlevel and velocity data to calibrate the hydraulic model			
S: good knowledge of the site at several flow conditions, cheap and easy data collection also in complex streams, software available	W: field time consuming, discharge dependent, low resolution of hydraulic data	O: additional (numerical) description of HMU types reduce subjectivity	T: subjectivity (HMU type, size and location of HMU, location of point measurement)		S: detailed information on study area, systematic data collection method	W: time-consuming	O: data useful for other river engineering questions	T: bathymetry based on cross-sections: too coarse to detect hydro-morphologic patterns, inaccuracies of hydrodynamic models possible
Evaluation of mapped GIS data with software SimStream				Model setup	Set-up of numerical mesh for the hydraulic model; Calibration / validation of the hydraulic model; Simulating different discharge conditions; Assessing the simulated hydraulic conditions with the defined habitat preferences			
S: easy and fast evaluation of mapped data, manuals, tutorials and support available, interactive data quality control by the software	W: currently commercial software	O: architecture flexibility allows easy modifications of criteria, easy data import with thorough data quality control	T: affected by Windows operational systems updates		S: set-up of hydraulic model standardized	W: time-consuming, high computational effort	O: hydraulic model useful for many questions, simulation of different flow conditions possible	T: hydraulic model can be used to simulate flow conditions outside the ranges of the suitability criteria
Parameter: HMU type, substrate, velocity, depth, cover types; Definition of suitable ranges for these 5 parameters; Comparing each 5 HMU characteristics to defined habitat preferences				Handling habitat preferences	Parameters: velocity, depth, substrate; Habitat preferences expressed as Fuzzy rule sets			

S: inclusion of hydromorphic pattern and cover structures, easily understandable conditional rules combining categorical and continuous variables as distributions for HMU	W: for point locations depth, velocity and substrate assessment spatially independent, high amount of expert knowledge or fish sampling data necessary	O: important parameters can be set "critical", to make sure these parameters are fulfilled	T: risk of over- and underestimation of habitat quality due to cut-off values, depth and velocity classes and "optimal" definition for 4 of 5 variables		S: fuzzy logic advantageous for imprecise data and gradual transitions, multivariate	W: high amount of expert knowledge necessary	O: various numbers of habitat parameters possible	T: difficult to trace/understand suitability assessment for user afterwards
HMU classification in "suitable", "not suitable" and "optimal"; Habitat rating curves				**Result representation**	SI-value for each cell; WUA and HSI value for the entire river stretch and in relation to flow			
S: clear description of habitat quality; higher weight for "optimal" habitat, then "suitable" habitat Effective habitat weights optimal habitats higher than suitable	W: less traditional results presentation, potential for arbitrary of weighting "optimal and "suitable" habitats	O: easy to interpret habitat quality for user, accounts for appropriate amount of higher quality habitat	T: difficult to compare with SI and WUA-based habitat models due to a less standardized form used		S: standardized form (SI, WUA, HIS), most widely used	W: numerical view, no biological meaning	O: possibility to perform calculations and comparisons	T: subjective interpretation of SI-values possible, difficult to distinguish between lots of poor habitat and little of very good one
River restoration, e-flow assessment (local a. regional), defining reference habitat templates, …				**Application**	River restoration, e-flow assessment, hydropeaking assessment, optimizing fish passes, …			
S: easy applicable for all river types and long river stretches, coupling with UCUT analysis for habitat times series analysis for dynamic flow augmentation, designed for community models	W: detailed data only for mapped flow conditions, interpolation and extrapolation increases uncertainties	O: can be facilitated using remote sensing technologies and aerial photographs, adequate for large river environments	T: simulated scenarios not validated with biological response yet		S: easily applied in rivers where hydraulic models can be set-up or already exist, various flow conditions can be simulated easiliy	W: limited for turbulent and highly diverse hydraulic conditions, size of model limited due to computational effort	O: Coupling with hydromorphological simulations possible, remote sensing technologies (e.g. LiDAR) facilitate and improve model set-up also for longer sites	T: often limited to short sites less representative for river management

4 CONCLUSION

The presented study demonstrates application of the two habitat modeling approaches of CASiMiR and MesoHABSIM, differing in the scale, at which they assess the instream habitat. Faster data collection and model set-up for mesoscale approaches, and higher resolution of the hydraulic parameters and the possibility to simulate different flow conditions for microscale approaches are often mentioned as main differences in the comparison of the two methods [e.g. 1]. However, additional aspects such as summarized within this study using the SWOT methodology can provide a guidance for users to select the adequate model for their specific application. For the spatially specific comparison and interpretation of both models, it is a difficulty, that they have different ways of illustrating their respective results. For a further comparative analysis of both approaches, it is recommended to focus on case studies with an extensive database including fish ecological information and mesohabitat information gained in the field.

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