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Assessment of the River Habitat Quality Using Bioindication in the Piedmont Stream Handlovka in Slovakia

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Abstract. The paper focuses on an assessment of a river habitat quality in piedmont streams using a bioindication by the brown trout. The study was performed at four sites, piedmont streams in Slovakia, but modelling procedure herein is particularly described only for the Handlovka River, in the Nitra basin. For the field and modelling work, a natural reference reach and a regulated reach have been chosen within each stream. Hydrometric, geodetic and morphological measurements were conducted. The paper focuses on modelling in the Hydrocheck software and Computer Software System for Environmental Flow Analysis (SEFA) based on the Instream Flow Incremental Methodology (IFIM) and result output is the Area Weighted Suitability (AWS). The abiotic parameters for modelling were chosen as depth and velocity rates. The biotic parameter was chosen as an ichthyologic abundance of the brown trout. The results show significant difference between natural and modified channel, presenting natural reach as more suitable for fish abundance with higher AWS score. The regulated reaches are significantly affected by the river regulation, construction of concrete panels and sever contamination from anthropogenic runoff. On the contrary, the natural channels offer enough morphological structure and various shelter possibilities for enhancement of fish population.

1. Introduction
For hundreds of years across the history of human development, rivers have been subject to human activities that have changed the flow regime, such as agricultural irrigation needs, hydroelectric powerplants construction, waterways, drinking purposes, but also climate change, invasive species and many other derogations [1, 2, 3]. As a consequence, the state of global aquatic biodiversity is much worse than in other ecosystems [4]. In most cases, regulated flows only fulfil the flood protection function but do not bring any value to the urbanized environment [5]. The rich geomorphological diversity of the riverbed, so necessary for river fauna and flora, and thus for the self-cleaning ability of the streams, has often been replaced by concrete panels that persist in many water courses up to this day. Thereby the fish shelters are in recession and the water temperature significantly rises. Initial attempts in the water management over the past centuries, which were influenced by anthropocentric perception of the world, are mainly responsible for gross and insensitive modifications of the channels [6]. Only recently, water experts have become aware of the complex mechanisms operating in such a dynamic environment, which is proven by several concepts and by an integrated approach to water resource management [7]. Aquatic ecosystems are known to be structured by the interaction of physical, chemical and biological processes at multiple overlapping rates where variations occur within the seconds or annually [8]. A complex view is therefore needed to describe such a complicated environment. Aquatic organisms of all kinds that inhabit and form river communities have evolved during the evolution of adaptation to remain in such a dynamic environment. But adaptations to such rapid and drastic changes in their habitat over the past centuries as pollution and structural modification caused by anthropological
activity and climate change have not yet been developed. Such impact can alter the occurrence and behaviour of individual species, contribute to their decline or even local extinction [9]. In order to protect and prevent the mass extinction of species, it is first necessary to identify the species that will be affected by structural and climate changes in river ecosystems the most and which species will remain resistant [10], as well as it is important to set morphological, hydrological, hydrobiological limits to propose appropriate flow adjustments according to appropriate landscape planning principles. This study focuses on the impact of changes in riverbed morphology on the preferences and prevalence of fish specific to the Slovak regions. Fish as a bioindicator have been selected, because they are suitable for assessing the ecological integrity of rivers, for their sensitivity to changes in river habitat, occurrence, longevity and mobility [11]. Changing the morphology of the riverbed and, therefore, faster water heating is a significant threat to fish as they are ectotherm animals, which means that their physiological heat sources are of little or negligible importance in controlling their body temperature and such organisms rely more on ambient temperature [12]. For this reason, the fish are physiologically strongly linked to local climatic conditions, which can eliminate their resistance and tolerance to climatic and anthropological changes [10]. An interdisciplinary approach that has led to the emergence of a new scientific discipline, Ecohydraulics, is needed to assess such a complex system. This study, too, is within the intentions of ecohydraulics, which presents adequate and interdisciplinary modelling and assessment of the current state of rivers and the design of revitalization measures and techniques to mitigate the anthropogenic impact [7]. The models based on the Instream Flow Incremental Methodology (IFIM) are highly suitable for analysis of this type. IFIM methodology is one of the first methodological frameworks for environmental assessment of the impact of abiotic changes in the riverbed on the quality of aquatic habitat, it is the most widespread model in the USA and one of the most widespread in the world [15].

2. Methodology

The following detailed procedure was chosen for modelling the influence of abiotic parameters on the quality of aquatic habitat. The field work concerned the field topographic and hydrological measurements in piedmont Slovak streams, which was oriented to 1D modelling, and eventually also to identification and measurements of individual microhabitats. Next step was initial processing of the data determining the flow and river basin character in the Hydrocheck software and hydraulic modelling of the reaches using generally derived habitat suitability curves from previous research on the brown trout [16]. The 1D software model SEFA based on the IFIM methodology was used. The last step was n evaluation of the results of an aquatic habitat quality by Area Weighted Suitability (AWS). The evaluation is focused on the effect of the microhabitats changes on ichthyofauna in the period of minimum flow (summer period). The preferred abiotic parameter is the water depth. Variability of the microhabitats in the river is a decisive factor, therefore from 9 to 11 cross-sections for each reach were used for modelling in the 1D model. Handlovka, Lehotský potok, Teplica and Štiavnica streams were selected for modelling with natural and regulated reaches within. The other streams underwent the same modelling procedure, but for this study only the Handlovka River modelling was selected and described. One-dimensional models are suitable for larger scale modelling, regionalization, or generalization of data for further research [17] and are aimed at expressing the discharge and basic abiotic conditions of microhabitats. Such modelling is therefore satisfactory for this study as it aims to generalize and simplify the river assessment methodology. For fish habitat preferences, the profile velocity is not decisive, but the local microhabitat conditions in the pit, shade, jet shadow or other obstructions seems to be important features. This characteristic requires hydrometrically measured vertical velocities and water depth. The topography of the section was focused on levelling of individual cross-sections.

2.1. Study area and input data.

Mountain and piedmont Slovak streams have several common or similar characteristics and therefore the negative impact of river modifications on their quality is also similar. The Handlovka River is a piedmont stream in central Slovakia, in the district of Prievidza. It is a left tributary of the Nitra River, it has a length of 32 km and occupies a basin of 178.3 km². The Handlovka natural reach was measured on the 19 June 2018, the hydrometric and topographic survey of the Handlovka River (18.88 r.km - 18.998 r.km) was carried out above the town of Handlová, below the town of Ráztocno. Nearby there is
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a sports field, cultivated land, road and dense riparian vegetation in the closest vicinity. Handlovka regulated reach was measured on the same day, the survey of the Handlovka River (23.671 r.km - 23.788 r.km) was carried out in the town of Handlová. The reach is in the middle of the urban area, in the vicinity of the railway and mining company Hornonitrianske bane. The reach has a character of a typical regulated stream, a trapezoid-shaped channel profile shape and a straight flow course with only a slight curvature; the banks were represented by mowed grass vegetation and at some places reinforced by a stone wall. The stream is clogged by the natural action of the helical movement of the water at the curvature points on the convex bank, resulting in benches overgrown with low vegetation. The section also comprises several transverse riverbed drops.

2.1.1 Terrain survey
Hydrometric and topographic measurement have been conducted. Hydrometric discharge measurement is one of the basic field works in the water management practice, on the basis of its results measurement curves have been constructed, that define the relationship between discharge rate and water level in individual profiles. Hydrometric propellers for point velocity measurements were used and the velocity profile was determined. The standard of Ministry of Environment SR OTN ŽP 3108 recommends measurements of 2 to 3 points at depths greater than three propeller diameters and less than 3 meters [18]. The measurements were taken at 3 points, 3 different propellers, at the lowest point type 1V120, at the middle point type V (101-1) and at the top point type V192, using calibration constants (α, β) and time T = 30s. Natural reach total discharge was $Q_{HAN,NAT} = 0.199 \text{ m}^3\text{s}^{-1}$ and for the regulated reach, the total discharge was $Q_{HAN,MOD} = 0.207 \text{ m}^3\text{s}^{-1}$.

Topographic measurements were conducted on geodetic surveying of the cross-sections in order to create a comprehensive longitudinal profile by total station Leica FlexLine TS02 and GPS GNSS Leica Viva (antenna GS15 and controller CS15) in the coordinate system of the Slovak Unified Trigonometric Cadastral Network (SJTSK). The natural reference reach was measured at a length of 118m in 11 cross-section profiles and 7 transverse bottom altitudes were measured with regular space. The regulated reach was measured at a length of 117m in 9 cross-sections, with 8-12 bottom altitude points within the cross-sections. The measured points also include the altitude of the deepest bottom and the water level. The overall situation of the reaches and the individual cross-sections profiles are shown in the Figures 1-2.

2.1.2 Flow modelling
In the first step, topographic data (.frt - output file from the total Leica FlexLine TS02 station) was processed using Hydrocheck software, in which longitudinal and cross-section profiles, with a steady flow situation and simulated the velocity field, were modelled.

Figure 1. Natural reference reach Handlovka.

Figure 2. Regulated reach Handlovka.

In the second step, the data (.hif output file from Hydrocheck) was converted into the input file (.xlsx - input Excel file) into the SEFA modelling software. Subsequently, the roughness, velocity calibration, graphical representation longitudinal and cross-section profiles were modelled in SEFA in detail. Model values of velocity field were also used for Handlovka reaches described herein, further for other streams (Lehotský potok, Teplica, Štiavnica) were not included, as the theory of generalization and
simplification of the methodology is tested, thus calculation with only one parameter, water depth, was used. In the third step, generalized habitat suitability curves for the brown trout for piedmont and mountain Slovak streams [16] were inserted into SEFA, according to average depth. For natural reach average depth 22.15cm, were chosen habitat suitability curves for the depth of water column 20-30cm. For the regulated reach with average depth 10.95cm, were chosen habitat suitability curves for the depth of water column 0-20cm.

3. Results
The result is a total Area Weighted Suitability (AWS) including two abiotic parameters, depth and velocity, along with the appropriate brown trout habitat suitability curves shown in the Figures 4-5 below. The display is not in real scale because of the clear graphical output and the flow curvature display is not realistic as the SEFA aligns the cross-section distances according to the first value in the profile into one vertical line, which is practically impossible hold in field measurements. However, the values, calculations, calibration and colour representation remain fully in line with reality.

Figure 3. Area Weighted Suitability (AWS) for Handlovka natural reach. Figure 4. Area Weighted Suitability (AWS) for Handlovka regulated reach.

Results show visible graphical differentiation between natural and regulated reach in favour of natural reach. The blue colour represents more suitable habitat for bioindicator, brown trout. On the contrary the yellow and orange colour insinuates the low habitat suitability. The natural reach offers significantly more suitable environment, with higher AWS score, for the brown trout than the regulated reach.

4. Summary
Interdisciplinary research considered in the principles of ecohydraulics so far the most accurately depicts real events and dependencies of abiotic and biotic factors in the flow area [19]. Based on such interdisciplinary approach, it is possible to propose responsible revitalization measures that fit into the environment and have a higher chance of success. The simple and accessible IFIM methodology in the SEFA software quantifies the biotic changes in the flow based on abiotic parameters, thus enabling a responsible assessment of the quality of the aquatic habitat according to WFD 2000/60/EC and the design of successful revitalization measures. The limits of current European scientific studies on this issue and comprehensive assessment lie in the lack of information on species, uneven data and their
quality [10] therefore this sphere represents a high potential for research. The quality of the aquatic habitat can be represented by the number of microhabitats and shelters appropriate to the species, which constitute an appropriate Area Weighted Suitability (AWS). As it is shown in results, the natural reach offers higher suitability for the bioindicator, the brown trout, than the regulated reach with poor suitability area representation. Although modelling based on the characteristics of bioindicators is not a universal solution to such complex problem as the quality of the river ecosystem is, nevertheless it is a significant step forward in the interdisciplinary approach to the design of revitalization measures. Further research will be aimed at developing a methodology for assessing the quality of habitats in accordance with the WFD 2000/60/EC.

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