Application of Extended Habitat Suitability Curves for Depth in Nitrica River

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Abstract. This study assesses the impact of basic stream abiotic parameters on the quality of aquatic habitat and inserts them to the aquatic habitat quality assessment of the mountain and piedmont streams. The created methodology was applied on the Nitrica River. The study is based on the objectification and modification of parameters of habitat suitability curve for the depth. The habitat suitability curve is one of the many basic parts of the Instream Flow Incremental Methodology (IFIM). IFIM is the methodology where the quality of aquatic habitat is interpreted according to a bioindication. The bioindication is provided by ichthyofauna. For this study, the minnow (Phoxinus phoxinus) was chosen as a bioindicator. The main reason for selecting the minnow as a bioindicator was that there was a sufficient frequency during the ichthyologic survey on the studied river. The basic result from the field measurement is the habitat suitability curve for depth. This measured habitat suitability curve is not adequate to describe the aquatic habitat. The suitability curve derived from just one measurement does not take into account the fact that the increase in flow has not changed the quality of the habitat until the time when the fish starts to be flushed out of the environment. This is the reason why this scientific research was oriented on the modification of habitat suitability curve for a wider range of flow. The evaluation was done by the System of Environmental Flow Analysis (SEFA). SEFA is a new software that implements the substance of the IFIM. The modification of the habitat suitability curve is applied on the Nitrica River.

1. Introduction

Stream quality of habitat is significantly affected by the ecosystem. Developed methods of the quality habitat assessment do not have adequate utilization rate; they are applied very rarely in most of the countries, including Slovakia. Their usage should be analogous to assess other aspects of the ecological status of the stream, such as quality of water, healthy riverbank vegetation [1] minimal stream flow, or biota integrity. There is a need for a comprehensive approach because the different species are related to a different range of habitat. The basic aim of our research was to objectify the habitat preference by fish in the range of specific discharges before the fish are washed out from their position. Fish are considered as the best bioindicator. The reason is mainly because of their long life cycle. Another reason is that fish are very sensitive to changes in channel morphology, and their ability to migrate underscores their importance as a bioindicator [2, 3, 4]. Minnow (Phoxinus phoxinus) was chosen as a bioindicator. Kottelat and Freyhof [5] refer that minnow prefers a wide range of cold and well-oxygenated habitats.
from small, fast-flowing streams to large Nordic lowland rivers and from small upland lakes to large oligotrophic lakes. Usually associated with salmonid fish. Spawning takes place over clean gravel areas in flowing water or on wave-washed shores of lakes. It spends winters in the coarse substrate or deep pools with low current.

Ecological status of stream is influenced by many factors [6]. The most important is the biotope of fauna and flora of the aquatic zone that characterizes the habitat. Stream habitat structure has a substantial impact on the organization and structure of biological communities [7]. The aim of the habitat quality modeling is mainly to provide a basis for assessment or prognosis of biological changes that should represent a potential impact on ecological changes that are important in the decision-making process of stream quality management. The standards in ecological water quality modeling are models that are based on the IFIM methodology. Specifically, model SEFA was used for this work.

Basic inputs for model SEFA are data of the ichthyologic survey. It represents the abundance of fish species with the parameters of their occurrence. Abiotic habitat characteristics, together with the characteristics of the ichthyofauna, are the basis for the development of suitability curves. Suitability curves show the preference of the chosen habitat parameter for a particular species bioindicator. Suitability curves are based on the assumption that a specific type of fish prefers certain combinations of abiotic parameters. These parameters may be different, but the highest impact is the depth of water, velocity in verticals, and a stream bottom substrate. Measured suitability curves characterized by frequency polygon reflect the behaviour of the bioindicator in relation to the stream discharge. Based on the measured data [8], a mathematical expression of suitability curves is described. Many studies have confirmed that specific species of fish prefer similar habitat characteristics even in different streams. There were done many works focused on the implementation of one-habitat characteristics in a different stream [9]. A limit for usage of measured suitability curves is their applicability to a specific discharge, where the measurements were realized. The usage of a wider range of discharges is not appropriate. Several studies have reported differences in the usage of suitability curves at different discharge rates [10, 11]. The studies mentioned above confirm that the usage of suitability curve determined at a single discharge should not be applied to other discharges.

Transformation of the suitability curves is documented on an example of the Nitrica River.  

2. Materials and Methods

Materials
- Network of characteristic points to create morphology of the stream channel in 1D hydraulic model. The field measure was done on 14th of October 2010.
- Characteristic of ichthyofauna according to measurement on 20th July 2010.

Methods
- Calculation of hydraulic parameters by 1D hydraulic model.
- Measured and extended Habitat Suitability Curves (HSC).
- Assigning the values of depth suitability.
- Calculation an Area Weighted Suitability.

2.1 The reference reach of the Nitrica River
The total length of the Nitrica River is 54.1 km. The basin of the Nitrica River is situated on 319 km². The spring area is located between the hills Homôľka (906.6m a.s.l.) and Vápeč (955.5m a.s.l.) at the altitude 760m a.s.l. The Nitrica River is characterized as a piedmont stream.

The reference reach of the Nitrica River (Figure 1) is located outside of the village Ježkova Ves. The reference reach is 465m long. The river bed is created by the sections with greater depths. These sections
are sharply cut into the stream alluvium. This segment is characterised by a sudden change of the directional flow routing and longitudinal slope of stream level, whose average value is 0.17%. The river bank is covered with deciduous trees and bushlands that shade a significant portion of the channel.

3. Results and discussions

3.1 Calculation of hydraulic parameters by 1D hydraulic model

The calculation of hydraulic parameters was realized in the 1D model. The model was calibrated for discharge \( Q_{\text{mt}} = 1,350 \text{ m}^3\text{s}^{-1} \approx Q_{180-90d} \) (\( Q_{\text{mt}} \) = discharge measured topology). Topographic and hydrometric measurements were realized in that discharge. The first modelled discharge was \( Q_{364d} = 0.213 \text{ m}^3\text{s}^{-1} \) and the second modelled m-day discharge was \( Q_{30d} = 6,233 \text{ m}^3\text{s}^{-1} \). For every mentioned discharge, the value of the average maximal depth (\( d_{\text{max}} \)) was derived. The average maximal depth was determined as an average of the maximal depths in every measured cross-section profiles. For every single discharge, the average maximal depths are:

- For discharge \( Q_{364d} \) is \( d_{\text{max}} = 0.30\text{m} \)
- For discharge \( Q_{\text{mt}} \) is \( d_{\text{max}} = 0.54\text{m} \)
- For discharge \( Q_{30d} \) is \( d_{\text{max}} = 1.30\text{m} \)

3.2 Measured and extended Habitat suitability curves (HSC)

The measured suitability curve is a direct output of the ichthyologic survey. Usually, there is created a suitability curve for each measured parameter, fish species, and stream. A minnow (Phoxinus phoxinus) was chosen as a bioindicator. The main reason for the selection of the minnow as a bioindicator was that there was a sufficient frequency during the ichthyologic survey on the 20. July 2010. The ichthyologic measurement was realized in discharge \( Q_{\text{mt}} = 1,350 \text{ m}^3\text{s}^{-1} \approx Q_{180-90d} \). Subsequently, the suitability curve for water depth parameter that is shown in Figure 2 was created. The mentioned suitability curve increase from 0.10 m to 0.24 m and decrease from 0.24 m to 0.50 m. The top of the curve is at the depth value 0.24 m, where the suitability value reaches 1. For the needs of aquatic habitat assessment in a wide range of modelled discharges, it was necessary to adjust the measured curve suitability. The basis of the modification was to extend the top of the measured suitability curve to the left and also to the right. The
value of the peak extension was derived from the differences in the average maximum depth $d_{\text{max}}$ in a modelling discharge.

The peak extension to the left is based on the assumption that $Q_{364d}$ is a minimal natural discharge. The value of average maximal depth in discharge $Q_{\text{mt}}$ was 0.53 m and in modelled discharged $Q_{364d}$ was 0.30 m. The difference between those two values was 0.23 m. However, the value for a peak extension of the curve from the value 0.24 m to the value 0.01 m does not make a sense. In this case, the peak extension to the left was not done.

The peak extension to the right was based on the assumption that $Q_{30d}$ is a maximal natural discharge. The value of average maximal depth in discharge $Q_{\text{mt}}$ was 0.53 m and in modelled discharged $Q_{30d}$ was 1.30 m. The difference between those two values was 0.77 m. Subsequently, the value was used for a peak extension of the curve from the value 0.24 m to the value 1.00 m.

![Habitat suitability curves of depth](image)

**Figure 2.** Habitat suitability curves of depth

Increasing part of the extended curve starts from a water depth of 0.1 m with the value from 0 to 0.24 m with the suitability index 1. Maximal value of suitability (1) is added to a depth range from 0.24 m to 1m. The decreasing part of the extended curve starts at the depth from 1 m to 1.26 m.

3.3 Evaluation of quality of aquatic habitat
A riverbed morphology was imported to the program SEFA where water depth was modelled. The depth values in the Hybica River in a modelled discharge $Q_{\text{mt}}$ reached the maximal value 0.88 m. In Figure 3 longitudinal profile in modelled discharge $Q_{\text{mt}}$ is shown. This figure is a graphical output from the SEFA program.

Both suitability curves were imported to the SEFA program too. The SEFA program was then used to assign the depth suitability values based on the measured and extended suitability curve.
3.4 Calculation of Area weighted suitability (AWS)
AWS value (area weighted suitability) was calculated based on the assigned values. The AWS value was calculated for every cell of the calculation network separately. The value of AWS represents a suitable area in m² per m of the longitudinal length of the stream that is usable for a minnow as a bioindicator (Phoxinus phoxinus). The final AWS values were calculated for flows in a range of 0 – 6.5 m³.s⁻¹.

The results based on the measured suitability curve are indicating the increase of value AWS from 0 m³.s⁻¹ to 1 m³.s⁻¹. After that, the values of AWS have a decreasing character from 1 m³.s⁻¹ to 2 m³.s⁻¹. The other higher flows have a stable value of AWS around 3.6 m²/m.

The results based on the extended suitability curve are indicating the similar increase of value AWS from flow 0 m³.s⁻¹ to 0.5 m³.s⁻¹. After that, the values of AWS have a similar increasing character as values of the full bank from 0.5 m³.s⁻¹ to 6.5 m³.s⁻¹.

The results of the calculation are graphically shown in Figure 4 and numerically shown in Table 1.
4. Conclusions

The aim of this paper was to assess the impact of basic abiotic parameters on the quality of aquatic habitat and to insert them to the aquatic habitat quality assessment of the mountain and piedmont streams. The created methodology was applied on the Nitrica River. From Figure 3, it can be said that there is a considerable difference between the qualities of aquatic habitat. The difference is caused when we assess habitat from one measured curve, or we assess the aquatic habitat quality by the modified curve that represents wider intervals of discharges.

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