Assessment of the quality of the Drietomica rivulet habitat by means of the IFIM method

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Abstract

During the years 1995-2005, the research on the impact of river regulation on the aquatic zone of the Drietomica rivulet was implemented. In this article the results of modeling of the microhabitat by means of the IFIM methodology are presented. For the 1-dimensional modeling, the RHABSIM (River Habitat Simulation System) and for the 2-dimensional modeling, River2D software, which are both intended for analysis of the interaction between the water flow, morphology of the riverbed and the biological components of the environment, were used. After the hydraulic calibration, the available fish habitat in the shape of a weighed usable area was simulated using both models.

The current stage of the research represents testing the differences between the various types of models and a comparison of the impact of the non-biotic parameters on the development of criteria curves, which define fish hiding-places as a microhabitat of the stream.

Keywords: IFIM, habitat, abundance, ichthyomass, weighed usable area

Introduction

The ecological state of a stream is affected by many factors, the most important of which are the habitat of fauna and flora in the aquatic part of the stream. The configuration of a habitat significantly affects the organization and structure of a biological community. Understanding the impact of human activity on a habitat's structure remains one of the most neglected research fields in water management. The loss of dead arms and reduction of the inundation area and natural riverbed segmentation is one of the primary reasons for negative changes in the aquatic part of a stream.

The entry of Slovakia into the European Union (EU) has determined the orientation concerning standard techniques used within the bounds of the EU. It is necessary to achieve compatible results which are usable during the process of the transposition, implementation and legal application of European frameworks in water management. Within the bounds of monitoring and assessing the ecological quality of water, the European framework directive 2000/60/ES requires the determination of the characteristic parameters of unaffected water bodies which correspond to a very good ecological quality. These conditions are declared as reference conditions of a given type of water body. If the stream lacks unaffected sections, modeling of the biological conditions in the stream is required. “Type-specific biological reference conditions based on modelling may be derived using either predictive models or hindcasting methods. The methods shall use historical, palaeological and other available data and shall provide a sufficient level of confidence about the values for the reference conditions to ensure that the conditions so derived are consistent and valid for each surface water body type.” [5]

Methods

The hydroecological quality of three reference sections of the Drietomica rivulet was evaluated using the RHABSIM 1-dimensional model. One of those sections was also evaluated using the River2D 2-dimensional model.

The characterization of the reference sections

The first reference section with a length of 100 m lies in the village of Drietoma. The riverbed has been modified into a simple trapezoid-shaped profile with slopes of 1:1.5. The slopes are stabilized by concrete feet and prefabricated components. The bottom of the riverbed is flat with an average width of 12 m. Riverbank vegetation is occasionally present. According to a granulometric analysis, the mean grain gauge is d_{50} =17.5 mm.

The second section with a length of 119 m lies above the village of Drietoma and is 1800 m away from the first section. The character of the riverbed is natural with a segmented bottom. The riverbanks are stabilized by a root system of willow and alder vegetation, the crowns of which shade most of the stream. The average riverbed width is 7 m with 1.2 m deep local potholes. The mean grain gauge is d_{50} =26 mm.

The third section, which was modeled using both 1D and 2D models, is 240 m long. It has a natural character and is connected to the second section upstream. That section was chosen because it incorporates various types of habitat including fish covers.

The water of Drietomica falls into the I. class of cleanness according to the oxygen regime factor, according to other factors, it falls into the II. class.

Assessment of the habitat quality of the aquatic part of the Drietomica stream

The models that we used in this study work according to the principle of the IFIM method (Instream Flow Incremental Methodology) [1, 2, 3, and 4]. It is an interdisciplinary decision-making system, which has arisen as a result of the knowledge that most fish species prefer certain combinations of water depths, flow velocities, hiding places and materials of a riverbed. If these values are known in a given stream reference section, it is possible to forecast the impact of changes to the biological environment of a stream.

The following procedure was used for modeling the quality of the Drietomica habitat:

Delineation of certain stream reference sections.

Measurements of the topographical parameters of the reference sections.

Hydrometric measurements during 3 various water levels of each reference section.

Conducting an ichthyological and hydraulic survey aimed at assessing the quality of the habitat for various fish species (determination of the criteria curves).

Processing data that characterizes individual types of habitat and criteria curves, and the quantification of the hydraulic and morphological characteristics of the stream using the fish as a bioindicator.

The ichthyologic measurements were implemented in cooperation with the Zoological Institute of the Slovak Academy of Science in Bratislava and the Department of Poultry Farming and Small Farm Animals of the Slovak Agricultural University in Nitra.

Ichthyologic characteristics of the reference sections

There is a significantly higher abundance of fish in the lower stream section than in the upper stream section. The seasonal changes in the abundance are related to fluctuations in biodiversity as a result of migration during the time of reproduction and increases in the frequency of growth. Regarding the ichthyomass, the changes in the first and second sections are tiny and statistically inconclusive. Under normal conditions the ichthyomass of the lower section should also be significantly higher. The cause of a contrary state is the river regulation of a certain section and, as a consequence, the lack of suitable life conditions for some fish species.

The diversity of species of the ichthyofauna in the Drietomica rivulet is listed in Table 1, the basic data for abundance and ichthyomass are given in Table 2.

Results

Quantification of the quality of a habitat in the IFIM methodology is represented by the weighed usable area (WUA), which is a direct function of discharges and represents the suitability of the entire modeled section divided into microhabitat levels. These outcomes are the proper basis for future decision-making and water-management planning.

Tab. 1: The diversity of species of the ichthyofauna in the reference sections of the Drietomica rivulet during the years 1995-2004.

Family – *Species*	Natural stream	River regulation
CYPRINIDAE		
Common minnow – *Phoxinus phoxinus*		
Gudgeon – *Gobio gobio*		
Dace – *Leuciscus leuciscus*		
Chub – *Leuciscus cephalus*		
BALITORIDAE		
Stone loach – *Barbatula barbatula*		
SALMONIDAE		
Rainbow trout – *Oncorhynchus mykiss*		
Brown trout - *Salmo labrax* m. *fario*		
Brook trout - *Salvelinus fontinalis*		
THYMALLIDAE		
Grayling - *Thymallus thymallus*		
COTTIDAE		
Bullhead - *Cottus gobio*	+	
Alpine bullhead - *Cottus poecilopus*	+	
Hybrid (*Cottus gobio* x *Cottus poecilopus)*	+	-
Number of species (not considering the hybrid)	8	9

Tab. 2. Basic data of the abundance (pcs.ha-1) and ichthyomass (kg.ha-1) in the reference sections of Drietomica during the years 1995 – 2004. The Italicized data are from fishing out in the summer.

	Abundance (pcs.ha^{-1})				Ichthyomass (kg.ha^{-1})			
Year	Natural stream – reference section 2		Regulated stream – reference section 1		Natural stream – reference section 2		Regulated stream – reference section 1	
	spring (1a)	autumn (1b)	spring (2a)	autumn (2b)	spring (1a)	autumn (1b)	spring (2a)	autumn (2b)
1995	-	2606	-	17425	-	64,1	-	152,3
1996	993	1374	1975	4258	16,1	35,8	31,9	51,3
1997	-	4822	-	6625	-	111,5	-	88,2
1998	1333	*3097*	5433	*6398*	32,3	*42,4*	79,1	*71,6*
1999	-	-	-	-	-	-	-	-
2000	5987	6391	3292	8300	191,9	123,2	39,9	46,0
2001	-	*10582*	-	*7144*	-	*100,0*	-	*41,7*
2002	7148	*9837*	8098	*26749*	108,6	*92,6*	81,7	*287,7*
2003	6361	-	22253	-	203,5	-	278,6	-
2004	-	*2507*	-	*34017*	-	*54,5*	-	*271,6*

After the hydraulic calibration of both models, we simulated a suitable habitat in the form of a WUA during various discharges (Fig. 2). There is an obvious difference between the results obtained by the 1-D and 2-D models (Tab. 3 and Fig. 1) which is due to the greater accuracy and larger detail of the 2-dimensional hydraulic module of River2D following from the 2D modeling principle. Unlike 1-D modeling it also considers the spatial direction of a stream (a certain model can simulate flow intensity in various directions) and the input topography of the riverbed is more detailed in the 2-D model. The effect of the implementation of the cover criteria curves into the model is also obvious from the table given of the comparison of the WUA share on the total water surface area. However, the decrease of this share as a result of the implementation of the cover criteria curves is a logical consequence of the embedment of the other parameter (cover) into the model, which follows from the WUA calculation method (a multiple reduction of the WUA by the mutual multiplication of the suitability rate of the individual parameters).

Tab. 3 (see also Fig. 1): Comparison of the weighed usable area (WUA) share on the total water surface area in the natural part of Drietomica during various discharges simulated by the 1-D and 2-D models, considering and not considering the fish cover places in determination of criteria curves (WCFC - without considering fish covers, CFC - considering fish covers).

		model	**River2D**			**RHABSIM – 1D**		
Q [m^3/s]	**Bioindicator *(Latin name)***	**method**	**WUA [m^2]**	**Total surface area [m^2]**	**%**	**WUA [m^2]**	**Total surface area [m^2]**	**%**
0.3	Alpine bullhead	WCFC	289	1235	23.40	263	1118	23.52
	(Cottus gobio)	CFC	181	1235	14.66			
	Brown trout	WCFC	194	1235	15.71	166	1118	14.85
	(Salmo trutta m. fario)	CFC	124	1235	10.04			
0.55	Alpine bullhead	WCFC	348	1385	25.13	449	1271	35.32
	(Cottus gobio)	CFC	218	1385	15.74			
	Brown trout	WCFC	287	1385	20.72	334	1271	26.27
	(Salmo trutta m. fario)	CFC	184	1385	13.29			
0.95	Alpine bullhead	WCFC	390	1520	25.66	665	1380	48.19
	(Cottus gobio)	CFC	233	1520	15.33			
	Brown trout	WCFC	379	1520	24.93	587	1380	42.54
	(Salmo trutta m. fario)	CFC	236	1520	15.53			
1.4	Alpine bullhead	WCFC	318	1605	19.81	717	1446	49.59
	(Cottus gobio)	CFC	186	1605	11.59			
	Brown trout	WCFC	364	1605	22.68	762	1446	52.70
	(Salmo trutta m. fario)	CFC	225	1605	14.02			

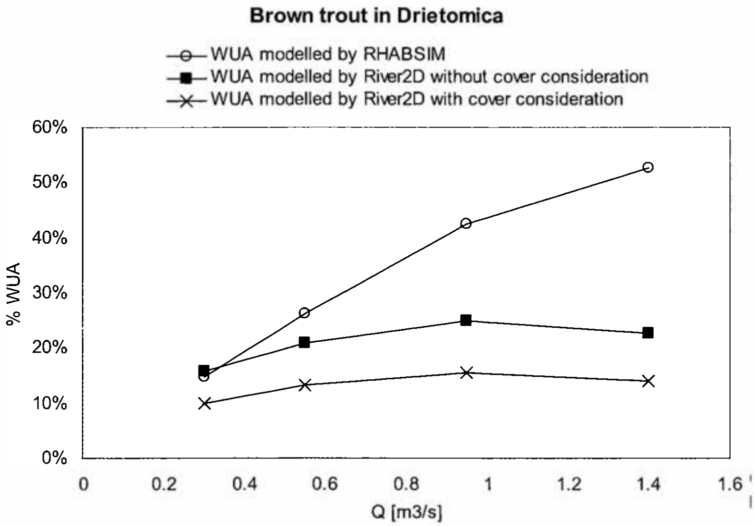

Fig. 1 (see also Tab. 3): Comparison of the weighed usable area (WUA) share on the total water surface area in the natural part of Drietomica during various discharges simulated by the 1-D and 2-D models, considering and not considering the fish cover places in determination of criteria curves (WCFC - without considering fish covers, CFC - considering fish covers).

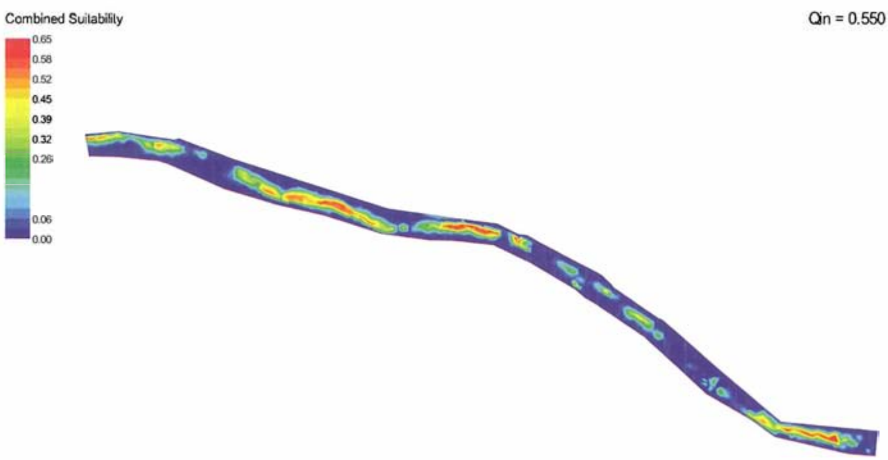

Fig. 2: Progress of combined suitability for Brown trout considering fish-covers in the natural section of Drietomica during the 0.55 m3/s discharge.

Discussion

From the existing results of our stream habitat modeling research [1, 2, 3, 4], it follows that the relationship between a fish population and the characteristics of its habitat as modeled by the IFIM methodology gives a true picture of the changes evoked by discharges and riverbed topography interference (for example, river regulation). A lot of various habitat models exist that are related to the stream biota, but their outcomes are incompatible. A greater uniformity aimed at a better compatibility of individual results would be more useful.

In the next developments in modeling stream biological conditions in Slovakia, attention should be directed to models using the IFIM methodology, and considering the greater accuracy of the 2-D models, their use is especially recommended. Initiate method also fulfils all conditions for standardizing the determination of the unaffected natural state of a stream by modeling, which is directly required by European Water Framework Directive 2000/60/ES.

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