# 1D hydrological model as a predictive tool for the assessment of aquatic habitat changes in floodplain rivers

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## 1 Introduction

Activities that directly affected the natural system of the large floodplain rivers were usually associated with river regulations. The related problems are increasingly recognised in society and interest has grown in restoring of regulated rivers. This recognition is emphasized in the EU Water Framework Directive (EC 2000) in which the improvement of the "ecological status" of river systems is one of the central considerations.

The Szigetköz section of the Danube (rkm 1850-1794) is one of Europe's last extensive inundated floodplains. River regulations have altered its natural geomorphologic processes and landscape dynamics since the end of the 19$^{th}$ century. The rehabilitation of river section is in the interest of several stakeholders, but the harmonisation of the stakes of hydropower utilization and nature conservation was difficult in the last decades. One of the main environmental objectives of rehabilitation is the re-modification of habitat structure for the revitalization of ecological functions of the river-floodplain ecosystem.

Predictions of changes of aquatic habitat structure in floodplains are essential for planners and decision-makers of river restoration programmes. In the frame of a preliminary ecological benchmark system developed for the evaluation of habitat changes in the Szigetköz (Guti et al. 2010), an assessment method was worked out to prognosticate the aquatic habitat structure according to the scenarios of rehabilitation measures. The present paper describes a method of habitat identification using results of a one dimensional (1D) hydrological model.

## 2 The study area

The Szigetköz floodplain is the right side of the extensive alluvial cone in the upper part of the Hungarian-Slovak section of the Danube, within the Kisalföld region (Little Danube Plain). Under undisturbed conditions the Danube changed its course on a broad scale forming a delta-like ana-branching channel pattern characterized by multiple channels, bars and unstable islands.

At the end of the 19$^{th}$ century, the modern time river regulations formed a unified and straitened main riverbed to ensure the navigation route. The wandering of the riverbed was stopped and the floodplain inundations were restricted with the construction of flood protection dikes. Further significant changes in the river section occurred by the construction of the Gabčikovo hydropower dam. Its operation started in 1992, and nearly 85 % of the river discharge was diverted to the hydropower bypass canal and the water level dropped 2-3 m in the floodplain branch-system. For mitigating the draining, a water replenishment system with the capacity of 40-180 $m^3\ s^{-1}$ was created to provide a seasonally variable discharge supply

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for the branch-system, but the major connections between the main arm and the branches were blocked by weirs (Guti 2002).

Despite of mitigation measures environmental degradation was significant due to change in discharge regime and disconnection between the main arm and branch-system. Several scenarios were worked out for rehabilitation of the river-floodplain connectivity from the middle of the 1990s, for instance:

- *“3 weirs” variant*: water level elevation by construction of 3 weirs in the main channel, dredging of point bars, clearing defined floodplain areas, additional check dams in side branches, removal of some side-arm closures;
- *“narrowing” variant*: raising level of existing vegetated point bars by 2 m comprising 1/3 of the channel area, side-arm closures left;
- *“optimum filling” variant*: raising the bed level by 3-4 m in order to obtain average water levels of the 1950s at a discharge of 350 $m^3s^{-1}$ in the main channel plus 80 $m^3s^{-1}$ in side branches.

# 3 Methods

The ‘functional sets’ concept (Amoros et al. 1987) is one of the most extensive classification systems of the floodplain water bodies. It based on hydrological, hydro-morphological and ecological analysis and subdivides the floodplain water bodies into four main types called functional sets. In this study, the habitat typology follows the ‘functional sets’ concept and the definitions are used for the Austrian section of the Danube (Hohensinner et al. 2005) with minor modifications.

***Table 1.*** *Definitions of the aquatic habitat types in the Szigetköz floodplain*

| Habitat type | Definition |
|---|---|
| *Eupotamon-A* | Main stream |
| *Eupotamon-B* | Always connected side channels, with permanent flow |
| *Parapotamon-A* | Highly dynamic side arms, intact downstream connection, blocked upstream by bare gravel/sand deposits |
| *Parapotamon-B* | Less dynamic side arms, intact downstream connections, blocked upstream by vegetated deposits |
| *Plesiopotamon* | Isolated water bodies, close to the main channel, often connected |
| *Paleopotamon* | Isolated water bodies (oxbows in the meandering sector), seldom connected |

The recent distribution of the aquatic habitats was analyzed using areal photographs and direct field observations. The future changes in structure and areal extent were predicted using results of 1D hydrological models produced by the MIKE 11 software according to the scenarios of the floodplain rehabilitation. Discharge, flow velocity and water depth data were used for habitat typology in the floodplain branch system. The habitat type (Table 1) of channel segments or individual beds were determined using the following key:

1) When the discharge input to the floodplain branch system is 40 $m^3 s^{-1}$ (low water level),
   – The flow velocity in the bed is > 0 (flowing), the habitat type is *eupotamon-B*.
   – The flow velocity in the bed is = 0 (stagnant), …………………………………..... (skip 2)
2) The bed is stagnant, when the discharge input to the branch system is 40 $m^3 s^{-1}$.
   – The minimum depth at the upstream or downstream end of the bed is > 0.…………(skip 3)
   – The minimum depth at the upstream and downstream ends of the bed is = 0 (disconnected), ………………………………………………………………………………………. (skip 4)

3) When the discharge input to the floodplain branch system is 80 $m^3 s^{-1}$,
   - The flow velocity in the branch is > 0, the habitat type is *parapotamon-A*.
   - The flow velocity in the branch is = 0, the habitat type is *parapotamon-B*.
4) When the discharge input to the floodplain branch system is 180 $m^3 s^{-1}$ (high water level),
   - The minimum depth at the upstream or downstream ends is > 0, the habitat type is *plesiopotamon*.
   - The minimum depth at the upstream and downstream ends is = 0 (disconnected), the habitat type is *paleopotamon*.

The 1D hydrological model was developed in 2009 by the EDUKÖVIZIG[2]. The 1D hydrological model does not cover all the side arms, 18% of them are outside of the model, mainly the *parapotamon-B* and the *plesiopotamon* type habitats. The results of the habitat classification are presented on GIS habitat maps and areal extent of the habitat types was computed using the ArcView 3.3 software.

# 4 Results

Flow velocities and discharge were calculated by the 1D hydrological model for all discharge scenarios. Graphs for the *3 weirs variant* (Figure 1) may demonstrate the results obtained in a similar way for the other variants.

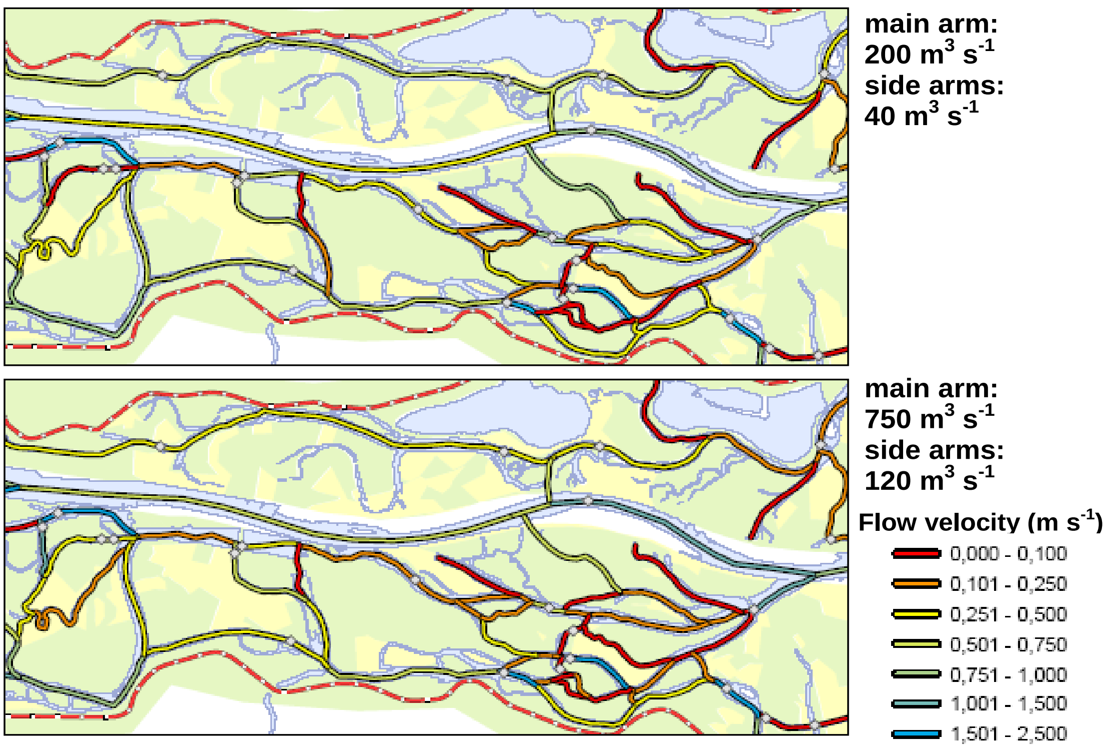


***Figure 1.*** *Spatial distribution of 1D flow velocities for the "3 weirs" variant at different discharge in the upper part of the Szigetköz floodplain*

[2] EDUKÖVIZIG = North Transdanubian Directorate for Environmental Protection and Water Management

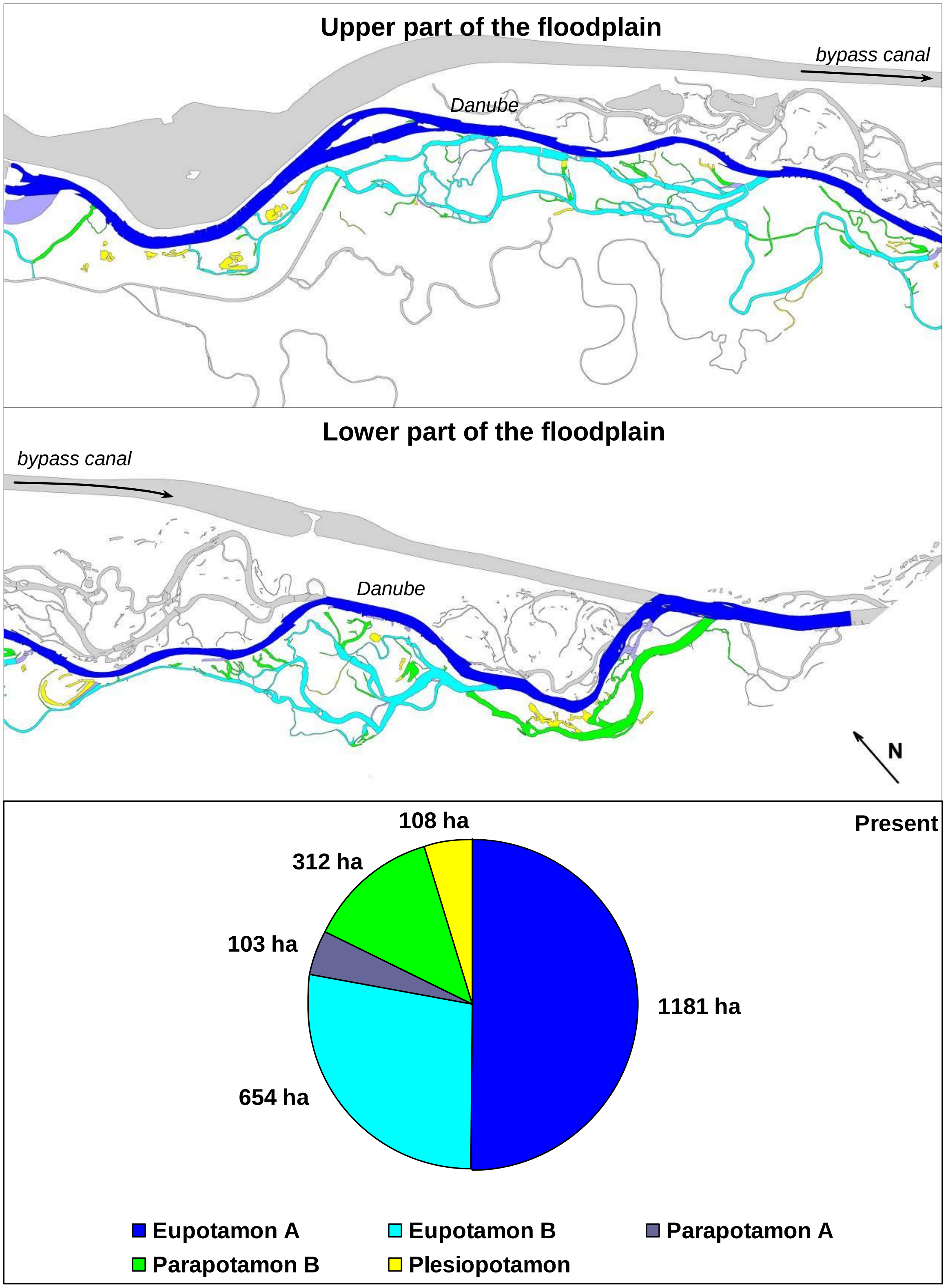


***Figure 2.*** *Map and areal extent of the distribution of aquatic habitats along the active floodplain of the Szigetköz in 2008*

The calculated total area of the main arm and the branch system is 2360 ha on the right side of the active floodplain between Rajka and Sap. The eupotamon-A habitat type has the largest areal extent (50%), followed by the eupotamon-B (28%), parapotamon-B (13%), plesiopotamon (5%) and parapotamon-A (4%) (Figure 2).

The calculated proportion of the aquatic habitats indicates the probable alterations of the floodplain branch system according to the different rehabilitation measures. A decrease of the parapotamon-B habitats is verifiable in case of the 3 weirs variant, but the narrowing and the optimum filling scenarios do not significantly alter the recent ratio of the main habitat types (Figure 3).

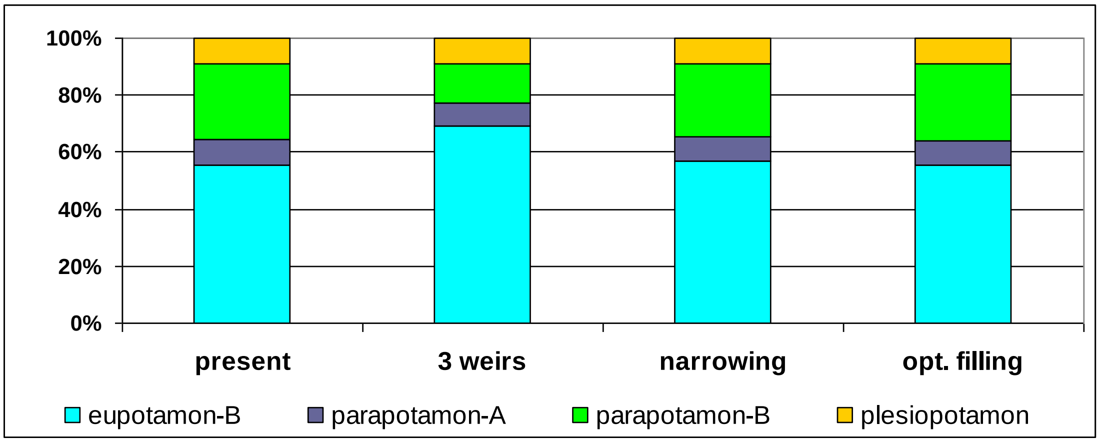


***Figure 3.*** *Comparison of the aquatic habitat structure in the floodplain branch system of the Szigetköz section of the Danube between the present situation and the different scenarios of rehabilitation*

# 5 Conclusion

The 1D hydrological model is a useful tool for river restoration programmes to predict the future composition of the main habitat types in the floodplain side arm systems. The distribution of flow velocities and discharge over space and time are the most important factor for identification of the *eupotamon-B, parapotamon-A, parapotamon-B, plesiopotamon* type habitats. The connectivity of the side arms can be estimated by the longitudinal distribution of the water depth.

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