Human induced change of the natural geomorphological system and its consequences for the biodiversity of the Sava River west of Zagreb

Changement induit par l'homme du système géomorphologique naturel et conséquences sur la biodiversité de la Sava à l'ouest de Zagreb

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RÉSUMÉ

La section de 12 km de long de la rivière Sava en amont de Zagreb, en Croatie, existe depuis les dernières 12.000 années de l'Holocène en tant que rivière de type anabranche. La gestion de la rivière et la construction, au cours des cent dernières années, de centrales hydroélectriques avec des lacs et barrages associés en amont de cette section ont provoqué un dérèglement de l'équilibre de ce système géomorphologique, ce qui a notamment conduit à l'incision accélérée du lit de la rivière, entrainant à son tour une modification des écosystèmes fluviaux. La morphologie originelle de la rivière a été oblitérée et la dynamique de la rivière a radicalement changé. La continuité longitudinale de la rivière a été perturbée par les barrages, et les mouvements des sédiments en aval ont pratiquement cessé. De nombreux habitats importants pour les poissons et d'autres espèces telles que les barres de rivières et eaux peu profondes ont été détruits, et les possibilités de leur formation considérablement réduites. Bien qu'exposée à un stress important, la biodiversité de cette étendue reste importante au niveau national. Les niches écologiques restantes fournissent l'abri et la nourriture aux espèces rares et menacées, soutenant ainsi les restes des populations autrefois plus grandes. Ceci peut être expliqué par la robustesse du système écologique, l'augmentation progressive des normes environnementales et, au cours des 10 dernières années, les efforts de conservation de la nature liés au réseau Natura 2000.

ABSTRACT

The 12 km long section of the Sava River in Croatia upstream of Zagreb, has existed in the past 12 000 years of Holocene as the anabranching river. Due to the river management and upstream construction of hydropower plants with associated lakes and dams in the past hundred years this geomorphological system was shifted out of equilibrium leading in particular to accelerated river bed incision with corresponding change of the river ecosystems. Original river morphology was obliterated and river dynamics drastically changed. Longitudinal continuity of the river was disrupted by dams and downstream movement of the sediment practically stopped. Many key habitats for fish and other species such as river bars and shallows were destroyed and possibilities for their formation drastically reduced. Though exposed to significant stress, the biodiversity of this stretch is still important on the national level. The remaining ecological niches provide the shelter and nourishment for rare and endangered species supporting remains of the previous larger populations. This can be explained by the robustness of the ecological system, gradual increase of the environmental standards and in the past 10 years, to nature conservation efforts related to Natura 2000 network.

KEYWORDS

Biodiversity, human impact, nature conservation, river morphology, Sava River

1. INTRODUCTION AND METHODS

River Sava is the longest river in Croatia and passes through its northern Pannonian part. Its source is in the Alpine area of Slovenia and its confluence to Danube in Serbia. Analysed stretch extends west of Zagreb, c. 12 km till Slovenian border. This section with comparatively few river training structures and settlements is bounded in the downstream direction by urban agglomeration Zagreb (around 1 million inhabitants), while the upstream stretch in Slovenia has also been heavily modified due to 5 hydropower plants with dams and lakes (2 in construction) and one nuclear plant situated on the river. In the past century and half due to the human impact this natural geomorphological system was shifted out of equilibrium with consequent change of river ecosystem. However, many endangered species and habitats are still present in this river section and the whole section is included in the Natura 2000 network. In this paper Holocene history of Sava River will be analysed and present situation will be compared with the natural state as indicated by the geological record and historical maps. The paper will try to address the changes in the riverine environment that had the most significant impact and also some contemporary river management approaches will be discussed.

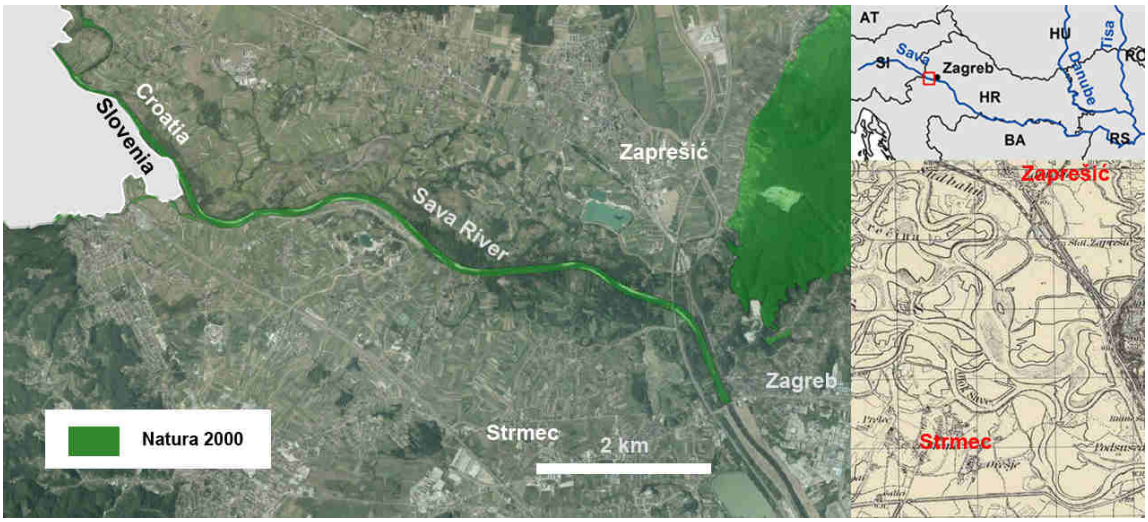

Figure 1: The present river course of the Sava west of Zagreb and the initial, natural river course from the end of 19th century (Hungarian Kingdom,1869-1887,1:25.000). Detail between Stremec and Zaprešić is shown.

2. RESULTS AND DISCUSSION

2.1 Holocene development of Sava River system and human impacts

The present course of the Sava River was formed at the beginning of Holocene when tectonic and climatic events induced opening of the Krško gorge permitting melting waters to flow in the south east direction and deposit large amount of alluvial sediments originated in the Alps. Holocene sediments analysed from the boreholes in the studied area (Velić & Saftć, 1991) have torrent characteristics and consist of limestone rich gravels, sands and silts. On the historical geographical maps of the area (Hungarian Kingdom,1869-1887,1:25.000) a riverine system of the anabranching type can be identified (Schwarz, 2016). Characteristic wide extent of the lateral movement of the flow and strong main course with numerous branches and relatively big stable islands are well pronounced (see Figure 1 area between Strmec and Zaprešić). Two mapped Holocene river terraces extending generally parallel to the Sava River course, represent natural changes in the slow process of river development which was generally characterised by long periods of gradual incision or aggradation. Present man-made channelized Sava course and anthropogenic changes on the banks have obliterated almost all natural geomorphic features of the anabranching river type leading to equally drastic change in depositional environments and consequently habitat distribution. Human impacts on the Sava River were especially pronounced since the middle of the twentieth century when construction of the hydropower dams was initiated, and system of flood protection dikes and training structures was developed stabilizing the river roughly at the centre of its former valley. The upstream power plants' dams have stopped the longitudinal sediment movement and intense gravel extraction has additionally disturbed natural morphology of the river bottom causing accelerated incision. The quality of the water in the river was affected by the upstream industry and sewage from the municipalities on the river sides, while cooling waters from nuclear power had impact on its average

temperature. However in the last two decades the gravel extraction on this section was gradually halted and the water quality was improved due to construction of purification systems. Dynamics of the remaining sediment achieved through working over of the banks and river bottom within the section, provides some bed load and enables formation of gravel bars and shallows that are the key riverine habitats for many fish and bird species.

2. Changes in biodiversity and nature conservation activities

The whole analysed stretch of the Sava River is a Natura 2000 site "HR2001506 Sava uzvodno od Zagreba - Sava upstream from Zagreb" that also encompasses its tributary Bregana. It is the only important site for fish Riffle dace, (*Telestes souffia*), inhabited with the 100% of known Croatian population as Bregana was not subjected to such drastic changes as the Sava river. However, ecological research indicates that river Sava is also important for Riffle dace conservation so protection of Sava together with its tributaries from further deterioration is of the primary concern regardless of the present altered conditions. The site is also important for other, threatened rheophilic fish species such as Streber (*Zingel streber*), Cactus roach (*Rutilus virgo*), Balkan loach (*Cobitis elongata*), Danubian spined loach (*Cobitis elongatoides*), Large spot barbel (*Barbus balcanicus*), Stone gudgeon (*Romanogobio uranoscopus*), Balkan golden loach (*Sabanejewia balcanica*) and Danubian brook lamprey (*Eudontomyzon vladykovi*). From the first half of the 20ieth century there are records of numerous catches of Huchen (*Hucho hucho*) in Sava near Zagreb, but at the present time such catches could occasionally occur, only theoretically, in winter season. Hydropower development, loss of river continuity and habitat loss are main threats to Huchen and pollution was probably important reason for its historical decline (Freyhof et al. 2015). Anthropogenic changes in water temperature together with effects of global warming also may have negative impact on this species and for this reason any increase of average yearly river temperature should be avoided. Restoration of microhabitats and continuity could return or improve population of this charismatic flagship species as well as other fish in this stretch. Appropriate Assessment (AA) in accordance with the Article 6 (3) of the habitats directive is a EU mechanism whose purpose is to stop further significant negative impacts on target species and integrity of the Natura 2000 site and it is performed for all river management projects and plans. In the process of assessment ecologists either from public agencies or as independent consultants communicate with water engineers about the possibilities for implementation of the project and best solutions from technical and ecological point of view. Zero option or minimal intervention is commonly preferred by ecologists and mitigation measures are defined if necessary. However, with the increased knowledge and communication, combination of intervention with restoration activities seems to be the best approach in such altered riverine ecosystems and it should be done as a coordinated cross border activity. To prevent the further deterioration of the site special attention has to be given to the repeating river management activities (such as mowing, driftwood removal) and thus to address that a system of mitigation measures has been developed in Croatia.

3. CONCLUSIONS

From the geomorphological point of view Sava River has been subjected to complete transformation from the anabranching river to stabilised channelized river course. Fish fauna has managed to find remains of the former widespread habitats and niches and to survive in the reduced population size. Tributary rivers such as Bregana that were regulated to the lesser extent, provide important ecological functions. In spite carried out alterations, due to the further encroachment of human activities towards river as well as increased risks associated with climate change; further interventions on the river are often required. Combination of restoration and flood protection activities remains the only viable approach. EU Habitats Directive through Natura 2000 and appropriate assessment mechanism represents the best approach to conserve remaining biodiversity on this stretch and possibly by careful interventions even restore some elements of former river habitats diversity and availability.

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