Inventory of Macrophytes and habitats along the river Danube in Croatia

SINIŠA OZIMEC[1], JASENKA TOPIĆ[2], GEORG JANAUER[3]

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1 Introduction

The length of the Danube course in Croatia is 137.5 km; it enters from Hungary (river km 1433), and stretches as a bordering river between Croatia and Serbia downstream to rkm 1295.5 (Figure 1). Main Danube tributaries in Croatia are: the Karašica River in Baranja (mouth at rkm 1425), the Drava River (confluence with the Danube at rkm 1382.5), and the Vuka River (mouth at rkm 1333).

In the Baranja section, between rkm 1433-1380, the Danube flows through a vast floodplain area, where a specific relief with oxbows, side arms, islands and sandbanks is formed due to meandering activity. The Danube course has been intensively modified due to regulation works in the past (Bognar 1990). Several wide meanders were cut: Šarkanj (1814-1820), Blaževica (1894), Siga (1894) and Srebrnica (1894). Since then, the former main channel and large side-channels became oxbows or semi-separated side-arms, called "Dunavci". Part of the Danube course between rkm 1412-1382 belongs to the protected area of Kopački rit Nature Park, which is also protected by the Ramsar Convention as a wetland area of world wide importance.

Figure 1. *The Danube course through Croatia.*

1 Department of Wildlife, Fishery and Beekeeping, Faculty of Agriculture, Josip Juraj Strossmayer University of Osijek, Trg Sv. Trojstva 3, HR-31000 Osijek, Croatia. e-mail: sinisa.ozimec@pfos.hr
2 Sisačka cesta, 2. odvojak 45a, HR-10020 Zagreb, Croatia. e-mail: jtopic@yahoo.com
3 Department of Limnology and Hydrobotany, University of Vienna, Althanstrasse 14, A-1091 Vienna, Austria. e-mail: georg.janauer@univie.ac.at

Between Erdut (rkm 1367) and Dalj (rkm 1354), the Danube performs a large curve, thus avoiding the relief barrier of Erdut hill, a horst (190 m a.s.l.) stretching for 15 km in W-E direction. Steep loess cliffs (20-40 m high) have been formed at the northern side of the hill as the result of fluvial erosion. Due to tectonic movements in the recent geological past, in the sector between Šarengrad (rkm 1306) and Ilok (rkm 1300) the Danube flows almost in a straight line (Bognar 1994). A strong asymmetry is evident between floodplain formed on the left riverside, and vertical loess cliffs on the right riverside. The Danube continuously cuts its main channel into the Vukovar loess plateau on the right riverside during high flow, while characteristic mean flow mechanisms such as meandering activities, erosion and sediment deposition, formation of side-arms, islets and sandbanks were not present in this sector.

An exceptionaly dry and warm period from February to early October 2003 resulted in drought in the Danube River. The mean water level at water gauging station in Batina (rkm 1425) in July 2003 was 41 cm, which is 285 cm lower compared to average water level of 326 cm for the period 1961-1998.

2 Material and methods

The inventarisation of aquatic macrophytes and assessment of habitat parameters along the Danube course were carried out during 2003-2004, comprising the right riverside which belongs to the Croatian territory. These tasks were part of the implementation of the international project “Multifunctional Integrated Study Danube: Corridor and Catchment –MIDCC” (Janauer 2002).

The distribution and abundance of macrophytes were assessed from the bank or using a boat in survey units of one river km length. In each survey unit, the following habitat parameters were assessed, using the methodology of Kohler & Janauer (1995): bank structure in the upper littoral, extending over the water level during mean discharges; sediment type in the littoral of the river where the aquatic plants are growing; flow class indicating the water velocity; Secchi depth transparency and land use type. The conservation status is determined according to the Red data book of Croatian vascular plants (Nikolić & Topić 2005), Annex I of the Bern Convention, and national legislation adopted under the Nature Protection Act (Anonymous 2009).

3 Results and discussion

The aquatic flora of the River Danube in Croatia is influenced by the bank structure along the main channel, sediment type, flow velocity, water transparency, and the land use type.

In the bank structure, steep slopes of fine inorganic material dominate, and make up 42% of the investigated river km. Other recorded types of bank structure are: riprap used for bank stabilization and river regulation (30%), flat slopes of fine inorganic material (21%), artificial material for the embankment (5%), and sand (2%). Urbanisation and industrialisation strongly influenced the bank structure between rkm 1353-1333, where 30% of the bank is made of concrete. An industrial centre with fabrics was built in Borovo. The centre of the Croatian Danube Region is Vukovar, situated at the mouth of the Vuka River (rkm 1333), hosting a large port.

The river bottom near the banks consists of fine inorganic material as dominant sediment type (64%), sand (29%), gravel (5%), and solid rock (2%). Medium flow velocity (35-65 cm/s) is most frequent and was recorded at 78% of investigated river km. Lower velocity (<30 cm/s) occurred in only 14%, and high velocity (>70 cm/s) in 8 % of the whole stretch. Secchi depth transparency ranged from 55-90 cm, with an average value of 70 cm.

Considering land use type, the most frequent are broad-leaved forests (86%), classified according to National Habitat Classification (Topić & Vukelić 2009) into habitat types: E.1.1 floodplain willow forests (Alliance *Salicion albae*), E.1.2 floodplain poplar forests (Alliance *Populion albae*), and E.9.3 plantations of allochthonous poplars. Scrub and open spaces with little or no vegetation make up 3%, agricultural area covers 3%, and industrial and urban areas were 4% each in the surveyed area.

In total 34 plant species were recorded, eleven of which: *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Myriophyllum spicatum, Potamogeton crispus, Potamogeton pectinatus, Ranunculus circinatus, Salvinia natans, Spirodela polyrhiza, Trapa natans* and *Wolffia arrhiza*, were restricted to the Danube main channel (Table 1). This indicates a low macrophyte diversity, similar to that confirmed in the adjacent reaches of the Danube course in Hungary (Szalma 2004) and Serbia (Vukov et al. 2006).

Table 1. *List of the macrophytes recorded on the right bank of the Danube in Croatia (rkm 1433-1295.5) and their conservation status*

Species	Conservation status		
	Croatian Red Data Book	**Croatian Nature Protection Act**	**Bern Convention Annex I**
Bidens tripartita L.			
Butomus umbellatus L.	Near threatened	Protected	
Carex pseudocyperus L.			
Carex vulpina L.			
Ceratophyllum demersum L.			
Cyperus fuscus L.	Vulnerable	Strictly protected	
Cyperus glomeratus L.	Vulnerable	Strictly protected	
Cyperus michelianus (L.) Link.		Strictly protected	
Echinochloa crus-galli (L.) Beauv.			
Elodea canadensis Michx.			
Galeobdolon luteum Huds.			
Gnaphalium uliginosum L.			
Iris pseudacorus L.			
Lemna minor L.			
Limosella aquatica L.	Critically endangered	Strictly protected	
Lycopus europaeus L.		Strictly protected	
Lythrum salicaria L.			
Myriophyllum spicatum L.			
Phragmites australis (Cav.) Trin.ex Steudel			
Persicaria amphibia (L.) Gray			
Persicaria hydropiper (L.) Spach			
Persicaria lapathifolia (L.) Delarbre			
Potamogeton crispus L.			
Potamogeton pectinatus L.			
Ranunculus circinatus Sibthorp			
Rorippa amphibian (L.) Besser			

Rorippa palustris (L.) Besser			
Sagittaria sagitifolia L.			
Salvinia natans (L.) All.		Protected	■
Spirodela polyrhiza (L.) Schleiden			
Stachys palustris L.			
Trapa natans L.	Near threatened	Protected	■
Veronica peregrina L.			
Wolffia arrhiza (L.) Horkel ex Wimmer	Vulnerable	Strictly protected	

In the Hungarian part of the Danube, between rkm 1468-1433 (bordering point to Croatia), four aquatic species were recorded on the right, and five on the left riverside. Recorded types of bank structure on both riverside are riprap used for bank stabilization and sand, while the most frequent sediment type is fine inorganic material. The flow is low, and Secchi transparency ranged between 40 and 50 cm.

On the left riverside in Serbia, between rkm 1410-1359, eleven aquatic plants were recorded in the Danube main channel. Compared to the investigated sector on the right riverside, sand is prevailing in bank structure (44%) and as sediment (58%), flow is medium, and Secchi transparency was 40-70 cm. This part of the Danube is characterized by medium to high flow, due to straitening the river after cut-off of a wide meanders in the past (Bognar 1990). Meandering activity of the Danube is evident even nowadays. The right (Croatian) bank is elevated and exposed to fluvial erosion, so the bank is more stabilized with riprap than left (Serbian) bank, which is more flat and suitable for deposition of eroded material.

The absence of favourable conditions for the reduction of the Danube flow velocity disables the occurrence of aquatic plants along the Danube course in Croatia. Significant increase in species diversity is recorded in Serbia, downstream of rkm 1155 (Vukov et al. 2008). The construction of the power plant and the dam Đerdap I altered hydrological conditions in a way that flow velocity was reduced, sedimentation rate was higher, and banks were enlarged. In the impoundment of Đerdap I, 37 plant species were recorded.

Our survey contributed to the enlargement of the Croatian flora, since *Veronica peregrina* discovered on the sandbank of a Danube oxbow at Zeleni otok (rkm 1423), was reported as new species (Topić & Ilijanić 2003).

Nine species of value for conservation were found in the area (Table 1). Depending on the degree of their vulnerability, six of the recorded aquatic plants (18 %) are included in different categories of the Red data book of Croatian vascular plants: *Limosella aquatica* as critically endangered; *Cyperus fuscus*, *Cyperus glomeratus*, and *Wolffia arrhiza* as vulnerable; *Butomus umbellatus* and *Trapa natans* as near threatened. According to the Croatian Nature Protection Act, six species have been protected under the category “Strictly protected native taxon”, and three as “Protected native taxon”. Two of the recorded species: *Salvinia natans* and *Trapa natans* are internationally protected under the Annex I of the Bern Convention.

4 Conclusions

Diversity of the aquatic macrophytes along the Danube course in Croatia is low, and it is similar to that recorded for the left and right riverside in the adjacent reaches in Hungary and Serbia. Medium to high flow velocity of the Danube, caused by meandering activity, is the main factor that disables the growth of the aquatic plants. However, the number of macrophytes is significantly larger in the Danube backwaters and area of Kopački rit Nature Park, with pronounced diversity of wetland habitats.

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