LIMNOLOGY AROUND THE WORLD: SERBIA

The Danube River in Serbia

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Over 2850 km long, the Danube River is certainly the most important river in Europe, flowing through Germany (687 km), Austria (358 km), Slovakia (172 km), Hungary (417 km), Croatia (138 km), Serbia (587 km), Bulgaria (472 km), Romania (1075 km), Moldovia (<1 km) and Ukraine (54 km) in a west-east direction, and representing a "water backbone" for many European countries located in its basin.

With an average annual flow of about 5,000 m^3/s near Belgrade, the Danube River is a significant natural resource, with multipurpose usages along its entire flow, providing extensive ecological services (Fig.1). For example, millions of people in the upper section

Fig. 1 Danube River Island in Belgrade, Great War Island (Zemun) (photo by M. Smederevac-Lalić)

Fig. 2 Tourist cruise ship on the Danube River (photo by M. Smederevac-Lalić)

are supplied with drinking water from this river. Unfortunately, countries in the lower Danube section, usually do not use water from the Danube River, primarily due to pollution. While significant amounts of water from the Danube are also used for irrigation along its course, in Serbia, only about 1.2% of agricultural land is irrigated, or between 40 and 50 thousand hectares (the world average is 17%) (Savić *et al.*, 2013).

Table 1. Protected natural areas along the Danube River in Serbia.

Protected area	Name
National Parks	NP Fruška gora NP Đerdap
Special Nature Reserves	Gornje Podunavlje Karađorđevo Koviljsko – Petrovaradinski rit (wetland) Deliblatska peščara (send)
Outstanding Natural Landscapes	Forland leve obale Dunava kod Beograda (wetland) Veliko ratno ostrvo (Great War Island) Karaš – Nera
Nature Parks	Tikvara Begečka jama
Monuments of Nature	Lesni profil kod Starog Slankamena Lesni profil Cot Lesni profil Kapela u Batajnici Zemunski lesni profil Ivanovačka ada
Protected Habitats	Veliko blato

Another ecosystem service provided by the Danube is navigation and river traffic (Fig. 2). The Danube is navigable for 2,415 km, from Kelheim to the confluence with the Black Sea. Since 1992, the Rhine-Main-Danube Canal (171 km long Main-Danube Canal) creates a navigable river connection with the North Sea and the Atlantic and Black Sea. This is also important for Serbia since river transport is the cheapest transport and is highly developed in Europe. The most important river ports in Serbia are Novi Sad, Belgrade, Pančevo, Smederevo, and Prahovo (Jolović, 2016).

Like most rivers, the Danube and its tributaries are recipients of waste water along its entire lenght. Waste waters originate from industry and agriculture, as well as from the numerous cities and settlements it flows through. Much waste is not treated and Serbia's capital, Belgrade, currently does not have a wastewater treatment plant.

Fig. 3 Petrovaradin Fortress ("The Gibraltar of the Danube") one of the many fortresess along the Danube River in Serbia. They were engineered as defensive outposts, for navigation security and border patrolling between empires. The cornerstone was laid in 1692 by Charles Eugène de Croÿ (photo by A. Hegediš).

Tourism is certainly one of the most developed economic sectors along entire course of the Danube because of the natural beauty along the river (Figs. 1; 2), safeguarded by the presence of National parks and protected areas. Serbia is no exception, with its numerous cultural and historical monuments, and an abundance of panoramic sights and natural beauty, and cultural-historical monuments (Fig. 3).

The Danube River passes through extraordinary areas rich with biological diversity. For millennia, Danube River was a traffic and

communications corridor, as well as the border of great empires. Today, the Danube with its entire drainage area, connects countries and cultures, and provides a living environment for over 81 million people. As a partial remedy to the many anthropogenic impacts of the last decades, an increasing number of protected areas and natural parks have been instituted. Just in Serbia, there are 17, with different levels of protection measures along the river (Table 1).

Fig. 4 A small Serbian wetland (Pančevački rit) that once characterized vast zones of the Danube floodplain (photo by A. Hegediš).

Many marshes and wetlands that were characteristic of the Danube that flows through the Pannonian Plain have disappeared. Since the 18th century, most wetlands have been drained, and physically separated from the Danube, by fortifying them with defensive embankments, and converting them to agricultural land. To a certain extent, these measures continue, further threatening the remains of the former great wetlands, now reduced to fragments such as: Pančevački rit, Bogojevački rit, Plavna rit - Bačko Novo Selo, Bukinski rit, Koviljsko - Petrovaradinski rit, Dubovački rit, and some smaller flood zones (Fig. 4).

Notwithstanding river and wetland fragmentation, the Serbian part of the Danube with its main branches and floodplain zones is home for 49 different types of aquatic macrophytes (Fig. 5). The most common are: *Ceratophyllum demersum, Potamogeton pectinatus, Spirodela polyrhiza, Rorippa amphibia, Potamogeton lucens, Butomus umbellatus, Potamogeton perfoliatus, Potamogeton gramineus, Lemna minor, Trapa natans, Potamogeton nodosus, Iris pseudacorus i Potamogeton crispus,* while the remaining 36 taxa were detected in less than 20% (Vukov *et al.*, 2017).

The Danube phytoplankton in Serbia is characterized by the absolute dominance of silicate algae (Bacillariophyta), with a total abundance of > 50%, followed by green algae and cryptomonads. Other groups are only present sporadicaly according to locality and season. This pattern indicates a fairly uniform set of environmental factors in this part of the Danube River (EPA, 2019).

The zooplankton community in the Serbian stretch of the Danube consists of >70 taxa. The most abundant are Rotatoria, with 47 taxa, among which the most common representatives are: *Brachionus (B. calyciflorus f. amphiceros, B. angularis, B.budapestinensis), Keratella (K. cochlearis, K. cochlearis* var. *tecta), Polyarthra (P. vulgaris, P. minor) and Trichocerca (T. rattus, T. pusilla).* Protozoa with 13 taxa are the subdominant group, and the main representatives are: *Carchesium polypinum, Vorticella microstoma and Staurophrya elegans.* The planktonic crustaceans Cladocera (9 taxa) and Copepoda (5 taxa) are more abundant in the lower sections of the Danube (downstream from Ritopek). Among the Cladocera, the most common species are *Moina micrura and Bosmina longirostris,* and of the Copepoda, the most common species is *Acanthocyclops robustus.* Another very significant component of the zooplankton community, is the larval stage of the non-native invasive mussel *Dreissena polymorpha,* with abundances varying between 6 and 42% (Čađo & Đurković, 2004; Zsuga, 2014).

The Danube and its floodplains is inhabited by a total of 414 taxa of macroinvertebrates from 19 groups, or 33% of the total number of recorded species for Serbia. The most abundant taxa are Diptera, Oligochaeta, Trichoptera, Odonata, and Gastropoda (68% in total), followed by Ephemeroptera and Bivalvia (13%), while the number of taxa in the remaining 12 groups is smaller (19%) (Petrović, 2014).

The Danube floodplain is a spawning ground for fish, a nesting ground for birds, an area that receives flooding waters and reduces the pressure on embankments, as well as a place where the polluted water is purified and returned to the river at least a class cleaner.

Fig. 5 Some aquatic macrophytes along the Danube in Iron Gate area between two dams, Serbia (photo by M. Smederevac-Lalić).

The list of birds of the floodplain area close to Belgrade is over 120 species. There are also mammals such as deer, rabbits, otters, wild cats, boars.

According to available data, there are 61 fish species in Serbian part of the Danube River. The inland waters of Serbia, which belong to the Black Sea basin, are characterized by a fish fauna dominated by the carp family (*Cyprinidae*). Among the endemics of the Black Sea Basin, you can find the Ballon's ruffe (*Gymnocephalus baloni*), the schraetzer (*Gymnocephalus schraetser*), cactus roach (*Rutilus virgo*) and the salmonid huchen (*Hucho hucho*). Particularly important are six species from the Acipenseridae family. All sturgeons are considered critically endangered species (CR status according to the IUCN), except for the sterlet, which is vulnerable (VU). In

Fig. 6 Sterlet (*Acipenser ruthenus*) (photo by M. Smederevac-Lalić)

Serbia, all sturgeon species are under moratorium. The major threats are more or less the same for migratory Danube sturgeon as for other fish species: overfishing, river flow regulation for flood control, canalization and construction of dams and reservoirs, loss of habitat, introduction of non-native species, water pollution and increase in average water temperatures (Lenhardt *et al.*, 2020). However, the decrease of Danube sturgeon population started with the construction of the Hydropower Iron Gate I and II dams.

For the five Danubian countries, Germany, Austria, Slovakia, Serbia and Romania, the Danube River represents an important energy source. The first hydropower plants in the upper reaches of the river

Table 2. Number of fishermen and catch (tons) for recreational and commercial fishing in Serbia from 2013 – 2021. Data are related to the Danube, Sava and Tisza together, although about 80% of the data refers to the Danube River.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021
				Number of fishermen					
Recreational fishermen (anglers)	77.589	82.750	77.109	77.345	81.944	85.426	88.991	96.001	109.606
Commercial fishermen	511	472	407	408	398	378	443	408	429
				Catch (tons)					
From commercial fishing	2.235	908	851	581	590	686	884	761	927
From recreational fishing	2.805	2.683	2.299	1.488	1.618	1.397	1.662	1.170	1.426

were constructed at the end of the XIX century in Germany. Much more important and located on the lower reaches of the Danube are the Hydropower Iron Gate I and II dams that represent the largest hydropower system in Europe, and are jointly managed by Romania and Serbia since the 1970s. Unfortunately, the negative effects of these dams are now obvious. The damming and fragmentation of river flow has caused the loss of the river continuum, thus interrupting the migratory routes of many river organisms, with negative impacts on both aquatic and surrounding terrestrial ecosystems. Habitat loss and fragmentation have especially impacted many economically important fish species (Lenhardt *et al.*, 2020) (Fig. 6).

Migratory routes to spawning areas have been cut off, pollution is increasing, and intensive fishing has continued. This situation led to a rapid decline of populations within a few decades. What was not possible for tens of millions of years and turbulent geological history, glaciations and interglaciations, transgressions and regressions, man succeeded in less than half a century (Hegediš *et al.*, 1994; Kostić *et al.*, 2012; Mićković *et al.*, 1993; Reyjol *et al.*, 2007; Smederevac-Lalić, 2013; Smederevac-Lalić *et al.*, 2017).

Fishing has been a traditional activity in Serbia for centuries (Smederevac-Lalić, 2013). People from the pre-historic Lepenski Vir culture were using fish migrations along Djerdap Gorge as an element for measuring time and entire communities during the Medieval Ages survived thanks to fishing. While there is a still significant level of recreational (Fig. 7) and commercial fishing (Fig. 8) (Table 2), the importance of this activity decreased in the XIX and especially in the XX century (Smederevac-Lalić *et al.*, 2017).

The decline of the Danube fish fauna is due to many anthropogenic impacts, such as unsustainable fishery, river damming, water pollution, dregging, water abstraction and non-native species invasions (Lenhardt *et al.*, 2020). One way to counteract this decline, for example for the migratory shad (*Alosa immaculata*)- considered as a vulnerable species of fish by the IUCN, is to develop forecasting models of catch oscillations to regulate sustainable fishing efforts and species conservation (Smederevac-Lalić *et al.*, 2018).

Historically, there are four sturgeon species in Serbia (beluga sturgeon- *Huso huso,* Russian sturgeon- *Acipenser gueldenstaedtii,* stellate sturgeon – *A. stellatus,* and sterlet- *A. ruthenus*), but sterlet has received the most attention, mainly because it is common potamodromous species. Although protective measures have been tightened and investigation of heavy metals contamination, histopathology and genotoxicity has been done, some basic life

Fig. 7 Recreational fishing along the Danube River (photo by M. Smederevac-Lalić).

Fig. 8 Commercial fishing on the Danube River in Serbia (photo by M. Smederevac-Lalić).

history traits such as spawning, nursing and wintering habitats, and population status are still unknown. Sturgeon fishing has been banned since 2006 in Romania, followed by Serbia and Bulgaria, but illegal fishing in the Lower Danube is ongoing, and only international cooperation will solve this problem (Lenhardt *et al.*, 2014). Many Danube fish species are in need of conservation efforts. Adequate protection and sustainable management of fish resources in the Danube in Serbia requires introducing an effective monitoring system, establishing and enforcing management plans, and research efforts must be increased on critical issues related to fish management and conservation (Lenhardt *et al.*, 2020).

The best way to ensure that future generations will inherit a healthy Danube is to engage our citizens in its protection and conservation. To do this we promote 'Environmental Citizenship', *i.e.* foster understanding, awareness, and responsible and respectful behaviour towards the environment both as individuals and as a society (Smederevac-Lalić *et al.*, 2020). Environmental Citizenship should be understood as a leading lifestyle that crosses the boundaries of theory and defines responsible personal pro-environmental behavior and practice for citizens. No one starts the day with the idea that one gets up in the morning and decides to intentionally damage the environment, contribute to climate change, water pollution, destruction of the ozone layer, deforestation, etc. What appear to be harmless daily decisions and actions often have far-reaching consequences on the planet. The aim should be to make everyone aware of their ecological footprint (defined as the influence of the everyday activities of every individual person on the planet Earth) through Environmental Citizenship. Acting on a personal level and participating in society through individual and collective actions, in the direction of preventing the creation of new environmental problems, solving environmental problems, achieving sustainability and developing a healthy relationship with nature is the only way towards well-being (Smederevac-Lalić *et al.*, 2020).

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Sunset on the Danube. Photo by M. Smederevac-Lalić