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Editorial

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Dear Readers,

Our association, the IAD, presents ongoing research from various fields highlighting the huge diversity, the interdisciplinary approaches and the amazing potential of this group of scientists from all over the Danube River Basin, working on an impressive number of specific topics. And many of these topics have a clear societal relevance and have the potential to shape future processes and developments. The contributions to this issue of our journal show the broad range of work devoted to different topics of relevance for the Danube River and its Basin.

Cristian Coman, working at the Institute of Biological Research (Cluj-Napoca), explores the critical role of antibiotics and related resistance in aquatic environments, and the Danube Delta in special. A methodological guide worked out on the basis of national and international cooperation shall support more and better research for this topic not so apparent to the public, but highly important for sustaining best possible water quality.

Adrian Stanica of GeoEcoMar (Bucharest) and his very international group of co-authors report about the achievements of an EU funded project: Danube macroregion: Capacity building and Excellence in River Systems (DANCERS), focusing on the development of new instruments and tools for environmental research in the Danube Region and the Black Sea System. Establishing a new regional research infrastructure is in process, and new educational programmes aim to build a network of involved institutions for a more efficient exchange of knowledge within the Danube Basin.

Gertrud Haidvogl and Martin Schmid (Vienna/Klagenfurt) used results of hydromorphology, fish diversity and pollution collected during the JDS 3 – Danube River Survey to describe aspects of socio-natural history in the Danube River Basin. The authors show that not so much in the 19th century, but rather in the 20th century intensive flood protection programmes were implemented, which resulted in a very considerable loss in 'active floodplain', i.e. the riparian land area still reached by flood events. The historical approach helps to understand the consequences of river regulation, and finally puts a light on the conceptions what type of 'nature' should be conserved.

Lubomir Adamec (Trebon) introduces us to a rare and very special group of aquatic plants, the bladderworts. Some of their physiological processes, e.g. the net photosynthetic rate, are among the most intensive recorded so far for aquatic plants, and their way of acquiring nutrients by catching small animals in bladders is a very rarely found way in the plant world. As most of the bladderwort species are highly endangered strict conservation of this group of aquatic plants and preserving their habitats is an undisputable requirement.

The presented topics illustrate the important role of science and show its potential in reaching societal aims basin-wide. Some of these topics are of high relevance for the current EUSDR process and are well linked to specific project activities in the Danube River basin.

Antibiotic resistance: not only the clinician's problem.

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Antibiotics and the antibiotic resistance phenomenon in aquatic environments

Antibiotics are substances produced naturally by several microorganisms or synthesised (semi-) synthetically in the laboratory. They can either destroy susceptible microorganisms (bactericidal effect) or inhibit their development (bacteriostatic effect). They are one of the most important discoveries in human medicine, regarded as "magic bullets" that could target pathogenic microorganisms selectively, this leading to an intensive usage since more than 7 decades ago. Antibiotics were produced in natural microbial communities for millions of years but the „antibiotic era" really began in the early 20th century. One of the major discoveries in the history of antibiotics is that of penicillin by Alexander Fleming in 1928, followed by the its mass production after 1940. From there on started a golden era of antibiotics with several new classes and compounds discovered, having different modes of action: interference with cell wall synthesis, inhibition of protein synthesis, interference with nucleic acid synthesis, inhibition of a metabolic pathway or disorganizing the cell membrane (Džidić et al. 2008; Gothwal and Shashidhar 2014). Antibiotics have saved millions of lives from deadly infections. However, their extensive use has led to the development of antibiotic resistance, rendering them ineffective against some pathogens. While the clinical side of this problem has been studied extensively, there is a less-studied environmental aspect.

With the increasing industrial production of antibiotics and their human and veterinary use these substances have started entering the environment due to incomplete metabolisation in the organisms (between 25 % and 75 %), incomplete elimination during sewage treatment, land application of animal waste that contains antibiotics, improper disposal of unused or expired drugs etc. (Jjemba et al. 2006; Park et al. 2007; Zheng et al. 2011). Surface waters, groundwater, wastewater, soil, sludge, manure have been reported for contamination with antibiotics (Gothwal and Shashidhar 2014 and references therein). They are regarded as persistent or pseudo-persistent because the rate of entering the environment is higher than the rate of elimination, having direct and indirect consequences on microorganisms, plants, animals, and humans. The direct effects are the potential toxic effects such as affecting the chloroplast and mitochondrial protein synthesis in plants (Kummerer 2009), phytotoxic effects by causing chromosomal aberrations and by affecting the plastid division (Brain et al. 2008), inhibition of assimilation rate (Opriș et al. 2013). The major issue of antibiotic release into the environment is their indirect effect of exerting a selective pressure in the environments they enter and modifying the metabolic activity of the microbiota towards selection of antibiotic-resistant mutants and the appearance of antimicrobial resistance phenomenon (Martinez 2009), with serious consequences on human and animal health. Antibiotic resistance is defined by the World Health Organization as the resistance to an antimicrobial drug that was originally effective for treatment of infections caused by it (www.who.int). Susceptible bacteria may become resistant to antibiotics through multiple and complex mechanisms, such as (i) exclusion of the antibiotic by the cell membrane; (ii) intracellular modification and/or deactivation of the antibiotic; (iii) reduction in sensitivity of the cellular target; (iv) extrusion from the cell; or (v) intracellular sequestration (Taylor et al. 2011). These mechanisms can evolve through mutation and selection (vertical transfer) or by acquiring resistance-encoding genes from other bacteria (horizontal gene transfer). In other words, a bacteria which does not present resistance to a certain antibiotic can pick up a resistance gene from another bacteria and therefore become resistant. The major concern is that human impact will increase the probability of transferring resistance genes into clinically relevant pathogens, the infections caused by them becoming harder and harder to treat.

Thus, because *antibiotics and antimicrobial resistance* genes have been detected in various compartments of the aquatic environment and in the soil and sediments (Stolker et al. 2004; Perret et al. 2006; Ye et al. 2007; Walsh 2013), and due to their effects, they *are getting attention as new classes of pollutants in the environment* (Martinez 2009; Yang et al. 2011; Gillings and Stokes 2012). From there they can recontaminate humans and animals, for example via drinking water, irrigation, soil, or foodstuff *(Fig. 1).*

Municipal wastewaters are considered to be major contributors to the environmental pollution with pharmaceuticals, antibiotic resistant bacteria and resistance genes (Göbel et al. 2004; Marti et al. 2013). Wastewater treatment plants use different methods to reduce the total number of bacteria, especially coliforms, in their final effluent, but the treatment is not efficient enough to remove antibiotic resistance genes from wastewaters, these being released into the receiving surface waters (Munir et al. 2011; Mokracka et al. 2012; Czekalski et al. 2014). *Hospital wastewaters* are also one of the most important factors contributing to the release of antibiotics and antibiotic resistance into the aquatic environment (Hocquet et al. 2016; Lien et al. 2016). In European acute care hospitals 20–30 % of inpatients undergo an antibiotic treatment, thus the large amount of antimicrobials eliminated in the sewage system creates an ideal ecological niche for antibiotic resistant bacteria and they facilitate the horizontal resistance gene transfer (Ansari et al. 2009). *Veterinary medicine and animal husbandry* are also a major source of environmental contamination with antibiotics and resistant microorganisms because the manure and slurry end up in the sewage or are either stored or immediately applied to the agricultural fields as fertilizers. The unmetabolized compounds present in the manure or their biologically active metabolites may move from the manure fertilized soil into groundwater and eventually surface water. Thus, antibiotics and especially resistant bacteria can spread by re-entering human and animal populations via drinking water, irrigation, soil or the food chain putting a serious threat on their wellbeing (Jerneja 2012).

The need for common efforts to tackle the antibiotic resistance problem

In the 2013 annual report on global risks, the World Economic Forum concluded that "[...] arguably the greatest risk to human health comes in the form of antibiotic-resistant bacteria" (Howell 2013). The spread of multiple antimicrobial-resistant pathogenic bacteria has been recognised by the World Organisation for Animal Health, the Food and Agriculture Organization, the World Health Organization (WHO) and other European organizations as a serious global human and animal health problem. For example, the European Centre for Disease Prevention and Control estimates that antimicrobial resistance results each year in 25 000 deaths and related costs of over €1.5 billion in healthcare expenses and productivity loss. A very recent report (O'Neill 2016) states very clear that if no joint action is taken, antibiotic resistance will be the first cause of death by 2050, being expected to claim more than 10 million lives each year worldwide and a cumulative cost of more than 100 trillion USD.

WHO developed the *Global Strategy for Containment of Antimicrobial Resistance*, with key recommendations to address the need for mitigating resistance that will hopefully lead to an increase of awareness on the antibiotic resistance problem, an improvement of antibiotic use in people and animal husbandry, increased resources for funding surveillance, research and education. Also, the European Parliament recognized that antimicrobial resistance is an important, largely unresolved, issue which has become a threat to public health in Europe and globally, resulting in longer, more complicated treatments, a diminution of quality of life, a greater risk of deaths, extra healthcare costs and productivity losses and adopted a resolution that calls for a further intensification of the fight against resistance to antimicrobial agents (EU resolution P7_TA(2011)0473). Overall, all the parties involved in the antimicrobial resistance issue recognize that excessive antibiotic usage is known to exert selective pressure on bacterial populations, that gene swapping among bacteria does occur, and an that an expanding number of people, animals and animal products transverse the globe much more quickly than ever before. They underline the need of collaboration among stakeholders, clinicians, environmental microbiologists, policy makers etc.

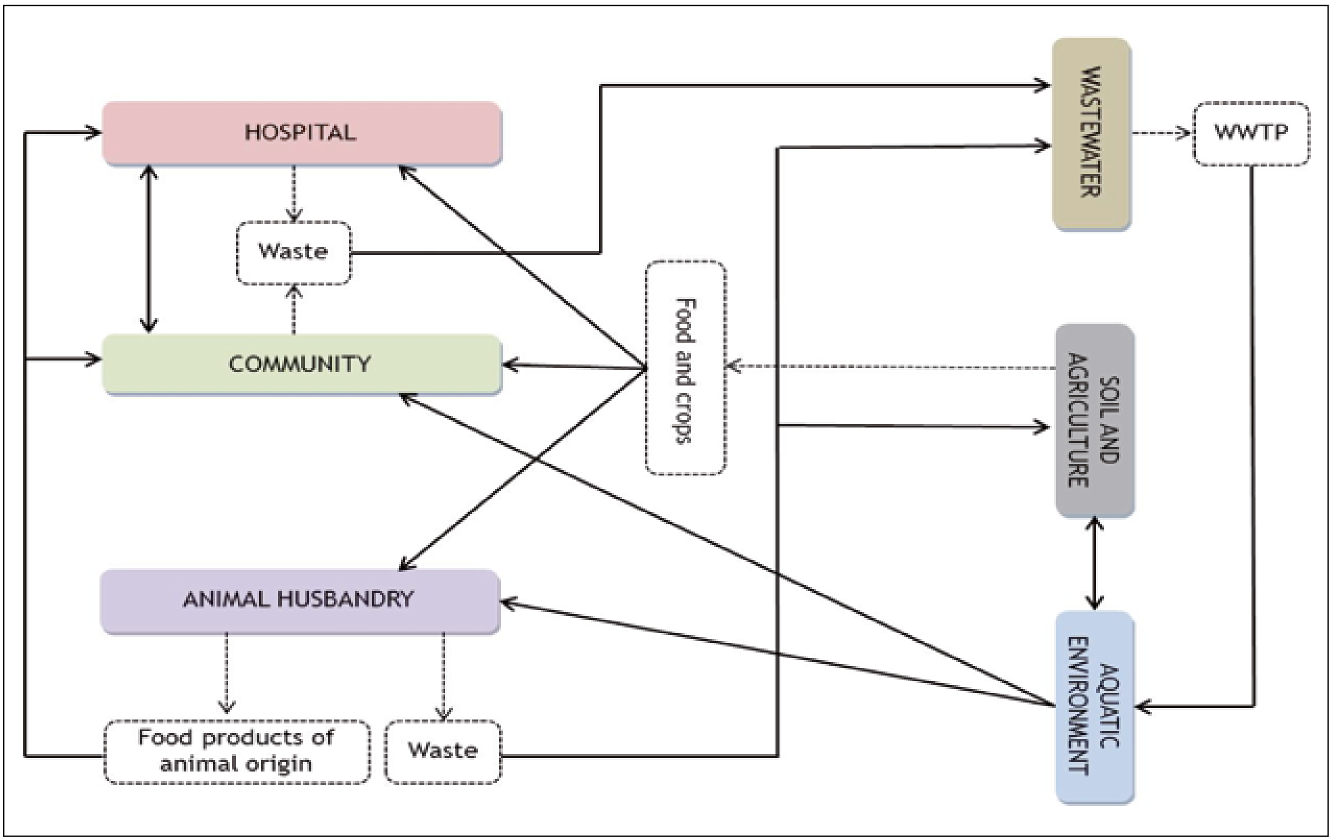

Figure 1. Schematic representation of major contributors to the spread of antibiotics and antibiotic resistance into the environment and possible routes for recontamination of humans and animals. Dash lines represent intermediary factors involved in the transfer. WWTP – wastewater treatment plant.

There has been considerable research effort to address the clinical ramifications of antimicrobial resistance and its mitigation. However, there remains a significant lack of information concerning the ecological risks from antimicrobial resistance present in the environment and the dissemination of causative agents, with limited regulations in place to mitigate these risks. It is more and more obvious that the environment plays an important role in the circuit of antibiotic resistance because it is either a natural source of antibiotic resistant bacteria and resistance genes (D'Costa et al. 2011) or it is receiving bacteria and genes released from human and animal husbandry activities that can spread across different ecological niches (Vaz-Moreira et al. 2014).

The antibiotic resistance in the Danube Delta – scratching the surface

The Institute of Biological Research Cluj-Napoca (ICB), branch of NIRDBS Bucharest, Romania is the coordinator of the EnviroAMR project – „Methodological guide for monitoring antibiotic residues and antimicrobial resistance in the environment as a supporting instrument for an enhanced quality management of surface waters and groundwater", financed through the EEA 2009–2014 Financial Mechanism through the RO04 – Reduction of hazardous substances programme. It is implemented in collaboration with the Biology and Geology Faculty from Babeș-Bolyai University luj-Napoca, with the Microbial diversity laboratory from the Norwegian University for Life Sciences and with the Nanostructured Systems Physics department from the National Institute for Research and Development for Isotopic and Molecular Technologies Cluj-Napoca. The general objective of the EnviroAMR project was to raise awareness in the matter of environmental pollution with antibiotics and the antimicrobial resistance phenomenon and to develop a state-of-the-art methodological guide for monitoring antibiotic residues and resistant microorganisms in the environment in order to design and implement efficient strategies for an enhanced quality management of surface waters and groundwater.

In May 2016, as part of the EnviroAMR project, project members took part in an extensive field trip in the Danube Delta due to a collaboration between ICB Cluj-Napoca (Dr. Cristian Coman) and the National Institute for Research and Development Danube Delta, Tulcea, Romania (Dr. Liliana Török). Eighteen lakes and six Danube points were sampled and a prescreening of antibiotic resistance genes was performed. Preliminary results show that several resistance genes are widespread in the Danube Delta underlining that microorganisms may present resistance to several clases of antibiotics (e.g, carbapenems, macrolides, aminoglycosides etc.). The most suprising fact is that mobile genetic elements shown to be actively involved in the horizontal antibiotic gene transfer are present in every sample investigated. As high abundance of these mobile genetic elements is linked to anthropogenic activity, it is important to perform a thorough investigation of this phenomenon in order to design cross-border strategies and policies for a sustainable development of the Danube – Danube Delta – Black Sea axis. The methodological guide developed in the EnviroAMR project would be a suitable research framework in this matter because it proposes different methods to investigate the antibiotic resistance problem at different complexity levels (phenotype, genotype, metagenome).

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Key messages from a two year EU funded project for the future development of science and ecosystem management in aquatic ecosystems – the DANCERS Project

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This paper summarises the main outputs of the project DANube macroregion: Capacity building and Excellence in River Systems (basin, delta and sea)' (DANCERS) which aims at developing new instruments and tools for environmental research in the Danube Region.

The project objectives were to:
Critically analyse achievements in integrated river – delta – sea management in the Danube – Black Sea region placing them within the wider international context;
Identify strong and weak areas of regional environmental research;
Derive a set of instruments to enhance environmental research and innovation in the region.

Since its start DANCERS has produced:
A Strategic Research and Innovation Agenda (SRIA) to 2020 and beyond;
A concept and a detailed plan for two existing distributed research infrastructures in the region which can implement the SRIA;
Proposals for an integrated educational programme (EDU).

Scientifically coherent solutions for integrated river-basin-sea management require an interdisciplinary approach that informs about decisions by society, industry and government. The SRIA addresses these research priorities in the context of the EU Strategy for the Danube.

Proposed Research Priorities for the Danube – Black Sea System

Restoring Ecosystem continuity throughout the DBS System

Two centuries of engineering work have heavily impacted ecosystems in the Danube River – Danube Delta – NW Black Sea continuum. Science must contribute to restoring longitudinal and lateral connectivity by implementing solutions to work with, rather than against, Nature.

Pathways of transport and accumulation of litter (especially plastic) and pollutants (including emerging pollutants) in the DBS System

We have to understand the transport and fate of key pollutants including microplastics and emerging pollutants.

Ensuring safe and continuous navigation while restoring the Danube green corridors

We need to reconcile the demands of navigation with the challenges of environmental restoration in the Lower Danube. Smart and innovative "nature based" solutions shall involve integrated sediment management and maximize ecosystem services, which are key prerequisite to ensure continuous navigation and the development of green corridors alike.

Mutual ecological and economic benefits from ecosystem restoration of eutrophicated ecosystems in the Danube – Black Sea interaction zone

We need a better understanding of the environmental benefits of ecosystem restoration.

Dealing with Eutrophication in the Danube – Black Sea interaction zone by using algae as 2nd Generation Biofuels

Efficient use of algae as raw materials for biofuel refineries requires understanding of freshwater – marine water interactions, variation of nutrient loads supplied by the Danube to the Black Sea, life cycle of algae development and blooming, as well as forecasting of dynamics of the marine area where algal blooms evolve.

Using latest Earth observation (EO) technologies coupled with in situ measurements for an upgraded DBS System environmental monitoring scheme

We need long-term research sites to capitalize on ESA's next generation EO capabilities and advances in sensor technologies, to develop innovative observation systems for transboundary basin scale water management in the Danube system.

Developing sustainable agricultural practices (crops, husbandry) for obtaining good water quality in the DBS System

Innovative methods are needed to ensure sustainable food production whilst ensuring good water quality in the Danube River – Danube Delta – NW Black Sea.

Understanding river-sea interaction processes in the Danube Delta transitional environments

A fundamental understanding of the functioning of complex, dynamic and vulnerable transitional environments and their relationship to social and economic pressures and global change, is a prerequisite for effective management.

Managing dams and reservoir lakes as critical sediment traps and bottlenecks for river habitats continuity in the DBS System

Dams act as traps, interrupting the natural flow and continuum of water, sediments and biota. As a result they contribute to ecosystem change and sediment accumulation in associated impoundments.

Restoring natural habitats in the Danube floodplains – Danube Delta and lagoon systems as support for fisheries revival.

Plans to support fisheries revival and sustainable aquaculture must include actions to restore spawning grounds and nursery habitats for native fish and other aquatic species.

Understanding Climate change impacts on the DBS System by applying the latest generation of models

Climate change will have differing impacts throughout the Danube River – Danube Delta – Black Sea system. Records of the thermal dynamics of lakes, lagoons and flowing waters are required to understand the effects of climate change.

Managing water resources by implementing new technologies for water abstraction, purification, distribution, collection, treatment and reuse in the DBS System

Fluxes of dissolved organic matter (DOM) from wetlands are the largest and most bioavailable pool of fluvial DOM. However, the subsequent transformation of DOM in the freshwater – marine transitional zone within the Delta is uncertain, yet this knowledge is fundamental to closing the carbon cycle.

Harmonising scientific data and monitoring protocols in the DBS System

Integrated management of the DBS system can be successfully implemented only by fully understanding the upstream – sea continuum and by having compatible indicators of the state of the environment. This requires a harmonisation of monitoring protocols in freshwater, transitional and marine systems.

Unfolding the cultural heritage potential of the DBS System by using scientific tools

The cultural resource of the DBS is threatened by land use change, development and climate change. Remote sensing coupled with geo-archaeology has the potential to uncover cultural heritage sites. Such approaches can inform management of these cultural landscapes to ensure their continued preservation.

Reducing future risks of invasive species in the DBS System

The impacts of invasive species on the DBS system must be reduced by (i) exhaustive risk management plans dealing with all human activities that may represent future routes of introduction and transmission and (ii) by identifying the attributes of native communities that promote resilience to invasion.

Interdisciplinary scientific support for the successful implementation of the Sturgeon 2020 Flagship Project in the DBS System

Existing projects and programmes must be coordinated to focus on solving the most important uncertainties and critical questions related to the restoration of the sturgeon populations.

Innovative means to harness water energy in the DBS System

Harnessing energy from water and other renewable sources in a way that does not significantly affect ecosystems is a major issue for the DBS system. Innovative engineering schemes are needed for sustainble energy generation, from the river water flow to the marine waves and currents.

Promoting Cross Border Environmental Stewardship in the DBS System through Citizen Science

Systematic and timely monitoring of large river-sea systems with complex geopolitical histories remains challenging. A number of emerging technologies, including smart-phones and inexpensive sensors which can be widely distributed now provide the framework for effective monitoring of water quality.

Detailed plans and concepts for a new regional research infrastructure in the field of integrated river – delta – sea management in the Danube – Black Sea area are in preparation.

This is an opportune time to address the challenges, identified above, by a cross-disciplinary distributed Research Infrastructure (RI) on freshwater – marine systems. The RI can build upon the world- leading capabilities of the European environmental science community to deliver a step-change in our understanding.

The initiative to develop RI in DBS is further enhanced by the coincidence of:

– Political framework including EUSDR and ESFRI.
– Timeliness of technical advances
– Resource exploitation
– European e-infrastructures initiatives (Geant & PRACE)
– Existence of the GEOSS and the COPERNICUS programmes

It is important to look forward and consider the degree to which the research needs can be addressed by the two new EUSDR flagship research initiatives in the Danube – Black Sea system (River, Delta and Sea). Together these initiatives (DREAM and DANUBIUS-RI) have the potential to provide world-leading facilities that will facilitate inter-disciplinary research and enhanced implementation within the Danube – Black Sea system.

The Human Capital Development Programme

DANCERS proposes a model for a new Danube educational programme that could lead to a better integration of the river-delta-sea management practices. In principle, the new Danube education programme has at its core a pyramid base and approach that aims to address different levels of education. The main aim of such a programme would be to build a network of institutions and develop agreements and mechanisms to facilitate knowledge exchange within the Danube Basin.

The major outcomes of the project will be published in a special issue of the scientific jounral Science of the Total Environment. FP7 DANCERS was funded under the EC Grant no. 603805. The in extenso results of the project were published in the following books, freely available also online (see below):

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JDS 3 from an environmental history and social science perspective – Part II: What the river told us about its socio-natural history

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Introduction

Following a first review of the third Joint Danube Survey (JDS 3) from an environmental history and social sciences point of view (Schmid and Haidvogl 2015), this second and final part discusses selected main results of this basin-wide survey (ICPDR 2015a). Our overall aim is to enrich and broaden the scholarly debate about the current state of the Danube by including long term, socio-ecological perspectives from environmental history. We concentrate on three topics that are also relevant for determining the 'ecological status' of a distinct river section as well as of the Danube river basin (DRB) as a whole according to the EU-Water Framework Directive (WFD):

hydromorphology, fish diversity, and pollution. We suggest interpreting pertinent results from JDS as a body of information not only on the current but also on past socio-natural states of the DRB. We argue that environmental history can help to address the dynamics of the social, cultural, and economic sphere that have caused the current state of the river – the very same state natural sciences observe and assess in important monitoring schemes such as JDS.

The hydromorphological status of the Danube

During JDS 3, hydromorphology and longitudinal connectivity of the Danube were investigated and evaluated based on the type and intensity of human alterations. The assessment used the 5-tiered scheme of the WFD. Following the approach of a "natural reference state", no section of the Danube was ascribed a 'near-natural' state. From an environmental history perspective this is not at all surprising, no one familiar with the region's history would expect river stretches without visible traces of (past) human uses in industrialized regions like the DRB. Along the upper Danube, more than 75 % of sites were classified as 'extensively' or 'severely modified' due to channelization, flood protection, hydropower dams and altered sediment transport. Hydro-morphological conditions are less modified in the lower Danube and in the delta, where more than 40 % were classified 'slightly altered' while only less than 20 % as 'severely' or 'extensively modified'. The middle section is in-between *(see Fig. 1).*

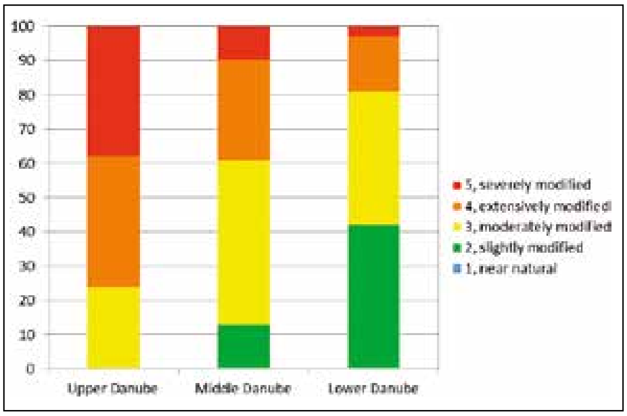

Figure 1. The hydromorphological situation of the upper, middle and lower Danube according to JDS 3 (Source: ICPDR 2015a)

Scrutinizing these findings from a long-term perspective, one has to discuss the role of river section-specific environmental features together with the political and socio-economic history of the riparian Danube countries. In other words: How did navigation, land use, urbanization and flood

Figure 2. The Danube in Vienna around 1837. Schweickhardt v. Sickingen, Perspektiv-Karte des Erzherzogthums Oesterreich unter der Ens

protection as well as hydropower evolve with environmental features along different Danube sections? In-depth socio-ecological studies of the entire Danube are still lacking, but the existing literature allows compiling some indications.

Environmental features of the upper Danube differ significantly from the middle and lower sections. Slope and subsequently velocity are important conditions for a river's navigability. The Danube's gradient drops from up to 1,4 ‰ in German sections to less than 0,1 ‰ in Hungary and even less than 0,04 ‰ in the lower Danube. In general, steeper slopes imply higher riverine dynamics. Thus, regulation works were more urgent in the upper Danube. After the 1830s, steam ships started to operate on the Danube. The larger these ships got, the higher was the water depth they needed. The adverse effects of unstable discharge and especially low-flow conditions on navigation increased. At the same time, new fossil energy sources enabled large-scale river regulation measures. In the 19th century, river channelization projects were subsequently not restricted to the upper Danube. In the middle and lower river sections, particularly the Iron Gates, a series of partly narrow gorges with high velocity, large water depths and dangerous boulders, was a focal point (Gatejel 2016). Larger engineering measures were also undertaken up- and downstream of Budapest and in the delta's Sulina channel. But until the middle of the 20th century, these measures were mainly limited to the construction of a middle or low-flow bed and did not cause a decoupling of floodplain water bodies at higher discharges (Schmid 2013; Lóczy 2007).

What made a difference between the upper, middle and lower Danube in practice was the different pace, scale and intensity of flood protection and, in the 20th century, the development of hydropower. Until the 19th century, land demand along the river was more intensive in Austria or Germany, were urban settlements and agriculture extended directly up to the river banks (see e.g. Haidvogl 2008). This required rather early flood protection measures especially in urban areas such as Vienna *(see Fig. 2)* already in the late 19th century (Winiwarter et al. 2013; Nenciu Posner and Armaş 2014). In contrast, along the middle and lower Danube, flood protection projects and floodplain drainage measures were often implemented only after World War II. For instance, in the 1960s, 5500 km^2 or 72 % of the Romanian floodplains were drained and transformed into arable land, commercial forest plantations and fish farms. In the Danube delta, c. 1000 km^2 were enclosed with polders for agriculture, forestry and aquaculture between 1960 and 1989 (Sommerwerk et al. 2009).

A major difference stems also from the role of hydropower in the different Danube sections. First plans to build hydropower dams in the present Slovakian and Hungarian section date back to the 1910s and thus to the same period when first hydropower projects for the Austrian Danube were developed (Jansky et al. 2004). However, especially in Hungary, 'political and economic turmoil, border and population shifts, and changing usage rights in the period during and between the two world wars hindered the further development and implementation of regulation projects in the middle Danube' (Jansky et al. 2004). Only in the 1960s, old plans for hydropower use downstream of Bratislava and in the Iron Gate *(see Fig. 3)* were revisited and implemented.

Fish diversity of the Danube and the concept of native and alien species

In accordance with the requirements of the WFD, fish serve as an indicator of human pressures in freshwater systems. Appropriate assessment methods have to identify the deviation of the present species composition, abundance and biomass from an assumed natural status without human influence. Based on sound fish ecological samplings, JDS 3 proved a high abundance of non-native and eurytopic species. Altogether, during JDS 3, 25 neophytes, 34 non-native macroinvertebrates and 12 non-native fish species have been found (ICPDR 2015a). In relative terms, the upper river section is more effected by species classified as non-native than the lower Danube, in particular in case of fish, because of the human-induced expansion of ponto-caspic species toward the middle and upper Danube. This indicates the effects of habitat destruction and a successful competition of non-native species against those perceived as native.

From a practical point of view, the use of native species diversity makes inasmuch sense as ecological assessments need some kind of reference point. However, from a historical perspective, such an approach poses several conceptual and methodological questions (Haidvogl et al. 2014). First, fish communities have been and are changing constantly due to shifts of environmental factors. The most prominent example is the ('natural') recolonization especially of warm water preferring fish species after the end of the last ice age, approximately 12,000 BP. Also during the last centuries the distribution and abundance of fish changed with climate,

Figure 3. The island Ada Kaleh around 1900. It was flooded after the opening of the Iron Gate dams. Library of Congress, Prints & Photographs Division, Photochrom Collection

e.g. when average temperatures decreased from a medieval climate optimum to the little ice age from the 13th and 14th centuries onwards – independently from human influences (see e.g. Luterbacher et al. 2016 for a recent long-term study of average summer temperatures; Pont et al. 2015). The effects of temperature shifts overlapped with those from millennia-long human alterations, which is one of the difficulties one encounters when reconstructing 'natural' fish communities. In addition, the differentiation between native and non-native species as main feature of biological assessments can be sometimes more complex than expected. Of course, for most of the Danube's fish species written historical sources and archaeological remains together with biogeographical knowledge support the determination of the native distribution at least when assuming more or less stable climatic conditions. However, there are also species for which this identification is difficult due to lack of information. An example for the Danube is the western tubenose goby *Proterorhinus semilunaris,* for which the distribution before the late 19th century is unclear especially for the middle Danube. Inconsistencies in the identification of the native range are the consequence (see Schotzko & Wiesner 2009, Wiesner et al. 2008). A similar case is Giebel *Carassius gibelio* for which reports of the 18th century for the lower Danube are unclear. As for various species of the Neogobiidae family Giebel seems to have spread towards the middle and upper Danube in and after the 1970s.

A long-term perspective can shed light on another aspect of the present ecological assessment of rivers and their biota. As explained in part I (Schmid and Haidvogl 2015), environmental objectives and concerns depend on specific interests of different societal groups in the river; these interests and thus the mode of perception depend on the socio-economic and cultural context and are thus highly variable over time. For instance, in the 19th century the main aim of experts managing fish populations was to improve fish productivity to supply humans with local and regional fish. Often, alien fish species promised better productivity, also because of an – at least assumed – better adaptation to environmental conditions in rivers which had been systematically altered for navigation, hydropower use or floodplain colonization. Since the late 1970s, a general sensitivity toward environmental change and pollution and in particular the recognition of the large-scale modification of rivers and their biota initiated a focus on conservation and restoration in river management. In accordance with the 'paradigm of an equilibrium' (cp. Schmid and Haidvogl 2015), ecologists and biologists nowadays favor a certain group of species (the so called 'native') while they are concerned against others (the non-native and/or invasive). Such action is not always based on detailed evidence about the effects non-native species (might) have on the native ones, thus such interactions need further studies as emphasized by ICPDR (2015b).

Pollution as a long-term problem: The legacies of polluted soils

During JDS water quality was investigated in terms of organic matter and nutrients input as well as in terms of hazardous substances released especially by industrial activities and agriculture.

Diffuse input of nutrients, herbicides and pesticides from the agricultural sector, which was rapidly industrialized after World War II all over the DRB (although with regional differences), is currently a main reason of water pollution and difficult to control and manage. Another source of water pollution is the industrial sector including mining activities. The communist era was characterized by planned economies stuck to classical heavy industries and in general to inefficient use of resources (Harper & Turnock 2002). Only little effort was put into sewage collection from industries and communes and their treatment. In addition, for the middle and lower Danube catchment the aftermath and long-term environmental costs of the Balkan Wars deserve more attention (e.g. UNEP – OCHA 2000). Environmental legacies of soil contamination in a more distant past are not yet addressed sufficiently in scientific studies. But two examples stemming from the more recent past can highlight the risk from such pollution sources.

On the evening of January, 30th, 2000, a tailings pond burst at a facility near the city of Baia Mare, Romania, which was reprocessing old mining tailings and re-depositing the waste sludge into a new tailings pond (Harper 2005). This led to approximately 100 000 m^3 of wastewater containing up to 120 tons of cyanide and heavy metals, which were released into the Lapus River, the Somes and Tisza rivers in Hungary before entering the Danube. On March 10th, 2000, another tailings dam burst in Baia Borsa in the same region close to the Ukrainian border. While some of this material was retained within the dam complex, 20 000 tons of sediments were released into the Novat River, a tributary of the Viseu and Tisza rivers. Baia Mare is a region of particularly intensive industrial development and this led to several incidents. Macklin et al. (2003) have studied the environmental legacies in the area and found an unexpected high rate of heavy metals in the sediment showing that the concentrations of heavy metals are long-standing. Spills are dangerous but the environmental problems in the area have not arisen in recent years. They have a much longer history as Macklin et al. (2003) conclude: "… more widespread contamination is clearly arising from ongoing mining activity in the Cavnic, upper Lapus, Sasar and Tisla catchments. While not downplaying the short term ecological effects of the spills, they should be seen more as compounding much longer term problems associated with many decades of poorly regulated, and largely untreated, industrial, mining and urban discharges into local rivers." (Macklin et al. 2003, p 256; see also Winiwarter 2013).

Pančevo, a small town in Serbia situated approximately 20 km northeast of Belgrade has a large industrial complex with petrochemical industry and a nitrogen fertilizer company. It has become infamous for 250 tons of liquid ammonia spilled into the Danube during the Balkan wars. This was not a direct consequence of military attacks but a preventive measure. A direct air strike on stored ammonia could have killed large numbers of people. “This release was probably responsible for fish kills reported in the Danube, up to 30 km downstream” (UNEP 1999).

While details about the two events described above are known, a heritage of a considerable number of former mining and industrial sites in the Danube catchment and in its floodplains remains largely unknown and difficult to reconstruct, e.g. because the sites have been closed decades ago and no detailed records are available (UNEP-Balkan Task Force 2009). Acknowledging the legacies of past economic activities and the subsequent environmental risk, river managers have started to compile major accident risk spots and the calculation of Water Risk Indices (ICPDR 2015b).

Conclusions

In this part of our review of JDS 3 we have used results of the survey to show how an interdisciplinary oriented, long-term perspective – as offered by environmental history – contributes to a more comprehensive interpretation of results of ecological assessments. The present hydromorphological state of different sections of the Danube or the level of water pollution reflect the history of the various regions and the changing patterns of how riparian human societies interacted with the river. Also, present biodiversity has a history as it is composed of recent and long-term fluctuations of the natural environment and to an even greater extent by human uses of the river and its floodplains. History can help to raise awareness of the consequences of our basic conceptions of nature, as in the case of ‘native’ and ‘non-native’ fish. This is not to blame the concepts of conservationists or to argue that they are obsolete. It rather shall initiate a reflection upon the time-dependence of the ways we perceive, use and modify rivers like Danube.

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European aquatic carnivorous *Utricularia* species – record-holders, but vanishing beauties of our nature

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Bladderworts *(Utricularia, Lentibulariaceae),* with at least 240 species, represent the most numerous genus of carnivorous plants. Out of these, ca. 60 species are aquatic or amphibious; they all are rootless. Seven aquatic species (*Utricularia australis, U. vulgaris, U. minor, U. bremii, U. intermedia, U. ochroleuca, U. stygia)* grow in Europe and can be found – more or less commonly – in the whole Danube watershed in all Danube countries.

Why are these plants so remarkable?

For all aquatic Utricularia species it is characteristic to bear 1–5 mm large suction traps in the form of hollow bladders, which form a negative pressure inside the traps and suck in their prey (small animals) into their deadly traps. European species are submerged or amphibious plants with thin, flexible linear stems 10 cm to 2.5 m long, bearing regular leaf nodes with dissected, filamentous leaves with numerous traps. Some species have non-differentiated shoots joining the photosynthetic and carnivorous function but the other species have distinctly differentiated green photosynthetic and pale carnivorous shoots with traps *(Figs. 1, 2)*. European Utricularia species usually grow in shallow standing, dystrophic (humic, i.e., brownish), nutrient-poor waters with elevated CO_2 concentration: in lake and fishpond shorelines, floodplain backwater pools and oxbows, peatbogs, fen lakes, and also in shallow sand-pits. They grow typically in loose reed or sedge stands. In these barren waters, carnivory is an additional ecological strategy to gain the growth limiting N, P and K from animal prey. Except for very common U. australis, the other species declared as strongly or critically endangered are demanding on their habitat factors. They all do not tolerate eutrophication, polluted waters, but mainly drying out of the site. Thus, their natural occurrence can indicate unpolluted waters with a stable hydrology. Moreover, three species (U. intermedia, U. ochroleuca, U. stygia) can only grow in peatbog or fen lakes – very rare and threatened habitats nowadays.

Physiological world records

Negative pressure of -0.16 to -0.25 bar is formed inside traps of European Utricularia species and during trap opening, water is sucked in during only 3–4 ms. This represents the fastest movement in the plant kingdom at all! There is permanent anoxia inside the deadly traps and preys caught die of suffocation. Moreover, in all traps, microbial symbiotic (commensal) communities (bacteria, ciliata, algae, rotifers) live, form a miniature food web, and help the traps to digest the caught prey. Under favourable conditions, the apical growth of their linear shoots is very rapid and can attain 2–4.5 new leaf nodes/day, while the basal shoot segments age and die at the same high rate. Also as a result of rapid propagation by branching the main shoots, the total plant biomass can double in only 6–12 days. A need for very rapid cell divisions associated with very rapid apical shoot growth probably led to genome

Figure 1. Very common Utricularia australis with monomorphic shoots can grow in different habitats Credit: Adamec 2016

Figure 2. Very rare U. intermedia with differentiated shoots grows only in peatbogs and fens. Its traps can be 5 mm large Credit: Adamec 2016

Figure 3. A shallow sand-pit pool near Suchdol nad Lužnicí, S Bohemia, Czech Rep., hosts native U. australis and introduced very rare U. bremii and carnivorous Aldrovanda vesiculosa (water-wheel plant, Wasserfalle) as a successful case that extracted sand-pits can create favourable habitats for endangered aquatic plants Credit: Adamec 2016

miniaturization – some species have minimal genomes as compared to other plants. The record rapid apical shoot growth requires several ecophysiological adaptations to be met: high photosynthetic rate, very efficient reutilization (recycling) of N and P from aged shoots, very effective mineral nutrient uptake by shoots from the ambient water and mineral nutrient gain from carnivory. Although all Utricularia species fix only free CO_2, their high net photosynthetic rate represents a world record among aquatic plants. The high photosynthesis is not only needed to cover the rapid plant growth and high respiration rate of traps, but also to support trap microbial communities by secreting great amounts of organic substances (sugars, organic acids) into the traps. Due to high photosynthesis and attaining the rapid growth, all aquatic Utricularia species require high CO_2 concentration of >0.1-0.5 mM in the water, whereas the concentration is usually one order of magnitude lower due to algal photosynthesis in eutrophicated waters.

Figure 4. Translucent traps of Utricularia stygia traps filled with organic detritus containing precipitates of humic acids and remains of algae. It is considered that traps can utipise a part of the nutrients for plant growth.

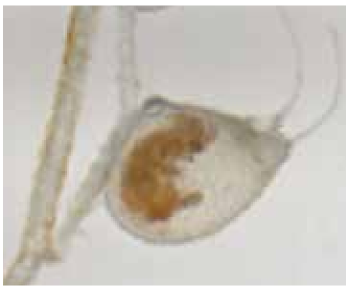

Figure 5. Utricularia stygia trap which had caught a macroinvertebrate prey (probably tiny insect larva)

The European Utricularia species usually do not produce dense stands at their sites, and except *U. australis,* they all are listed as strongly or critically endangered or as extinct species according to national floras in many countries. Also due to their remarkable characteristics, they all merit conservation *(Fig. 3).*

Figure 6. Winter buds (turions) of Utricularia vulgaris are round-shaped, condensed storage organs (numerous individual leaves sitting on an extremely shortened axis), size up to 25mm. Usually they overwinter on the bottom of water bodies, while the rest of shoots decays during the winter period. In the spring time, turions rise to the water surface, where higher light intensities and warmer water are available.

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Highlights of the 41st IAD conference "Tributaries as Key Elements in Sustainable Management of the Danube River Basin" and the CEEPUS Network

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The IAD would like to thank the organizers of the 41st international IAD conference held at the "Lucian Blaga" University of Sibiu, Romania, Angela and Doru Banaduc, and their team for the perfect organization and the great time all IAD members enjoyed.

From 13th to 16th September, 2016, more than 60 scientists and representatives of the Danube River Basin have met in Sibiu at the 41st international IAD conference with the guiding topic "Tributaries as Key Elements in Sustainable Management of the Danube River Basin". There was general agreement that research is the basis for environmentally sound and sustainable decisions by managers and politicians. IAD as a well-established network of experts active since 1956 in the Danube region can bridge the gap from science to management and implementation, mainly lying within the responsibility of the ICPDR, where the tools for the implementation of the EU WFD and the new EU Danube Strategy are elaborated.

At the conference topics ranging from biodiversity, connectivity, ecosystem functions, ecosystem services, climate change effects, restoration, and management with special emphasis on the WFD, had been addressed in more than 70 presentations. The political dimension and implication for the Danube Region had also been discussed by high level representatives from Hungary and the EUSDR. The keynote lectures covered the role of biological water quality elements, the use of water resources, the EUSDR and the status of the sturgeon in the Danube River System. Topics of the scientific sessions presented during the week ranged from significant water management issues in the DRB, like various aspects of pollution and hydromorphological alterations and experiences in the WFD assessment, to issues addressed in the EUSDR priority areas 1, 2, 4, 6 and 7.

The 41sth international IAD conference is well in line with the successful past of 60 years of IAD and highlighted the sensitive issues with regard to the Danube and its tributaries as key elements and future challenges for particular sub-catchments and their contribution to the whole region. The worldwide dimension of global change including temperature increases, alteration in hydromorphology, hydropower development, eutrophication and invasive alien species are some of the selected topics presented at the conference. A key effort for the future is the consideration of sustainable development of society, including economic, ecologic and social aspects of development and environmental history as tools to meet these challenges by understanding the past and integrating societal and economical aspects in sustainable development perspectives. Still, the interplay of ecology, economy and social aspects is not addressed in equal manners in current management approaches. Thus, new scientific approaches and more interaction with stakeholders might be needed to bridge these gaps. A resolution based on the results of the conference was approved and has been published on the website of IAD (www.iad.gs).

Further details can be found on the website of the organizers (http://conferences.ulbsibiu.ro/conf.iad/html/index.php). Printed copies of the extended abstracts and the book of abstracts are available from the organizers at the "Lucian Blaga" University of Sibiu.

The new CEEPUS network in aquatic ecosystem research and management had started in 2016.

A new umbrella network within the CEEPUS (Central European Exchange Program for University Studies) program started in 2016/17. The CEEPUS program „EcoResNet - Aquatic ecosystem research: interdisciplinary challenges and management issues in inland waters and coastal environments and their catchments", involves 14 universities and six additional academic partners from nine countries in educational activities in the field of interdisciplinary aquatic ecosystem research. The CEEPUS is built on existing networks for scientists like the IAD (International Association for Danube Research, www.iad.gs) as well as on the university network CASEE. Topics are well in line with targets of successfully established EUSDR flagship projects such as conservation of endangered species, exploring sustainable ecosystem service and sustainable development by enhanced interdisciplinary and participative cooperation, developing innovative research infrastructure to meet future challenges in the field. The majority of the states with partner universities in the Danube region already support a diversity of programs related to aquatic sciences and river basin management in the field of natural and engineering sciences as well as environmental humanities, in particular environmental history. Recent EU projects (EU FP7 project Dancers) identified major short comings in joint programs related to integrated river basin management for example. As pointed out in literature there is no coherent network related to training in aquatic sciences, water management and sustainable development in South East Europe. Progress in addressing the multi-layered environmental challenges within the Danube River basin and adjacent regions, including issues related to floodplain management and research also in sites outside the Danube River basin requires further aligning of economic, environmental and educational policies, advancing the EU Bologna Process across the region, and the development of dedicated training programs that combine technical and relational skills and foster a broader cooperation between research and educational institutions.

CEEPUS Objectives in a nutshell

The CEEPUS network aims to address major challenges for inland and coastal waters and their management in East and South East Europe by an enhanced interdisciplinary cooperation of universities and research institutions in the frame of EUSDR initiatives and well- established scientific networks as well as intensified collaboration with various stakeholders regarding the key issues outlined in the Danube River Basin Management Plan as well as for other river basin of partners in the network, and to improve the scientific excellence in the region. A key aspect of the CEEPUS network will be to support activities and aims of several EUSDR flagship projects (Danube:Future, Danubius-RI, DREAM and Sturgeon2020).

More detail about the network and the mobility activities can be found at this link: https://www.ceepus.info/public/network/network.aspx#nbb (CIII-AT-1101-01-1617 Umbrella network EcoResNet). Coordinator: Thomas Hein at BOKU – University of Natural Resources and Life Sciences, Institute of Hydrobiology and Aquatic Ecosystem Management, Vienna, Austria

News and Notes

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Following the decision of the Jury the Austrian Committee 'Danube Research' (AC-IAD) donated again the 'Reinhard Liepolt Award for Danube Research' (RLA). Laureates of the call 2015 (awarded: Sept. 2016):

- Aaron Lechner – Shoreline configurations affect dispersal patterns of fish larvae in a large river (Lechner et al. 2014, ICES Journal of Marine Science. Doi:10.1093/icesjms/fst139 [RLA]; (and other Danube related publications)
- Domenico Savio – Bacterial diversity along a 2600 km river continuum (Savio et al. 2015, Environmental microbiology 17, 4994-5007 [RLA];

Scientific Appreciation Award – Diploma/Master Theses [SAA-RLA]:

- Markus Anibas – Choriotop-Analyse an der Donau – Schotterbänke im Einflussbereich des Kraftwerks Freudenau – 15 Jahre nach dem Einstau (Choriotope-Analysis at the Danube – Gravel banks influenced by the Hydro-Power Plant Freudenau 15 years after impoundment) [SAA-RLA];
- Nadine Ebm – The diet of *Neogobius melanostomus* (Pallas, 1814) in the area of hydropower plant Freudenau (Danube River) [SAA-RLA].

Special achievements award AC-IAD:

- Georg A. Janauer was awarded the 'RLA in recognition of long-time special achievements in the field of limnological research of the Danube River'.

On behalf of the IAD Board Meeting held in Sibiu at the 41st IAD Conference

Two new country representatives have been approved during the IAD board meeting in Sibiu and are welcomed in the IAD board:

- New Czech country representative: Dr. Petr Paril, affiliated to the Masaryk University Brno, following Prof. Jan Helesic
- New country representative of Romania: Dr. Eng. Grigore Baboianu, present-day Governor of the Danube Delta Biosphere Reserve, following Prof. Dr. Marian-Traian Gomoiu.

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Hydrological catchment of the River Danube

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