43rd IAD Conference

Rivers and Floodplains in the Anthropocene: Upcoming Challenges in the Danube River Basin

June 9 – 11, 2021

– Proceedings –

Edited by:

Aueninstitut Neuburg/Donau
Schloss Grünau
86633 Neuburg/Donau
Germany
aueninstitut@ku.de

Preface

Dear Participants of the 43rd IAD Conference,

Living in pandemic time it is not easy to organize an international conference. However, such conferences are very important for the scientific community, especially if this community is so diverse regarding countries and topics as IAD is.

This year, IAD celebrates a special event: 65 years since its establishment and its continuous presence in limnological research in the Danube River Basin. For many decades, IAD was among the very few scientific fora ensuring connectivity between the Western and Eastern research teams, facilitating knowledge exchange, as well as joint projects and publications in the region.

The IAD Conference always was a 'jour fixe' to meet colleagues of the IAD family from the entire Danube Basin. However, this year we have to celebrate IAD anniversary in a virtual way, as unfortunately, it is still not possible to meet personally due to the particular situation of our countries, with lockdowns and travel restrictions still in place.

Our hope is that the upcoming event – carried out as an online conference – can at least partly substitute the usual way of meeting and foster active exchanges between the participants.

The number of registered participants, over 100 persons, makes us hopeful! Furthermore, there are 41 presentations (39 oral and 3 posters) which show the wide thematic range on the one hand, and the interest of the scientists working within IAD to present their work on the other hand. Additionally it proves the interest of all of us to listen to the latest scientific developments in aquatic ecology research in the Danube Region.

We hope that this 'special' conference will be successful and interesting for IAD and will represent the transition to normal times in the future!

Cristina Sandu (President of IAD)

Bernd Cyffka (Head of Conference)

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Detailed Conference Programme

Pre-conference events, 8 June 2021 (Tuesday)	
13:00 h	IAD Board Meeting (board members only)
16:00 h	Technical consultation session (testing presentations etc.) (until about 18:00 h)

Conference, 9 June 2021 (Wednesday)	
09:00 h	Welcome speeches: – PROF. DR. BERND CYFFKA (Head of Conference) – DR. CRISTINA SANDU (IAD President) – PROF. DR. GABRIELE GIEN (President of CU Eichstaett-Ingolstadt) – PETER VON DER GRÜN (Head of District Neuburg-Schrobenhausen) – PROF. DR. MARTIN GRAMBOW (Bavarian State Ministry of the Environment and Consumer Protection)
09:55 h	*Zoom rules / technical arrangements*
10:00 h	Keynote speech: **Back to the wilderness – a vision?, Prof. Dr. GREGORY EGGER**, Karlsruhe Institute of Technology
10:45 h	*Coffee break*
11:00 h	***Anthropocene/Strategies*** *– Convenor: Bernd Cyffka* – BLOESCH J. & JANAUER G.: Expert debate: Floodplains and Oxbow Lakes in the context of science, politics and law – IONITA M. et al.: Danube River discharge under climate changes – trends and future projections – KORCK J. et al.: River basin management in transition: The new Bavarian integrated strategy for river development – SCHWARZ U. & LAZOWSKI W.: The Alpine Carpathian River Corridor
12:20 h	*Lunch break – break filler presentation*
13:05 h	***Floodplain and Floodplain Restoration*** *– Convenor: Barbara Stammel* – KÜGEL B.: River and Floodplain Restoration on the upper Danube by re-establishing river continuum and ecological flooding – TAMÁS E. et al.: Hydrological indicators of the riverbed incision along the free-flowing Danube River reach from Budapest to Slankamen relevant for the lateral connectivity between the river channel and floodplains – TÓTH P.: Floodplain evaluation matrix (FEM) application for Hungarian section of the Tisza River – ZAMFIR A.G.: Human impact on the Lower Sector of Jiu River Floodplain
14:25 h	*Coffee break*
14:40 h	***Ecosystem Services –*** *Convenor: Thomas Hein* – TSCHIKOF M. et al.: Can multi-functionality of floodplains be restored? An analysis of regulative and cultural ecosystem service synergies and trade-offs – PUSCH M.: Ecosystem services of an impounded navigable river (Lahn, Germany) – PEROSA F. et al.: The role of floodplains for flood mitigation and enhancement of ecosystem services in the Danube – NATHO S. et al.: Nutrient retention in the Danube Floodplain National Park – how much lateral connectivity is needed for an observable reduction of nutrient loads?
16:00 h	*Coffee break – Gather Town Instructions*
16:15 h	***Miscellaneous –*** *Convenor: Florian Betz* – MOUSAZADEH H.: Content analysis challenges of Danube river basin in the perspective of Anthropocene: A qualitative study – IVANOVA-RADOVANOVA P.: Determining high quality landscapes in support of environmental planning at local and community level
17:00 h	**Gather Town – movies & discussions**

Conference, 10 June 2021 (Thursday)	
09:00 h	Keynote speech: **The Rhône, a transdisciplinary laboratory of integrative riverine sciences, Prof. Dr. HERVÉ PIÉGAY**, University of Lyon
09:45 h	***Water Quality*** *– Convenor: Cristina Sandu* – TEUBNER K. et al.: New Emphasis on Water Clarity as Socio-Ecological Indicator for Urban Water – ĐORĐEVIĆ J. et al.: Genotoxicity assessment of Danube River: in situ and in vitro methods – JOVANOVIĆ MARIĆ J. et al.: Mapping of the microbiological water quality of surface waters in Serbia overlooked by the National monitoring programme – KIRSCHNER A. et al.: Occurrence and spread of human-induced antimicrobial resistance in a large river water system: developing a holistic picture based on the Joint Danube Survey 4 activities
11:05 h	*Coffee break*
11:20 h	***Makrophytes and Wetland Plants*** *– Convenor: Katrin Teubner* – OZIMEC S. & ROŽAC V.: A retrospective of ten years of the botanical exploration in Nature Park Kopački Rit (Croatia) – GERM M. et al.: Distribution and abundance of macrophytes in the Ižica River in the years 1996, 2000 and 2016 – NOVKOVIĆ M. et al.: Relationship Between Water Quality and Macrophyte Assemblages in Seasonal Wetlands along the Danube River in Serbia – DOROFTEI M. et al.: An alternative in monitoring invasive plant species in wetlands – CVIJANOVIĆ D. et al: A role of habitat complexity generated by macrophytes and hydromorphological attributes for the recovery of commercial fish stock in the free-flooding Middle Danube wetlands (Serbia)
13:00 h	*Lunch break – break filler presentation*
13:45 h	***Flood and Flood Risk I*** *– Convenor: Attila Lovas* – DOBÓ K.: Developments on the protected side – DROBOT R. et al.: Best Operation rules of Stanca-Costesti reservoir on Prut River during exceptional floods – MIHALJEVIĆ M. et al: Extreme floods of the Danube in 2013 – track changes of the ecological state of the river applying the phytoplankton assemblage index
14:45 h	*Coffee break – Gather Town Instructions*
15:00 h	***Poster presentation via Gather Town*** *– Convenor: Florian Betz; (10 minutes per poster plus short discussion)* – KOLLER M. et al.: Non-wild type antibiotic resistant *Escherichia coli* in the River Danube: a six-year-comparison – LEOPOLD M. et al.: A comprehensive, quantitative study concept on the occurrence and spread of human-induced antibiotic resistance in Lower Austrian rivers – SCHACHNER I. et al.: Extent and origin of fecal pollution in water and biofilms along the Danube River
16:00 h	**General Assembly of IAD, Chair: Cristina Sandu (IAD President) (seperate Zoom link!)**

Conference, 11 June 2021 (Friday)	
09:00 h	***Flood and Flood Risk II*** *– Convenor: Georg Janauer* – PRÁVETZ T. et al.: Problems with the water conveyance capacity and the possibilities of improving it along the Hungarian Middle Tisza River section based on a pilot area – VIZI D.B.: Floodplain restoration with dyke relocations in the Middle Tisza District, Hungary – KEVE G.: Useful method in fluvial ice monitoring
10:00 h	*Coffee break*
10:15 h	***Aquatic Biota I*** *– Convenor: Teodora Trichkova* – EVTIMOVA V. & FRUMENTO P.: Characterisation of water levels in the Lower Danube River and their association with primary production – EVTIMOVA V. et al.: Mayflies, stoneflies and caddisflies (Arthropoda: Insecta) from the Lower Danube River – MEULENBROEK P. et al.: Fish eDNA survey on the major tributaries of River Danube – PENGAL P. et al.: In search of elusive sterlet (*Acipenser ruthenus*) in Slovenia
11:35 h	*Coffee break*
11:50 h	***Aquatic Biota II*** *– Convenor: Georg Janauer* – TRICHKOVA T. et al.: Invasive alien species in the Danube River Basin: Results of the JDS4 – HROMOVA Y.: Zooplankton of different types of water bodies in the Danube delta – EGRI A. et al.: Beacon lights for the protection of night-swarming mayflies
12:50 h	Wrap-up of Conference and closing remarks: Cristina Sandu & Bernd Cyffka
13:00 h	End of Conference

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Expert debate: Floodplains and Oxbow Lakes in the context of science, politics and law

Jürg BLOESCH[a], Georg JANAUER[b],*

[a] Emeritus Eawag-ETH Dübendorf, Stauffacherstrasse 159, 8004 Zürich, Switzerland
[b] Ao.Univ.Prof.ret., Sen. Lecturer, University of Vienna, Department of Limnology and Bio-Oceanography, Althanstrasse 14, 1090 Wien, Austria

** Corresponding author: juerg.bloesch@emeriti.eawag.ch*

This article exemplifies the controversy in river protection addressing dynamic floodplain side arms (lotic) and standing oxbow lakes (lentic) with specific reference to the Danube River Basin (DRB). The respective expert debate was provoked by the different goals of the EU Water Framework Directive (WFD) and the EU Nature Directives (Birds Directive and Habitats Directive, BHD). The scientific facts, i.e. ecosystem function, including abiotic components and biota, and different types of ecosystems as well as natural or near-natural reference state, are the basis for any decisions just as the management perspective and the pragmatic political compromise of how to implement different EU Water Directives for protecting aquatic ecosystems.

In a natural river course, from its source to its mouth, great morphological heterogeneity is reflected by large habitat variability and biodiversity in any of the various typical zones. The precarious situation of rivers in the Anthropocene apparently is a tremendous lack of space needed for natural river discharge dynamics, even increased by climate change effects. Many river constructions caused irreversible alteration of the aquatic ecosystem. Designated as Heavily Modified Water Bodies (HMWB) in the WFD these rivers fall under the category of "Good Ecological Potential". A healthy river features good water quality and intact morphological structures. While in the Upper Danube clean water is running in regulated channels, polluted water is running in more intact channels in the Lower Danube. However, neither one is a totally-well functioning ecosystem. Floodplains, including connected lotic side arms and partly cut off lentic oxbow lakes (meander loops), are specifically subject to, and dependent on seasonal discharge fluctuation and groundwater flow.

It comes as no surprise that hydromorphological alteration is one out of four significant water management issues (SWMI) in the DRB. From both an ecological and economic perspective, the general management concept should be: conservation first, restoration second. While the WFD supports the restoration of rivers by increasing natural flow dynamics and floodplains, the BHD aims to conserve oxbow lakes and their biota. However, both are important elements needing respective care and protection to maintain overall river system functions. In other words, river basin management should be achieved by a "both … and" solution rather than an "either … or" solution of competitive character. This should be in full agreement with the overall WFD and BHD requirements. In a political context, this means to leave the WFD and BHD in their original state, but possibly create an Amending Directive, which may resolve the discrepancy between river dynamics and lentic communities and may achieve the aim of "Good Ecological Status" or "Good Ecological Potential" (WFD) and "Favourable Conservation Status" (BHD) as well.

Danube River discharge under climate changes - trends and future projections

Monica IONITA[a], Cristina SANDU[b], Cristina TRIFU[c], Mirjana LENHARDT[d], Viorica NAGAVCIUC[a]*

[a] Alfred Wegener Institute, Bremerhaven, Germany (Department, University, City, Country)
[b] International Association for Danube Research, Vienna, Austria
[c] National Institute for Hydrology and Water Management, Bucharest, Romania
[d] Institute for Multidisciplinary Research, University of Belgrade, Republic of Serbia

** Corresponding author: sanducri@yahoo.com*

The impacts of climate change encompass increasing air and water temperatures, glaciers melting, altered precipitation and river discharge regimes, as well as higher frequency and intensity of floods and droughts. These impacts became increasingly visible in recent years, affecting more and more aquatic ecosystems. Besides the direct effect on aquatic biodiversity, these changes impact also the services provided by aquatic systems to human society, such as provisioning of drinking water, food, oxygen, regulation of atmospheric composition, mitigation of floods/droughts, recreation, as well as water use (water abstraction for households and agriculture, navigation, hydropower, tourism, etc.), thus having also social and economic effects.

The Danube, the second largest river in Europe, crossing the territory of 10 countries and supporting a large human population with its services, plays a major role in Central and Eastern Europe It is a key part of the natural, cultural, social and economic heritage of the region. As other European rivers, the Danube is also affected by climate change, experiencing severe floods as well as prolonged droughts, impacting aquatic communities and reducing its capacity to provide ecosystem services and water uses. A preliminary analysis of monthly discharge in different sectors has shown that in the past century almost all gauging stations along the main course of the river recorded a decreasing trend, especially in summer. The most affected region is the lower sector of the Danube River.

The regional climate scenarios for the Danube River Basin reveal that the impacts will aggravate in the future: in the Upper part, the wet regions will become wetter, while in the southern part, the dry regions are expected to become drier. Future climate projection, under the Representative Concentration Pathway (RCP) 4.5 and 8.5 indicates that the precipitation and runoff in the lower part of the Danube River Basin will decline progressively with global warming. Significant changes are expected to occur in the seasonal precipitation distribution, with summer months to become drier (up to -58%) and winter months wetter (up to +34%); moreover, the intensity and frequency of extreme weather events are also expected to increase (ICPDR, 2018).

The predicted evolution of Danube River discharge and rainfall regime in the catchment area provides useful information to water managers and stakeholders involved in agriculture, hydropower operation, nature conservation, navigation, flood prevention, and tourism. They can adopt integrated strategies aiming to increase the resilience of the Danube River and reduce the ecological and economic impact of climate changes. This preliminary analysis aims to provide a glimpse of the expected impacts on Danube discharge and trigger the elaboration of a more detailed investigation at basin wide level, including major tributaries, as well as the elaboration of an adaptation strategy on water uses in the Danube River Basin.

River basin management in transition: The new Bavarian integrated strategy for river development

Jane KORCK[a], Martin GRAMBOW[a], Klaus ARZET[a], Dieter RIEGER[a], Wolfgang RIEGER[b], Tom HENSCHEL[b]*

[a] Bavarian State Ministry of the Environment and Consumer Protection, Munich, Germany
[b] Bavarian Environment Agency, Augsburg, Germany

** Corresponding author: jane.korck@stmuv.bayern.de*

In a so-called “Fitness Check” for the key European water related Directives, the European Commission recently concluded that both the Water Framework Directive (WFD) and the Floods Directive (FD) are “fit for purpose, with some scope to improve”. The Commission also assessed whether the Directives are suited to facing future challenges, such as “climate change, water scarcity and pollutants of emerging concern (e.g. micro-plastics and pharmaceuticals)” – all hallmarks of the Anthropocene. This was found to be the case, as long as Member States continually adapt and enhance their approaches as the dynamic situation evolves. Actions at different levels – local, national, international – indicate that this message has been understood by many. However, the pressures of the Anthropocene are mounting and the time, resources and knowledge needed to adequately protect and where possible restore our rivers and floodplains will clearly exceed estimates made in the past.

In this light, the federal State of Bavaria is now taking another important step forward: The new Bavarian integral strategy for river basin development sets out to provide a long-term effective response to a wide range of water-related challenges. The aim is to balance and harmonise ecological, economic and social aspects of river basin management planning in order to focus on the implementation of holistic measures, anchoring the fundamentals of Integrated Water Resources and Flood Risk Management even more firmly in day-to-day water management. The initial focus is on the immediate future until 2030, whilst also preparing the ground for the decades that follow. The new strategy comprises three central “pillars”: I) flood protection and prevention – II) water issues and ecology and biodiversity – III) water issues and social and recreational benefits. The latter is already set to receive increasing attention in the future, as the importance of access to green spaces for the population’s mental and physical health has become widely recognised in the context of the global pandemic. With a systematic approach that builds on early best practice examples (i.e. Isar-Plan, WertachVital, . . .), the three pillars will be combined within integrative planning concepts and projects, e.g. the development of natural floodplains, which ensures flood retention on the one hand but also an improvement of ecology, water balance and habitats on the other. In accordance with the principles of "good governance", the programme also includes a commitment to improve target group specific (risk)communication and continually build on a wide and growing knowledge base, integrating input from NGOs, practitioners and administration as well as involving stakeholders in the implementation of measures on the ground. This way, the new strategy will allow the best possible use to be made of existing and potential synergies between the WFD, the FD and the “Nature Directives” with a vision that goes beyond all three to ensure that the challenges of the Anthropocene that are impacting our river basins can be met in the long term.

The Alpine Carpathian River Corridor

Ulrich SCHWARZ[a], Werner LAZOWSKI[b]*

[a] TB FLUVIUS, Vienna, Austria
[b] TB Ökologie, Vienna, Austria

** Corresponding author: Ulrich.Schwarz@fluvius.com*

Transboundary ecological connectivity has become an important issue, relevant for planning and conservation measures. Any argumentation for it, sometimes as part of political discussions, often uses some model projects, mainly to exemplify the meaning of connectivity in space and functionality. In some cases transboundary not only means a going beyond geographical or state borders, but also seeing broader scopes of nature, natural ecological units and landscapes.

One of these contemporary projects is the Alpine-Carpathian Corridor (ACC) at the border of Austria and Slovakia. The corridor first was developed as a classical wildlife corridor. But as he comprehends both land and water ecosystems, in particular wetlands and river floodplains, cultural landscapes, lowland and mountain woods, steppe vegetation stands and sandy dunes, its very importance became clear. In this sense ecological connectivity is a means of preserving biological, spatial and ecological diversity. Now the concept of the Alpine-Carpathian Corridor is aiming at its integration into spatial planning and an overall improvement of landscape functionality (WWF 2008).

Further project steps are focusing on running water corridors and their surroundings within the ACC, because of their importance in building up the natural structure of the concept. So the Alpine-Carpathian Corridor is characterized by a manifold of riparian landscapes, including the Danube, its tributaries in Lower Austria, and some tributaries of the Morava river in Slovakia. So, e. g. the Schwechat and Fischa catchment areas origin in the Vienna Woods and pass through the southern part of the basin of Vienna to the Danube. Alpine River characteristics and groundwater influences respectively are making their running waters unique. In the Záhorie Lowland extensive brooks like Myjava, Rudava and Malina are stretching between the Small Carpathian Mountains and the Morava river floodplain, by connecting sandy biotopes, mires and various types of forests.

While Danube and Morava rivers, representing the main axes of the ACC, have been long term research and conservation objects (National park, Ramsar sites, Natura 2000 areas), the smaller tributaries alongside were no important subjects of ecological analyses so far. In the last decade land use patterns within the ACC have been analysed, at last leading to the implementation of green bridges over highways. Now the current project has to analyze the status of the running water and floodplain corridors, especially their potential for connectivity, flood protection and ecological restoration. The work focuses on more than 130 floodplain areas (including some complexes with several smaller parts), of which around 40 floodplain objects are probably of great importance for nature conservation in each country, and additionally at least 50 presumeable restoration areas.

River and Floodplain Restoration on the upper Danube by re-establishing river continuum and ecological flooding

*Benno KÜGEL [a]**

[a] Bavarian State Office for Water Management and Catholic University of Eichstaett-Ingolstadt, Germany

** Corresponding author: benno.kuegel@wwa-in.bayern.de*

The upper Danube and its floodplain lost natural dynamic and river continuum in the 19th and 20th century due to river regulations. Consequently groundwater fluctuations and flooding events declined. Additional, hydropower dams are preventing migration of aquatic organism and caused a loss of stream habitats. Measures have been taken to improve river continuum, flood dynamic and groundwater variation. Three major measures have been performed to enhance ecological conditions in the largest remaining alluvial forest with 2.100 hectare between Neuburg and Ingolstadt on the German Danube: 1. Construction of an eight km long river system bypassing Bergheim hydropower dam in order to create new stream habitats and to provide length and lateral connection. 2. Frequent controlled ecological flooding of the alluvial forest. 3. Artificial changes in groundwater table to support flood plain vegetation.

Total investment of the project was 15 Mio. € including a 1 Mio. € monitoring of the aquatic system and of the floodplain forest to evaluate the efficiency of the taken measures.

Hydrological indicators of the riverbed incision along the free-flowing Danube River reach from Budapest to Slankamen relevant for the lateral connectivity between the river channel and floodplains

E.A. TAMÁS [a], D. ĐORĐEVIĆ[b], B. KALOCSA[c], A. VUJANOVIĆ[d]*

[a] *Faculty of Water Sciences, National University of Public Service, Baja, Hungary*
[b] *Faculty of Civil Engineering, University of Belgrade, Belgrade, Serbia*
[c] *Palustris Co., Baja, Hungary*
[d] *Institute of transportation CIP Ltd, Belgrade, Serbia*

** Corresponding author: tamas.eniko.anna@uni-nke.hu*

Hydrological regime plays a primary role in the sustainable management of floodplains, as floodplain ecosystem dynamics and balance are largely based on the dynamics of the flow regime of rivers. In the 1980's a drying process of the floodplains on the lower Danube reach in Hungary became evident. The first statistical analyses were made for the Hungarian reach in 1992, because foresters noticed an alarming drying process of the floodplain forests. Analyses indicated the lowering of the riverbed of the Danube River. It is considered that the river training works were the main reason for the incision of the riverbed.

To the authors' knowlege, no comprehensive analysis of the changes in the water regime for the whole alluvial reach of the middle Danube has been made to date.

To fill this gap, authors analyse available time series of the waterlevel and discharge data for the free-flowing alluvial reach of the Danube River, downstream of Budapest, Hungary to the confluence of the Tisa River, in Slankamen, Serbia. This analysis aims at: 1) recognising hydrological indicators of the incision and/or aggradation of the riverbed, 2) estimating the extent of the two processes and the rate of change of the riverbed in time based on these indicators, as well as 3) estimating possible consequent changes in the frequency of extremities (low flows and high flows).

According to the Water Framework Directive (WFD) the „good status" of the Danube River reach must be achieved. As the river and its floodplains constitute a complex ecological system, this can only be done through the harmonisation of the nature protection aspect reconstruction projects, WFD programmes of measures, flood management measures and navigation development.

If traditional river training activities continue, riverbed erosion will persist or increase in the future, resulting in slow, but continuous drying of floodplains, that are very important nature conservation areas. Consequently, the majority of floodplain reconstruction works' effects might become negligible, while navigation problems will remain unsolved.

In the EU Floods Directive, natural flood management is an important issue, with a focus on increasing water retention capacities by e.g. the re-connection of rivers with their floodplains and restoration of wetlands which can store flood water and help "slow the flow" of flood waters. In this respect, lateral connectivity is one of the most essential issues, as it is for the species inhabiting floodplains and rivers. However, floodplain lateral connectivity is already severed by the decreasing frequency and extent of indundation. The studied hydrological regime is the most important determinant of floodplain habitats.

Floodplain evaluation matrix (FEM) application for Hungarian section of the Tisza River

*Péter TÓTH [a]**

[a] Middle Tisza District Water Directorate, PhD candidate

** Corresponding author: toth.peter@kotivizig.hu*

Floodplains are among the most valuable habitats in the world and play a major role in the dynamics and the ecological integrity of riverine landscapes. Furthermore, floodplains provide a broad range of ecological and socio-economic goods and services, including flood peak decreasing and groundwater recharge, and recreational values. During the major river engineering works (river regulations) for the Tisza river in the mid of 19th Century, this former dynamic floodplain has been disconnected from the main channel by the construction of a flood protection levee. Lateral embankments along the main river channel have severely altered the geomorphic and hydrological dynamics and have impeded the natural sequence of erosion and sedimentation.

It is crucial to determine which floodplains are highly relevant for preservation and/or restoration not only concerning flood protection (hydrology/hydraulics) but also for ecological and sociological reasons. Therefore, the aims of this presentation are to define on different spatial scales those hydrological-hydraulic, ecological and sociological parameters that are important for an integrated evaluation of floodplain effectiveness in case of Tisza River.

The results are finally assembled in the multidisciplinary floodplain evaluation matrix (FEM) serving as decision support for the relevant stakeholders and indicating where efforts of floodplain preservation/restoration should be spent first within an integrated flood risk management.

Keywords: Tisza, floodplain, flood, preservation, restoration

Human impact on the Lower Sector of Jiu River Floodplain

*Andreea-Gabriela ZAMFIR[a]**

[a] PhD student, Department of Geography, Faculty of Science, University of Craiova, Craiova, Romania

** Corresponding author: andreeaz2004@yahoo.com*

The Jiu River Floodplain and the main channel that crosses it (the Jiu River) have undergone important changes over time. These changes were induced by humans in order to "facilitate" their existence. Human stress in the Jiu River Floodplain has targeted: the construction of buildings by expanding settlements (Craiova city – urban sprawl); changes in land use; opening ballast quarries to extract sand and alluvial gravel; tailings (Ișalnița); or raising defensive levees (after every significant flood). All these human-induced changes influenced the geomorphological processes within the river banks and in the floodplain, its biodiversity, and even the nutrient cycle (through agricultural practices, or industrial pollutants of the river).

In this study, I discuss the case of the Lower Sector of Jiu River Floodplain, located in Dolj county, on the left side of the Danube, using Landsat 5 and Sentinel 2 satellite images to detect changes and some statistical data. I also used an unmanned aerial vehicle (Dji Phantom 4 Pro v. 2.0 Drone) to survey the floodplain at a very low altitude to accurately identify those changes. After creating maps, I tried to quantify the human impact within the Jiu River Floodplain through different indices of human pressure.

Can multi-functionality of floodplains be restored? An analysis of regulative and cultural ecosystem service synergies and trade-offs

Martin TSCHIKOF[a,b,], Andrea FUNK[a,b], Barbara GRÜNER[a], Kerstin BÖCK[a], Elisabeth BONDAR-KUNZE[a,b], Stephanie NATHO[c], Thomas HEIN [a,b]*

[a] *Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Vienna, Austria*
[b] *WasserCluster Lunz, Lunz am See, Austria*
[c] *Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany*

** Corresponding author: martin.tschikof@boku.ac.at*

Floodplains are hotspots of productivity and biodiversity and recognised to fulfil vital ecosystem functions and services. Restoration measures of the decoupled Danube floodplains east of Vienna aim to re-establish multiple functions, i.e. ensure navigation, preserve and restore unique fluvial and riparian habitats and revitalize natural processes. Side arms are proposed to be reconnected and embankments and groins to be removed.

We evaluated how a given programme of measures may impact the quantity and diversity of relevant ecosystem services (ES) and therefore, the overall multi-functionality compared to the actual situation. Therefore, regulating ecosystem services (RES), including nutrient retention (nitrate nitrogen and total phosphorus) and habitat provisioning were modelled and predicted using multivariate regression models and the potential of cultural ecosystem services (CES) was assessed by mapping recreational activities. We analysed quantitative (e.g. spatial extent, amount of nutrients) and qualitative (e.g. biodiversity, nature experience) changes of ES, as well as potential synergies and trade-offs.

Our results show clear synergies, especially for RES (habitat for the rheotopic community and nutrient retention) and the qualitative CES of nature experience. Those have a weak and local trade-off with the quantitative availability of opportunities for recreation and the provisioning of habitat for the stagnotopic community. However, stagnotopic habitats will be still widely preserved after restoration and beta-biodiversity in the floodplain is predicted to increase. Overall, our results show that the restoration measures have a high potential to increase the multi-functionality of the system, in particular by fostering the potential habitat for endangered rheotopic species, nutrient retention and qualitative CES.

Key words: River-floodplain-system, river restoration, ecosystem services, nutrient retention, red list species, recreation

Ecosystem services of an impounded navigable river (Lahn, Germany)

*Martin PUSCH[a]**

[a] Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany

**Corresponding author: pusch@igb-berlin.de*

How can an impounded river be restored that is intensely used by hydropower and recreational boating? This question is currently discussed at the Lahn River (Hessia & Rhineland-Palatinate, Germany). Currently, there are strongly diverging sectoral objectives and interests on the Lahn, and thus considerable conflicts of interest, especially among recreational navigation, hydropower, tourism, and with the agencies in charge to implement the EU WF and FFH directives. The state governments aim at restoring longitudinal connectivity, as well as at re-activating some floodplains. The request of some NGOs to re-establish a self-sustaining population of salmon in the Lahn seems to be incompatible with motorized boating and hydropower generation.

In order to approach to that complex management challenge, an EU LIFE project has been acquired named “Living Lahn (Lila)” (www.lila-livinglahn.de). The Lila project aims at upgrading the Lahn ecologically and at the same time making the river and life on the river more liveable. In doing so, the interests of shipping and other competing uses are to be combined with ecological requirements, such as the restoration of semi-natural banks, floodplain areas and linear passability, as far as possible. Also, Lila conducts an intense dialogue with stakeholders in order to identify the views of the various stakeholder groups on the development goals for the Lahn. The results will influence the design of a development concept for the Lahn ("Lahn concept") by the Lila project.

In order to identify the benefits of the river for adjacent communities as well as for tourists, the availability of various ecosystem services were assessed for the status quo. For that purpose, the newly developed River Ecosystem Service Index (RESI) was applied. The RESI represents an assessment tool that evaluates the total range of ecosystem services provided by rivers and their floodplains, thus showing the multifaceted significance of riverine landscapes for humans (see article in *Danube News* 20 (38), 6-10). The application of RESI in spatial planning thus supports the identification of options for multifunctional management actions and their prioritisation on the basis of various sectoral and legal objectives, in order to reduce the trade-offs between individual uses and development objectives (see the RESI application manual [in German, English translation in prep.] (www.resi-project.info/handbuch).

At present, a small number of ecosystem services and natural capital of the Lahn is used intensely, while other ecosystem services are less well known, and in some cases are even strongly affected by current management practices. Today, the Lahn represents a 150-km long federal waterway regulated by 26 old weirs and locks, which is no longer used for freight shipping, and public passenger cruises are only offered locally. Environmental NGOs request re-introducing several typical target species, incl. salmon,which would however require full up and down passability of weirs.

The Lahn thus represents an exemplary case for the complexity of the user interests, which must be adequately taken into account when designing the intended change in current management practice. The use of RESI aims to support these complex decision-making processes by presenting equally-structured knowledge on all ecosystem services, as well as visualising them in maps. This will support

to have more fact-based discussions, and to develop management scenarios optimized to multi-functionality that serve as many sectoral objectives as possible. This approach to identify future mangement principles for the Lahn is therefore considered a pilot project for the adaptation of further secondary waterways in Germany to current needs. The results could thus also support the further development of the respective German federal programme "Blue Ribbon Germany".

The role of floodplains for flood mitigation and enhancement of ecosystem services in the Danube

Francesca PEROSA [a], Aude ZINGRAFF-HAMED [b], Markus DISSE [a]*

[a] Chair of Hydrology and River Basin Management, Technical University of Munich, Munich, Germany
[b] Chair for Strategic Landscape Planning and Management, Technical University of Munich, Munich, Germany

** Corresponding author:* francesca.perosa@tum.de

Municipalities located in the Danube River Basin (DRB) are in danger of being affected by major floods along the Danube, but also along its tributaries. Floodplain restoration measures can have a role in mitigating flood waves, flood damage, and consequently flood risk. At the same time, these measures, like other nature-based solutions (NBS), bring other benefits to humanity, such as greenhouse gases sequestration, provisioning of goods, or nutrients retention. However, these ecosystem services (ES) are related to complex and interconnected phenomena, so that the effects of a restored floodplain can differ among application cases due to other external variables. To understand whether and when floodplain restoration is suitable against floods and whether and how it can improve ES, five study sites are analyzed in the DRB. There, flood risk reduction and other ES are estimated and compared. This is done with the help of 2D hydrodynamic models results, by following the guildelines of the TESSA Toolkit, and by setting up a database containing ES studies and their assessed results. The database is also enriched with freely available georeferenced geo-physical (e.g. land use) and socio-economic (e.g. population) data. The work done will help to increase the understanding of co-benefits of floodplains, bridging together the knowledge of flood management, restoration, and ecosystem services, but also raising awareness about nature-based solutions to decision-makers and stakeholders affected by flood risk.

Nutrient retention in the Danube Floodplain National Park – how much lateral connectivity is needed for an observable reduction of nutrient loads?

Stephanie NATHO[a], Martin TSCHIKOF[bc], Elisabeth BONDAR-KUNZE[bc] and Thomas HEIN[bc]

[a] Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany
[b] Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Vienna, Austria
[c] WasserCluster Lunz, Lunz am See, Austria

**Corresponding author: natho@uni-potsdam.de*

Floodplains are known to provide a multitude of ecosystem services, in case they are connected to the river hydrology, and the river hydromorphology has not been altered. Both, reductions in connectivity between floodplain and river, so called lateral connectivity, as well as alterations in river hydromorphology have been carried out worldwide and with an exceptional high intensity in central Europe where population density is high. As a result, most floodplains are degraded. One of the few free flowing river sections fo the Upper river Danube in close vicinity to the capital of Austria is protected as a national park. To improve its overall state, restoration measures have been carried out and are planned in the future in accordance with navigation purposes.

Land availability is low, nutrient inputs remain high, biodiversity in particular of floodplains is threatened. Nevertheless or perhaps because of this, politics start acknowledging the ecosystem services floodplains provide considering functions of biodiversity, nutrient and water retention to name a few. And we wanted to know how much connectivity is needed to reduce nutrient loads in the upper Danube River by 1%. Would the planned measures be enough?

We therefore compared two modelling approaches complementing each other in terms of spatial and temporal resolution to calculate nutrient retention (nitrate-nitrogen and total phosphorus) in the floodplain of the 35km river stretch in different hydrological years and different scenarios of carried out restoration measures. The statistical model bases on nutrient measurements in three of the seven considered side-arms and the semi-empirical model couples current hydrology from gauges, nutrient inputs from monitoring stations, inundation area from an empiric discharge-area relation and an existing nutrient retention model on the landscape scale.

Assuming that all measures will be carried out to improve lateral connectivity of the seven side-arms on average one sixth of the total considered floodplain area is contributing to nutrient retention. As a result, the semi empirical model calculated a river load reduction of 0.07% - 0.1% for NO_3-N and 0.05% - 0.07% for TP (range of dry, wet and average hydrologic conditions). To achieve a retention of 1% of river load, a floodplain area 8.8 and 13.2 times bigger than the current floodplain would be needed.

As land is scarce and giving rivers more space is wanted but difficult to implement, we suggest increasing reconnection not only by side-arm connection but better connection of the floodplain as a whole for very frequent floods and for higher sedimentation. Only when reconnection leads to more extensive inundated areas of the floodplain area as a whole at discharges between MQ and HQ1, a significant amount of river nutrient load can be retained in the national park.

Content analysis challenges of Danube river basin in the perspective of Anthropocene: A qualitative study

*Hossein MOUSAZADEH [a]**

[a] Department of regional science, Eötvös Loránd University, Budapest, Hungary

** Corresponding author: hmosazadeh5575@yahoo.com*

Anthropocene started to be perceived as a scientific discipline relatively recently. There is increasing recognition of the importance of practical or quantifiable advantages that governments derive from nature and rivers. Referred to as Nature's Gifts in the intergovernmental platform on biodiversity and ecosystem services conceptual framework. Danube river plays this international role in many countries. Hungary is situated within the heart of the Danube river basin, and seem many challenges put pressures on the Danube and its network of tributaries in manifold ways. The recognition that past, current and future challenges in river basins, it can help with planning and policy-making, this shows the importance and necessity of this research. The purpose of the present study was to determine the challenges of Danube river basin in the perspective of Anthropocene in Hungary. This research is based on the qualitative paradigm and using content analysis research method. Therefore, we provided a review of the most important research documents that are related to this topic, all collected from the Web of Science. The most important scholars, reports, and journals in the field are identified via documents and citations among them. Data analysis and coding of the study was conducted by employing the software MAXQDA-2020. however, this is the first attempt to construct this kind of research in content analysis related to the topic of challenges. Finally, the framework of the result of themes and sub-themes of the findings of the study and the relations between them was formed. The results revealed Pollutions, Environmental concerns and flood, transportation, people's awareness and knowledge, climate changes, infrastructure and basic factors, regional security, resource management and quality of water, and policies challenges are the main challenges of Danube river basin in the perspective of Anthropocene. It seems that Hungary should provide the necessary context for the participation of the private sector, local authorities and peoples to deal with these challenges. Further, it should design and implement long and short-term strategies in proportion to the challenges raised. Innovative solutions, education and environmental awareness and research grants will also be useful in addressing these challenges. We believe that the Content analysis procedures used in this paper provide an excellent tool to study such a relevant phenomenon.

Keywords: Content analysis, challenges, Danube river basin, Anthropocene, Hungary.

Determining high quality landscapes in support of environmental planning at local and community level

*Petja IVANOVA-RADOVANOVA[a]**

[a] Climate, Atmosphere and Water Research Institute to The Bulgarian Academy of Sciences, Sofia, Bulgaria

** Corresponding author: p.radovanova@gmail.com*

Summary:

In all situations and sites, whether global or local, there is an uneasy balance to strike between the continued stability of natural systems and the welfare of communities who depend, directly or indirectly, on the exploitation of resources. The article contributes the sustainability arguments which stress the need to view environmental protection and continuing economic growth as mutually compatible activities and not necessary confliction ones. Here it is argued that the actions should be taken where the best of our wildlife and landscape be found and observed prior to development of the management plans on local level.

Research was based on originally designed methodology for Rapid Landscape Assessment - RLA (Radovanova, P., Samardjieva,M., 2003) developed for the management plan of the territory of Rila Monastery Nature Park. The investigation had been initiated with identification of group of specific indicators, which characterized particular features of the surface such as: interesting rock formations, vegetation, rare plant and animal species, the presence of tourist attractions and presence of human interactions and infrastructure. Not surprisingly, the results show that almost whole territory of the "Rila Monastery" Nature Park included high quality, beautiful and very impressive landscapes with magnificent views towards the tops of the mountain, rivers lakes, flora and fauna -53,2% has been evaluated as very high quality, 28,1 % received high quality mark and only 18,7% possess to the third category with average quality landscapes, because of anthropogenic influence.

In conclussion, sustainability of management and community valorization plans is visible if it is based on solid knowledge and understanding for quality of resources available. The case presented is a good example for testing a tool designed to be applied in relatively short time, by applying specific criteria, according not only to the physical characteristics of the landscapes in nature, but also according to socio-psychological impact of the landscapes on the respondents. It is possible to be multipliued in a variety of sites - nature parks, protected sites and landscapes along the rivers.

New Emphasis on Water Clarity as Socio-Ecological Indicator for Urban Water

Katrin TEUBNER[a], Irene E. TEUBNER[b], Karin PALL[c], Wilfried KABAS[a], Monica TOLOTTI[e], Thomas OFENBÖCK[f], Martin T. DOKULIL[g]*

[a] Dept of Functional & Evolutionary Ecology, University of Vienna, Vienna, Austria
[b] Research Group Climate and Environmental Remote Sensing, TU Wien, Vienna, Austria; Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Vienna, Austria
[c] Systema GmbH, Vienna, Austria
[e] Department of Sustainable Agro-ecosystems and Bioresources, Mach, Michele all'Adige, Italy
[f] Municipal Department 45 – Water Management, Vienna City Administration, Vienna, Austria
[g] Research Institute for Limnology, University of Innsbruck, Mondsee, Austria

** Corresponding author: Katrin.Teubner@univie.ac.at*

Water transparency can serve as a key indicator of multi-functional socio-ecological values to assess near natural assets of green-blue spaces and ecosystem health as exemplified for Alte Donau in Vienna. Our study covers a 32-year observation on this urban oxbow lake. It includes man-made nutrient enrichment in the late eighties to early nineties due to the inclusion of the riverine landscape in the urban area, followed by lake restoration with an ecosystem shift from a nutrient-rich, algal-turbid water body to a nutrient-poor, clear-water macrophyte controlled system. In addition to the ecosystem response due to wax and wane of nutrients, the impact of global warming was analyzed.

Measuring water transparency by disk visibility in the water body goes back to observations in the ocean (and not lakes) in 1815. Measuring the optical properties in the ocean water was key to identify the distance to the bottom for navigation. With the eutrophication of lakes, water-clarity went beyond being an optical parameter of lake physics but also of lake biology. Trophic classifications schemes in the late 60ies to 80ies were expanded to link an increasing algal biomass yield by eutrophication, with gradual deterioration of water-clarity. In turn, increasing water-transparency, became the main aim of lake restoration - it offered the key target for indicating an overall success of lake restoration. In our case study Alte Donau, we describe what minimum light requirements for sustained growth of submerged macrophytes secure to suppress in the long-term planktonic algal growth.

Judgment of water clarity by public perception is further of great importance for communicating the success of restoration or urban planning in modern cities life. In ecological terms, water transparency identifies the overall success of lake restoration or ecosystem health status if no other impacts than local nutrient surplus or global risk by climate warming pose potential threats. The critical water transparency forcing alternate nutrient allocation from planktonic algae under nutrient-rich conditions to submerged macrophytes of nutrient-limitation, however, exceeds requirements of water transparency that is satisfying people's awareness by littoral "lake bottom view", i.e. judging good water quality by bathing aesthetics in Alte Donau. Our results suggest that annual Secchi transparency of 3.5 m or even higher is required to accomplish the still ongoing, last step of sustained lake restoration in Alte Donau, i.e., to further the increase of charophytes above 20% macrophyte yield contribution. This step at the expense of tall-growing *Myriophyllum spicatum* aimed at further stabilizing the clear-water state in this shallow urban water. In this view, even if water transparency can be indeed judged as reliable socio-ecological indicator, annual surveys of recreational waters

should still go further beyond measuring Secchi disk transparency. A knowledge in advance, which goes beyond Secchi depth readings, contributes further to mitigating the superimposed response by climate warming and other potential threatening impacts in the accelerated man-made age, which seem to hamper water transparency in general during extreme hot summer seasons and favor long-term thermophilic macrophytes such as *Myriophyllum spicatum* in particular.

Genotoxicity assessment of Danube River: *in situ* and *in vitro* methods

Jelena ĐORĐEVIĆ[a,d,], Jovana KOSTIĆ-VUKOVIĆ[a], Karolina SUNJOG[a], Stoimir KOLAREVIĆ[b], Željka VIŠNJIĆ-JEFTIĆ[a], Srđan SUBOTIĆ[c], Zoran GAČIĆ[a], Mirjana LENHARDT[a,b] and Branka VUKOVIĆ-GAČIĆ[c,d]*

[a] *Department of Natural Resources and Environmental Sciences, Institute for Multidisciplinary Research, Kneza Višeslava 1, University of Belgrade, Belgrade, Serbia*
[b] *Institute for Biological Research "Siniša Stanković", Despota Stefana 142, University of Belgrade, Belgrade, Serbia*
[c] *Faculty of Biology, Studentski Trg 16, University of Belgrade, Belgrade, Serbia*
[d] *Center for Genotoxicology and Ecogenotoxicology, Chair of Microbiology, Faculty of Biology, Studentski Trg 16, University of Belgrade, Belgrade, Serbia*

** Corresponding author: jelenadjo@imsi.rs*

Water quality in the Danube River Basin is largely influenced by the inputs of pollutants - particularly excessive nutrients, organic material, and hazardous substances, which affects the whole ecosystem at various levels. The major goal of this study was to evaluate the level of genotoxic potential at the site at Danube River, Novi Banovci, which is under significant anthropogenic pressure of untreated municipal and industrial waste waters.

DNA damage *in situ* was assessed in 5 specimens of white bream (*Blicca bjoerkna*) erythrocytes, liver and gills cells with comet assay and in erythrocytes with micronucleus test. Additionally, genotoxicity of native water samples collected from the site and upstream and downstream of the site was evaluated by the comet assay on HepG2 cells. Microscopic images of comets were scored using Comet IV Computer Software (Perceptive Instruments, UK) and tail intensity was chosen as parameters to assess the DNA damage.

Comet assay on white bream showed that gills were the most affected tissue, while liver showed the smallest values. Micronuclei frequency was low in general, with mean of 1 micronuclei in 5000 scored erythrocytes, with no significant correlation to the values of comet assay in erythrocytes. Comet assay on HepG2 cells showed significant difference between values of negative control samples and samples of water from effluent site and downstream of wastewater discharge. There was no significant difference between negative control and upstream samples of water.

Our results showed that great impact of municipal and industrial wastewaters on the river ecosystem. The application of *in vitro* and *in situ* tests gives a better insight into genotoxic effects. More importantly, because Serbia still doesn't have waste water treatment plants, this kind of research points out the imperative for implementation of this facilities.

Mapping of the microbiological water quality of surface waters in Serbia overlooked by the National monitoring programme

Jovana JOVANOVIĆ MARIĆ[a, b], Stoimir KOLAREVIĆ[a,b], Margareta KRAČUN-KOLAREVIĆ[a], Jelena ĐROĐEVIĆ[b, c], Momir PAUNOVIĆ[a],Branka VUKOVIĆ-GAČIĆ[b]*

[a] Institute for Biological Research"Siniša Stanković"- National Institute of Republic of Serbia, Department of Hidroecology and Water Protection, University of Belgrade, Belgrade, Serbia
[b] Faculty of Biology, Center for Genotoxicology and Ecogenotoxicology, University of Belgrade, Belgrade, Serbia
[c] Institute for Multidisciplinary Research, Department of Natural Resources and Environmental Sciences, University of Belgrade, Belgrade, Serbia

** Corresponding author: jovana_jovanovic992@yahoo.com*

Surface waters in Serbia are under high anthropogenic pressure. One of the major problems is untreated municipal and industrial wastewaters. Unfortunately, Serbia processes only 5 % of wastewaters before discharging. As a consequence, pollutants such as metals and metalloids from industrial wastewaters, pharmaceuticals, compounds from personal care products, etc. directly endure into surface water. Microbial faecal pollution, as an indicator of presence of human or/and animal pathogens, due to health hazard limits water usage for drinking, recreation, irrigation, etc. In regulations, faecal coliforms, with *Escherichia coli* as dominant representative, are widely used as faecal indicator bacteria The aim of this study was to investigate the microbiological al water quality in the Republic of Serbia at the sites which are not routinely investigated within the national monitoring programme. In this purpose 78 sites situated on canals, mountain springs, as well as lowland rivers were selected. Defined Substrate Technology was used for determination Most Probable Number (MPN) of *E. coli* using Colilert-18 System. The water classification system, developed for the Danube River (Kavka et al., 2006) was used.

The results indicated that more than 47 % of selected sites are under critical (21.79 %) or strong (25.64 %) faecal pollution. On the other hand, about 32 % (32.05 %) of sites are little polluted and 20.51 % of sites showed moderate pollution. The increasing levels of faecal pollution detected on sites situated downstream of settlements indicated discharge of untreated municipal wastewaters directly into surface water. In further research, the focus will be placed on the determination of the origin of pollution by the employment of microbial source tracking technique. Obtained data will be used for modelling and predicting the effect of detected contamination on the water quality of the major water bodies in the Republic of Serba.

Occurrence and spread of human-induced antimicrobial resistance in a large river water system: developing a holistic picture based on the Joint Danube Survey 4 activities

Alexander K.T. KIRSCHNER[a,b,h], Clemens KITTINGER[c], Iris SCHACHNER[a,h], Stefan JAKWERTH[a,h], Michael KOLLER[c], Stoimir KOLAREVIĆ[d], Margareta KRAČUN-KOLAREVIĆ[d], Marwene TOUMI[e], Rosza FARKAS[e], Erika TÓTH[e], W KANDLER[f], M SULYOK[f], Domenico SAVIO[b,g,h], Andreas H. FARNLEITNER[b,g,h], Gernot ZARFEL[c]*

[a] *Institute for Hygiene and Applied Immunology – Water Microbiology, Medical University Vienna, Austria*
[b] *Division Water Quality and Health, Karl Landsteiner University of Health Sciences, Krems, Austria*
[c] *Institute of Hygiene, Microbiology and Environmental Medicine, Medical University Graz, Austria*
[d] *Institute for Biological Research ¨Siniša Stanković¨, National Institute of Republic of Serbia, Department for Hydroecology and Water protection, University of Belgrade, Serbia*
[e] *Department of Microbiology, Eötvös Loránd University, Budapest, Hungary*
[f] *Institute for Bioanalytics and Agro-Metabolomics, University of Natural Resources and Life Sciences, IFA Tulln, Austria*
[g] *Institute for Chemical, Environmental and Bioscience Engineering, Vienna University of Technology, Austria*
[h] *Interuniversity Cooperation Centre Water & Health, www.waterandhealth.at, Austria*

[*] *Corresponding author: alexander.kirschner@meduniwien.ac.at*

The problem of human-induced antimicrobial resistance (acquired due to human activities) is an emerging concern in aquatic environments. The isolation of (facultative) pathogenic organisms with acquired antibiotic resistance, even concerning last-line antibiotics, from rivers and lakes, is well documented throughout the world. In the last few years, there has been a rapid increase in the number of studies addressing these topics and their possible implications for human health. However, most studies concentrate on a relatively limited methodology, e.g. applying non-quantitative and either cultivation-based or direct-detection based molecular biological methods. In addition, often only small geographic areas and short periods of time are covered. This is one of the reasons why many relevant questions concerning the occurrence and spread of antimicrobial resistance in aquatic ecosystems still remain unanswered.

The largest European river water survey (Joint Danube Survey 4) offered a unique opportunity to study the occurrence and spread of human-induced antimicrobial resistance along the whole Danube River. Within the research project, isolates from samples from the entire course of the Danube and their main tributaries, including high frequency sampling at selected locations, have been collected and analysed. Samples from the water compartment but also from submerged biofilms have been considered. State-of-the-art quantitative molecular biological techniques and culture-based analyses targeting different bacterial organisms have been combined with a large set of physical, chemical and biological parameters to obtain a robust and comprehensive picture of the occurrence and spread of human-induced antimicrobial resistance in the Danube River.

Based on the findings of this quantitative, integrative study approach, it seems likely to significantly improve the current understanding on the importance on the spread and stabilization of human-induced antibiotic resistance in large rivers. The results of this study will also be useful to guide future monitoring and management strategies.

A retrospective of ten years of the botanical exploration in Nature Park Kopački Rit (Croatia)

Siniša OZIMEC[a], Vlatko ROŽAC[b]*

[a] Faculty of Agrobiotechnical Sciences in Osijek, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia
[b] Public Institution Nature Park Kopački rit, Kopačevo-Bilje, Croatia

** Corresponding author: sozimec@fazos.hr*

Nature Park Kopački Rit is a large fluvial-marshy floodplain, situated in the northeastern Croatia along the middle course of the Danube River (river km 1,412-1,382). Due to its biological and ecological values, Kopački Rit has been protected since 1967, and proclaimed a Nature Park in 1999, at surface of 23,126 ha. In July 2012, Nature Park Kopački Rit is incorporated in the UNESCO Transboundary Biosphere Reserve Mura-Drava-Danube.

Public Institution Nature Park Kopački Rit started with implementation of the Action Plan for Conservation of the Aquatic and Wetland Habitats in the Nature Park Kopački Rit, as the permanent activitiy since 2010 year. Over a ten-year period, from May 2010 to September 2019, an intensive field floristic investigations were done, combined with monitoring of populations of rare and threatened plants, and terrestrial, aquatic and wetland habitats. An important achivement of these activities is an updated inventory list of flora and broadened knowledge on overall flora and habitats.

The floristic list, published in 2002 in the draft document of the Management Plan, that contain 385 registered taxa, was used as a baseline. As the result of the field investigations, and checked all available literature sources, 140 plant taxa were found and recorded as new in the flora of Nature Park Kopački Rit.

The current floristic diversity comprise 525 taxa (507 species, 18 subspecies), representing 298 genera and 97 families of the aquatic mosses, pteridophytes and angiosperms. Total number of recorded taxa makes 10.4% related to 5,046 taxa in the vascular flora of Croatia. The most abundant families are *Asteraceae* (44 taxa), *Poaceae* (40), *Lamiaceae* (34), and *Cyperaceae* (30). The most diverse genera are *Carex* (17 taxa), *Ranunculus* and *Veronica* (10 each), and *Potamogeton* (9). Invasive allien species are represented by 26 taxa, about 5% of the total flora. During the field investigations, some of the listed taxa were failed to be found or confirmed, like *Acorus calamus, Marsilea quadrifolia,* and *Typha minima*. Knowledge on the diversity of orchid family (*Orchidaceae)* expands from two previosuly recorded taxa to nine taxa of the forest and meadow orchids. Rufous Bulrush (*Scirpus pendulus*) has been discovered in July 2011, which is the first record of this adventive species for the Croatian flora.

The threats for the floristic diversity of Nature Park Kopački Rit are: increased fluctuations in flooding intensity of the Danube River, lack of rainfalls, increased summer air temperatures, prolongation of dry season, accumulation of bedloads and natural succession of the wetlands. Comprehensive knowledge on flora and habitats provide an important tool for planning and implementation of measures and activities with an aim to conserve and protect rare and threatened plants and their habitats in Nature Park Kopački Rit.

Distribution and abundance of macrophytes in the Ižica River in the years 1996, 2000 and 2016

Mateja GERM[a], Andrej PETERNEL[a], Igor ZELNIK[a], Alenka GABERŠČIK[a]*

[a] Department of Biology, Biotechnical faculty, University of Ljubljana, Ljubljana, Slovenia

** Corresponding author: mateja.germ@bf.uni-lj.si*

Macrophytes are crucial for the structure and functioning of riverine ecosystems, since they are involved in energy transfer, nutrient cycling, and sedimentation processes. Macrophytes increase habitat complexity, affect the physical structure and provide shelter for other aquatic organisms. They are important as bioindicators in evaluation of the ecological status of the rivers. The presence and abundance of macrophytes are affected by urbanisation and agricultural activities, which change with time. These changes are reflected in the distribution and development of aquatic vegetation, which can be used as a bioindicator of water quality. The aim of the present reserch was to compare the presence, abundance, and distribution of macrophytes in the Ižica River, which flows through agricultural landscape, between the years 1996, 2000 and 2016.

The Ljubljansko barje moor is a 163 km^2 large area in the southern part of the Ljubljana Basin in Central Slovenia. It is a tectonic depression between the Alpine and Dinaric area, built by alluvial and lacustrine sediments. As a karst spring river, it springs at the surface in the centre of the city of Ig, flows along the Ljubljansko barje moor and inflows into the Ljubljanica River after 10.5 km.

Presence and abundance of macrophytes were surveyed in the peak vegetation period. Surveys were carried out within the whole length of the stream in the years 1996, 2000 and 2016. The river was divided into 26 stretches of different lengths according to changes in macrophyte distribution, or according to environmental changes. Macrophyte species abundance was estimated as a relative plant biomass using a five-degree scale: 1 = very rare; 2 = rare; 3 = common; 4 = frequent; 5 = abundant, predominant. Relative plant abundance (RPA) was calculated for the all studied years. The environmental conditions of the river were assessed using the modified Riparian, Channel, and Environmental (RCE) Inventory. In 1996, morphological characteristics of the Ižica River by the RCE inventory were estimated on 6 stretches, while in 2016, these were estimated on 26 stretches.

The number of macrophyte taxa in the Ižica River ranged from 38 in 1996, 25 in 2000, and 31 in 2016. The highest RPA value was achieved by *Potamogeton natans* in 1996 and 2000, and was also high in 2016. The parameter with the greatest impact on the abundance and distribution of macrophytes was pH, that explained 15% of the species variability, followed by temperature and content of orthophosphate, explaining 5% each.

RCE inventory revealed some differences in morphological condtions between the years. The environmental status has deteriorated in the lower part of the Ižica River, probably because of partial removal of riparian vegetation in 2015. These changes enabled the colonisation of riparian zone by invasive alien species, such as *Solidago gigantea*, *Echinocystis lobata*, *Impatiens glandulifera* and *Fallopia* sp. The changes in species composition of the macrophyte community, namely the dominance of *Sagittaria sagittifolia,* and abundant filamenous algae in the lower part of the Ižica River, can be a consequence of 20 years of agricultural activities along the river that affected macrophyte growth and ecosystem status.

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Relationship Between Water Quality and Macrophyte Assemblages in Seasonal Wetlands along the Danube River in Serbia

M. Novković[a], J. Weidendorfer[b], S. Radulović[a], Dj. Miloševic[c], B. Cyffka[b], B. Damnjanović[d], M. Stojković Piperac[c], L. Galambos[e], V. Simić[f],* N. *Gluvaković[g], D. Cvijanović[b]*

[a] *University of Novi Sad, Faculty of Sciences, Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia*
[b] *Katholische Universität Eichstaett-Ingolstadt, Ostenstraße 14, 85072 Eichstaett, Germany*
[c] *Department of Biology and Ecology, Faculty of Science and Mathematics, University of Niš, Višegradska 33, 18106 Niš, Serbia*
[d] *Department for Medical and Business-Technological Studies, Academy of Professional Studies Šabac, Hajduk Veljkova 10, 15000 Šabac, Serbia*
[e] *Institute for Nature Conservation of Vojvodina, Province Radnička 20a, 21000 Novi Sad, Serbia*
[f] *University of Kragujevac, Faculty of Sciences, Radoja Domanovića 12, 34000 Kragujevac, Serbia*
[g] *University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia*

** Corresponding author: maja.novkovic@dbe.uns.ac.rs*

Fluvial lakes and ponds in seasonal wetlands (with natural hydrological regime) along the Danube River in Serbia were recognized as sites of high conservation importance at national and European levels. Understanding the relationship between water quality and macrophyte vegetation is necessary for the effective conservation management of these habitats. Although most of these areas have already been nationally and internationally protected, their current ecological status is still not properly assessed. The aim of the study was to select relevant and significant water quality variables for the development of macrophyte vegetation in fluvial lakes and ponds along the Danube river floodplain in Serbia (1400-1250 rkm).

Macrophyte data were collected within the circular plots (60) 16-25m² in diameter using the DAFOR 5-point scale. The following physico-chemical parameters were measured on each of macrophyte survey points: pH, electroconductivity, temperature, dissolved oxygen, nitrate-nitrogen, chemical oxygen demand, biological oxygen demand, total organic carbon, orthophosphates and turbidity. Canonical Correspondence Analysis (CCA) with Forward Selection and Monte Carlo permutation test was used to determine the relationship between macrophytes structure and environmental parameters.

In total, 44 different macrophyte species were recorded at 17 water bodies. CCA analysis showed that total organic carbon, electroconductivity, and dissolved oxygen were the most significant variables for structuring macrophyte assemblages. This finding implies the importance of natural hydrological regime and regular flooding for these habitats.

An alternative in monitoring invasive plant species in wetlands

Mihai DOROFTEI, Silviu COVALIOV, Marian MIERLĂ, Cristian TRIFANOV*

Danube Delta National Institute for research and Development, Tulcea

** Corresponding author mihai.doroftei@ddni.ro*

Floodplain areas host unique ecosystems displaying exceptional habitats with high biodiversity. Under the recent human-induced influences and the occurrence of extreme climate phenomena, these vulnerable ecosystems become highly exposed to a wide range of environmental threats. Therefore, one of the leading pressures on habitats and biodiversity is related to biological invasions via accidental or induced spreading. Wetlands proving to be among the most vulnerable ecosystems to invasive plant species. The paper is aiming to identify and analyze the key biological indicators able to reveal the occurrence, development and spread of the invasive plant species in wetlands. Based on several field surveys and the scientific cross-references, the authors were able to relate significant biological indicators (abundance, frequency, ecological significance etc.) with relevant key natural (hydrology, soil, geomorphology, habitats etc.) and human-induced (transport network, build-up areas, waste deposits, etc.) driving forces. Assessing biological invasion is increasing importance due to their potential impact on indigenous flora, their ecological significance and specific habitats of this protected area.

Keywords: wetlands, invasive species, Danube Delta Biosphere Reserve

A role of habitat complexity generated by macrophytes and hydromorphological attributes for the recovery of commercial fish stock in the free-flooding Middle Danube wetlands (Serbia)

Dušanka CVIJANOVIĆ[a], Milica STOJKOVIĆ PIPERAC[b] , Djuradj MILOŠEVIĆ[b], Maja NOVKOVIĆ[a], Snežana RADULOVIĆ[a], Laszlo GALAMBOS[c], Dubravka ČERBA[d], Bojan DAMNJANOVIĆ[e], Bernd CYFFKA[g,f], Johanna WEIDENDORFER[g], Mészáros MINUCSÉR[a], Dragoslav PAVIĆ[a], Vladica SIMIĆ[h], Oksana Y. BUZHDYGAN[i]

[a] *Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia*
[b] *Faculty of Sciences and Mathematics,University of Niš, Niš, Serbia*
[c] *Institute for Nature Conservation of Vojvodina Province, Novi Sad, Serbia*
[d] *Department of Biology, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia*
[e] *Higher Medical and Business-Technological School of Applied Studies Šabac, Šabac, Serbia*
[g] *Mathematisch-Geopraphische Fakultät, Katholische Universität Eichstaett-Ingolstadt, Eichstaett, Germany*
[f] *Floodplain Institute Neuburg, Catholic University of Eichstaett-Ingolstadt*
[h] *Faculty of Sciences,University of Kragujevac,Kragujevac, Serbia*
[l] *Institute of Biology, Freie Universität Berlin, Berlin, Germany*

** Corresponding author: dusanka.cvijanovic@dbe.uns.ac.rs*

A negative trend in the fish stock have been observed in the Middle Danube Section. It was reported that the fishery shifted towards smaller, shorter-lived, early-maturing species, more resilient to fishing, and situated at lower trophic levels. Floodplain areas with the natural hydrological regime are of high potential and importance for maintaining the fish diversity in the main river channel but across the whole basin as well. The role of macrophytes as physical structures that increase habitat complexity and heterogeneity in aquatic ecosystems is widely recognized. They are considered fine-scale engineers of hydrogeomorphological processes, influencing the composition of other aquatic communities.

This study aimed to explore the role of habitat complexity generated by macrophytes and hydromorphological attributes for the recovery of commercial fish stock in the free-flooding Middle Danube wetlands (Serbia). Filed sampling was performed during July and August 2019 at the 53 sampling sites, located on the 22 lentic water bodies (12 oxbow lakes and 10 ponds). Data for aquatic vegetation, fish communities, and habitat hydromorphological conditions were collected simultaneously from 1-4 sample points per water body. To explore the role of habitat complexity on the commercial fish stock in study area, the fish metrics (abundance, species richness), were analyzed using the Generalized Linear Mixed Model in R Package against hydromorphological and macrophyte cover variables.

The most important positive predictors for the commercial fish metrics were showed to be the extent of natural land cover types in the riparian zone, the diversity of littoral habitat features, the total macrophyte cover, and the cover value of submerged fine- and dissected-leaved macrophytes. On the other hand, the fish variables were negatively predicted by the cover of emergent macrophytes, filamentous algae, as well as by the proportion of invasive macrophytes in vegetation stands. Selected macrophyte variables could be used to guide the potential restoration management within the studied area.

Developments on the protected side

*Kristóf DOBÓ [a]**

[a] Head of Department, General Directorate of Water Management of Hungary

** Corresponding author: kristof.dobo@ovf.hu*

By using flood hazard and risk maps based on the EU Floods Directive, we can approximate the need for future improvements by examining changes from the saved side. A change of approach is expected on this issue as we are no longer approaching the flood protection strategy from the resistance side, but from the impact side, namely the side risk reduction. This way the same saved side risk can be realized. The method of calculating the resulting differentiated flood levels shows a significant change compared to the previous practice. In order to stagnate new flood levels, it is essential to maintain the water capacity of the high water course. This will prevent our developments so far from losing their value.

Best Operation rules of Stanca-Costesti reservoir on Prut River during exceptional floods

Radu DROBOT [a], Aurelian DRAGHIA [a], Cristian Dinu [a], Petrisor MAZILU[b]*

[a] Departement of Hydrotechnic Engineering, Technical University of Civil Engineering, Bucharest, Romania
[b] National Administration Romanian Waters, Flood Defence Departement, Bucharest, Romania

** Corresponding author: radu.drobot@utcb.ro*

Stanca-Costesti reservoir is located on Prut river, representing the border between Romania and the Republic of Moldova. The reservoir is operated in common by both parties, being based on agreements periodically updated.

The flood considered during the designing phase (which corresponds to a probability of exceedance of 1%) was characterized by a maximum discharge of 2800 m^3/s, while the flood with a return period of 1000 years has a maximum discharge of 4200 m^3/s. Two major floods occurred in 2008 and 2010: the maximum discharge of the first one was evaluated at 4240 m^3/s, while the flood volume of the latter was 2500 million m^3. The hydrological parameters of the registerd floods dramatically changed following these events. The statistical processing of the maximum discharges following these exceptional floods indicated the new values for the maximum discharge: Q 1% = 4800m^3/s, while Q 0.1% = 7500m^3/s. The flood volumes are: V 1% = 2865 million m^3, while V 0.1% = 5000 million m^3 .

The storage capacity for flood attenuation is of 550 million m^3, much less than the estimated flood volumes even for the current floods (1% probability of exceednce). A forecast of 10 days allows the downstream water release creating a supplementary volume for floods attenuation. Combining this measure with best operation rules of the bottom gates and spillways, while keeping under control the maximum water level in the reservoir as well as the maximum discharge downstream the reservoir, the dam can be safely operated at least for the 100 years flood. Taking into account the climate change this flood represents the maximum potential of flood control by the reservoir. For greater floods new spillways should be designed in order to save the dam, despite the huge discharge which will occur downstream the reservoir.

A detailed hydrological modelling of the upstream ribver basin, coupled with hydraulic modelling along the Prut river and followed by reservoir operation is a necessry step to check if the maximum discharges and flood volumes provided by the statistical processing can be acceped or should be amended based on physical processes in the river basin.

Extreme floods of the Danube in 2013 – track changes of the ecological state of the river applying the phytoplankton assemblage index

Melita MIHALJEVIĆ, Andrea KOLOBARIĆ, Dubravka ŠPOLJARIĆ MARONIĆ, Filip STEVIĆ, Tanja ŽUNA PFEIFFER, Nikolina BEK*

Department of Biology, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

** Corresponding author: mmihaljevic@biologija.unios.hr*

Extreme hydrological events, such as the occurrence of strong rainfall floods, have become more frequent and intensive in the Danube River Basin, indicating global climate changes. The highest ever recorded discharge (8.374 m^3/s) of the Danube at the entrance to Croatia (river 1424.85 km) was in June of 2013, with an estimated return period of about 90 years. The aim of this study was to evaluate changes in the ecological status of the river during the year with an extreme event focusing on the phytoplankton assemblages.

Sampling was performed monthly in the period April – November 2013 at the site in the main river channel at river 1388.0 km. Analyses of physical and chemical water properties and phytoplankton assessment were done according to the standard procedures. Phytoplankton species were sorted into the functional groups *sensu* Reynolds (FGs), their relative shares to the total biomass multiplied by the factor number (F) and the sum of these scores is presented as phytoplankton assemblage index (Q-index). The theoretical maximum of the Q index is 5, and the minimum is 0.

Notable patterns in the river water properties included the peak of ammonium, nitrites and nitrates concentrations in April and their significant decrease during the extreme event in June and afterwards, indicating a dilution effect caused by huge rainfall floods. In accordance with hydrological conditions, the lowest phytoplankton abundance (0.26 x 10^6 ind./L) and biomass (1.32 mg/L) were found during extremely high water discharge in June. Conditions of prolonged residence time in summer allowed phytoplankton development and consequently, phytoplankton abundance (6.43 x 10^6 ind./L) and biomass (16.31 mg/L) reached the highest values in August.

A total of 119 phytoplankton species sorted into 20 FGs were found, among which only codons **C**, **D**, **G**, **J**, $\mathbf{L_0}$, **P, S1** and $\mathbf{T_B}$ achieved >5% in the total biomass at a certain period. Codon $\mathbf{T_B}$, represented by benthic diatom species, was the most successful during the whole investigated period and dominant in the conditions of extreme floods. Since this group can be considered as a reference assemblage in the upper river segments, it has the highest factor number (F=5). During the extremely high water discharge and short residence time, the river phytoplankton was enriched with **D** group dominated by centric diatoms, considered as typical and permanent Danubian species. Therefore this group has a high factor number (F = 4). Consequently, the highest value of the Q-index (4.49) was established in the condition of extreme floods, indicating the *excellent* ecological state.

The worst ecological state was in April, in the conditions of high nitrogen concentrations in riverine water. Volvocalean green algae (group **G**) had the highest relative share in phytoplankton biomass. This group has low F value (1) and is characteristic for waters enriched with nutrients and highly alkaline conditions. As a result, the value of the Q index was 2.48 indicating *poor* ecological status. This shows that the Q index is sufficiently sensitive to human impacts.

Altogether, our results have shown that the ecological status of the River Danube changed from *poor* to *good* and *excellent* status during the year of 2013. It can be concluded that the assemblage index is a reliable instrument to assess the ecological status of large lowland rivers influenced by extreme hydrological events.

Non-wild type antibiotic resistant *Escherichia coli* in the River Danube: a six-year-comparison

Michael KOLLER[a], Kerstin HACK[a], Irina DIELACHER[a], Julian WACHTER[a], Iris SCHACHNER[b,g], Stefan JAKWERTH[b,g], Stoimir KOLAREVIĆ[c], Margareta KRAČUN-KOLAREVIĆ[c], Erika TÓTH[d], Domenico SAVIO[e,f,g], Andreas H. FARNLEITNER[e,f,g], Clemens KITTINGER[a], Alexander K.T. KIRSCHNER[b,e,g], Gernot ZARFEL[a]*

[a] *Institute of Hygiene, Microbiology and Environmental Medicine, Medical University Graz, Austria*
[b] *Institute for Hygiene and Applied Immunology – Water Microbiology, Medical University Vienna, Austria*
[c] *Institute for Biological Research ¨Siniša Stanković¨, National Institute of Republic of Serbia, Department for Hydroecology and Water protection, University of Belgrade, Serbia*
[d] *Department of Microbiology, Eötvös Loránd University, Budapest, Hungary*
[e] *Division Water Quality and Health, Karl Landsteiner University of Health Sciences, Krems, Austria*
[f] *Institute for Chemical, Environmental and Bioscience Engineering, Vienna University of Technology, Austria*
[g] *Interuniversity Cooperation Centre Water & Health, www.waterandhealth.at, Austria*

[*] *Corresponding author: Michael.Koller@medunigraz.at*

Introduction

The emerging occurrence of human induced antibiotic resistant bacteria (ARB) is not only limited to clinical surroundings: they can also be found in the human population, animals and the water environment. Large rivers are of great concern as regards the spreading of ARB. Thus, this ongoing study´s aim is to analyze the major propagation pathways and sources of ARB in the Danube, and to do a six-year-comparison with data obtained in 2013.

Study design and methods

Within the frame of the 4th Joint Danube Survey (JDS) of the International Commission for the Protection of the Danube River (ICPDR), water samples were taken at 36 sampling points along the whole Danube. *Escherichia coli* as clinically relevant organisms were isolated and tested for their susceptibility to 20 different antibiotics.

Results

1298 *E. coli* isolates have been tested so far. 11.33 % of them were multiresistant and 23.19 % were resistant to one or two classes of antibiotics. The preliminary data show a very similar pattern compared to the data obtained in 2013 (629 isolates) when 9.70 % of the isolates were multiresistant and 29.09 % were resistant to one or two classes of antibiotics. Most of the resistances are still to ampicillin and tetracycline. There are no resistances to carbapenems, colistin, amikacin and tigecycline. But there is a significant increase in resistances to amoxicillin with clavulanic acid, moxifloxacin and piperacillin with tazobactam and a significant decrease regarding tetracycline. 21 isolates are confirmed ESBL-producers while in 2013 there were four.

Discussion

In comparison the data of 2013 and 2019 show a similar pattern regarding multiresistance. Regarding resistances to single antibiotics significant changes could be determined. However, there are still many of the isolates to be tested until the final analysis.

A comprehensive, quantitative study concept on the occurrence and spread of human-induced antibiotic resistance in Lower Austrian rivers

M LEOPOLD[a,b], A KABICHER[a,b,c], M KOLLER[d], R LINKE[b,c], W KANDLER[e], M SULYOK[e], C ASPÖCK[f], IJ PAP[f], G ZARFEL[d], C KITTINGER[d], AKT KIRSCHNER[a,b,g] & AH FARNLEITNER[a,b,c]*

[a] *Division Water Quality and Health, Karl Landsteiner University of Health Sciences, Krems, Austria*
[b] *Interuniversity Cooperation Centre Water & Health, www.waterandhealth.at*
[c] *Institute for Chemical, Environmental and Bioscience Engineering, Vienna University of Technology, Austria*
[d] *Institute of Hygiene, Microbiology and Environmental Medicine, Medical University Graz, Austria*
[e] *Institute for Bioanalytics and Agro-Metabolomics, University of Natural Resources and Life Sciences, IFA Tulln, Austria*
[f] *Clinical Institute for Hygiene and Microbiology, University Clinics St. Pölten, Austria*
[g] *Institute for Hygiene and Applied Immunology – Water Microbiology, Medical University Vienna, Austria*

**Corresponding author: melanie.leopold@kl.ac.at*

River water is used for a variety of human applications (e.g. drinking water production, recreation, irrigation). Microbiological contamination of rivers from point sources (e.g. wastewater treatment plants) or diffuse inputs (e.g. agriculture) can pose a threat to human health. Via faecal inputs, human-induced (acquired due to human activities) antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARG) can enter rivers, in addition to faecal transmitted pathogens. In recent years, many studies have shown the presence of human-induced ARBs and ARGs in rivers. However, most studies used limited methodology (application of non-quantitative or either only cultivation-based or only molecular biology methods). In addition, they often covered only small geographic areas and short time periods.

The aim of this ongoing study is to comprehensively investigate the distribution patterns, dispersal pathways and influencing factors of human-induced ARB and ARG in Lower Austrian rivers spatially and temporally. In addition to comprehensively determining the extent and origin of the faecal pollution as well as important hydrological, chemical and physical environmental factors, ARB and ARG will be determined in a combined quantitative cultivation and DNA-based approach. Both river water and submerged biofilms will be considered. Among others, we will investigate to what extent the detected human-induced ARB and ARG are coupled to the extent of faecal pollution from sewage treatment plants and whether there is an accumulation of resistance, especially in biofilms, due to co-selection by pesticides or heavy metals.

During one year, samples of four Lower Austrian rivers are taken and analysed at five time points along gradients of faecal pollution (inflow of small to large wastewater treatment plants), river size (small river headwaters to the Danube) and the extent of wastewater (influence of small to large clinics). In addition, at a representative sample point downstream of a wastewater treatment plant, a comparison of the antibiotic resistances found with resistances from the clinic whose wastewater enters this wastewater treatment plant is made.

With this holistic quantitative approach, the study will provide much more comprehensive insights into the occurrence and spread of human-induced antimicrobial resistance in rivers, which are important for deeper understanding and sustainable management of microbiological water quality in the future.

Extent and origin of fecal pollution in water and biofilms along the Danube River

I SCHACHNER[a,b], J VIERHEILIG[b,c], D SAVIO[b,c,d], C KOLM[b,c,d], G ZARFEL[e], M KOLLER[e], C KITTINGER[e], S JAKWERTH[a,b], S IXENMAIER[b,d], R LINKE[b,d], AH FARNLEITNER[b,c,d] & AKT KIRSCHNER[a,b,c]*

[a] *Medizinische Universität Wien, Institut für Hygiene und Angewandte Immunologie - Wassermikrobiologie, Wien*
[b] *Interuniversity Cooperation Centre Water & Health, www.waterandhealth.at*
[c] *Karl Landsteiner Privatuniversität für Gesundheitswissenschaften, Fachbereich Wasserqualität und Gesundheit, Krems*
[d] *Technische Universität Wien, Institut für Verfahrenstechnik, Umwelttechnik und technische Biowissenschaften, Wien*
[e] *Medizinische Universität Graz, Institute für Hygiene, Mikrobiologie und Umweltmedizin, Graz*

** Corresponding author: iris.schachner@meduniwien.ac.at*

Europe's second largest river, the Danube River, was investigated for the fourth time in summer 2019 in the course of the Joint Danube Survey (JDS) from its headwaters to the delta to study its microbiological-faecal pollution patterns. The standard fecal indicator bacterium *Escherichia coli* (*E. coli*), which has already previously proven to be an excellent indicator for the assembly of a water quality map of the entire Danube River, was quantified using the Colilert system. In general, longitudinal pollution patterns showed a comparable picture to previous surveys, with low to moderate pollution in the upper reaches (Germany, Austria) and critical to heavy pollution in the middle and lower sections, especially in Serbia. However, in Hungary (downstream of Budapest) and parts of Romania (downstream of Bucharest), significantly lower loads were found than in previous JDSs, likely due to the commissioning of large wastewater treatment plants.

To trace back the origin of fecal pollution, human- and animal-associated fecal genetic markers were detected in river water using quantitative PCR. In agreement with previous results (2013), mainly human-associated genetic markers were detected. The influence of animal pollution (ruminants, pigs), can be assumed as low and only of local importance.

In addition to the detection of *E. coli* in the water compartment, its occurrence in biofilms along the course of the entire river bank was investigated for the first time. The occurrence in biofilms may indicate permanent pollution or even colonization, which is not only caused by temporary pollution events. Biofilms could also act as reservoirs for anthropogenically introduced microorganisms such as antibiotic-resistant bacteria.

A comparison of the proportion of *E. coli* in total bacterial showed that the relative abundances of *E. coli* in biofilms along the entire Danube were 1-2 $\log_{10}$ levels lower than in water samples. The only exceptions were biofilms of a few tributaries (Inn, Drava, Russenski Lom, Arges) and two sites at the Danube River in Romania. Despite lower *E. coli* concentrations in biofilms, these may still harbor more persistent or resistant strains. This will be determined in subsequent analyses.

Problems with the water conveyance capacity and the possibilities of improving it along the Hungarian Middle Tisza River section based on a pilot area

Tamás PRÁVETZ, András FICZERE, Annamária SÜTŐ, Dávid Béla VIZI*

Middle Tisza District Water Directorate
Hungary, Szolnok, Boldog Sándor István krt. 4, H-5000

**Corresponding author: pravetz.tamas@kotivizig.hu*

Over the past decades, several extraordinary floods have drifted off the rivers in the Danube River Basin. Each of the flooding levels that emerged were one of the 100-year return waves that caused significant human and economic damage in the affected countries. To handle increasing flood risks within the European Union the No. 2007/60/EK Directive requires almost all river basin districts to identify areas where is a significant potential flood risk or likely to occur. The identified flood risks are needed to be reduced as much as possible to ensure greater human and material security. In the case study we try to identify the problems with the water conveyance capacity, especially in connection with the land use and forest management on the floodplain areas. According to our measurements, these have a significant effect on the runoff ability of the floodplain directly and indirectly also. Land use on the floodplains have changed continuously in the last decades. The increase of forest area resulted in a decrease of the water conveyance capacity on the floodplain. It caused significant negative impact in connection with water velocity, sediment accumulation and level of floods also. The main challenge is to develop a new agricultural and forestry practices related to use of the landscape for improve the conveyance capacity, taken into consideration the Water Framework Directive and the maintenance of ecosystem services. In a pilot area, after dyke relocation we tested the optimal land use and a new afforestation technique that can significantly improve runoff. Based on the modeling results, the flow properties and conveyance capacity of the floodplains can be increased. If the case study gives satisfactory results in practice on the pilot area, it could be applied to other similar river sections in the Danube catchment area.

Floodplain restoration with dyke relocations in the Middle Tisza District, Hungary

*Dávid Béla Vizi [a]**

[a] Hydrologist, Middle Tisza District Water Directorate

** Corresponding author: vizi.david.bela@kotivizig.hu*

The river regulation and dyke construction works were finished on the Hungarian section of the Tisza River in the early 20th century. These measures created a new situation for the Hungarian flood protection. Over time, we had to face with new problems after the river has been situated between the dykes. The major challenges are that the river can only deposit the transported sediment between the embankments and the percentage of floodplain forests has increased tenfold over the last hundred years. These processes reduce the conveyance capacity of the floodplain areas and also increase flood peaks. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the runoff on the floodplain area.

The presentation introduces the current challenges along the Hungarian section of the Tisza River and also focusing on the upcoming climate change induced flood related issues. It presents the characteristics of the Tisza River which are endangered by hydrological extremes. Further aim is to demonstrate the applicability of a two-dimensional hydrodynamic model to study the effects of the dyke relocations. The presentation also introduces the modelling results of the pilot action on the Danube FLOODPLAIN project which is focusing on reducing the flood risk through floodplain restoration along the Danube River and its tributaries.

The Hungarian pilot area is located in the Middle Tisza District. Extreme flood events are often impact this region.

Useful method in fluvial ice monitoring

*Dr. Gábor KEVE[a]**

[a] Associate professor, acting head of department: Department of Regional Watermanagement, University of Public Service Faculty of Water Sciences, Baja, Hungary

** Corresponding author: keve.gabor@uni-nke.hu*

An unlucky combination of hydro-meteorological conditions can produce serious frosts, and consequently ice floods on the Hungarian reach of the Danube river. The effect of ice flood is a real danger for the whole river basin and especially for floodplains. This situation can be experienced even in spite of global warming processes. Therefore a monitoring system was developed during the last 15 years in the region for a 130 km segment of the Danube. All together five cameras were installed at a 30-40 km interval to achieve optimal observational capabilities along the river. In January 2009 and later in February 2012 next in January 2017 three ice events were successfully recorded at the monitoring locations.

István Zsuffa's 1978 pioneering black-and-white industrial camera's continuous ice observation system has been revitalized and upgraded to create an ice-detect service based on ice coverage in real time, which is rarely can be found in the world. This system contributes greatly to the success of the ice floods and ice floe damage prevention work for the water resources agencies. In addition, it creates the possibility of scientific research on ice floes, data supply for in situ numerical modeling.

The research establishes and validates an automated process that can be used to measure the rate of ice coverage and the transverse distribution of the ice surface yield per unit width in consecutive flow cross section. Collection of the in-situ datasets requires serious effort, especially when the measurements are taking place on an icy river. Video recording is safe, but the thickness measurements needed to determine the ice volume flow must be carried out manually on the river. For the manual ice thickness measurements, I created and validated a device that allows simple and quick measurements on icebreaker ships. This result is extremely useful because from the dense timeseries of the transverse ice area ratio further analyzes can be conducted.

This work creates the basis for the modernization of the Hungarian ice-monitoring network. The operation of such a network provides the condition that in the future on the larger rivers ice floe forecasting and alarm systems may be established. The time series collected over the past decades provide data for national research on river ice phenomenon’s

The new findings contribute to a more accurate understanding of the spatial and temporal structures of ice floes in rivers, as well as the methodological development of their measurability and reproducibility.

Characterisation of water levels in the Lower Danube River and their association with primary production

Vesela EVTIMOVA[a], Paolo FRUMENTO[b]*

[a] Department of Aquatic Ecosystems, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria
[b] Department of Political Sciences, University of Pisa, Pisa, Italy

** Corresponding author: vesela.evtimova@gmail.com*

The Danube River is the second longest river in Europe, with a drainage basin spanning over ten ecoregions and 19 European countries. This makes it a major international hydrological basin and ecological corridor, but also contributes to the high pressure on the ecosystem from diverse sources, e.g. fragmentation, alteration of its hydrological regime, land-use change and the related high concentrations of nutrients. Further, the Danube River is affected by the increase of climate variability, in particular the higher frequencies and intensities of extreme climate events, concurrent with the development of navigation and hydropower generation, and will inevitably lead to further hydromorphological alternation, i.e. modification of water-level fluctuations (WLF). Our study aimed at: (i) exploring the hydrological regime of the Lower Danube River and (ii) relating water chemistry and hydrological metrics with changes in the primary production (quantified as chl a) of the river. We described the amplitude and variability of WLF in the Bulgarian section of the Lower Danube River between 2008 and 2014. The analyses used four temporal scales and were based on data for eight stations. We found annual and longer-term cycles, as well as seasonality in the WL. We then tested the importance of a parsimonious subset of hydrological metrics and factors for the content of chl a in the Lower Danube River. According to our results, of greatest importance were environmental factors for the big and small concentrations of chl a, while only pH was statistically significant for the median concentrations of chl a. The analyses identified total phosphorous and the amplitude of WLF as important predictors of the primary production, followed by the month of sampling and the water temperature. These results indicated that the primary production of the water column in the Lower Danube River was associated not only with availability or excess of nutrients but also with the seasonal dynamics and the fluctuations in its water levels.

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Mayflies, stoneflies and caddisflies (Arthropoda: Insecta) from the Lower Danube River

Vesela EVTIMOVA[a], Violeta TYUFEKCHIEVA[a], Yanka VIDINOVA[a]*

[a] Department of Aquatic Ecosystems, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria

** Corresponding author: vesela.evtimova@gmail.com*

Macroinvertebrate communities are often used as indicators of health of aquatic ecosystems. Mayflies (Ephemeroptera, E), stoneflies (Plecoptera, P) and caddisflies (Trichoptera, T) or EPT taxa are orders of semi-aquatic insects: their immature stages usually inhabit very diverse freshwater habitats. Some of the species of these orders are particularly sensitive to environmental stress. We summarise data on EPT taxa from the Lower Danube River along both longitudinal and temporal scales. A total of 49 taxa from 50 localities are known from the Bulgarian stretch of the Lower Danube River: 24 mayflies, three stoneflies and 22 caddisflies. They belong to 27 genera: 13 of Ephemeroptera, three of Plecoptera and 11 of Trichoptera. Three of the listed mayfly species are classified as regionally extinct in the Red Data Book of Bulgaria, three as critically endangered, one as endangered and one as vulnerable. Historically, only three species of Plecoptera have been recorded from the Bulgarian stretch of the Danube River. However, during the last century, their populations have dramatically decreased and these stoneflies are currently considered extinct. Three of the recorded caddisfly taxa are considered rare, while seven are very rare for Bulgaria. Moreover, a negative tendency of the EPT taxa richness of the Lower Danube River is apparent when comparing the studies on the benthic fauna over the last 50 years. Numerous threats along the Danube River basin could further affect the distribution and richness of EPT taxa, e.g. deforestation, extraction of inert materials and pollution. In order to protect and preserve these sensitive insect groups, it is essential to protect the environments that are vital for the development of their aquatic stages.

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Fish eDNA survey on the major tributaries of River Danube

Paul MEULENBROEK[a], Didier PONT[a],* Alice VALENTINI[b], *Pauline JEAN[b], Tibor ERŐS[c], Ladislav PEKÁRIK[d], Mirjana LENHARDT[e], Thomas FRIEDRICH[a] and Thomas HEIN[a, f]*

[a] *Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Vienna, Austria*
[b] *SPYGEN, Le Bourget du Lac Cedex, France*
[c] *Centre for Ecological Research, Balaton Limnological Institute, Tihany, Hungary*
[d] *Plant Science and Biodiversity Center, Slovak Academy of Sciences, Bratislava, Slovakia*
[e] *Institute for Biological Research, University of Belgrade, Belgrade, Serbia*
[f] *WasserCluster Lunz, Lunz, Austria*

** Corresponding author: paul.meulenbroek@boku.ac.at*

Since its first application to macroorganisms in 2008, environmental DNA (eDNA) has increasingly appeared to be a promising non-invasive method for improving aquatic biodiversity monitoring. eDNA refers to DNA obtained from environmental samples without the prior isolation of any target organism. In the case of water samples, eDNA contains both intra-organism DNA (e.g., small planktonic organisms) and extra-organism DNA (e.g., from fish) which can be cellular or extracellular and degraded. With the emergence of next-generation sequencing (NGS) platforms coupled with and the use of universal PCR primers (eDNA metabarcoding), large collections of taxa can be identified via a single sample. This not only offers the possibility to detect rare or evasive species without a priori but also allows the rapid biodiversity assessment of large communities and even the reconstruction of ecological and evolutionary processes from easy-to-collect samples. We tested the ability of this approach to characterize fish communities in multiple medium sized tributaries of the Danube. In total **18 major tributaries** were sampled across the whole Danube River basin in 2019. These are, listed from upstream to downstream: Lech, Isar, Inn, Traun, Enns, Morava, Raab, Hron, Ipel, Drava, Tisza, Sava, Velika Morava, Olt, Rusenski Lom, Arges, Siret and Prut. Preliminary results reveal that at least **55 species** were detected, including several protected, native as well as non-native and invasive species. The spatial pattern of fish community structure described by all eDNA metabarcoding detections at the catchment scale allows a better characterization of the spatial representativeness of this method. All samples were taken within a period of two weeks, revealing a standardized snapshot of fish biodiversity of diverse communities over a large scale, covering a distance of more than 2400 river kilometers along the Danube. In conclusion, eDNA metabarcoding is an easy way to give a confident and comprehensive description of local fish biodiversity in the studied systems.

In search of elusive sterlet (*Acipenser ruthenus*) in Slovenia

Polona PENGAL[a], Eva HORVAT[a], Blaž COKAN[a]*

[a] REVIVO, Institute for ichthyological and ecological research, Šmartno pri Slovenj Gradcu 172, Šmartno 2383, Slovenia

** Corresponding author: polona.pengal@ozivimo.si*

One of the aims of the MEASURES project in Slovenia is to determine the wintering (W), spawning (SP), nursey (N) and feeding (F) habitats of migratory fish species (in Slovenia: sterlet (*Acipenser ruthenus*), nase (*Chondrostoma nasus*), barbel (*Barbus barbus*), cactus roach (*Rutilus virgo*) and vimba bream (*Vimba vimba*)) with an emphasis on sterlet habitats in the Mura and Lower part of Sava River by field sampling and analysing written and personal records. The aim is to identify the most efficient method for scientific sampling and monitoring of migratory fish species and as well as mapping their habitats in Danube tributaries which is the basis for future conservation actions.

Sterlet used to be a regularly occurring fish in Slovenian part of the Mura and Sava rivers, while the Russian sturgeon (*Acipenser gueldenstaedtii*; Govedič&Friedrich, 2018) was less frequent. However, their natural populations declined dramatically and only one sterlet catch has been confirmed in the last 20 years in Slovenian rivers, with the fish origin traced to Austria (Govedič&Friedrich, 2018). There were additional records reported before 2000 by local fishermen, but those cannot be confirmed through photographic record.

Potential habitats were identified and described in 2018 and 2019 by scanning the river with a sonar and sampling the sediment and macroinvertebrates. The locations were then classified into the 4 potential habitat groups (W, SP, N, F). In the second step, feeding habitats were sampled using long lines, but no target species was found. Underwater visual census method was tested to identify wintering habitats, but the strong, diverse layered current prevented us from reaching the top positions. Thus far, the sampling of wintering locations using fixed trammel nets was the most successful method tested, resulting in the highest diversity of fish detected, including 3 of the target species as well as a number of other endangered species. Sampling of fish during migration to their spawning and feeding places was performed in spring 2020 using fixed trammel nets and the comparative evaluation of these methods is presented here for the first time.

Invasive alien species in the Danube River Basin: Results of the JDS4

Teodora TRICHKOVA[a], Béla CSÁNYI[b]*, András WEIPERTH[c], Katarina ZORIĆ[d], Vinzenz BAMMER[e], Péter BORZAF[f], Alexander WEIGAND[g], Ana Cristina CARDOSO[h], Miroslav OČADLIK[i], Kateřina BUBÍKOVÁ[j], Igor STANKOVIĆ[k], Milcho TODOROV[a], Ivan BOTEV[a], Marian KENDEROV[l], Zdravko HUBENOV[m], and Momir PAUNOVIĆ[d]**

[a] *Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria*
[b] *Retired Hydrobiologist, Göd, Hungary*
[c] *Institute for Aquaculture and Environmental Safety, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary*
[d] *Institute for Biological Research "SinišaStanković", University of Belgrade, Belgrade, Serbia*
[e] *Institute for Water Ecology and Fisheries, Federal Agency for Water Management, Mondsee, Austria*
[f] *Danube Research Institute, Centre for Ecological Research, Budapest, Hungary*
[g] *National Museum of Natural History, Luxembourg, Luxembourg*
[h] *European Commission, Joint Research Centre (JRC), Ispra, Italy*
[i] *WWF Slovakia, Bratislava, Slovakia*
[j] *Nature Conservation Agency of the Czech Republic, Prague, Czech Republic*
[k] *Central Water Management Laboratory, Zagreb, Croatia*
[l] *Biological Faculty, Sofia University 'St. Kliment Ohridski', Sofia, Bulgaria*
[m] *National Museum of Natural History, Bulgarian Academy of Sciences, Sofia, Bulgaria*

** Corresponding authors: bela.csanyi@gmail.com; trichkova@hotmail.com; mpaunovi@ibiss.bg.ac.rs*

The co-existential pattern of native and alien species was investigated along the Danube River Basin (DRB) during JDS4 (2019). A total of 51 JDS4 sites was sampled in the entire Danube River, and additional sites in the Lower Danube. The standard operational procedures adopted by ICPDR, and – for the first time – eDNA-based tools were used for the sampling. A smartphone application 'Invasive Alien Species in Europe' developed by the European Commission's Joint Research Centre and specifically updated to include invasive alien species concerning the DRB was additionally applied for data collection.

Six alien aquatic plants, 35 benthic macroinvertebrates and 17 fish species were recorded in DRB during the survey. Two groups of invasive species should be mentioned: 1) Ponto-Caspian species that do not have to cross very strong hydro- and geographical barriers during their spreading; and 2) Species that cross large geographical distances to arrive to the DRB (originated from North America and Asia). An overall decrease of the former abundance of *Corbicula fluminea* was recognised in some Danube sections. An extreme large amount of Ponto-Caspian amphipods was detected in the Upper Danube: *Echinogammarus* sp. and Gammaridae gen. sp., representing one third of the overall individual number of the macroinvertebrates detected in the Upper Danube (Austria). New Decapoda species (*Procambarus clarkii, Pacifastacus leniusculus*) appeared at new locations of the Middle Danube, indicating their recent spreading. A new Ponto-Caspian snail species (*Clathrocaspia knipowitschii*) was distributed along extended sections of the Lower and Middle Danube. The magnificent bryozoan *Pectinatella magnifica* was recorded for the first time in the Bulgarian shoreline zone of the Danube River. The (e)DNA-based detection revealed the presence of 5 macroinvertebrate species which were not recorded by other methods. The level of biocontamination of the Danube River was estimated as moderate to high, with higher levels for the Upper (high to severe biocontamination) and Middle

Danube (moderate to high biocontamination), in comparison to the Lower Danube (low biocontamination). The results show that DRB is under considerable influence of biological invasions. The number of identified alien species has increased over three times since 2007. The (e)DNA-based method has proved to be an effective additional tool in aquatic IAS monitoring. The smartphone app may greatly facilitate the access and update of IAS records for management and control purposes and contribute to IAS awareness raising in the Danube countries by involving actively the citizens in future surveys.

Zooplankton of different types of water bodies in the Danube delta

*Yuliia HROMOVA[a]**

[a] Institute of hydrobiology National Academy of Sciences of Ukraine, Kyiv, Ukraine

** Corresponding author: yulia.gromova@gmail.com*

The Danube delta is rich in different types of water bodies, such as river branches of different order, bays and lagoons of the sea edge, lakes etc. Along the course of the river, the hydrological and physicochemical parameters of the water change, which is also associated with penetration of the sea waters into the delta. In July 2019, a comparative analysis of the zooplankton composition and quantitative parameters in the water bodies of different types and at different distance from the Black Sea was carried out: the main river upstream branching (nearby the Reni town), the Kiliia branch of the delta (the largest), the Bilgorodskiy branch and the bay of the sea edge of the delta – Soloniy Kut, where the Bilgorodskiy branch falls. During the period of investigations, the water temperature varied from 25,2°C (Soloniy Kut Bay) to 28,7°C (main river). The salinity in the sampling water was close – within 0,24–0,26‰, except the Soloniy Kut Bay, where it reached 5,61‰.

Maximal taxonomic richness of zooplankton was found in the Soloniy Kut Bay – 15 LIT (the lowest identified taxon), 1–10 LIT was registered in the watercourses. The similarity of the taxonomic composition of the water bodies did not exceed 0,48 by the Sørensen index. Copepoda prevailed in the bay and branches of the river. On contrast to the mainly freshwater zooplankton character in the watercourses, in the Soloniy Kut Bay occurred the brackish and euryhaline marine forms such as *Acartia tonsa* Dana, *Halicyclops neglectus* Kiefer, juveniles of Balanus and Polychaeta etc.

The zooplankton abundance in the water bodies of the Danube delta was low. However, in the Soloniy Kut bay, it was significantly higher (6730 ind/m^3, 40,23 mg/m^3) than in the watercourses (30–410 ind/m^3, 0,01–7,03 mg/m^3). With the exception of the main river site upstream the branching, where only Rotifers were found, juveniles of Copepoda quantitatively prevailed in the branches and the bay.

Thus, the mixed composition of zooplankton, consisting of freshwater, brackish-water, and marine taxa, as well as an increase of its taxonomic richness and abundance in the bay of sea edge of the Danube delta, indicates the existence of the river/sea-type ecotone zone.

Beacon lights for the protection of night-swarming mayflies

Ádám EGRI[a], Ádám MÉSZÁROS[a], György KRISKA[a,b]*

[a] Danube Research Institute, MTA Centre for Ecological Research, Budapest, Hungary
[b] Biological Institute, Eötvös University, Budapest, Hungary

** Corresponding author: egri.adam@okologia.mta.hu*

Negative impact of artificial nocturnal illumination on animals is gaining increased attention. Several nocturnal insects are also affected, including the protected night-swarming Danube mayfly (*Ephoron virgo*) (ecological value per individual in Hungary = 10000 HUF ≈ 30 EUR). When huge swarms of egg-carrying females encounter illuminated bridges during their compensatory flight, they get attracted to the public lighting on the bridge and perish with their eggs in astronomical numbers due to their positive phototaxis. Besides the loss in the population, the surface of the bridge become slippery and dangerous because of the thick layer of carcasses. Recently we showed that the mayfly swarms can be prevented from being perished on the dry land with light sources attached to the bridge structure, when the bridge lights cannot be switched off due to traffic safety reasons. These beacons attract the mayflies, keep them above the water and the exhausted mayflies end up in the river with their eggs, as naturally should happen. We also measured the wavelength dependence of phototaxis of *E. virgo* in the human-visible spectral range. We found that the attraction is highest in the blue range, gradually decrease with wavelength and red wavelengths are the least attractive for *E. virgo*. With this information, we can estimate the attractiveness of different light source types used widely in public lighting. We also participated in the construction of the first, permanently installed, spectrally optimized mayfly protecting beacon system on the bridge of Tahitótfalu (Hungary).

List of Participants

No.	Title	First name	Name	Institute	City
1	PhD	Karina Paula	Battes	Babes-Bolyai University	Cluj-Napoca/Romania
2		Isabell	Becker	Department of Wetland Ecology, KIT	Karlsruhe/Germany
3		Nikolina	Bek	Josip Juraj Strossmayer University of Osijek, Department of Biology	Osijek/Croatia
4	Dr.	Florian	Betz	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
5	Dr.	Juerg	Bloesch	IAD (Emeritus Eawag-ETH)	Zürich/Switzerland
6		Tim	Borgs	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
7	Dr.	Krisztina	Buczkó	Danube Research Institute Centre for Ecological Research	Budapest/Hungary
8	Assoc. Prof.	Dušanka	Cvijanović	Faculty of Sciences, University of Novi Sad	Novi Sad/Serbia
9	Prof. Dr.	Bernd	Cyffka	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
10		Kristóf	Dobó	General Directorate of Water Management of Hungary	Budapest/Hungary
11		Jelena	Đorđević	Institute for Multidisciplinary Research	Belgrade/Serbia
12	Prof. Dr.	Dejana	Đorđević	University of Belgrade, Faculty of Civil Engineering	Belgrade/Serbia
13		Mihai	Doroftei	Danube Delta National Institute for research and Development	Tulcea/Romania
14	Prof.	Radu	Drobot	Technical University of Civil Engineering, Bucharest	Bucharest/Romania
15	PhD	Edith	Durisch	Privat	
16	Prof. Dr.	Gregory	Egger	Karlsruhe Institute of Technology (KIT), Department Floodplain Institute	Karlsruhe/Germany
17	Dr.	Ádám	Egri	ELKH, Centre for Ecological Research, Institute of Aquatic Ecology	Budapest/Hungary

18	Dr.	Vesela	Evtimova	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Sofia/Bulgaria
19		Helga	Fazekas	Middle Tisza District Water Directorate	Szolnok/Hungary
20		Sabine	Fürst	Catholic University of Eichstaett-Ingolstadt	Eichstaett/Germany
21		Marion	Gelhaus	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
22	Prof. PhD	Mateja	Germ	University of Ljubljana, Biotecnical Faculty	Ljubljana/Slovenia
23		Stefan	Giehl	Technical University of Munich	Munich/Germany
24	Prof. Dr.	Gabriele	Gien	President of Cath. University of Eichstaett-Ingolstadt	Eichstaett/Germany
25	Prof. Dr.	Martin	Grambow	Bavarian State Ministry of the Environment and Consumer Protection	Munich/Germany
26		Peter	von der Grün	Head of District Neuburg-Schrobenhausen	Neuburg/Germany
27	Dr.	Gertrud	Haidvogl	Univ. of Natural Resources and Life Sciences (BOKU), Inst. of Hydrobiology	Vienna/Austria
28	Prof. Dr.	Thomas	Hein	University of Natural Resources and Life Sciences, Vienna & WasserCluster Lunz	Vienna/Austria
29		Sophia	Helgert	Catholic University of Eichstaett-Ingolstadt	Eichstaett/Germany
30		Eva	Horvat	Institute for ichthyological and ecological research	Šmartno/ Slovenia
31	Dr.	Yuliia	Hromova	*Institute of hydrobiology National Academy of Sciences of Ukraine*	Kiev/Ukraine
32	Dr.	Monica	Ionita	Alfred Wegener Institute	Bremerhaven/Germany
33	Prof.	Vera	Istvánovics	MTA-BME Water Research Group	Budapest/Hungary
34	Assist. Prof. Dr.	Petja	Ivanova-Radovanova	Climate, Atmosphere and Water Research Institute - Bulgarian Academy of Sciences	Sofia/Bulgaria
35	Dr.	Georg	Janauer	University of Vienna	Vienna/Austria

36		Jovana	Jovanović Marić	Institute for Biological Research"Siniša Stanković"	Belgrade/Serbia
37		Hossein	Kazemi	University of Potsdam	Potsdam/Germany
38	Assoc. Prof. Dr.	Gábor	Keve	Department of Regional Watermanagement/ University of Public Service Faculty of Water Sciences	Baja/ Hungary
39	Assoc. Prof. Dr.	Alexander	Kirschner	Medical University Vienna	Vienna/Austria
40	Dr.	Harald	Koethe	International Centre for Water Resources and Global Change (ICWRGC)	Koblenz/Germany
41		Michael	Koller	Medical University Graz	Graz/Austria
42		Jane	Korck	Bavarian State Ministry of the Environment and Consumer Protection	Munich/Germany
43	Prof. Dr.	Benno	Kügel	Bavarian State Office for Water Management	Ingolstadt/Germany
44		István	Láng	General Directorate of Water Management of Hungary	Budapest/Hungary
45	Dr.	Werner	Lazowski	TB Ökologie	Vienna/Austria
46		Melanie	Leopold	Karl Landsteiner Private Univesity, Division Water Quality and Health	Krems/Austria
47		Gabriela	Lesanu (Sasu)	National Administration Romanian Waters	Bucharest/Romania
48		Attila	Lovas	Middle Tisza District Water Directorate	Szolnok/Hungary
49		Borislava	Margaritova	WWF	Bulgaria
50	Dr.	Paul	Meulenbroek	University of Natural Resources and Life Sciences (BOKU)	Vienna/Austria
51	Assoc. Prof.	Melita	Mihaljević	University of J.J. Strossmayer	Osijek/Croatia
52		Hossein	Mousazadeh	Eotvos Lorand University	Budapest/Hungary
53		Stephanie	Natho	Institute of Environmental Science and Geography/ University of Potsdam	Potsdam/ Germany
54		Maja	Novković	University of Novi Sad	Novi Sad/ Serbia
55	Prof. Dr.	Sinisa	Ozimec	Josip Juraj Strossmayer University of Osijek Faculty of	Osijek/Croatia

				Agrobiotechnical Science	
56	PhD	Polona	Pengal	Institute REVIVO	Slovenj Gradec/Slovenia
57		Francesca	Perosa	Technical University of Munich	Munich/Germany
58		Andrej	Peternel	Agencija RS za okolje (Slovenian Environment Agency)	Ljubljana/Slovenia
59	Prof. Dr.	Hervé	PIÉGAY	Directeur de Recherche CNRS Laboratoire EVS - ENS de Lyon	Lyon/France
60		Maryna	Pohorielova	Institute of Hydrobiology of NAS of Ukraine	Kiev/Ukraine
61	PhD	Tamás	Právetz	Middle Tisza District Water Directorate	Szolnok/Hungary
62		Matthias	Pucher	Wassercluster Lunz / BOKU	Lunz/Austria
63	PD Dr.	Martin	Pusch	Leibniz Institute of Freshwater Ecology and Inland Fisheries	Berlin/ Germany
64		György	Rátfai	Middle Tisza District Water Directorate Tisza Office	Szolnok/Hungary
65		Biljana	Rimcheska	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Sofia/Bulgaria
66		Annika	Rippert	Cath. University of Eichstaett-Ingolstadt	Eichstaett/Germany
67	Dr.	Larysa	Samchyshyna	Institute of Fisheries NAAS	Kiev/Ukraine
68	Dr.	Cristina	Sandu	International Association for Danube Research	
69		Iris	Schachner	Institute of Hygiene and applied Immunology, Medical University of Vienna	Vienna/Austria
70		Iris	Schachner	Center for Pathophysiology, Infectiology and Immunology, Institute for Hygiene and Applied Immunology	Vienna/Austria
71	Dr.	Alja	Schmidt-van Dorp	Hydrobia Research	

72		Nikola	Schulte-Kellinghaus	International Commission for the Protection of the Rhine	Koblenz/Germany
73		Christian Rene	Schuth	Cath. University of Eichstaett-Ingolstadt	Eichstaett/Germany
74	Dr.	Ulrich	Schwarz	Fluvius	Vienna/Austria
75	Dr.	Barbara	Stammel	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
76		Sophia	Steinbacher	Karl Lansteiner University	Krems/Austria
77	PhD	Filip	Stevic	Josip Juraj Strossmayer University of Osijek, Department of Biology	Osijek/Croatia
78	PhD	Milica	Stojković Piperac	University of Niš	Niš, Serbia
79	PhD	Enikő Anna	Tamás	University of Public Service, Faculty of Water sciences	Baja/Hungary
80	PD Dr.	Katrin	Teubner	University of Vienna	Vienna/Austria
81		Péter	Tóth	Middle Tisza District Water Directorate	Szolnok/Hungary
82	Assoc. Prof. Dr.	Teodora	Trichkova	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Sofia/Bulgaria
83	Dr.	Maria Christina	Trifu	National Institute of Hydrology and Water Management Romania	Bucharest/Romania
84		Martin	Tschikof	University of Natural Resources and Life Sciences (BOKU)	Vienna/Austria
85	Dr.	Violeta	Tyufekchieva	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Sofia/Bulgaria
86		Melinda Gabriella	Váci	Middle Tisza District Water Directorate Tisza Office	Szolnok/Hungary
87	Assoc. Prof.	Yanka	Vidinova	Insitute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Sofia/Bulgaria
88		Dávid Béla	Vizi	Middle Tisza District Water Directorate	Szolnok/Hungary
89		Mira	Vontz	Cath. University of Eichstaett-Ingolstadt/ Aueninstitut Neuburg	Eichstaett+Neuburg/Germany
90		Andreea-Gabriela	Zamfir	Department of Geography, Faculty of	Craiova, Romania

				Science, University of Craiova	
91	Dr.	Gernot	Zarfel	Medical University of Graz	Graz/Austria
92		Magdalena	Lauermann	Cath. University of Eichstaett-Ingolstadt	Eichstaett/Germany
93	Dr.	Herta	Heger		Vienna/Austria
94		Vinzenz	Bammer	Federal Agency for Water Management	Vienna/Austria
95	Assoc. Prof.	Tanja	Žuna Pfeiffer	Josip Juraj Strossmayer University of Osijek Department of Biology: Sveuciliste	Osijek/Croatia
96	Assoc. Prof.	Dubravka	Špoljarić Maronić	Josip Juraj Strossmayer University of Osijek Department of Biology: Sveuciliste	Osijek/Croatia
97	PhD	Péter	Borsa	Institute of Aquatic Ecology, Centre for Ecological Research	Budapest/Hungary
98		Gerhard	Nagl	Danube Environmental Forum	Deggendorf/Germany
99	Dr.	Andras	Abonyi	WasserCluster Lunz	Lunz/Austria
100		Olga	Kolychalow	Bundesanstalt für Gewässerkunde	Koblenz/Germany
101	Prof. Dr.	Erika	Schneider	KIT Karlsruhe, Abteilung Auen-Institut	Karlsruhe/Germany
102	Dr.	Anita	Kiss	Institute of Aquatic Ecology, Centre for Ecological Research	Budapest/Hungary
103		Madlen	Gerke	Bavarian Environment Agency	Augsburg/Germany