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Editorial

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Dear readers,

As editors of Danube News, we are delighted to present in this volume the results of two scientific investigations of the Danube River and another project funded by the Danube Transnational Programme. Clemens Kittinger and his colleagues address the spread of antibiotic resistance in waterborne bacteria of the Danube. They summarize recent studies and focus in particular on knowledge gaps. Closing them in future research is without doubt a crucial contribution to environmental change and human health. The article of Ionel Sorin Rîndașu Beuran and colleagues offers insights to another project, which is currently funded by the Danube Transnational Programme. DANUBE FLOODPLAIN aims at linking flood protection and ecological needs of the Danube and selected tributaries. The project will develop tools and guidance to achieve long term solutions via floodplain restoration and conservation, while simultaneously decreasing flood risk. Wolfram Graf and his co-authors present a survey of macroinvertebrate fauna in instream structures of the Austrian Danube hydropower plant Freudenau, Vienna. Their findings have proven the role of such structures to the overall biodiversity of benthic macroinvertebrate fauna in impounded rivers. The volume closes with news and notes, among them announcements of recent publications as well as information on an open call for the funding price "Living Danube". We thank all authors for their exciting contributions!

State of knowledge on the spread of antibiotic resistance in the waterborne bacterial populations in the Danube: a mosaic with a lot of missing tiles

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The presence of human induced antibiotic resistance has become normal in aquatic environments

It is an unfortunate finding that the presence of human-induced antibiotic resistance in the environment can no longer be seen as an exceptional occurrence. Even in the most untouched areas of the world, this phenomenon can be found which did not exist there 20 years ago. Aquatic ecosystems are specifically affected by these developments. Humankind abuses them as a huge cesspool in which the most diverse leftovers of our civilization are disposed. This has initiated a selection process within the bacterial communities that can contribute in the long run to the blunting of one of the most important weapons against infectious diseases: antibiotics (Kummerer 2009, Livermore 2012). In reaction to this, the WHO has developed a global action plan on antimicrobial resistance (https://www.who.int/antimicrobial-resistance/global-action-plan/en/), for which a research agenda was set up in 2015 for water, sanitation and antimicrobial resistance, defining the need for "Identification and quantification of sources, occurrence, and transport of antimicrobial resistant bacteria (ARB), antimicrobial resistance genes (ARG) and antibiotic residues from humans and animals in the environment" (Wuijts et al. 2017). Most recently, the EU Antimicrobial Resistance (AMR) Action Plan has demanded concrete actions to close knowledge gaps on AMR in the environment to be implemented in all EU member states (European Commission 2018).

The specific knowledge of the input, the influencing factors and the exact mechanisms of the spread, accumulation and loss of antibiotic resistances in aquatic ecosystems is unfortunately still largely lacking. Mostly small-scale studies and short temporal courses form an increasingly dense network of mosaic stones, but the limitations of these studies are not compensated by their numbers. The network and plasticity of aquatic ecosystems (which do not end at national borders or estuaries) are the real challenge. Another challenge is the high genetic flexibility and genetic diversity within the affected bacterial species (and together with a very short reaction time the adaptation to treatment schemes) (Kummerer 2009, Fernandez-Astorga et al. 1992, Aminov & Mackie 2009, Juhas et al. 2009).

Therefore, persistence of these human-induced genes and bacteria varies from case to case. As a rule, it is not the resistance itself that is the decisive factor, but above all the host bacteria and the mobility of the genes between species, genera or across family borders (Fernandez-Astorga et al. 1992, Juhas et al. 2009).

Every bacterial species is telling a different story

Enterobacteriacaeae – This family plays a special role as carrier of antibiotic resistance in aquatic ecosystems. On the one hand, *E. coli* is one of the most common facultative pathogens, which has increasingly appeared in multi-resistant variants in recent years, and on the other hand it is an important water quality indicator. Therefore, it is not surprising that the data situation for this species is relatively good as far as the spread of resistances in water ecosystems is concerned. This focus may lead to comparability and a better database for estimating the spread of *E. coli,* but the question remains if the changes that occur in the *E. coli* population in rivers, lakes and the sea can be transferred to other bacterial species (Oliveira & Reygaert 2019, Bain et al. 2014).

Besides *E. coli,* the so-called ESKAPE *(Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa and Enterobacter* species) are the most important germs with resistance problems. With the exception of *Staphylococcus aureus,* these are also species that can be found abundantly in the water ecosystem (Santajit & Indrawattana 2016). As far as the spread of resistance in the environment and in the water ecosystem is concerned, *E. coli* should be a good example for its genus and the family of *Enterobacteriaceae.* The exchange of resistance genes takes place easily via various genetically mobile elements and resistances that can be found in *E. coli* can also be detected in other species (Livermore 2012, Poirel et al. 2018). In contrast to many other *Enterobacteriaceae, E. coli* is not a typical environmental bacterial species. Nevertheless, dominant *E. coli* surface water isolates can be identified that differ from the dominant strains in healthy humans, animals or patient samples. For example, the strain MLST type ST131 should be highly dominant in the extended spectrum beta lactamases (ESBL) forming *E. coli,* as it is in the human population. However, this type is found relatively rarely in water, especially in the vicinity of wastewater discharges. For example, only three of 17 isolates of *E. coli* ESBL isolates isolated in 2013 during the Joint Danube Survey (JDS3) could show this ST type. In other studies from tributaries their proportion was even lower (Kittinger et al. 2016, Zurfluh et al. 2013, Korzeniewska & Harnisz 2013).

In contrast to *E. coli,* the majority of *Klebsiella pneumoniae* environmental isolates found with ESBL resistance can be assigned to the same strains that dominate clinical isolates. Another difference to *E. coli* is that multi-resistance was more than five times higher in the *E. coli* isolates than in *Klebsiella* isolates from the River Danube (9.7 %) *(Figure 1).* This data is in concordance with other existing studies on resistance in *Klebsiella* isolates. Screening studies also showed a dominance of *E. coli* over the other *Enterobacteriaceae* (Kittinger et al. 2016, Poonia et al. 2014). A higher inflow of resistant *E.coli* from humans and animals may be a possible reason. It is interesting to note that the variance in the resistance distribution of *E. coli* over an entire river such as the River Danube is quite low. The proportion of multiresistant, resistant and nonresistant *E.coli* remains roughly the same from the upper reaches to the delta. However, at higher polluted sites and after discharge of wastewater, strains with extreme resistance behavior can be found which are not found in other sections or only very rarely. Nevertheless, their occurrence has hardly any influence on the total share of the multi-resistant population (Kittinger et al. 2016).

For other bacteria, the situation is probably very different. Also with *Klebsiella* one can find strains with many resistances primarily in the proximity of discharges. In contrast to *E. coli,* however, a different pattern of resistant *Klebsiella* can be observed along the course of the River Danube with the clearly highest proportion in the third section of the river *(fig. 1)* (Kittinger et al. 2016).

Pseudomonas spp. - In the case of *Pseudomonas* spp., the distribution of the strains with fewer human-induced resistances are found in the delta and those with very high rates in the upper course of the River Danube. *Pseudomonadaceae* also show physiological differences that lead to a different occurrence and spread of resistance in this family. In contrast to *E. coli* and many other *Enterobacteriaceae*, Pseudomonads have a very adaptive set of cell membrane associated efflux pumps that can easily mediate resistance to various toxic substances. By mutating these pumps, they can broaden this spectrum to get rid of other toxic substances at any time. Therefore, it is not surprising that Pseudomonads also choose this route of using efflux pumps as primary mechanism against toxins in surface water populations (Suzuki et al. 2013, Tummler et al. 2014, Kittinger et al. 2016). One example for this mechanism is the resistance to the most important class of last line anti-

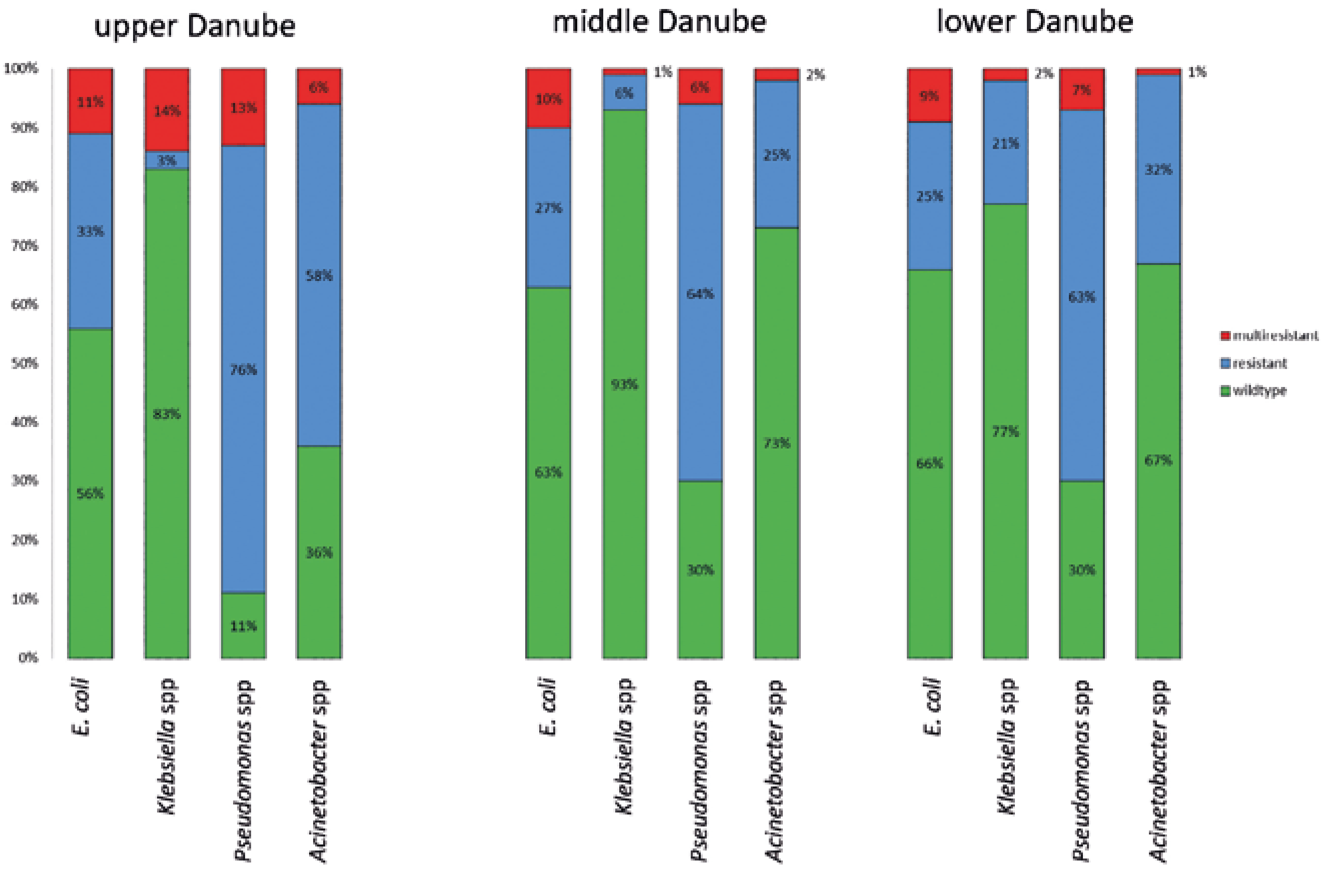

Figure 1. Comparison of populations of E. coli, Klebsiella spp, *Pseudomonas* spp *and Acinetobacter* spp. *isolated from the same River Danube water samples (JDS3 2013). Graphs are divided according to wildtype resistance pattern, acquired resistance (resistance to 1–2 classes of antibiotics) and multi-resistance (3 or more classes).*

biotics: the carbapenems. While the resistance of *Enterobacteriaceae* isolated in the River Danube (but also in other river studies) to carbapenems is almost exclusively mediated by enzymatic destruction using special beta-lactamases, the situation in the pseudomonads is different. In less than 10 % of the carbapenem resistant Pseudomonads beta-lactamases are responsible for the resistance; the resistance is mostly mediated by efflux pumps. The isolates all over the course of the River Danube showed high resistance rates against meropenem (30.4 %) *(fig. 1).* Although the resistance against carbapenems in *Pseudomonas* spp. is mostly mediated via efflux pumps, carbapenem resistance poses a challenge for therapy, regardless of the underlying mechanism. For example, *Pseudomonas putida* are increasingly involved in hospital infections. These infections come up with severe complications and high mortality rates (up to 40 %). In most of these cases, multiresistant *Pseudomonas putida* were the reasons for the infection or nosocomial outbreaks (Kim et al. 2012, Kittinger et al. 2016). This dependency on efflux pumps has two consequences. Pseudomonas is not so reliant on the acquisition of new genetic elements and the broad range of substances affected by this pumps leads to development of resistance without the presence of specific antibiotics (co-selection).

Acinetobacter spp. – The genus *Acinetobacter* is a similar threat as *Pseudomonas* in hospital settings. It also has a high innate level of resistances against many antibiotic classes and is also an environmental species. The acquisition of antibiotic resistance over the course of the River Danube shows some similarities with the genus Pseudomonas, not when comparing total numbers of resistant bacteria but nevertheless in observable trends showing the highest numbers of resistant and multiresistant isolates in the upper section of the river (Oliveira & Reygaert 2019, Santajit & Indrawattana 2016, Kittinger et al. 2017) *(fig. 1).*

How to fill the gaps in the mosaic

– In most studies, either the culture method (which is restricted to a few species), or the detection at the DNA level (which does not allow species and genes to be assigned), are used as the only method, leading to a limited resolution of the antimicrobial resistance situation. Regarding mobile genetic elements, the drawbacks of using one method alone becomes even more apparent. In addition, focusing on a particularly closely examined species *(E. coli)* further increases the imbalance. In order to gain a better understanding of the resistance situation in a large international river like the Danube, it is essential to understand the transfer mechanisms within the bacterial community. It is not only the presence or absence of resistance genes at the DNA level that must be investigated, but one also has to look for the reasons of the whereabouts and losses of resistance in the individual species. It is absolutely necessary to conduct these studies in parallel with isolates of different species in order to be able to identify the main influencing factors and to initiate countermeasures.

- As a basis for the understanding of sources, spread, accumulation and loss of antimicrobial resistance, reliable quantitative information must be available. So far, most studies provided only qualitative information on the presence or absence of ARB and ARG. Such quantitative data can also serve as a basis for the development of future guideline values demanded by health authorities.
- In order to develop effective management strategies, specifically the sources of antimicrobial resistances have to be identified. As input of ARB and ARG are most likely tightly linked to microbial fecal pollution, either of human (input primarily from municipal wastewater treatment plants) or animal origin (input primarily from agriculture and life-stock farming), the specific origin of fecal pollution has to be tracked with modern “microbial source tracking” tools.
- Moreover, only the comprehensive assessment of environmental conditions (the identification of sites where selection or co-selection for antimicrobial resistance may occur through e.g. heavy metals or pesticides) will enable a fundamental understanding of the mechanisms and importance of antimicrobial resistance in aquatic ecosystems.

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Danube countries review their options on flood risk management and include green infrastructures besides traditional measures in planning for a sustainable Danube

Interreg Danube Transnational Programme
Danube Floodplain

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Abstract

In compliance with the Flood Directive (FD) and Water Framework Directive (WFD), both the 1st Danube River Basin Management Plan (DRBMP) from 2009 (updated in 2015) and the 1st Flood Risk Management Plan for the Danube River Basin District (DFRMP) put forward ambitious targets

for floodplain restoration, recognizing the multiple benefits for flood risk management, nutrient retention, water quality, biodiversity and the ecosystem and set out appropriate environment and flood risk management objectives covering the Danube Basin. Opportunities towards gaining synergies and key issues requiring coordination are clearly foreseen for the programmes of measures within the plans. Floodplain restoration and creation of new retention and detention capacities, in particular based on natural water retention, are likely to provide the most significant direct contribution to both Flood Directive and Water Framework Directive objectives but also to conservation objectives as contribution to Birds and Habitats Directive. (ICPDR, 2004)

By addressing the need to develop an action policy framework in relation to floodplain restoration in the Danube River Basin, the DANUBE FLOODPLAIN project is meant to provide tools and guidance to achieve long term solutions through floodplain restoration and conservation, decreasing the flood risk (discharge peaks) of the Danube River and selected tributaries. The project is expected to solve the challenge of implementing actions into restoration projects, to involve and to have the support of stakeholders (who are concerned about losing fishery, land and income) and to balance investments in flood risk management with other public infrastructural investments.

Introduction

Past and recent regularization works – dams and dikes, discontinuity of the longitudinal and lateral connectivity, changes in land use – that took place along the Danube basin, have led to a massive reduction of grassland surfaces. The reduction of these areas by up to 68 % in the last 100 years has had disastrous effects on both – local communities that have been exposed to floods and on biodiversity. From 1980 to 2016, the total reported economic losses caused by weather and climate-related extremes in the European Economic Area (EEA) amounted to approximately EUR 436 billion (in 2016 Euro values) (EEA Annual Report, 2017). The Danube meadows have always played a role in natural protection against floods caused by rapid floods and overflows, so the decrease of their surface, along with the torrential rains caused by climate change, have entailed massive floods in Europe since 2002. At the same time, a further effect of the meadow reduction consists in the loss of habitats for many species, the loss of connections between ecosystems and implicitly the decline in biodiversity, a wealth of these areas in the past.

The Danube River Basin Management Plan (DRBMP) underlines that wetlands/floodplains and their connection to river water bodies play an important role in the functioning of aquatic ecosystems and have a positive effect on the water status. Connected wetlands/floodplains play a significant role when it comes to retention areas during flood events and may also have positive effects on the reduction of nutrients and the improvement of habitats. As an integral part of the river system they are hotspots of biodiversity, also providing habitats for e.g. fish and waterfowl that use such areas for spawning, nursery and feeding sites.

The 1st Danube River Basin Management Plan from 2009 concluded that compared to the 19th century, less than 19 % of the former floodplain area has been preserved in the entire Danube River Basin (i.e. 7,845 km^2 out of once 41,605 km^2). This was caused in particular by the expansion of agricultural uses and the disconnection from water bodies due to river engineering works concerning mainly flood control, navigation and hydropower generation. The disconnected wetlands/floodplains are potential pressures to aquatic ecosystems on the basin-wide level and the largest possible area with potential for reconnection should be restored in order to support the achievement of the environmental objectives (ICPDR, 2015).

Danube countries of basin-wide importance decided that more sustainable, nature-based solutions are needed to reduce the impact of floods

Being fully aware of this complex problem, the Danube countries, all of them members of the International Commission for the Protection of Danube River (ICPDR), decided to jointly develop a Danube River Basin project – DANUBE FLOODPLAIN Project – in order to analyze the potential floodplain restoration areas, considering flood retention potential and other aspects such as ecological ones and biodiversity conservation, which should guide the future Programme of Measures (PoM) in the Danube River Basin.

The DANUBE FLOODPLAIN Project will contribute to (1) updating the disconected wetlands/floodplain areas inventory and their ranking using the Floodplain Evaluation Matrix – FEM, (2) assessing the efficiency of floodplain projects in the Danube District by using the pre-selected pilot areas and (3) developing tools for increasing the knowledge and cooperation of experts, practitioners, decision makers and stakeholders on floodplain restoration.

The project partnership consists of different levels e.g. policy makers, water managers, researchers, as well as stakeholders of water and flood risk management from the DRB who are involved in a permanent cooperation and interaction to develop the project. By involving policy makers and national water competent authorities the project ensures that possible floodplain restoration and preservation approaches for managing the risks of floods and reaching environmental and conservation objectives will be implemented in the future transnational water management activities. The most relevant stakeholders involved in floodplain management will not only contribute to the project implementation, but will be the beneficiaries of the project outputs. The main project target groups are ministries, river basin authorities, practitioners and stakeholders (AF, 2018).

The partnership is represented by institutions from ten countries of the Danube River Basin from upstream to middle and downstream, nine EU members and one accession state (Serbia). The active implication of the ICPDR and its relevant technical expert groups during the project implementation process will ensure that the project results are transposed into further actions within the whole Danube River Basin.

Identifying floodplain areas and interventions along the Danube River and its tributaries which will integrate the most beneficial ecological and flood protection advantages.

In figure 1 the main project activities are presented grouped in three main chapters relating to

(1) the Danube floodplain evaluation,
(2) selected pilot areas of the Danube Floodplain project and
(3) the outputs of the project.

(1) The innovative character of the DANUBE FLOODPLAIN project is given by the application of the Floodplain Evaluation Matrix (FEM) by all partner countries and by developing a general evaluation tool for potential further assessment of floodplain restoration projects. The Floodplain Evaluation Matrix (FEM) is a multicriteria holistic and integrative decision support system that helps to determine which floodplains are highly relevant for preservation and/or restoration concerning not only flood protection (hydrology/hydraulics) but also ecological and socio-economic reasons. The FEM approach will be supported by a stakeholder ranking, which results in a priority list and proposal of potential preservation and restoration sites considering flood and ecological aspects and stakeholders interests.

During the first phase of implementation, FEM will be applied to active floodplains. Active floodplain was defined based on simultaneous compliance of the following conditions:

- the ratio between the width of the floodable area (Li) and the riverbed width (La) is greater-than-unity (Li / La > 1)
- floodable area surface is larger than 500 ha.

According to FEM, determination of the hydraulic efficiency presumes to assess the water stage corresponding to 100 Qmax (maximum flow rate of 1 % annual probability of exceedance) derived within the following assumptions regarding the streamflow section:

- streamflow section is delimited vertically at the line representing the banks level H1,
- streamflow section corresponds to the current development situation H2,
- streamflow section corresponds to the flood defence works (dikes) relocating scenarios

Figure 1. General illustration of the activities in the Danube Floodplain project and their interdependencies. Source: TU Munich, Johannes Mitterer.

The project partners will review and update active and former floodplain areas (including data collection and analyses of these data using GIS), with the aim to provide a spatial reference framework alongside the related database containing a comprehensive inventory of floodplain areas and their multicriteria analysis along the Danube River and selected tributaries. The resulting theoretical and actual floodplain areas inventory will provide the main spatial reference base, where other hydrological, hydraulic and biophysical parameters will be analyzed. The geodatabase will also be accompanied by a list of associated existing measures identified from national and international Flood Risk Management Plans and River Basin Management Plans, which have the integrative positive effect on both – flood protection and ecological improvement.

(2) The other major part of the project is the assessement of the efficiency of preservation and restoration projects for flood risk reduction and improvement of ecosystem services on the Danube and its major tributaries using pre-selected pilot areas in the Danube basin. A comprehensive analysis, assessments of different measures concerning flood risk reduction in pre-selected pilot areas (including qualitative and quantitative impact on biodiversity, habitat networks and ecological system services), costs and benefits and governmental procedures are executed in the project.

Ecosystem Services (ESS) and a comprehensive analysis of biodiversity are done in the pilot areas in order to quantify the potential positive effects of the measures and to integrate, as far as possible, these projects into the overall biodiversity concept of the Danube.

Figure 2. Stakeholder Workshop on ecosystem services (ESS) in Port Cetate, Romania, 2019. Photo: Anemari Ciurea

It is important to distinguish between the current ESS, on which many detected stakeholders have already been relying, and the potential ones. Therefore, the project partners organize workshops where project partners and stakeholders meet to discuss the prevailing ESS. The experiences

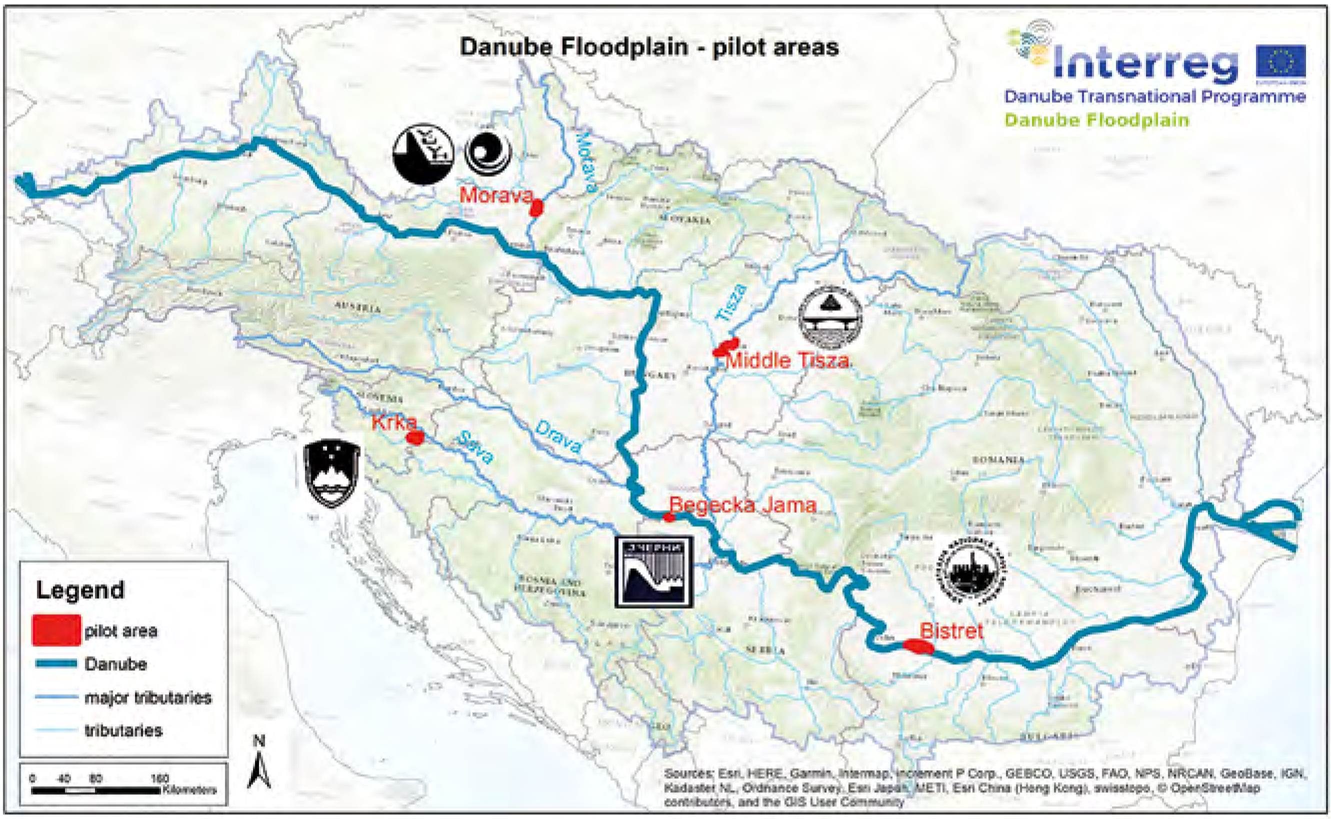

Figure 3. Pre-selected pilot areas for the assessement of the efficiency of preservation and restoration projects. Source: TU Munich, Johanna Springer.

Figure 4. Danube Floodplain project outputs and deliverables

gained from other projects, like River Ecosystem Service Index (RESI; BMBF, Germany) constitute the basis for the assessment of ESS.

The selected pilot areas are Krka in Slovenia, Begečka Jama in Serbia, Morava on the border between Slovakia and the Czech Republic, Middle Tisza in Hungary and Bistret in Romania.

(3) The main outputs of the project are shown in the Figure 4.

The objective of the project is to increase the knowledge and cooperation of experts, practitioners, decision makers and stakeholders on floodplain restoration especially for the purpose of flood risk mitigation and agreed next steps towards achieving such projects.

In order to accomplish the above mentioned different target groups, the project produces three types of helping tools:

Danube Basin Wide Floodplain Restoration and Preservation Manual: mainly addressed to practitioners; it explains technical details of the key restoration approaches, potential win-win measures to mitigate flood risk through floodplain restoration and conservation actions; furthermore, it contains a step by step explanation on how to plan and implement restoration projects, how to solve potential conflicts in an integrated way involving all related stakeholders.

Danube River Basin Sustainable Floodplain Management Strategic Guidance, summarizing the key findings of the Manual but targeting a wider audience.

Danube River Basin Roadmap, which will use the results of the ranking process and the thorough analysis of pilot areas, providing an action plan on how to move forward in order to realize further multipurpose restoration projects after the end of the project. These necessary actions, agreed deadlines on a Danube wide level, and responsibilities will be defined on Danube basin and national levels. Decision makers and planners are the target groups of the DRB Floodplain restoration Roadmap which will directly serve as an input for developing the 3rd Danube River Basin Management Plan and the 2nd Danube Flood Risk Management Plan and to support national planning as well.

All the information included in these output documents will support the implementation of the Water Framework Directive, the Flood Directive and biodiversity strategy within the Danube basin countries.

Conclusions

The main results of the project will be an improved and sustainable transnational flood risk mitigation management within the Danube River Basin. The concrete measures identified in the frame of the project pilot areas, alongside the measures related to priority areas, will contribute to increase potential capacities in natural flood retention, to improving retention and flood protection downstream from pilot and future restoration sites and to advancing the Danube Flood Risk Management Plan and Danube River Basin Management programme of measures. Furthermore, the project results will contribute to a harmonized approach for dealing with floodplain conservation and restoration measures, to a consensus of local stakeholders on priority measures and to a wider public support for integrating flood management with floodplain conservation and restoration.

Acknowledgements

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The importance of instream reservoir structures for the biodiversity of the benthic macroinvertebrate fauna in the Viennese Danube

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Abstract

Dam-created reservoirs adversely affect riverine biotic communities, such as macroinvertebrates. To mitigate these negative effects, multiple mitigation measures have been proposed, including the creation of lateral widenings and gravel bars and islands as instream structures in the reservoir section. Here, we examined the potential of eight such shoreline habitats for the biodiversity of benthic macroinvertebrate fauna in the impounded Viennese Danube (hydropower station Freudenau). We found 79 different taxa present in the shoreline habitats, therefrom 43 taxa were unique to these habitats as they did not occur in the main channel. Both, the non-metric multidimensional scaling and the cluster analysis grouped the eight shoreline habitats and showed that they differed from sampling sites in the main channel (reservoir and free-flowing section). Hence, our results demonstrate the importance of such instream structures to the overall biodiversity of benthic macroinvertebrate fauna in impounded rivers, such as the Danube River.

Introduction

Dams have been built for millennia, but especially since the mid-20th century, dam construction rates boosted due to economic development (Schmutz & Moog 2018). However, dam development is still ongoing. From 2007 to 2016, about 8,000 new large dams were built globally, resulting in a total of >58,000 dams with a height greater than 15 meters (Liro 2019). Unsurprisingly, 48 % of all rivers worldwide (expressed as river volume) are moderately to severely affected by flow regulation and/or river fragmentation, and 25–30 % of pre-disturbance sediment flux is stored in reservoirs (Schmutz & Moog 2018). Whereas most research has focused on studying impacts and mitigation measures downstream of dams, comparably little attention has been paid to upstream river sections (Liro 2019).

Dams create reservoirs (impoundments) which turn a free-flowing river into an entirely new ecosystem which is neither river nor lake. Such reservoirs usually exhibit a longitudinal gradient from the dam (lentic zone) to the upstream reaches (riverine zone). Between the two, a transition zone often develops which shows both, lentic and lotic features (Schmutz & Moog 2018). These changes significantly impact riverine biota, in particular, aquatic communities associated with the hyporheic interstitial, such as benthic macroinvertebrates. For example, when fine sediments are deposited in the reservoir, the river bottom becomes clogged, which causes a reduction of benthic biodiversity as most taxa disappear while few taxa, such as chironomids, become dominant. In general, river type-specific rheophilous organisms are replaced by fine-sediment dwellers of standing water-bodies. Hence, the ecological status of the macroinvertebrate community in reservoirs is mostly classified as "poor" or "bad" according to the EU Water Framework Directive (Ofenböck et al. 2011).

To mitigate these adverse ecological effects caused by reservoirs, multiple mitigation measures have been proposed (Jungwirth et al. 2005). Measures in the head sections (riverine zone) include lateral widenings and the creation of gravel bars and islands as instream structures. In the lentic reservoir zone, the construction of artificial stabilized sand/silt islands along the embankments may provide suitable habitat for aquatic organisms. In this study, we examined the potential of eight shoreline habitats to enhance the biodiversity of benthic macroinvertebrate fauna in the impounded Viennese Danube.

Study sites and methods

The run-of-the-river hydropower station Freudenau, located in Vienna, is the last hydropower station situated along the Austrian Danube. After a six-year construction phase from 1992–1998, it was put into operation in 1999,

Figure 1. Overview of the eight sampled shoreline habitats (i.e., bays or side channels/islands as instream structures) created along the left bank of the Viennese Danube (habitat G and H were not sampled). "KW Freudenau" indicates the hydropower dam (Source: Stadt Wien - data.wien.gv.at, modified by P. Leithner).

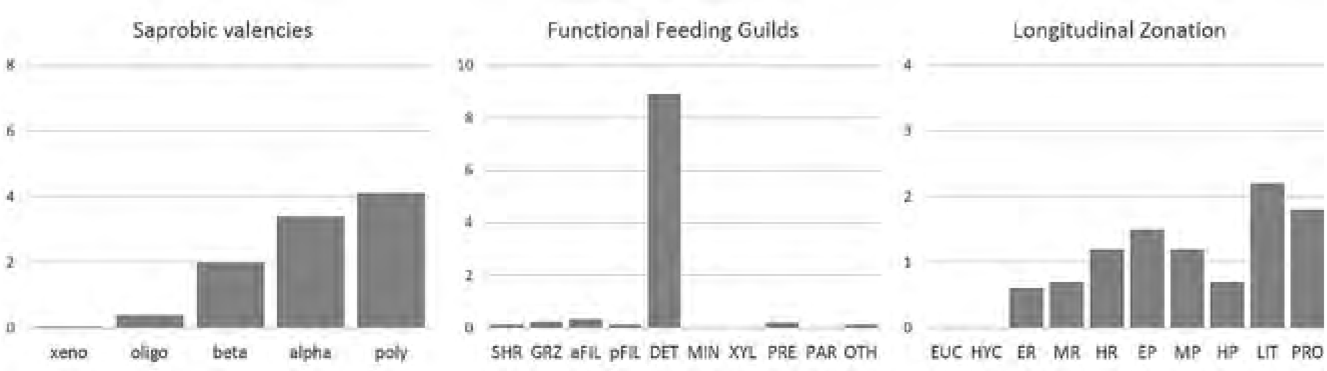

Figure 2. Saprobic valencies (xeno = xenosaprobic, oligo = oligosaprobic, beta = beta-mesosaprobic, alpha = alpha-mesosaprobic, poly = polysaprobic), distribution of functional feeding types (SHR = shredders, GRZ = grazers, aFIL = active filter feeders, pFIL = passive filter feeders, DET = detritus feeders, MIN = miners, XYL = xylophagous, PRE = predators, PAR = parasites, OTH = other feeding types), and longitudinal zonation (EUC = eucrenal, HYC = hypocrenal, EP = epirhithral, MR = metarhithral, HR = hyporhithral, EP = epipotamal, MP = metapotamal, HP = hypopotamal, LIT = littoral, PRO = profundal) of the benthic community.

resulting in the damming-up of around 28 river kilometers. As one of the mitigation measures for damming the river, eight shoreline habitats (i.e., small- to medium-sized bays or side channels/islands as instream structures, connected either directly to the main channel and/or through pipe culverts) were created along the left river bank (rkm 1922.7–1936.0) – four in the main reservoir section (lentic zone), and four in the transition zone *(fig. 1).*

Fifteen years after the start of the hydropower operations, we sampled the benthic macroinvertebrate fauna of these eight shoreline habitats and compared the results to those of both, the reservoir and free-flowing section, which were investigated between 21 and 24 July 2014 by twelve airlift samples each. On 5 May 2014, we collected macroinvertebrates in the shoreline habitats with 25×25 cm hand nets through a multi-habitat sampling (MHS) approach to form [separate] substrate-type groups. Hence, depending on substrate diversity, we sampled two to five substrate groups per habitat.

All data were processed with the Ecoprof Software version 4.0 (Moog et al. 2013). To understand the importance of these shoreline habitats to the overall macroinvertebrate biodiversity of the Freudenau impoundment, we conducted non-metric multidimensional scaling (NMS) analysis, as well as cluster analysis using flexible beta linkages (-0.25) and the Sørensen (Bray-Curtis) distance measure of similarity. Both analyses were done with the software PCOrd 6.19 (McCune & Mefford 2011).

Results

The assessment of habitat B (fig. 2) – as one representative shore-line habitat – regarding saprobic valencies revealed high alpha-mesosaprobic and polysabrobic shares, which is typical for stagnant areas such as littoral zones. Concerning feeding types, we found almost exclusively detrivorous taxa. Regarding river regions, the highest values were detected for the littoral and profundal zones. Worms (Oligochaeta) and non-biting midges (Chironomidae) combined accounted for 95% of the total abundance in the sediment core.

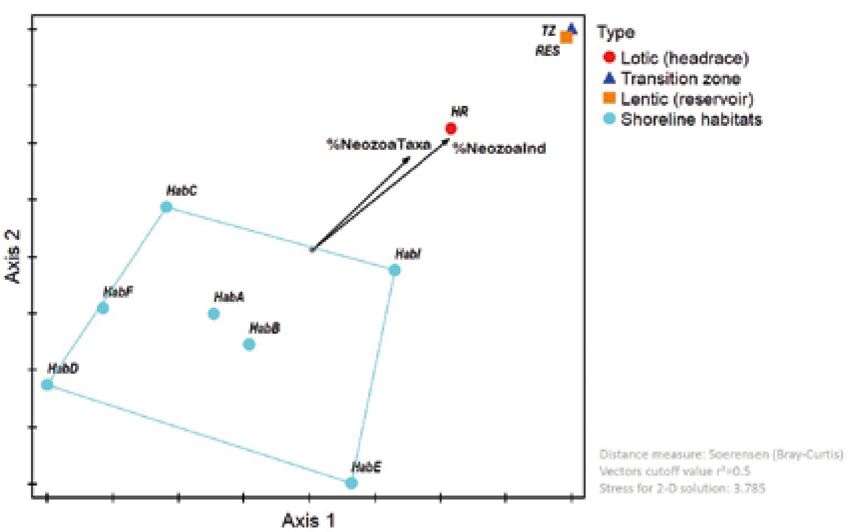

Figure 3. Non-metric multidimensional scaling (NMS) analysis regarding macroinvertebrate abundance per habitat reach. Abundance was log-transformed (n+1). HabA–HabI = shoreline habitats, HR = lotic habitat close to the headrace, TZ = transition zone, RES = lentic reservoir zone, %NeozoaTaxa = share of neozoa taxa (taxa count), %NeozoaInd = share of neozoa taxa (individuals).

In total, we discovered 79 taxa in the shoreline habitats through the MHS scheme. Comparing this taxa number to those found in airlift samples conducted in the main channel (reservoir and free-flowing section), it became evident that 43 taxa are unique to the shoreline habitats in the reservoir (Graf et al. 2016). The number of "exclusive" taxa per shoreline habitat ranged from 0–28 (mean = 11.1). The lowest number of taxa solely present in the shoreline habitats were found in the

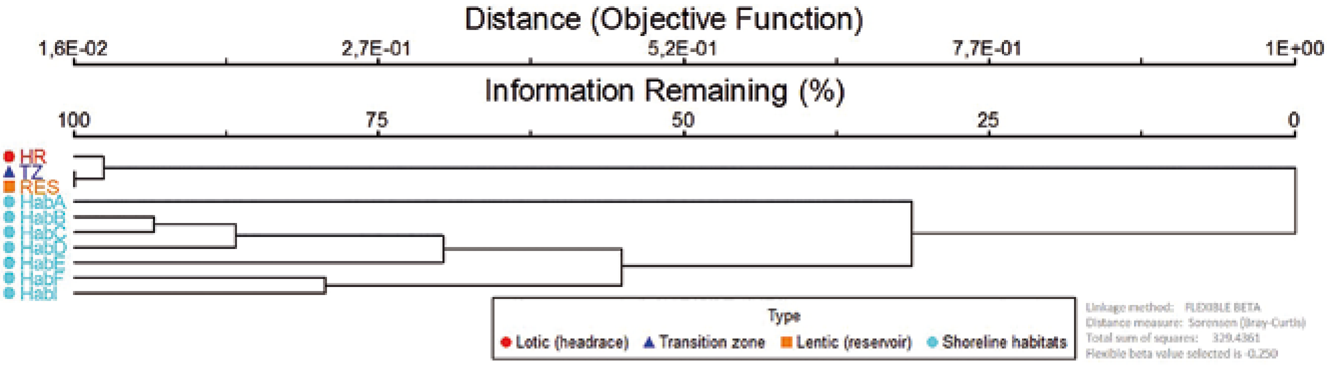

Figure 4. Cluster analysis: single samples are grouped per habitat reach. Abundance was log-transformed (n+1). For habitat codes see Figure 3.

four upstream sites situated in the transition zone of the impoundment (4, 0, 4, and 7 unique taxa, respectively). In contrast, the highest numbers of taxa only present in the shoreline habitats were discovered in four habitats located in the lentic zone of the reservoir. For example, in habitats B, C, and D, we found 14, 28, and 19 exclusive taxa, respectively. Interestingly, the 13 unique taxa which occurred in habitat A resulted from two substrate groups only.

The non-metric multidimensional scaling (NMS) analysis translates (dis)similarities between sampling sites into a special proximity. The results in figure 3 show that all eight shoreline habitats are separated from the sampling sites in the main channel. Hence, this result indicates that particularly the studied shoreline habitats are of high importance for the overall biodiversity of macroinvertebrate fauna in the heavily-modified Viennese Danube.

The cluster analysis *(fig. 4)* revealed that the biocenosis of the free-flowing and impounded sections within the main channel is rather similar to each other. The benthic community in the riverine impoundment zone shows greater similarity to the one in the lentic impoundment zone than that on the near-by gravel bar areas. Furthermore, all of the eight man-made shoreline habitats are clearly distinguished from the other habitat samples.

Analysis of species composition revealed that most organisms are primarily associated with palaeopotamon habitats which, in a natural floodplain river, would be located far off from the main channel. Hence, the presence of such species underlines that these shoreline habitats, as well as other stagnant waterbodies along the artificially constructed Viennese “Danube island” (Donauinsel), are important surrogate habitats in a cultivated landscape. Furthermore, these habitats constitute a vital contribution to overall biodiversity and are crucial stepping stone biotopes which connect floodplain elements of the Danube River.

The share of non-native macroinvertebrates within the eight shoreline habitats ranged from 4.5–65.0 %. However, each of the five most downstream habitats contained ≤ 10 % neozoa. Only the two most upstream sites, where the Danube current flows through, showed high shares of non-natives, with 50 % and 65 %, respectively. There, the macroinvertebrate community resembles the overall assemblage of the flowing sections of the Austrian Danube near Vienna.

Conclusions

15 years after inundation of the Freudenau reservoir, we sampled the macroinvertebrate fauna in eight shoreline habitats created as compensation measure. We found a high number of taxa in these shoreline habitats that we did not detect in the adjacent main channel. Further analysis revealed that all shoreline habitats were distinct from main-channel sites as the composition of benthic invertebrates was typical for floodplain habitats far away from the main channel. Hence, our results demonstrate that such instream structures are important to enhance the overall biodiversity of benthic macroinvertebrate fauna in impounded rivers, such as the Danube River.

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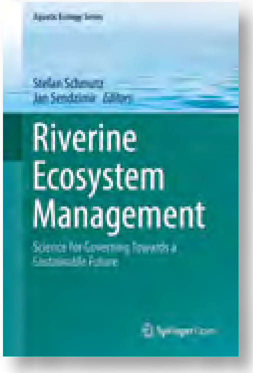
News and Notes

Riverine Ecosystem Management. Science for Governing Towards a Sustainable Future



A newly published open-access book surveys the frontier of scientific river research and provides examples to guide management towards a sustainable future of riverine ecosystems. The book is dedicated to those interested in the natural and social sciences and elements of governance that will support the sustainable management of rivers and aquatic ecosystems. Elements of nature and society interact to determine the integrity and trajectory of social-ecological systems (SES) such as riverine ecosystems.

This book opens the door to these topics in four steps. It begins by explaining why a book dedicated to river management and science is needed at this point. In the second part, it outlines the history of some of the major developments that challenge the integrity of SESs worldwide. In the third part, it describes several of the principal tools used to study as well as manage SES. Tools to measure the degree of degradation of an SES include indicators of biological integrity, ecosystem health, and resilience. Tools to assess and manage the trajectory of an SES include the DPSIR and adaptive management.

Rivers are among the most threatened ecosystems of the world. For more than a century, river science has evolved to define these threatening trends and the mechanisms that cause them. What has emerged, while still incomplete, is a picture of imposing complexity, especially for managers, policy makers, and any concerned citizens interested in addressing these threats. This book surveys the frontier of scientific research and provides examples to guide management toward a sustainable future of riverine ecosystems. Principal structures and functions of the biogeosphere of rivers are explained; key threats are identified, and effective options for restoration and mitigation are provided.

Rivers increasingly suffer from pollution, water abstraction, river channelization, and damming. Fundamental knowledge of ecosystem structure and function is necessary to understand how human activities interfere with natural processes and what interventions are feasible to rectify this. The specifics of such management leverage points become clear through elucidation of cause-effect relationships, especially how socioeconomic drivers create pressures on rivers and how those pressures alter ecosystem functions and impact fauna and flora.

Modern water legislation strives for sustainable water resource management and protection of important habitats and species. However, decision-makers would benefit from more profound understanding of ecosystem degradation processes and of innovative methodologies and tools for efficient mitigation and restoration. This becomes especially important for threats where current policies are ineffective, and both policy and management must support research that identifies solutions.

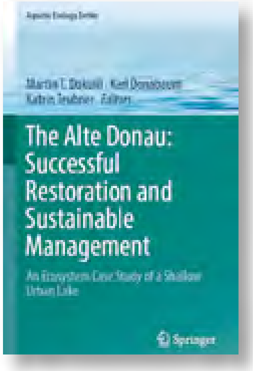
The book provides best-practice examples of sustainable river management from on-site studies, European-wide analyses, and case studies from other parts of the world. It will be of interest to researchers (graduate and post-graduate) in the fields of aquatic ecology, river system functioning, conservation and restoration, to institutions involved in water management, and to water-related industries.

Schmutz S. & Sendzimir J. (Eds., 2018): Riverine Ecosystem Management. Science for Governing Towards a Sustainable Future. Springer Aquatic Ecology Series 8. Springer International Publishing. Open-access version available at https://www.springer.com/de/book/9783319732497

Stefan Schmutz: *Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences Vienna*

The Alte Donau: Successful Restoration and Sustainable Management – An Ecosystem Case Study of a Shallow Urban Lake

The book «The Alte Donau: Successful Restoration and Sustainable Management – An Ecosystem Case Study of a Shallow Urban Lake» (Dokulil MT, Donabaum K, Teubner K, eds) takes the reader on a popular urban lake in Vienna. This lake study over more than 20 years is released in the Aquatic Ecology Series of Springer and illustrates the long-term restoration efforts in the urban seepage lake Alte Donau. The restoration was initiated by the municipal authority 45-Water Management Vienna (Magistrat 45-Wiener Gewässer) in 1993, and was supported by them over more than two decades. The editorial work for the book was partly financially supported by the Austrian Committee (ÖK) of the IAD.



Alte Donau is an oxbow lake, a cut-off arm of the former main channel of the Danube River *(fig. 1)*. In the 1980ies, it was a mesotrophic cyprinid-dominated lake, which became hypertrophic in the 1990ies making restoration measures necessary. This book tells the story of how the transition from hypertrophic back to mesotrophic conditions was successfully accomplished. Through implementing an integrated lake management plan including external and internal measures, Alte Donau gained increasing popularity as recreational area in recent times.

The book comprises 20 Chapters and provides practical and empirical knowledge about the restoration of Alte Donau as presented by 25 authors from universities, technical offices and municipal departments in Vienna. The book covers three main aspects:

1 Site description including the history, morphometry, hydrology, sediment and climate (chapters 1–7).
This section introduces to Alte Donau and describes mainly the lake history, morphometry and hydrology. It further provides information step-by-step about the integrated lake management plan of external and internal measures and refers in particular to schedules of the chemical treatment for phosphate precipitation and to the long-term effort for sustained recovery. In addition, the physico-chemical conditions of the water body are highlighted over the times span of 28 years from 1987 onwards. These aspects are central for interpreting the response of biota to environmental change and the new public awareness of an attractive recreational area as discussed in other chapters of the book.

2 Analysis of the biota found in Alte Donau including their ecology and production (chapters 8–16).
The description of biota comprises pelagic assemblages (microbial and viral loop, ciliate protozoans and metazoans, algae and cyanobacteria), benthic macroinvertebrate assemblages, fish community, underwater vegetation including the reed belt, and water birds. For all these biotic assemblages, several phases of the ecosystem development were described. In case of planktonic heterotrophic bacteria, phytoplankton including primary- and secondary production, planktonic ciliates and other metazoan zooplankton, macrozoobenthos, yield of fish and of underwater vegetation, the book highlights inter-annual changes over up to 22 years. The superimposing climate warming in Alte Donau and its impact on zooplankton from rotifers to freshwater jellyfish further refers to the ongoing debate about global warming.

3 Hygiene aspects, design of riparian zone, new urban landscape planning and synthesis (chapters 17–20).
Hygiene aspects for bathing, the new design of the riparian zone and a new urban landscape planning (Master plan) are presented in view of the popular use of this recreational area (chapters 17–20). Finally, a synthesis summarizes scientific aspects of the successful restoration of Alte Donau.

Figure 1. Alte Donau, an urban oxbow lake in Vienna, serves as popular recreational area (photo: 2015, www.lakeriver.at)

The main path in this book starts with describing the many hydrological-chemical to biological aspects for the heavily eutrophied lake in 1993/1994. The heavy blooms of the cyanobacterium *Cylindrospermopsis raciborskii* associated with a poor water transparency in 1993/1994 prevented the use of this urban lake for bathing, fishing and other recreational activities and thus provided arguments to start restoration measures. A five-year restoration period followed, which included a treatment by chemical phosphate precipitation (Riplox-method), which was applied twice. Another seven-year period was designated to a successful re-establishment of macrophytes which was mainly due to an increase in water transparency and thus favourable underwater light conditions for stimulating the growth of submerged vegetation. The last period of once again mesotrophic «stable conditions» lasting over recent years relied mainly on the sustained underwater vegetation and the modified fish stocking of less cyprinids and more predatory fishes. According to surveys, the success of the

Figure 2. Mesotrophic Alte Donau successfully restored, mirrored by the clear-water macrophyte dominated state (photo: Myriophyllum spicatum, 2015, www.lakeriver.at)

restoration has increased public awareness of this recreational area in Vienna.

In view of lake science, Alte Donau exemplified that an in-lake restoration strategy which primarily uses a bottom up control is possible if it is going hand in hand with external measures of an integrated lake management plan. With the drastic reduction of lake-internal phosphorus, accomplished by short-term chemical precipitation treatments, the growth of underwater plants was triggered at the expense of algal growth. Different from other lake restoration strategies which attempt to strengthen the top down-control by fish removal and completely new fish stocking afterwards, for Alte Donau no fish were removed other than by recreational fishing. A gradual transition away from overwhelming cyprinids-dominated conditions was accomplished by modified fish stocking in recent years. Thus, the sustained success of restoration in Alte Donau relies mainly on the alternate nutrient allocation from planktonic algal community to the re-established underwater plants which guaranteed primarily sustained mesotrophic conditions. The success of restoration was mirrored by high water transparency. This shift from a nutrient rich algal turbid water-body to a nutrient-poor clear-water macrophyte state (fig. 2) was linked to alterations in the planktonic food web and thus provides a further signature of sustained successful rehabilitation of Alte Donau.

The book provides practical guide for restoration measures as e.g. the phosphate flocculation in the water body, the planting of underwater vegetation and the subsequent water-plant management by mowing, the re-establishment of the reed belt and fish-stocking biomanipulation experiments in addition to the manifold other mainly scientific aspects of this successful lake restoration.

The Alte Donau book journey along the four main management periods is illustrated by historical maps, scientific tables and graphics, photographs or photo tables showing representative micro-organisms, plants and animals in this urban seepage lake. The many facets of management measures, their impact on biotic assemblages shaping habitats from sediment, water body and riparian zone of this urban lake one the hand and the implementation of landscape architecture for creating an attractive recreational area and generating a new public awareness on the other hand, highlight the diverse perspectives of such an urban lake restoration project.

The Alte Donau: Successful Restoration and Sustainable Management - An Ecosystem Case Study of a Shallow Urban Lake. Dokulil MT, Donabaum K, Teubner K (eds) 2018, Springer.
https://www.springer.com/us/book/9783319932682

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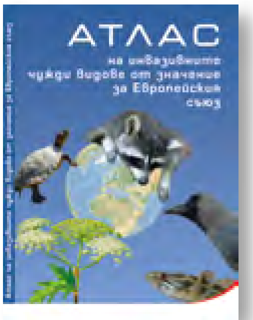
Guide to invasive alien species of European Union concern



A 'Guide to invasive alien species of European Union concern' has been prepared within the frame of the East and South European Network for Invasive Alien Species (ESENIAS) and the Danube Region Invasive Alien Species Network (DIAS) and published by ESENIAS and the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences (IBER-BAS). The Guide has been prepared and published under the project 'East and South European Network for Invasive Alien Species – A tool to support the management of alien species in Bulgaria (ESENIAS-TOOLS)', with the support of the Financial Mechanism of the European Economic Area 2009–2014, Programme «BG03 Biodiversity and Ecosystem Services».

The Guide aims to provide relevant information about the invasive alien species (IAS) of European Union (EU) concern in order to raise awareness and to facilitate the implementation of the Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species in Bulgaria and in the Danube Region.

It contains information and original data from Bulgaria for 37 species included in the first list of IAS of EU concern, adopted in 2016. The list contains 14 plants, 7 invertebrate and 16 vertebrate animals. Of them, 4 plant and 9 animal species have already been recorded in the Danube Region. The information for each species is presented in 6 sections: 1) General characteristics and biology (with data on taxonomy, morphology, diagnostic features and biological traits); 2) Origin and general distribution; 3) Distribution in Bulgaria; 4) Habitats; 5) Pathways of introduction and spread; and 6) Impact. The articles are illustrated with photos of each species.

The Guide is designed for a wide range of readers, including scientists, teachers, decision-makers (ministries, agencies, national and nature parks, state forest and hunting farms, etc.), managers, students, and the general public. The book is also available online.

Trichkova T., Vladimirov V., Tomov R., Todorov M. (Eds.) 2017. Guide to invasive alien species of European Union concern. IBER-BAS, ESENIAS, Sofia, 184 pp. (In Bulgarian) ISBN 978-954-9746-43-3; Available at: http://esenias.org/files/ESENIAS_Atlas_WEB.pdf

Teodora Trichkova, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences

Foundation price “Living Danube”

The private foundation „Naturerbe Donau“ of the Countess Du Moulin Eckart and the Count of Brühl for the first time awards the international foundation prize “Living Danube“.

The prize addresses key stakeholders throughout the Danube region to support their valuable efforts for sustainable development along the Danube. It is intended to reward efforts and achievements that contribute in an exemplary manner to the protection and preservation of the natural heritage along the entire river.

The price is endowed with € 15,000 (€ 10,000 in cash and a gold medal worth € 5,000).

The foundation prize “Living Danube” is intended for individuals, groups and associations whose innovative activities, successful research results or life achievements have contributed remarkably to the sustainable improvement of the Danube region.

The application process begins on 1 March 2019 and ends on 31 July 2019

The focus is on the implementation of measures to strengthen the biodiversity and dynamic processes in the river system and the floodplain of the Danube from the source to the mouth, on the creation of structures and collaborations that sustainably support these goals and scientific research, that provides the basis for it. The merits should be so convincing that a counterfeiting effect is achieved.

Innovative, network integrated solutions across national borders and services that further cooperation with an interdisciplinary nature are given special consideration.

The prize will be awarded every two years, starting in 2020 with the first award.

Applicants may apply to one of the following institutions or persons who then submit the application to the foundation, or by submitting their application in digital format (PDF file) directly to the foundation (stiftung-naturerbe-donau@gmx.de) by 31 July 2019. Applications may also be submitted directly by the nominating institutions and persons.

Entitled for the proposal are:

- The members of the Foundation Council of the Foundation “Naturerbe Donau”
- The Board of the Foundation “ Naturerbe Donau “
- The association for the promotion of the Auenzentrum Neuburg
- The Aueninstitut Neuburg
- Members of the Priority Area 6 Steering Group of the EU Danube Region Strategy

Further information can be found on the homepage of the foundation (http://www.stiftung-naturerbe-donau.de)

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danube news

Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

donau aktuell

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Hydrological catchment of the River Danube

General Secretary:

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