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Editorial

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Dear Readers,

The year 2022 was connected with our hope of overcoming the Covid pandemic, if not completely, then at least a bit more than in the past two years, so that contacts and our network in the Danube basin could once again become as personal and face-to-face as in the years before. But now we are additionally confronted with the war in Ukraine, a Danube Basin country. As a scientific NGO, we would like to express our solidarity with the people of Ukraine in these times. Every death is one too many and in the meantime, there are far too many victims to mourn, so that our sincere hope is that the fighting will end soon and a dialogue for a long-lasting peace can begin. This will also bring back our network to its previous activities and beyond.

As the new president of the IAD, I would like to promote and strengthen this inter- and transnational cooperation in order to bring us scientists and water managers closer together and to make improvements in the field of our rivers in the entire Danube basin. Through this, and through actions such as the International Danube Day, the people of the Danube basin will come closer and ultimately understand each other better. Let us work together for this vision!

Due to the war in Ukraine, it will not be possible to carry out the 44th IAD Conference in Kiev, as scheduled. In agreement with the Ukrainian colleagues, the IAD Presidium has decided to hold the conference in Krems/Austria in February next year – thanks to the organizers in advance! Detailed announcements can be found in the corresponding emails and on the IAD homepage in due course. An IAD conference in Ukraine is not cancelled, only postponed! It will be held there at a later date!

The problems in the Danube basin need collaboration of all countries and should be inter- and transdisciplinary. The EU projects of the Danube Transnational Programme (DTP) show how successful such a kind of cooperation can be. The MEASURES project (see report in this issue) was designed to create ecological corridors for migratory species along the Danube and its tributaries. This issue also presents results of investigations on sediments in the Danube and its tributaries, mainly based on the DTP project Danube Sediment. Both articles are the start of a short series of reports on EU projects. In the next issue, the Danube Floodplain project will follow. This project was funded in order to create a win-win situation of flood protection and floodplain biodiversity. All these projects, and there are more to come, would not be possible without international cooperation.

Furthermore, there are reports on the problems of hydropower and on the progress made regarding dam removal in this issue as well as a report on ecological research of Lake Neusiedl.

Sadly, our deepest sympathies go out to the families and friends of two outstanding and long-term members of IAD who passed away in 2021: Prof. Dr. Roumen Kalchev (Bulgaria) and Prof. Dr. Marian Traian Gomoiu (Romania).

Let us hope for a future in peace and health! Enjoy reading this issue and stay well!

Sediment research and management – Transnational tasks along the Danube River

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Abstract

Sediment transport is an essential element of any river system. It affects a variety of sectors that are directly or indirectly related to the river. These include hydropower utilization, inland navigation, agriculture, flood protection, water supply and also the habitats that the river provides for animals and plants. Several ongoing and recently completed international projects collect data and perform numerical as well as physical modelling to improve the knowledge of the sediment transport in the Danube River. These data are an important basis to identify the driving forces behind changes in sediment regime and to investigate and develop measures for a more sustainable sediment management.

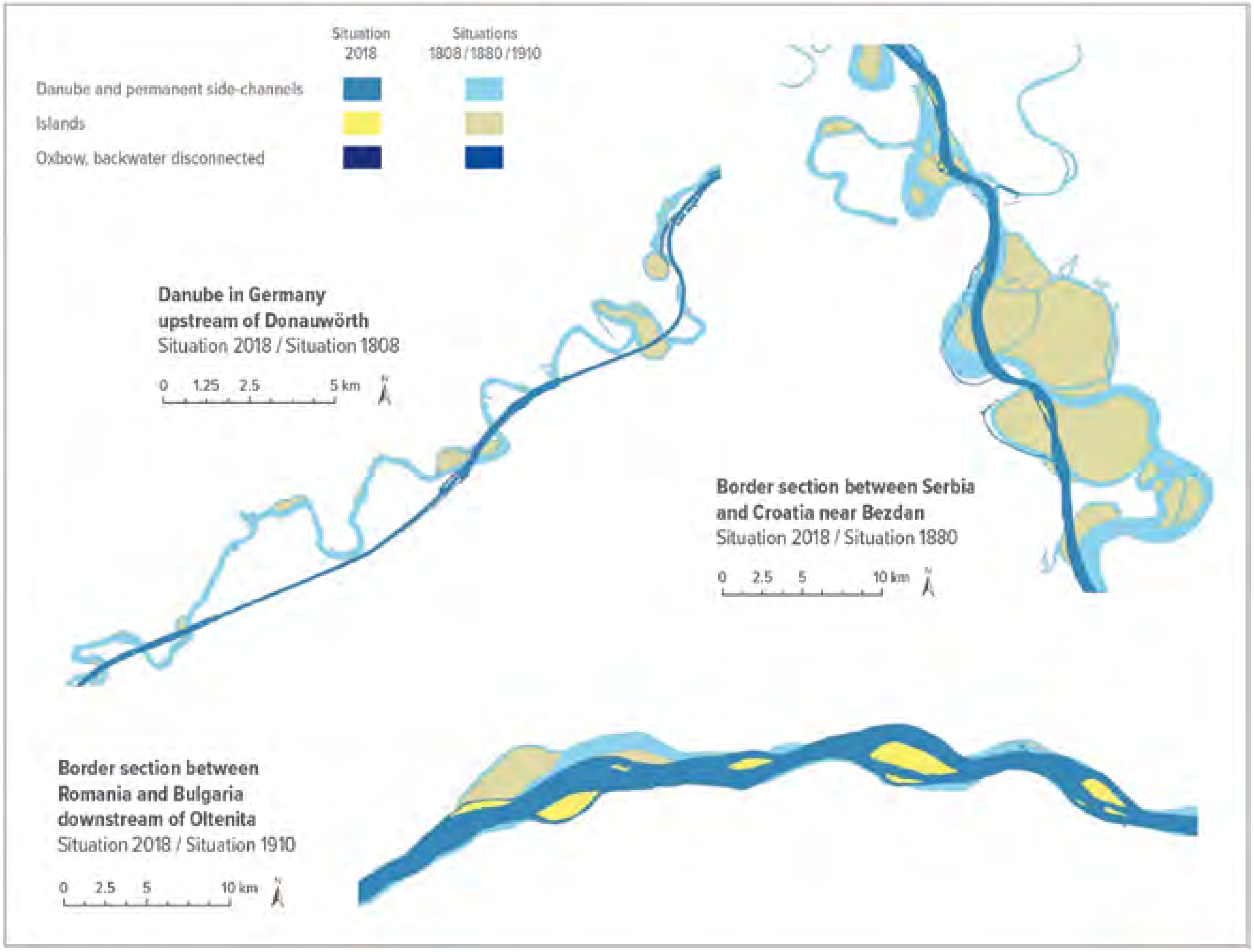

Figure 1. Top left: Danube in Germany upstream of Donauwörth. Top right: Border section between Serbia and Croatia near Bezdan. Bottom: Border section between Romania and Bulgaria downstream of Oltenita (based on data collected for the DanubeSediment Report 'Long-term Morphological Development of the Danube in Relation to the Sediment Balance'). (Habersack et al. 2019a).

Human intervention

Since the 18th century, humans have intervened considerably in the river system of the Danube. For inland navigation and flood protection, but also for land reclamation for settlements and agriculture, the course and banks of the river were changed by straightening and narrowing. Bank protection measures and cut-off side channels as well as flood protection dykes hinder the lateral exchange of sediments. At several sections of the river, significant dredging activities took place in the past, to gain construction material. More recently, the Danube River and many of its tributaries were dammed by transverse structures to generate energy from hydropower.

This has significantly altered the dynamic processes of sediment transport and morphodynamics typical for the rivers. When sediment input to and transport in rivers is reduced or absent, this might lead to severe erosion of the riverbed. This, in turn, results in a drop in the water level and instability of structures on and in the river. In impounded areas, as found upstream of transverse structures, sediments were deposited, which can endanger flood protection or can cause problems with hydropower utilization. But sediment management is also necessary from a nature conservation perspective, because the deterioration of the sediment balance, such as the retention of sediments at dams, leads to the loss of spawning habitats in the river and to a drop in the groundwater level in the floodplains, among other things.

Already a decade ago, the International Commission for the Protection of the Danube River (ICPDR) addressed the changes in the sediment regime of the Danube River as a problem in the first Danube River Basin Management Plan (DRBMP) of 2009 describing the sediment budget of most major rivers of the Danube basin as disturbed or severely altered (ICPDR 2009). However, the exact effects of these alterations were unknown. For this reason, the overall picture of the Danube's sediment regime was to be investigated in the transnational project DanubeSediment (co-funded by the European Union funds ERDF and IPA in the frame of the Danube Transnational Programme).

Morphological changes

Investigations performed in the project DanubeSediment showed to what significant extent the morphology of the Danube River was changed. In the Upper and Middle Danube, larger sections have changed from the former complex river morphology with meandering and sinuous river types with several multi-thread anabranching reaches to a single thread sinuous river type *(fig. 1)*. Especially in these two sections,

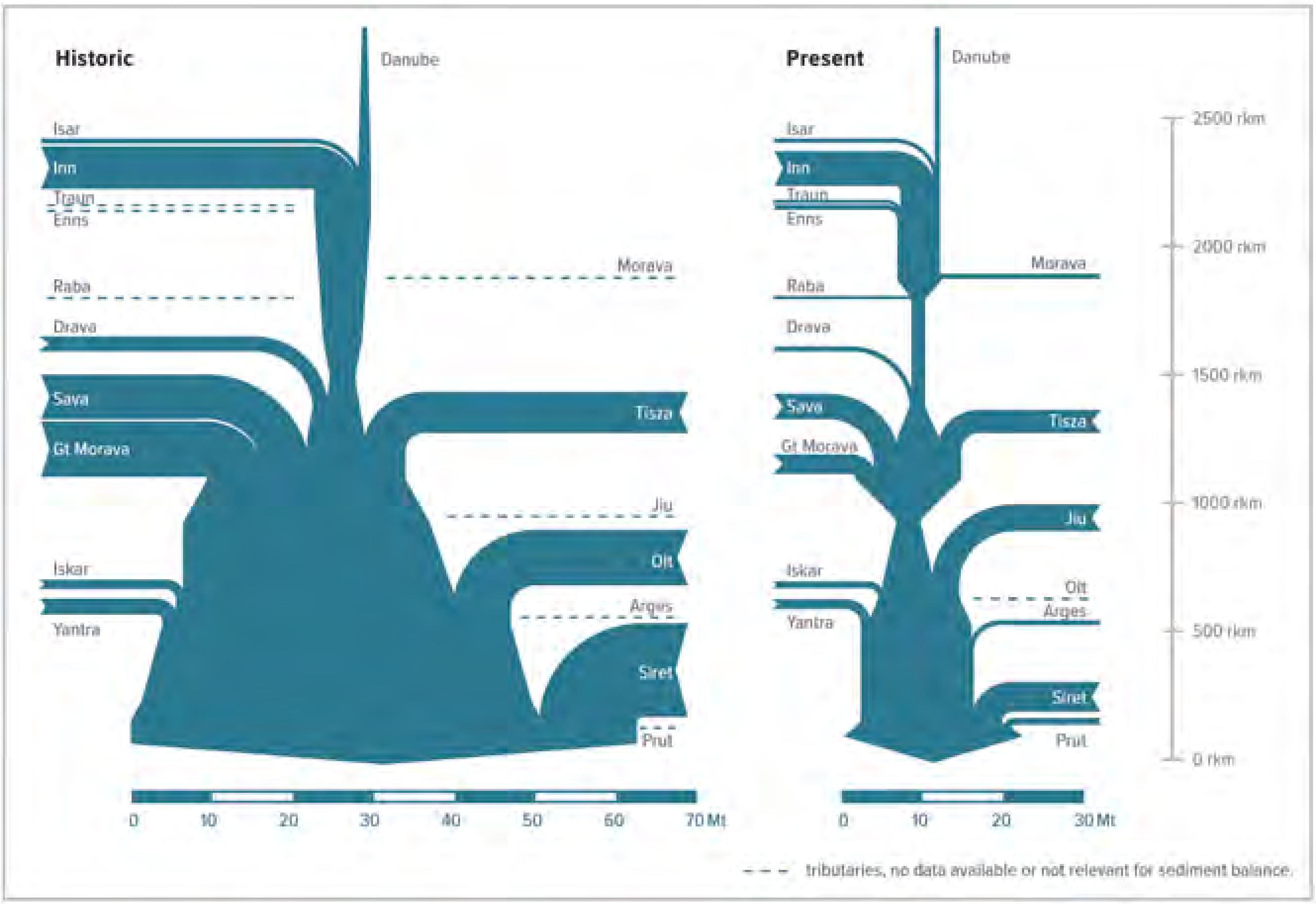

Figure 2. Suspended sediment balance along the Danube River and its major tributaries before (left) and after (right) HPP construction on the Danube River (dashed lines: tributaries, where no data are available or which are no longer relevant for the suspended sediment balance). The horizontal scale (Mt) applies for both the Danube River and its tributaries (based on data from the DanubeSediment report 'Analysis of Sediment Data Collected along the Danube') (Habersack et al. 2019a,b).

the width of the Danube River and its floodplains as well as the river length were significantly reduced. The total length of the Danube was shortened by 134 river-km, thereof 98 river-km (11%) on the Upper Danube and 31 river-km (4%) on the Middle Danube. In the Upper Danube, the total width was decreased on average by 39% (the active width by 22%) and in the Middle Danube by 12% (the active width by 1%) (Habersack et al. 2019 a,b). The construction of artificial structures such as guiding walls and groynes further reduced the width at low water level. As a consequence of these changes, various forms of riverbed degradation occurred and naturally-formed sediment bars, islands, side channels and oxbow lakes have been substantially reduced in the remaining free-flowing sections. The results of this project show that the lateral restrictions due to river training are less severe in the case of the Lower Danube River. Thus, the length decreased only about 1%, and the mean total width changed by 4%, whereby the width of the active river increased by 1% (Habersack et al. 2019a,b).

First sediment balance at the Danube River

The first step in establishing the sediment balance of the Danube River was to collect and analyse a large amount of sediment transport data. The majority of the sediment monitoring stations (more than 60) collect data on suspended sediments, while only eight stations with data on bedload are available. Since bedload has a large effect on river morphology compared to suspended sediment, its monitoring is of considerable importance for the sediment balance.

After harmonising the different data sets, a suspended sediment balance of the Danube River could be set up for two different time periods also considering the most important tributaries at their most downstream monitoring stations *(fig. 2)*. Since the construction of the large hydropower plants on the Danube River and its tributaries, the annual suspended sediment load reaching the Danube Delta and the Black Sea has decreased by up to 60%. Historically, about 60 and 40 million tonnes reached the Danube Delta and Black Sea annually, whereas today only about 20 and 15 million tonnes of suspended sediments arrive (Habersack et al. 2019a,b). The interruption of river continuity also prevents the bedload transport, resulting in a lack of river-forming sediments.

In order to compile the first sediment balance of the Danube River, further data such as dredging and feeding amounts of sediments and the composition and grain size of the transported sediments and bed material were collected. Furthermore, longitudinal and transverse profiles were used to investigate changes in bed levels for different time periods.

Overall, the assumption was confirmed that sediment tends to be deposited in impounded areas, while erosion mainly occurs in the free-flowing sections. An overview for the entire Danube River is shown in *Figure 3*. Around 733 river-km of the Danube are characterised by erosion. In the Lower Danube, the data are insufficient for long

Figure 3. Reaches at the Upper, Middle and Lower Danube showing sedimentation and erosion (from the DanubeSediment report 'Long-term Morphological Development of the Danube in Relation to the Sediment Balance') (Habersack et al. 2019a,b).

stretches, but point data at gauging stations indicate an erosion trend for about 670 river-km downstream of Iron Gate II. Altogether, about 56% of the entire Danube River is subject to an erosional tendency. In contrast, sedimentation prevails on about 857 river-km, especially upstream of the power plants Aschach, Gabčíkovo and Iron Gate I. Along 241 river-km or 10% of the Danube River, a more or less dynamic equilibrium can be observed or no significant changes occur (Habersack et al. 2019 a,b).

Significant Water Management Issue

The project results highlight that the sediment regime at the Danube River is out of balance. As a consequence of the project results, the ICPDR Heads of Delegations identified the sediment balance alteration as a new sub-item under the existing Significant Water Management Issue "Hydromorphological alterations" in the 2021 Update of the Danube River Basin Management Plan (ICPDR 2021a).

Furthermore, the project provides recommendations, summarized in the Danube Sediment Management Guidance (Habersack et al. 2019a), to reduce the impacts of the disturbed sediment balance. Project results and recommendations were integrated to the Danube River Management Plan and the Danube Flood Risk Management Plan published by the ICPDR and thus the project directly contributed to transnational water management and flood risk prevention (ICPDR 2021a,b).

Bilateral cooperation

Nevertheless, the project results of DanubeSediment also highlighted deficits and needs for actions, for example in data acquisition and needs for harmonization of monitoring and modelling tools, especially in border regions. Two transnational projects, that address these sediment issues in bilateral cooperation between Austria and Slovakia as well as Austria and Hungary, are 'Danube River Research and Management in Slovakia and Austria, DREAM SK-AT' (Interreg V-A SK-AT) and 'Sediment Research and Management on the Danube II, SEDDON II' (Interreg V-A HU-AT). Research in SEDDON II is carried out in the stretch east of Vienna, focusing on a 10 km long stretch near Hainburg, and in the upper section of the Hungarian Danube, whereas DREAM SK-AT concentrates on the common border section of the Danube River. In these two projects, sediment monitoring stations are set up in Slovakia and Hungary to measure the suspended sediment transport continuously based on the methodology already used in Austria. Furthermore, joint measurements are carried out to compare monitoring devices and to harmonize the monitoring method for suspended sediments and bedload *(fig. 4).*

The collected monitoring data also serve as input data and for calibration and validation of models on sediment transport and morphodynamics. With the help of numerical

Figure 4. Comparison of different monitoring devices to determine suspended sediments during a joint measurement: US-P61-A1 suspended sediment sampler, Acoustic Doppler Velocimeter (ADV) and turbidity sensor

simulations *(fig. 5a)* and physical model tests *(fig. 6),* basic investigations are carried out to better understand sediment-related processes. As sediment is difficult to scale, the set-up of large-scale experiments are required and thus a special focus is given on scaling effects – from small flumes to 1:1 experiments – to improve process understanding. Innovative Methods of modern measurement instruments (LDA = Laser Doppler Anemometry, PIV = Particle Image Velocimetry) are also investigated on different scales. Furthermore, results for modern river engineering and sediment management measures are provided. The spectrum ranges from measures to reduce bed incision for the improvement of the ecological status and optimisations in connection with reservoirs. In the border reach *(fig. 5b)* effects of sedimentation and ecological impacts in sidearms in the headwater of the reservoir (Gabčíkovo) are investigated with the help of numerical models.

Furthermore, in Slovakia and Hungary, lab facilities are renovated and improved and in Vienna a new hydraulic engineering laboratory with a discharge up to 10 m³/s is constructed. This leads to a fundamental improvement of the research infrastructure and cooperation between research institutions in the Danube Region. This new hydraulic engineering laboratory, in combination with the existing laboratories, offer a unique opportunity for the application of physical models on a large scale, from basic to applied research. Especially the large-scale model tests are very important in sediment transport research, as many currently used formulas show limitations in practice and scale effects can then be observed. Moreover, this innovative research site enables new possibilities also for joint research and international cooperation.

Stakeholder Involvement

In addition to enhanced scientific exchange, the improvement of knowledge and the knowledge transfer from science to river management is considered particularly important in all these projects. Thus, stakeholder workshops are organized, where the project results are presented

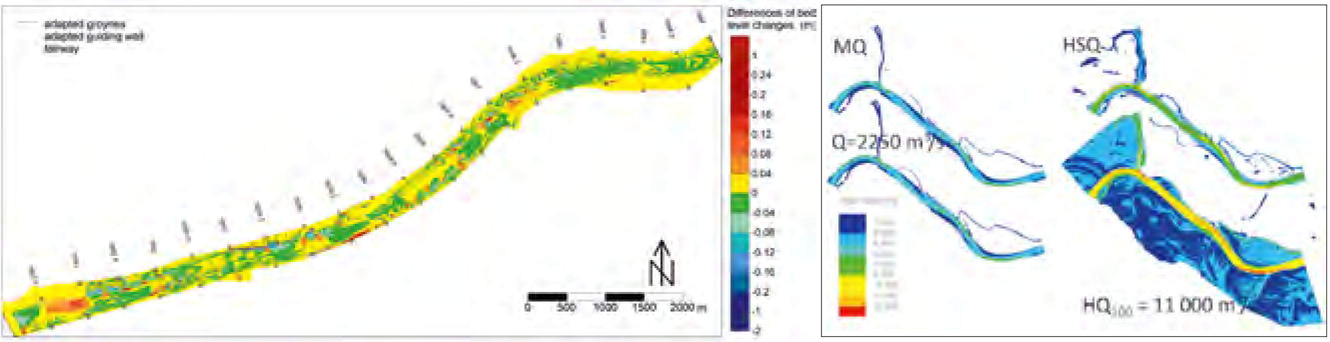

Figure 5. *Examples of numerical simulations including (a) sediment transport and morphodynamic model results in the reach near Hainburg (SEDDON II) and (b) 3D hydrodynamic models in the border reach for sediment and ecologically related issues (DREAM SK-AT).*

Figure 6. *Physical model experiments at different scales.*

and discussed together with participants from universities, waterway and water management authorities, environmental organisations (e.g. national parks), hydropower companies and companies working in the field of water management.

Furthermore, the project DanubeSediment specifically targeted the key stakeholders and their roles in its second major output: The Sediment Manual for Stakeholders (SMS) (Habersack et al. 2019b). The SMS provides guidance for sediment-related actions in the Danube River Basin and for future programs of sediment-related measures. The document also provides background information of good practice implementation in each field which can assist decision-makers and practitioners in planning future sediment management measures.

Further information

The Construction of the new hydraulic engineering laboratory of BOKU in Vienna is co-financed by EU funds (Interreg V-A SK-AT, Interreg V-A HU-AT, Interreg V-A AT-CZ, IGJ/ERDF); Austrian Federal Ministry of Agriculture, Regions and Tourism; Austrian Federal Ministry of Education, Science and Research; City of Vienna and Federal Government of Lower Austria).

Further information on the projects can be found under:
DanubeSediment: https://www.interreg-danube.eu/approved-projects/danubesediment
DREAM SK-AT: https://dream-sk-at.jimdosite.com/
SEDDON II: http://www.interreg-athu.eu/seddon2

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Interreg Danube Transnational Programme DanubeSediment

Interreg Austria-Hungary European Union – European Regional Development Fund SEDDON II

Interreg Slovakia-Austria European Regional Development Fund

Developing hydropower plants in nature protected areas – the case of hydropower complex in Jiu Gorge, Romania

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Abstract

Despite being promoted as 'green' energy, hydropower plants have a strong negative impact on the environment mainly due to irreversible habitat alterations and species loss. The situation is even worse when small and medium plants are constructed in nature protected areas, established with the goal to safeguard species and habitats of community importance. This article presents the case of the hydropower complex built in the middle of Jiu River protected areas, without a proper consideration of the environmental legislation. We argue that, based on technological progress, other renewable energy sources such as wind and solar energy, coming with far lower costs for the environment and economy, should be promoted in the future.

Background

Aquatic biodiversity and freshwater ecosystems are of particular importance worldwide, due to their essential role for life and provisioning of numerous ecosystem services to human society. Yet, a report of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES 2018) highlights that biodiversity, including in aquatic ecosystems, is under serious threat in Europe.

Although freshwater ecosystems play a key role in enhancing resilience to global environmental challenges and are protected particularly by the requirements of the EU Water Framework Directive, Nature Directives and Biodiversity Strategy 2030, aiming among others to restore at least 25,000 km of EU rivers to a free-flowing state (COM 380, 2020), rivers are subject to multiple pressures such as habitat fragmentation (by hydrotechnical constructions, land use change), water abstraction, pollution, climate change (altering temperatures, precipitation regimes and frequency of extreme weather events), etc.

The development of hydropower plants, strongly promoted as 'green' energy in the past decades by ignoring the high environmental costs for the freshwater ecosystems, mainly in terms of habitat destruction and species loss, represents a major threat to European rivers. The Living Planet Report for Migratory Fish emphasizes that at European level, the migratory freshwater fish declined by 93%, one prominent cause being habitat fragmentation and the lack of free-flowing rivers in Europe (WFMF 2020).

In this context, continuing to develop small-to medium-sized hydropower plants in protected areas will have a devastating effect on the already endangered species and habitats sheltered by these ecosystems as both, rivers and their adjacent environment, are drastically affected by e.g. disruption of river continuum and sediment transport, change of lotic to lentic habitats (upstream the dam), altered discharge (downstream) and groundwater level, etc. (Bunn & Arthington 2002; Schmutz & Moog 2018). The energy production of these small hydropower plants does not contribute significantly to renewable energy production in the context of a sustainable energy strategy to mitigate climate change. In addition, their significant contribution to greenhouse gas emission and hindering of carbon sequestration is largely ignored (Deemer et al. 2016; Maavara et al. 2017).

In Romania, the implementation of the EU Renewable Energy Directive triggered a significant boom of small hydropower plants, mainly due to state subsidies. Despite the fact that small hydropower plants account for 70% of the total number of hydropower in Romania, they produce only 11.1% of total hydropower energy, i.e about 3% of Romania's total electricity production (Eurostat 2019, cited by Costea et al. 2021). Yet, they generate severe negative impacts on ri-

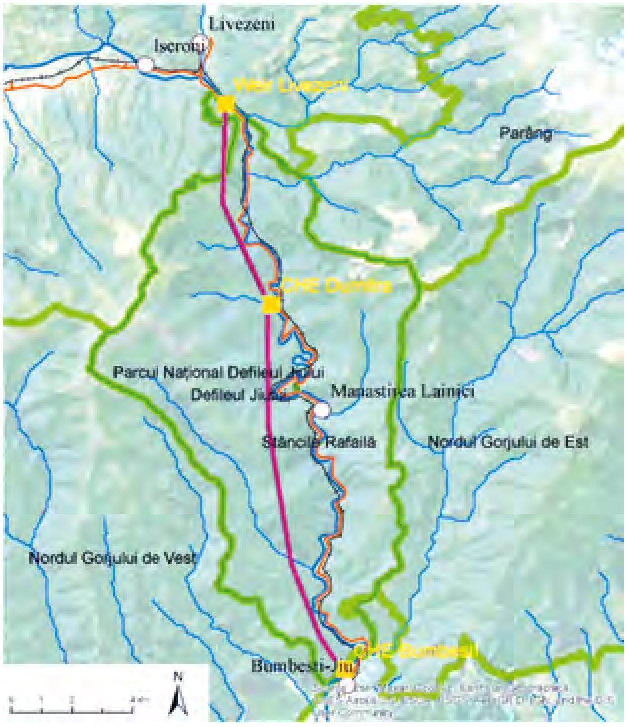

Figure 1. The projected hydropower plants within the Jiu breakthrough in the protected areas: In light green the boundaries of Natura 2000 areas (in thin dark green the national park boundaries); in orange the planned facilities of the hydropower plant complex (the hydroelectric plants CHE Dumitra and CHE Bumbesti, the weir Livezeni is completed but out of operation so far, the planned parallel headrace tunnel is shown in purple, CHE = Centrala Hidroelectrica).

vers, as e.g. in case of hydropower plants built on headwater streams, the trout *(Salmo trutta fario)* and bullhead *(Cottus gobio)* populations often disappeared completely, remaining in only 38% of the stream reaches, isolated either upstream or downstream of the plants (Costea et al. 2021).

The case of hydropower complex in Jiu Gorge National Park

The Jiu River is among the largest rivers in Romania and one of the main tributaries of the Danube River. The Jiu Gorge, located in the Southern Carpathians between Valcan and Parang Mountains, is approximately 30 km long and encompasses several minor tributaries flowing into Jiu River (Telcean et al. 2017). Due to its high biodiversity, Jiu Gorge was declared a National Park in 2005, and two years later, after Romania's accession in the EU, the area was included in Natura 2000 network as site of community importance ROSCI 0063 Defileul Jiului.

The hydropower complex is located at the heart of the National Park Jiu Gorge and Natura 2000 protected area *(fig. 1).* The development of the first stages of this project started in 2004, but despite the severe environmental impact expected due to the river flow alteration and habitat fragmentation, construction permits were issued in 2008, 2012 and 2016 without a proper environmental assessment procedure, the project being accomplished about 72 % (according to the Romanian Government) by ignoring the environmental requirements. Consequently, the Romanian Appeal Court annulated the last two permits in December 2017, rendering the whole construction illegal.

The hydropower complex encompasses two hydropower plants and several hydrotechnical constructions along Jiu Gorge *(fig.1).* The first hydropower plant, Dumitra, includes an intake dam at Livezeni *(fig.2),* a 7 km long headrace tunnel, a penstock and Dumitra powerplant, the whole ensemble covering roughly one third of the Jiu Gorge. The second hydropower plant collects the water from Dumitra hydropower plant plus the water from the Jiu secondary inlet and Dumitra River, passing through a 12.5 km headrace tunnel, to the end of Jiu Gorge, where Bumbești powerplant is located. A second tunnel aims to capture the flow of Bratcu River, a right tributary of Jiu River, and bring it to the powerplant.

Based on the water management permit released in 2003, an ecological flow of only 2.7 m^3/s will remain in the Jiu River, representing roughly 10% of the natural flow. According to the National Forest Administration (Romsilva 2010), it is expected that the average water depth downstream Dumitra will decrease dramatically to levels far too low to sustain the life of the protected species and habitats sheltered by Jiu Gorge, increasing the risk that the river will completely dry-out during the dry season.

The Standard data form (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ROSCI0063) lists the key habitats and species for which ROSCI 0063 Defileul Jiului was declared a protected area. The flow reduction of about 90% along the entire length of the gorge (Telcean et al. 2017) will severely affect habitats located along the river, such as e.g. Alpine rivers and the herbaceous vegetation along their banks (habitat code 3220), Alpine rivers and their ligneous vegetation with *Myricaria germanica* (habitat code 3230), Alpine rivers and their ligneous vegetation with *Salix eleagnos* (habitat code 3240) and priority habitat Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)* (habitat code 91E0*).

The impact on species is expected to have even more far-reaching consequences, considering that water diversion will affect not only the aquatic and semi-aquatic species, but entire food webs, including the terrestrial species inhabiting the gorge slopes. The aquatic species will be the first impacted by the dam construction and drastic flow reduction as their lotic habitat will be dramatically changed. Besides four Natura 2000 fish species with acknowledged conservation value: *Barbus balcanicus* (code 5261), *Cottus gobio* all other (code 6965), *Romanogobio uranoscopus* (code 6145) and *Sabanejewia balcanica* (code 5197), an endemic species only present in Romania in a very limited range inhabits this area, *Sabanejewia romanica* (Telcean et al. 2017). *Alburnoides bipunctatus* (code 2500), a fish species protected under Bern Convention An. II, will also be impacted. Further, herpetofauna species such as e.g. *Bombina variegata* (code 1193), *Rana dalmatina* (code 1209), *Rana temporaria* (code 1213), *Salamandra salamandra* (code 2351), *Triturus alpestris* (code 2353), *Triturus cristatus* (code 1166), *Natrix tessellata* (code 1292), will be negatively affected by the water uptake, most species requiring aquatic habitats for reproduction, development of young stages of life and feeding. Among other species harmed by habitat degradation are the semi-aquatic beetle *Carabus variolosus* (code 4014) and a primeval forest relict beetle species *Agnathus decoratus* protected in countries from Central Europe (Eckelt et al. 2017).

Due to the severe decline of fish populations, it is expected that another priority species, the otter *(Lutra lutra,* code 1355), will also decline. Another protected species, *Austropotamobius torrentium* (code 1093) inhabiting the Jiu riverbed, is also expected to register a sharp decline. The same decline will take place for the lynx *(Lynx lynx,* code 1361) population in Jiu Gorge National Park (as proven by similar experiences in Macedonia), along with other large mammals living on the forested slopes of the gorge. Also, bat species feeding around the river, such as *Barbastella barbastellus* (code 1308) will record a drastic decrease if the hydropower project will be completed.

The legal problem

A rapid analysis of the development of this hydropower complex shows that at least 3 environmental directives were already or will be breached when the complex will become operational.

Environmental Impact Assessment Directive 2011/92/EU. The directive on the assessment of the effects of certain public and private projects on the environment (EIA directive) stipulates that environmental considerations shall be taken into account at the earliest possible stage and integrated into the project's design. However, it was not the case for this project, as public and environmental expert comments were roughly ignored. Given the fact that valuable protected habitats were already destroyed by the constructions and endangered species were already affected by this project, we consider the attempts to issue a new environmental permit for this construction as obsolete: an EIA cannot be performed after completing the biggest part of the project.

Water Framework Directive 2000/60/EC. The Water Framework Directive (WFD) requires the assessment of the ecological status of freshwater bodies based on chemical, biological and hydromorphological quality elements. The significant change of the river discharge (up to 90 % of the flow being diverted from the river into tunnels), the regulation of Dumitra River and the construction of the dams, fragmenting river habitats, altering migration and sediment transport, and changing the upstream sections into lentic ecosystems while downstream section will suffer from insufficient flow, especially during seasons with low precipitation regime, will significantly alter the biological components (especially fish, macroinvertebrates and macrophytes communities), hydromorphological parameters (hydrological regime, river continuity, morphological conditions, in particular as large reaches (60%) fulfill currently reference conditions), and even the chemical quality elements (mainly oxygen regime). It is expected that, if the complex will become operational, the ecological status of the river will drop significantly for at least two or even three classes, representing a violation of the non-deterioration principle of the WFD and a breach of Art. 1a & 1b, Art. 4.1a, para (i), Art. 4.1c.

Habitats Directive 92/43/EEC. The Habitats Directive requires the establishment of Natura 2000 network of protected areas to preserve species and habitats of community importance in each EU member state. Along the Jiu River, the National Park Jiu Gorge and the Natura 2000 site (ROSCI 0063) with the same name were established with the support of the Romanian Ministry of Environment to protect the biodiversity of this free-flowing river stretch. However, the planned uptake of up to 90 % of the river flow will have a severe negative effect on several sensitive habitats, located along the river banks and directly dependent on the river flow. It is expected that water diversion, leading to a drying river bed over long periods of time, will affect not only the alpine river habitats but could lead also to changes in water availability for the riparian forests leading to a decline of 80-90% of these habitats. Of particular concern is the priority habitat 91E0 (alluvial forests), as according to Habitats Directive, projects impacting priority habitats should be allowed only in very special conditions. Hence, we consider that articles Art. 6.2, Art. 6.3, Art. 6.4, Art.10 of Habitats Directive will be breached by this project.

Quo vadis biodiversity conservation in Romania?

As a consequence of the war in Ukraine and the momentum to gain energetic independence from Russian fuel sources, the Romanian Parliament adopted recently a controversial law (PL-x 132/2022) allowing the modification of nature protected areas limits and giving green light for the finalization of hydropower plants constructed over 60%, considered projects of overriding public interest and of national security, until the end of 2025. As a compensatory measure, the Ministry of Environment, Water and Forests will propose for protection a new area, with similar biodiversity as the one occupied by the hydropower plant construction. Such projects are considered exceptional situations regarding the environmental impact assessment. The law was challenged for unconstitutionality by Union to Save Romania (USR), a ruling being expected soon.

This law conflicts with the requirements of the EU environmental directives, in particular with the non-deterioration principle of Water Framework Directive. The ruling of the European Union Court of Justice C 461/13 states the binding force of WFD Art. 1 on the Member States to prevent deterioration of water bodies and to protect and enhance the status of aquatic ecosystems and terrestrial ecosystems directly depending on the aquatic ecosystems. It also conflicts with the Romanian Constitution, which guarantees the right to a safe environment. Considering the projected impacts of climate change on the southern part of Romania, with decreasing precipitation levels and water scarcity (ICPDR 2019), it is expected that the discharge of Jiu River will decrease, while water demands from all the consumers (households, tourism, hydropower plants, etc) will increase, reducing the efficiency of energy production. Moreover, the construction of new reservoirs will increase the local emission of greenhouse gases, counteracting the efforts to mitigate climate change impacts.

Taking into account the low amount of energy production estimated for the hydropower complex in Jiu Gorge, compared to the major environmental losses in the protected areas, this project cannot be considered of overriding public interest, to benefit from exemptions under Water Framework Directive or Habitats Directive. Moreover, the fact that the project was developed without proper environmental considerations is even more aggravating, as allowing its continuation means encouraging similar behavior from other stakeholders. The stretch of Jiu River in Jiu Gorge National Park is the area with the highest degree of protection by law. If species sharply decline or disappear from such a strongly protected area, it is a clear signal that they can also disappear from other river stretches with a lower degree of protection.

In addition, due to the development of other renewable energy sources, hydropower lost its advantage of being the cheapest energy source. The power generation costs for solar and wind energy have fallen sharply over the past decade (IRENA 2021), mainly due to technological

Energy type	Levelised cost of electricity (2020 USD/kWh)		
	2010	2020	Percent change (%)
Bioenergy	0.076	0.076	0
Geothermal	0.049	0.071	45
Hydropower	0.038	0.044	18
Solar photovoltaic	0.381	0.057	-85
Concentrating solar power (CSP)	0.340	0.108	-68
Onshore wind	0.089	0.039	-56
Offshore wind	0.162	0.084	-48

Table 1: Levelised cost of electricity trends by technology, 2010 and 2020. Source: International Renewable Energy Agency (IRENA, 2021).

improvements and competitive supply chains, becoming increasingly attractive and accessible for new energy investments. Between 2010 and 2020, the global weighted-average cost of electricity from onshore wind fell by 56 %, while for solar energy the cost dropped by 85%; over the same period, the hydropower generation costs increased by 18%, surpassing the costs for onshore wind energy *(tab. 1).*

Considering that hydropower energy comes with dramatic environmental costs and is losing its price attractiveness due to the current progress of other renewable energy sources, we consider that a revision of the energy policy of Romania is needed, based on current developments at the international level and state-of-the-art data and projections, not on reviving projects abandoned for decades and breaching environmental legislation.

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Dam removal: just a trend or a fast forward strategy for healthy rivers?

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The importance of river connectivity for biodiversity and ecosystem services of rivers is common knowledge today. River connectivity is perceived in four dimensions: longitudinal, lateral, vertical and temporal. Rivers are pathways not only for water, but also for sediments, organic matter and of course wildlife (Grill et al. 2019; Zeiringer et al. 2018). Rivers have been utilised by man for thousands of years and by doing so river ecology and especially the connectivity were altered in many ways. Already a few centuries ago, the apparent negative effect of barriers, especially on fish, was detected and first mitigation measures like technical fish-ways have been built. Given the enormous degree of fragmentation, the re-establishment of connectivity has become one of the main pillars of river restoration and river basin management.

While dam removal is by far not new to water management (on the contrary, historical evidence shows that construction of weirs and dams happened frequently), it still seems to be the second choice, when it comes to today's river restoration. For example, the river basin management plan for Austria (BMLRT 2021) does not mention dam removal at all, nor does the guideline for fish-passages. This is remarkable, as it is clear that dam removal is by far the most effective, and in the long-run cheapest way to deal with obstacles (BMLFUW 2017). Moreover, it is the only way to fully restore longitudinal connectivity.

There are three excellent reasons that indicate a special focus on dam removal: First of all, recent research revealed that the amount of river fragmentation has been underestimated significantly. By means of field-proofing Belletti et al. (2020) estimate, that only 50% of barriers are recorded in official databases. In total, up to 1.2 million barriers could fragment rivers in Europe. Furthermore, we would require a uniform definition of when a transverse structure is considered a (full) barrier to migration. Secondly, there is clear evidence that dam removal is also a very successful river restoration technique, which has delivered positive results in many cases (Gough et al. 2018). Finally, it is important to note that the European Commission with the new Biodiversity Strategy expressed a strong determination to restore river ecosystems by means of dam removal and floodplain reconnection (European Commission 2022).

WWF is partner of the Dam Removal Europe Initiative. In 2021, WWF presented a first analysis of reconnection potential through barrier removal for the whole of Europe (Schwarz 2021), WWF teamed up in several projects to remove barriers. Currently the authors started to compile an inventory of dam removal projects in Austria with promising first results.

River fragmentation in Europe and the Danube basin

The AMBER consortium (2020a) collected information on more than 630,000 barriers in Europe from different sources. But accurate field-proofing in pilot catchments showed, that the actual density of barriers is much higher, than official records. Taking undetected barriers into account Belletti et al. (2020) estimate that in total, up to 1.2 million barriers intersect the river continuum in Europe. Most of these barriers are less than 2 m high.

With regard to the height, it is important to note that barriers up to a height of approx. 0.3 m can usually be easily overcome by adult salmonids, but can represent an impassable obstacle for small fish species and juveniles in general. Barrier structures with a height of more than approx. 0.7 m can only be passed by single individuals that have a special physical fitness.

The transboundary river basin management plan for the river Danube (ICPDR 2021) records about 1,000 interruptions in large rivers with a catchment area spanning over 4,000 km². It is stated that the main driver for fragmentation is hydropower generation. Austria has the largest share of barriers. The total amount of barriers in the entire river network is of

Figure 1: Dam removal at the Hornbach (Tyrol). To reduce river-bed degradation and related safety risks at the Lech River, several sediment control structures - up to 16 m high - were removed in relevant tributaries. At the Hornbach, 900.000 m³ of bedload are released again step by step, contributing substantially to ecosystem functions and habitat availability. About 16 km of river-stretches are reconnected (Credit: Toni Vorauer/WWF).

course much higher. The AMBER atlas locates 45,000 dams in the Danube river basin (AMBER Consortium 2020a). Taking again into account that many dams have not been documented, it is clear that actual figures are even higher.

Austria and Germany are among the countries with the highest density of barriers with one, resp. two barriers per river kilometre. About 28,000 barriers which are unpassable for fish were identified in Austria.

Barriers fulfil different functions in Europe. Hydropower production, flood protection and irrigation are the most common purposes (EEA 2021). River regulation also necessitates transverse structures to reduce the sole gradient due to the loss of course length. However, it is remarkable that the purpose of a large quantity of dams is unclear. It is estimated that up to 100,000 barriers in Europe are even obsolete (AMBER Consortium 2020b).

From technical fish-passes to the removal of barriers

Re-establishment of connectivity is a common measure to improve the ecological status of rivers. First fish passages date back to the 18th century (Birnie-Gauvin et al. 2018). In Austria, the connectivity was improved for about 1.665 barriers between 2006-2021. According to the Danube river basin management plan along the large river stretches only one third of the barriers are equipped with fish passages (Haidvogl et al. 2021). Compared to the amount of barriers, it is obvious that the number of measures taken is extremely small. The implementation of the Water-Framework Directive is not on track and progress is delayed.

Additionally, the impact of technical mitigation measures is subject to intense discussions. Effectiveness of fish-ways is considered low (Noonan et al. 2012), fish migrating downstream still face a huge mortality risk (Radinger et al. 2021) and the alteration of ecosystem functions and effect of barriers on habitat availability is often not taken into consideration. A comparative analysis of measures clearly showed that removal of barriers is more effective and cheaper than the construction of technical fishways (BMLFUW 2017). It is clear that the difference between removing a barrier and constructing a fishway is enormous and the first question in the decision-making process should always be, whether a barrier is necessary at all (Birnie-Gauvin et al. 2018).

Accordingly, it is good news that approximately 5,000 barriers have been removed in Europe in the past decades (Dam Removal Europe 2022). France, Sweden and Finland can be seen as early adopters in terms of dam removal in Europe. Meanwhile, other countries of the Danube basin like Germany, Austria, Slovakia, Romania and Ukraine also started to contribute to the overall reduction of barriers. In Austria, 198 barriers were completely removed in recent years (BMLRT 2021). This accounts for 11.9% of all measures that target barriers. According to the datasets of the Austrian river basin management plan (BMLRT 2021)

Figure 2: Removal of a small weir at river Maltsch (Upper Austria). The Maltsch River is protected under Natura 2000. Several obsolete small barriers interrupted the river. In 2021, the water management agency removed several dams, entirely freeing about 10 km of the river again (Credit: Sarah Höfler/blattfisch).

mainly small dams along alpine river stretches were removed. The obstacles had served flood-protection and to a smaller amount hydropower production.

Many different examples – from gigantic hydropower plants and check-dams to small ramps - show, that removal of barriers is feasible and a powerful mean to restore rivers. In figure 1 to 3 different examples are presented. Many additional cases are available (www.damremoval.eu, https://dam-removal-goes-alps.de/start.html).

Dam removal on top of the EU restoration agenda

It is obvious that the number of barriers removed is small compared to the huge amount of existing barriers. Nevertheless, recent projects are of great importance to get removal started. Member states of the European Union now are ready to go one step further. The new Biodiversity Strategy contains clear and ambitious restoration objectives: ´It sets a target to restore at least 25,000 km of rivers into a free-flowing state, through two main types of action: removal of barriers and the restoration of floodplains and wetlands by 2030´ (European Commission 2022). The European Commission made clear, that this objective goes beyond the WFD obligation to reach good ecological status of water-bodies. The strategy refers to the concept of free-flowing rivers, which encompasses all four dimensions of river continuum. To achieve the set goal a thorough concept to identify promising river stretches and to prioritise obstacles is needed. A comprehensive study commissioned by WWF identified more than 850 barriers with high reconnection potential and more than 7,200 obstacles with good ecological preconditions for reconnection in Europe (Schwarz 2021). These barriers are qualified by a great potential to restore long free-flowing stretches, have potential for floodplain reconnection or improvement of protected areas. Of course, the dam removal concept has to be embedded in more holistic strategies for river restoration, like the concepts presented in the MEASURES project for the Danube River (Haidvogl et al. 2021). The large number of removals that are necessary to achieve the set 25,000 km target show that dam removal is key to river recovery.

To reconnect and restore rivers it is necessary to mainstream dam removal. Given the fact that hardly any free-flowing rivers are left in Europe (Grill et al. 2019), 70-90%

Figure 3: Removal of lateral barriers at the Danube with the EU Life project Dynamic-Life-Lines-Danube (Lower Austria). In the Nationalpark Donau Auen, lateral connection of Danube side-arms was re-established by removing solid traversal structures and river embankments. This action contributes to restoration of lateral connectivity and near-natural processes (Credit: Tögel/viadonau).

of floodplains are environmentally degraded (EEA 2021) and the fact that thousands of more dams are planned even in protected areas (Schwarz 2019), it is time to boost removal - especially of thousands of outdated or even obsolete dams.

Today it is common sense to keep our environment free of harmful waste. Abandoned dams are like waste as they harm rivers and reduce their ecosystem services. With that in mind, it should be taken for granted that dams are removed if they are not needed anymore. To do so, formal procedures have to be improved and technical and financial support must be made available.

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Interreg
Danube Transnational Programme
MEASURES

Managing and restoring aquatic ecological corridors for migratory fish species in the Danube River Basin (MEASURES)

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Danube´s migratory fish species suffer from habitat change, continuum interruption and in some sections also from overfishing and poaching, respectively. All sturgeon species are particularly affected and solutions to save and restore their severely threatened or even extinct populations are urgently needed. Besides these ancient species, Danube shads and potamodromous fish are concerned, too. Transnational cooperation and national endeavors have reached important milestones such as temporary or permanent sturgeon fishing bans in most Danube countries except Slovenia, Croatia and some Austrian provinces, or the construction of fish migration aids in the Upper Danube. But still, many pressures remain.

The Interreg-funded project 'Managing and restoring aquatic Ecological corridors for migratory fish species in the Danube River Basin' (MEASURES) aimed to create ecological corridors by identifying key habitats and initiating protection measures along the Danube and its main tributaries. Sturgeons and other migratory fish species acted as flagship species in support of the project goals. MEASURES acknowledged that sturgeons and other migratory fish species represent a historical, economic and natural heritage of the Danube and are indicators of the ecological status of its watercourses, especially concerning the function of the river as an ecological corridor. Transnational management of these corridors and restoration actions, as well as restocking with indigenous species are essential.

Identification and mapping of key habitats of migratory fish species

MEASURES partners developed and tested joint methods to identify and map spawning, nursery, feeding, wintering and resting habitats of selected migratory species (Cokan et al. 2021). Diverse sources such as reports, field protocols or museum specimens were used to determine potential habitats. Further, maps, aerial and satellite images, bathymetry maps and field measurements were analyzed using ecological traits of species. The actual use of potential habitats was verified by scrutinizing the results of recent field surveys and sampling campaigns during the project. The

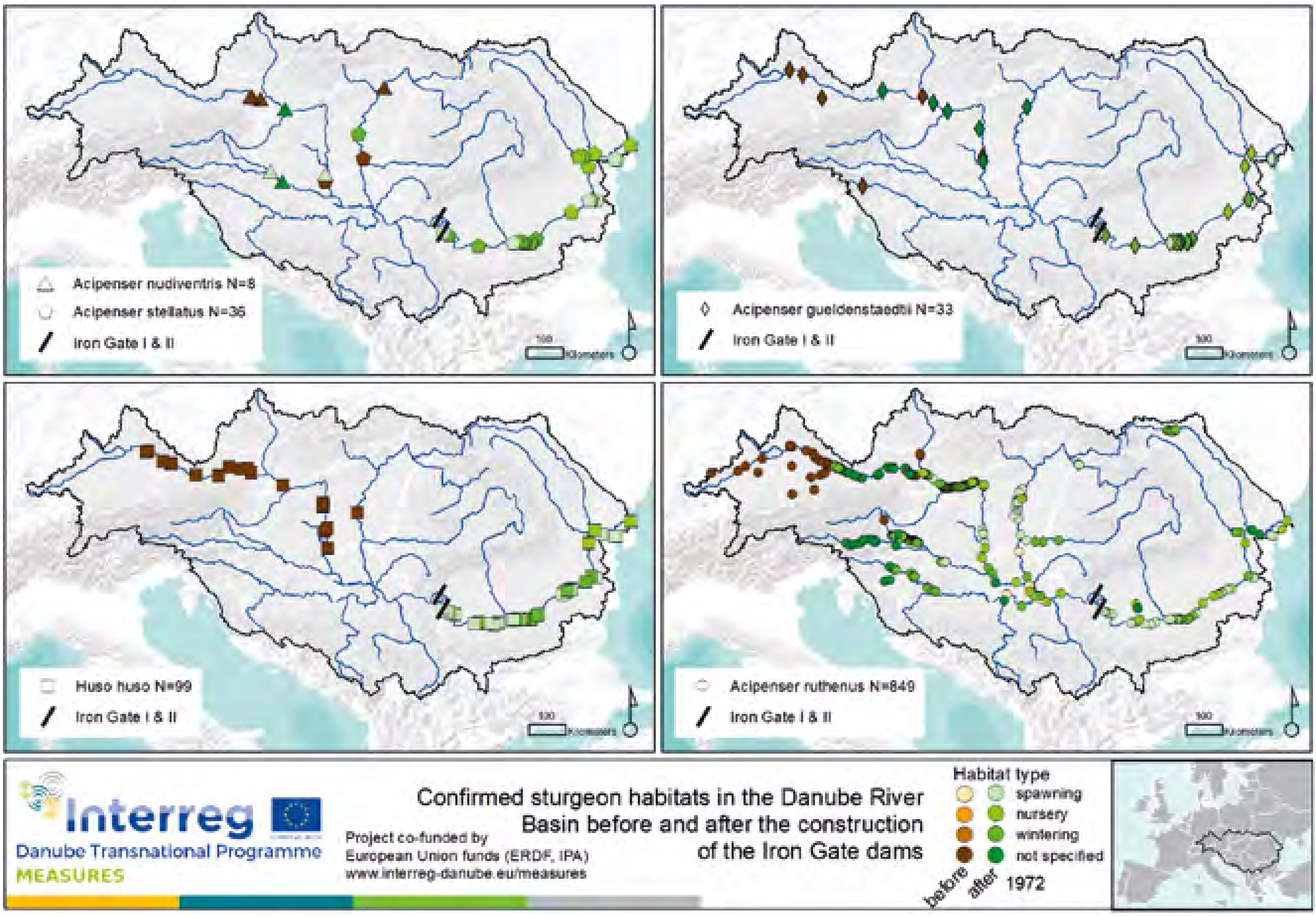

Figure 1: Confirmed sturgeon habitats in the Danube River Basin before and after the construction of the Iron Gate dams

latter included different types of sampling gears as well as tagging. For the 16 migratory fish species considered, about 2200 locations in the Danube and selected tributaries were identified as potential habitats and recorded in a migratory fish database. Roughly 50% of these habitats could have been confirmed as actually used.

A focus was on the Danube sturgeon species, namely on the critically endangered Beluga Sturgeon *(Huso huso),* the Stellate Sturgeon *(Acipenser stellatus),* the functionally extinct Russian Sturgeon *(A. gueldenstaedtii),* the Ship Sturgeon *(A. nudiventris),* which is considered extinct in the Danube and the Sterlet *(A. ruthenus).*

Conservation stocking of two native sturgeon species

Because of the critical situation of the Danube sturgeon species genetic analysis and ex-situ measures are instantly needed to conserve their genetic pools and to strengthen or restore their populations in the wild. During MEASURES, eDNA-markers for monitoring purposes were identified for Sterlet and Ship Sturgeon and tested at selected Danube sites. No proof of ship sturgeon was possible, but the presence of stellate sturgeon, for which an eDNA marker was already available, and sterlet could be documented based on eDNA sampling of the whole Danube River during the fourth Joint Danube Survey in 2019. Further, brood-stocks of the Russian Sturgeon and the Sterlet were collected for scientific hatcheries in Hungary and Austria (NAIK-HAKI 2020). Such ex-situ gene stocks keep viable sturgeon populations under safe and controlled conditions over longer periods. Broodfish are frequently propagated for continuous releases of genetically suitable juveniles that are fit for survival in the wild to strengthen the remaining wild sturgeon populations or for reintroduction into formerly inhabited parts of the system as potential habitats were identified during the project.

Figure 2: Release of young Sterlet in the Hungarian Danube near Ercsi in 2019 (Photo: MATE 2019)

In 2019 and 2020, 6,500 Sterlet juveniles were released in the Hungarian Danube and 24,000 Sterlet fry was released in tributaries. In the same years release of 2,500 juvenile Russian Sturgeons took place in the Romanian Danube. Juvenile fish were individually tagged. Some weeks after, 26 tagged Sterlets were caught downstream in Serbia, which proofs the rapid spread of restocked fish. Also tagged Russian Sturgeons were reported in the Chilia branch in October 2020 (Mozsár et al. 2021).

The MEASURES Information System (MIS)

During MEASURES a free online information tool was developed (http://85.204.145.162/measures/metadata/). The MEASURES Information System (MIS) provides scientists, decision makers and the general public with information about ecological corridors and the connectivity of habitats for long and medium-distance migratory fish of the Danube River Basin. The MIS is an interactive website integrating original data, published papers and grey literature stemming from all Danube bordering states. Its goal is to enhance capacity at national and transnational level through collecting basic information that helps integrating water management and nature conservation by strengthening the conservation of migratory fish and improving ecological corridors. The MIS can be searched using thematic keywords related e.g. to specific locations, data and publication types, media content or for resources in particular languages.

As of July 2021, when the project ended, the MIS metadatabase contained 747 different datasets, out of which 561 were defined as publicly available, 163 as available to MEASURES partners and stakeholders and 23 are marked as for MEASURES partners only due to specific access rules of data owners (Schmidt-Kloiber 2021).

Stakeholder integration and networking for migratory fish

Integrating stakeholders to achieve a shared understanding of the project tasks and results and to ensure support for the implementation of proposed measures at the national and basin level was a core interest of the MEASURES project. Based on a 'stakeholder strategy' developed by MEASURES partners at the beginning of the project, stakeholders from nature protection, conservation and restoration, river management and flood protection, fishery, hydropower, navigation and agriculture were invited to three rounds of national workshops organized in all eight partner countries during the project. These groups form a pool of potential members for future local migratory fish networks, which shall play a key role in the implementation of the measures proposed in the MEASURES strategy (Scherhaufer & Haidvogl 2021).

Figure 3: During the MEASURES project three rounds of national stakeholder workshops were organized in all partner countries. The picture above was taken during the 2nd Austrian workshop (Photo: B. Grüner)

Developing a harmonized strategy

A major output of the MEASURES project is the 'Strategy for ecological corridor conservation and restoration in the Danube catchment', which proposes measures to secure the Danube and its tributaries and relevant areas of the Danube Delta and Black Sea as an ecological corridor for migratory fish and to ensure conditions for stable or growing populations. Thus, the measures address physical connectivity, habitat availability and viable populations via eight general types of measures, which consist of specific activities and priorities. Three of the Types of Measures (ToM) directly address the management of the Danube River and its tributaries as an ecological corridor: (1) Assessing, mitigating or eliminating the negative effects of migration barriers; (2) Protection and restoration of migratory fish habitats; (3) Green infrastructure for flood management and nature-based solutions for navigation. The fourth ToM strives to secure and support viable populations of migratory fish and ToM 5 aims to improve and harmonize the monitoring of habitats and fish populations. Three ToMs are of organisational and supportive nature: developing National Activity Plans for Migratory Fish Species; creating, establishing and facilitating 'Local Migratory Fish Networks' and improving public participation and support for local migratory fish networks (Haidvogl et al. 2021).

Project facts

The MEASURES project lasted from June 2018 to July 2021 and was funded by the Danube Transnational Programme. The consortium consisted of twelve partner institutions from Austria, Bulgaria, Croatia, Hungary, Serbia, Romania, Slovakia and Slovenia. Several national and international institutions and organizations supported the project as associated partners, among others the International Commission for the Protection of the Danube River and the World Fish Migration Foundation. Further project details and publicly available outputs can be found on the project webpage https://www.interreg-danube.eu/approved-projects/measures.

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Lake Neusiedl and Seewinkel: a hotspot area of long-term ecological research in the Danube River Basin

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Abstract:

The Lake Neusiedl area near Vienna (Austria) has been of scientific interest for a long time. Based on the number of publications, research activity on terrestrial and aquatic ecosystems increased from 1960-1990 and declined thereafter. More interesting is the long-term change in research topics, which reflects the state of science and the impact of human activities, such as agriculture and tourism, on the one hand, and the growing awareness of wetland conservation on the other. During an early epoch, at the time of the last drying up of the lake (1865-1868), faunistic and floristic lists of species around Lake Neusiedl and its soda pans were common. The research focus shifted from 1930-1959 to biocoenological studies of flora and fauna, from 1960-1989 to species conservation issues and from 1990-2020 to themes of habitat conservation. From 2008 onwards, the research emphasis lies on ecosystem services and on the overwhelming impact of global warming.

Figure 1. Soda pan, National Park, 2015 (photo: Katrin Teubner)

Results and Discussion: Ecological research perspectives from 1860 to 2020:

The steppe lake Neusiedl is surrounded by soda pans ('Salzlacken', *fig. 1, 2)* and builds up a wetland impacted by remarkable water level fluctuations (Dinka et al., 2004). Its location near Vienna, the capital of Austria, has already attracted much attention, at least for scientific investigations during two centuries until now. A compilation of plant species from botanical surveys by more than 30 botanists for the Neusiedler See area was published as a species list (page 470 ff 'Pflanzen-Aufzählung', of about 950 plant species) by Szontagh (1864). This publication, however, goes beyond a botanical work and describes the geology and the salt composition of soils of the soda lake area, and thus documents a high level of interest at early times. It was published when the shallow Lake Neusiedl began to dry up. The last complete desiccation of the lake, which had no outflow at all that time, occurred from 1865 to 1868 (Herzig 2014, Tolotti et al. 2021). In the following the Hanság- or Einser-Channel was built between 1909 and 1911, connecting the lake to the Danube River. It was aimed to drain the water body for using the lake area for agriculture, which however has never been achieved. Today the lock in the channel is used to regulate the water level of the lake, to ensure mainly that water level will satisfy tourism activities such as e.g., boating and swimming.

The number of publications shown in figure 3 includes articles in journals, books, university theses and published scientific reports in the Neusiedler See area and refers to the literature database 'Literature Vogelwarte 2' (Lazowski 2020, available at: http://biologische-station.bgld.gv.at/portfolio/interreg-projekt-vogelwarte-ii-2016-bis-2021/)

created within the project INTERREG 'Vogelwarte Madárvárta 2'. This database contains in total 1300 entries. The publication activity has gradually increased since 1930 and reached its highest number of 327 publications from 1980 to 1989, followed by the subsequent decade, 1990-1999, with a total of 269 publications. Afterwards, the number of publications per decade steadily decreased. The bar chart about the number of publications in figure 3, however, does not provide any information about the scope of the extent of published work and, therefore, the interpretation of the publication activity per decade should be here considered with caution. More important seems here to consider the evolution of research topics over the long period of time for the soda lake Neusiedl and its associated Pannonian wetland area.

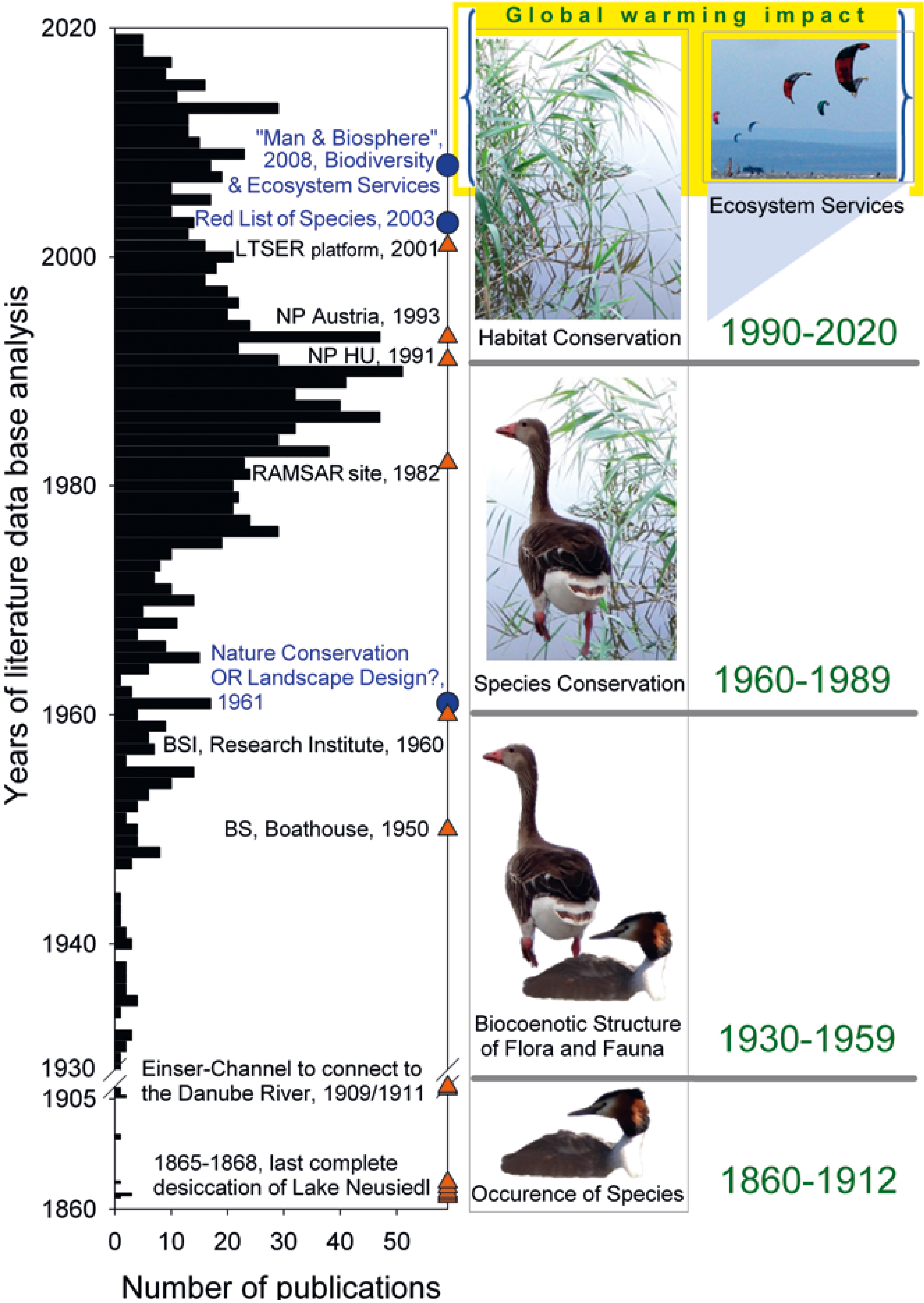
From 1930 to 1960, a number of animals and plants were systematically surveyed, as e.g., species of mammals, birds, fishes, amphibians, arthropods, arachnids, insects and molluscs as well as fungi, cryptogam flora and higher plants. Biocoenological studies of flora and fauna, as e.g., shown by Franz et al. (1937), became more common at that time. Apart from providing floristic and faunistic maps, the interpretation of the occurrence of terrestrial organisms started focussing more on the ecological context of their habitats. An outline of research advance at that period from geology, terrestrial fauna and flora including the reed belt and short reports about phyto- and zooplankton of Lake Neusiedl and some soda pans was published in a multi-author compilation entitled 'Landschaft Neusiedlersee (Lake Neusiedl landscape)' by Sauerzopf as editor (1959). The construction of a biological station, first a furnished boathouse (wooden construction on stilts) in the reed belt (1950, near Neusiedl am See) and later as a larger research institute on land (1960, near Illmitz), underpinned the importance of research interest in this unique wetland area *(fig. 3).* The situation of the late 50ies is described by Sauerzopf (1961) with an insightful article about the contemporary landscape situation under the pressure of urban development, entitled 'Neusiedlerseeraum – Erhaltung oder Gestaltung, Problematik der Großlandschaft' (Lake Neusiedl Area – protection or designed landscape contracting, facing a large sized landscape region). He described in detail the conflict of interest of the attempt to protect nature on one hand and of the rural adjustment due to large local interests for intensifying agriculture and tourism development on the other. According to a long-term assessment of the ecological vulnerability of the shallow steppe Lake Neusiedl by Tolotti et al. (2021), the late 50ies and following decade till 1970 are marked by excessive nutrient enrichment due to human activities (cultural eutrophication) as responded by algal and cyanobacterial blooms.

For the period 1960 till 1989, the focus of scientific studies was about increasingly endangered wetland species and thus the need for species conservation measures (nature conservation). Furthermore, wetland observations called for spatial landscape planning to control and modify

Figure 2. Soda pan, 2019. Trend of much earlier dry out in summer, than years before (photo: Katrin Teubner)

risks by eutrophication, pollution and urbanisation. Apart from this, new methods as e.g., by airborne optical imaging for ecological habitat monitoring (lake bottom and the reed belt of Lake Neusiedl see Csaplovics 1989, and also later publications as e.g., Csaplovics and Nemeth 2014) but also advances in limnology about deterioration of ecosystems by eutrophication (e.g., Löffler 1979) increasingly attracted research interest. As a result, a culminating number of publications in local and international journals was achieved in the 80ies as mentioned before. In view of this broad knowledge increase, the late 80ies became marked by establishing the National Park 'Neusiedlersee-Seewinkel/Ferto-Hanság Nemzeti Park', which was agreed upon in a bilateral cooperation and finally appointed for Hungary in 1991 and afterwards for Austria in 1993 for each wetland territory respectively *(fig. 3).* According to Borsdorf and Lange (2005a), this was the 5th category to protect Neusiedler See area from 1932 onwards (among others e.g., the nomination of Lake Neusiedl and the lakes in Seewinkel as a Ramsar site in 1982), followed by the designation as a Natura 2000 area (year 2000), as cross-border cultural landscape Fertö/Lake Neusiedl of UNESCO World Heritage Site (in year 2001) and 'Neusiedler See-Leithagebirge Nature Park' (in year 2005).

According to priority settings on the biosphere reserve of the Pannonian soda lake Neusiedl wetland, understood as an integration of diverse conservation categories (Borsdorf and Lange 2005b), also the topics of publications about species were beyond simple surveying but focused on habitat conservation, habitat availability and landscape-scale conservation from 1990 to 2020. In particular, endangered species were of research interest during this study period as for example of birds (Dvorak et al. 2017) and fishes (Wolfram and Mikschi 2003), but also for selected taxa (e.g., gastropod species Vertigo angustior by Schrattenecker-Travnitzky and Zechmeister 2020). Furthermore, surveys of the ecological habitat status and conservation concepts in parti-


Global warming impact
Habitat Conservation
Ecosystem Services
1990-2020
Species Conservation
1960-1989
Biocoenotic Structure of Flora and Fauna
1930-1959
Occurence of Species
1860-1912
"Man & Biosphere", 2008, Biodiversity & Ecosystem Services
Red List of Species, 2003
LTSER platform, 2001
NP Austria, 1993
NP HU, 1991
RAMSAR site, 1982
Nature Conservation OR Landscape Design?, 1961
BSI, Research Institute, 1960
BS, Boathouse, 1950
Einser-Channel to connect to the Danube River, 1909/1911
1865-1868, last complete desiccation of Lake Neusiedl
Years of literature data base analysis
2020
2000
1980
1960
1940
1930
1905
1860
0
10
20
30
40
50
Number of publications

cular for the soda pans and related issues became relevant (Krachler et al. 2012). From 2008 onwards, research and nature protection activities were stimulated by biodiversity and ecosystem service studies in view of a sustained development of the Lake Neusiedl area (see 'Man & Biosphere' in Wrbka et al. 2012). The application of advanced limnological methods to quantify the degradation of Lake Neusiedl points in the same direction of preserving the ecosystem services underlying human well-being (e.g., Kirschner et al. 2008, Duleba et al. 2021). In recent decades it became evident, that habitat changes due to urban development are increasingly superimposed by global warming impact forcing a water level decline in the wetland area *(fig. 2)*, concerning the habitats of Lake Neusiedl and soda pans (Dokulil and Herzig 2009, Eitzinger et al. 2009, Weyhenmeyer et al. 2019, Tolotti et al. 2021, Zimmermann-Timm and Teubner 2021). Thus, high-resolution measurements of water bodies, i.e., Lake Neusiedl and soda pans, by recently installed on-line sensors during the project INTERREG Vogelwarte Madárvárta 2 are most relevant for climate research and thus contribute to track habitat change (Teubner and Lazowski 2020) in addition to monthly ecological monitoring or surveys in the wetland ecosystem. Since 2001, the biosphere Lake Neusiedl and Seewinkel has been designated as a platform for long-term ecological research, being part of data networks of Long-Term Socio-Ecological Research (LTSER, https://www.lter-austria.at/ltser-plattform-neusiedler-see-seewinkel/) and of Dynamic Ecological Information Management System - Site and Dataset Registry (DEIMS-SDR, https://deims.org/1230b149-9ba5-4ab8-86c9-cf-93120f8ae2).

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◀ *Figure 3: Number of publications from 1960 to 2020 according to literature data base 'Literature Vogelwarte 2' (Lazowski 2020). Bars – number of publications, triangles – achievements concerning the landscape development, blues dots – major achievements documented by publications:*
Sauerzopf (1961), Wolfram and Mikschi (2003), 2008 begin of project 'Man & Biosphere', see Wribka et al. (2012). The four main periods of publication activities associated with major research topics in biology are described in the text. Abbreviations: LTSER - Long-Term Socio-Economic and Ecological Research, NP – National Park, HU – Hungary, BS – Biological station, BSI – BS Illmitz, RAMSAR - Convention on Wetlands of International Importance.

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Hydrological catchment of the River Danube

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