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Scientific cooperation in the Danube River Basin: Tackling present and future environmental challenges of a European riverscape

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Organized by:
Karl Landsteiner University of Health Sciences, Krems
ICC Water & Health
ÖK-IAD (Austrian Committee of the IAD)

The 44th IAD conference will be held under the patronage of the Austrian committee of the IAD at the Karl Landsteiner University of Health Sciences in Krems, situated in the beautiful landscape of the Wachau, next to the Danube River. This young university (founded in 2013) has a strong research focus on water quality and health, being a key player in this research field in the Danube River Basin. Here, health is considered in a holistic, transdisciplinary way under the "One Health" concept of the WHO, combining human, animal and environmental health in an ecological context. Thus, the conference shall bring together scientists and experts from different disciplines for discussing the present and future environmental challenges of our Danube riverscape. Main topics are dedicated to:

- Pollution and health under the "One Health" concept
- Climate change and land-use change impacts on aquatic ecosystems
- Integrated water management – from environmental monitoring to sustainable solutions
- Status and future trends of aquatic species and habitats
- Protected areas and biodiversity conservation
- Floodplain ecology and restoration – constraints and perspectives
- The Human Dimension – rivers as socio-ecological systems
- Riverine landscapes and wetlands
- The Danube River delta and coastal ecosystems

The 44th IAD conference was originally planned to be organized by our Ukrainian IAD-colleagues at the Institute of Hydrobiology of the National Academy of Sciences in Kyiv, but due to the Russian aggression this became impossible. We wish our esteemed colleagues all the best for their future.

For further details and registration please visit the conference webpage:
https://www.oen-iad.org/congress2023/

Restoration and ecology of sterlets in the Austrian Danube – The way from LIFE-Sterlet to LIFE Boat 4 Sturgeon

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Abstract

Sturgeons are an essential faunal element of the Danube and provided a link between the Alpine Danube basin and the Black Sea through their migration in the past. Today, two out of six Danube sturgeons are already regionally extinct, and the remaining species are threatened with extinction due to poaching, bycatch, migration barriers and habitat loss. A variety of projects are pushing conservation and reintroduction efforts. However, those projects only have a chance of success in a coordinated manner and within international cooperation. The aim of the LIFE-Sterlet project was to strengthen the population of the highly endangered sterlet (*Acipenser ruthenus*) in the Upper Danube and to increase the knowledge about habitat use, migration and autecology. The follow-up project LIFE Boat 4 Sturgeon builds upon the methods and results of the LIFE-Sterlet project and has the aim to create a genetically diverse captive broodstock of mature animals of the last four Danube sturgeon species.

Introduction

For more than 200 million years, sturgeons have inhabited the aquatic ecosystems of the northern hemisphere. However, populations have reached an all-time low and sturgeons are considered the world's most endangered animal group (IUCN 2022). In addition to their characteristic physique and sizes of over five meters, sturgeons are characterized by their longevity, they can live over a hundred years and, depending on the species, a very late sexual maturity from 5 to 22 years with reproductive intervals from up to 6 years. As long-distance migrants, they require different habitats in order to complete their life cycle. Most of the species are anadromous fish that live in the sea and migrate upstream into rivers for spawning. In the past, enormous distances were covered for example more than 2000 km from the Black Sea into the Bavarian Danube (Bemis et al. 1997; Billiard & Lecointre 2001). For the potamodromous sterlet (*Acipenser ruthenus*), migration distances up to 300 km were documented (Holčík 1989).

Due to their life cycle and longevity, sturgeons are indicators for long-term functioning and sustainably used river ecosystems and are therefore so-called flagship and umbrella species. Two of the main reasons for their decline are blocked migration routes by dams and a loss of access to spawning habitats. Since the construction of the hydropower plants (HPP) at the Iron Gate between Serbia and Romania, only the lowest 900 km of the Danube are freely accessible and a massive decline as well as extinction of the anadromous species in the upper parts of the Danube were observed (Bemis & Kynard 1997; Hensel & Holčík 1997; Lenhardt et al. 2006; Sandu et al. 2013). Potamodromous species are not dependent on migrations between salt- and freshwater. However, due to river fragmentation, subpopulations are no longer in contact resulting in a depletion of the gene pool (Ludwig et al. 2009). Currently available fish passes along the Upper Danube are unsuitable for sturgeons, based on monitoring results and the sturgeon's ecology.

In addition to the destruction of important habitats and migration routes, overfishing further threatens sturgeon populations. In earlier centuries, overexploitation in the Upper and Middle Danube led to grave decline of larger sturgeon species. A long life cycle, late sexual maturity and perennial reproduction cycles make sturgeons particularly vulnerable to overfishing and stocks take a long time to recover. Nowadays, fishing bans in all countries along the Lower Danube and in the Black Sea exist for all native species and trading with wild sturgeon products is prohibited. However, poaching and by-catch still contribute illegally to overexploitation. Main drivers are the high economic value of caviar, continued popularity of sturgeon meat in countries bordering the Black Sea and the difficult socio-economic situation.

As a result of river regulations, the availability and habitat diversity dramatically decreased causing bottlenecks for some stages in the life cycle (Friedrich et al. 2018). Additional stressors are water pollution (Lenhardt et al. 2006) and hybridization with escaped or illegally stocked allochthonous sturgeon species from aquaculture (Ludwig et al. 2009). Of the six Danube sturgeon species, the European sturgeon (*Acipenser sturio*) is already extinct in the catchment area of the Black Sea. Due to the lack of evidence through traditional surveys, eDNA studies or documented by-catch, the ship sturgeon (*Acipenser nudiventris*) is considered as functionally extinct. The remaining three anadromous species, namely the Beluga sturgeon (*Huso huso*), stellate sturgeon (*A. stellatus*) and Russian sturgeon (*A. gueldenstaedtii*), are threatened with extinction and restricted to the Lower Danube below the first dam of the Iron Gates. For Beluga sturgeon and stellate sturgeon low reproduction rates are documented, whereas last reproductions of Russian sturgeons were recorded in 2007 and 2011 and recently in 2022 (Paraschiv pers. comm.). The sterlet is a freshwater species and was formerly widely distributed along the Danube. Over the last decades populations were

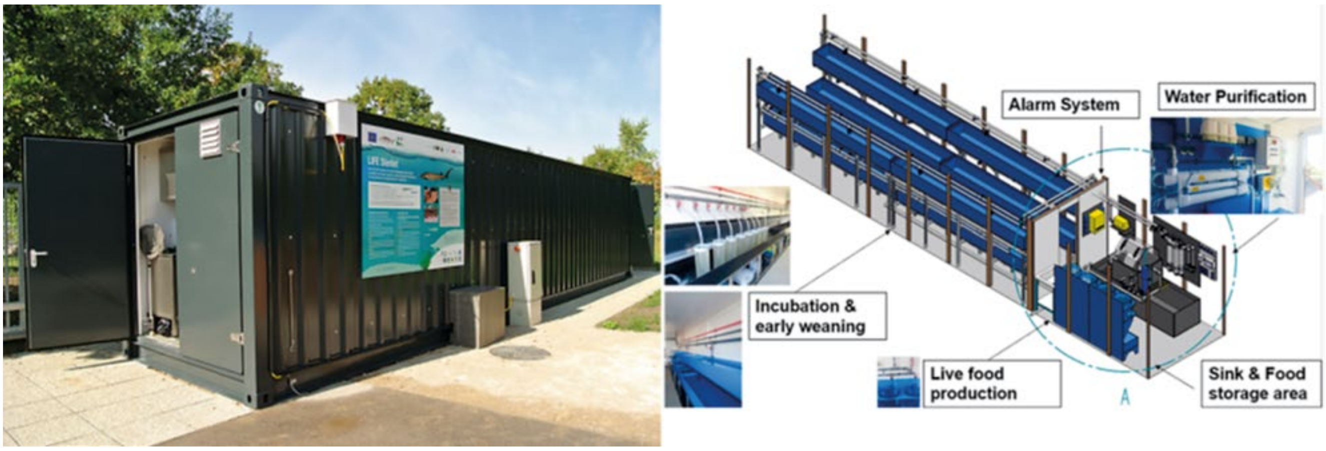

Figure 1. The hatchery container: left - outside view; right - technical sketch

declining, especially in the Upper and Middle Danube. In the Upper Danube only one self-sustaining population in the area of Jochenstein is known (Friedrich et al. 2014, 2018). In the Austrian Danube, the sterlet is classified as "critically endangered" by the Austrian Red List (Wolfram and Mikschi, 2007).

Against this background, the LIFE-Sterlet project (2015-2022) aimed to strengthen the remnant sterlet population in Austria by reintroducing juvenile sterlets, to study the migration behaviour and to gain knowledge on the autecology and population size of the sterlet in the Austrian Danube.

Methods

Hatchery

A prerequisite for the successful reintroduction of highly endangered fish species or fish species that have become extinct in the wild is the use of locally adapted, genetically autochthonous strains which should also exhibit a high level of genetic diversity. In addition, young fish have to be imprinted to the water body to initiate "homing" behaviour. The rearing methods should focus on fitness and adaptation in the wild. From 2017 to 2022, eggs from mother fish in the Hungarian Danube were used. During monitoring surveys, a residual population of old sterlets below Vienna was detected. From 2018 to 2022, wild fish from this population could be independently propagated. The incubation of the eggs and rearing of the fish took place in a rearing container on the Viennese Danube Island (*fig. 1*) using Danube water. The water was not treated biologically, chemically or thermally in order to simulate conditions in the wild as closely as possible. The young sterlets (*fig. 2*) were first fed with live nauplii of brine shrimps (*Artemia sp.*) and later with chopped up or whole midge larvae (Chironomidae, Culicoidea) and shrimp (*Mysis sp.*). The release of juveniles into the project areas Wachau, Nationalpark Donau-Auen and Morava-Thaya system took place at irregular intervals from the feeding postlarval stage in mid-May until September when juveniles have already reached total lengths of 25 to 35 cm. The stocking of especially younger stages was done by boat, far from the shore in order to avoid direct exposure to the feeding pressure of invasive Gobiidae in rip-rap areas or wave impact by shipping. Some of the juveniles were marked with PIT tags in order to be able to allocate recaptures.

Habitat and migration monitoring

An acoustic telemetry study was implemented to collect information on habitat use and migration patterns of wild and stocked sterlets. A total of 38 sterlets were tagged with hydroacoustic transmitters, released in the Nationalpark Donau-Auen and observed between 2020 and 2021 for 1.5 years. Five of the sterlets were wild fish that were caught via netfishing below the HPP Freudenau. The stocked sterlets were reared under semi-natural conditions in the course of the LIFE Sterlet project and hatched in the years 2016, 2017 and 2018. The study area was located between the two HPPs Freudenau (AUT) and Gabčíkovo (SVK) with a free-flowing section of roughly 45 km and 40 km of impoundment. Along this section, 14 hydrophones were distributed and fixed on navigation buoys. In addition to the continuously collected data from the stationary hydrophones, mobile tracking was carried out monthly. Additionally, a study on small scale habitat use of sterlet was conducted. During spawning season from March to May 2021, an area of 17.000 m^2 was observed over 43 days using an array of five hydrophones

Figure 2. Juvenile sterlets

below the HPP Freudenau (*fig. 3*). The study focused on five sterlets which were caught in the study area.

Population monitoring

A population monitoring in the section east of Vienna was carried out from 2018 to 2021 via netfishing in the tailwater of the HPP Freudenau (Neuburg & Friedrich in prep.) Trammel nets with inner and outer mesh sizes of 100 and 40 mm were set overnight in deep areas below the weir fields, fixed to the bottom with anchors and marked with buoys on the surface. Captured sterlets were examined for PIT tags and marked if none was present. After length and weight was measured and genetic samples were taken, the fish were returned to the Danube. During spawning season, suitable sterlets were temporarily transferred to the rearing container on the Danube Island for the purpose of artificial reproduction. The population size was determined with the mark-recapture method. Due to the marking with PIT tags, each sterlet can be identified, creating an individual record history for each fish. The recaptures serve as a basis for calculating the population size (Pollock 1980). The population size for the sampled area was calculated with a model for an open (POPAN; cf. Schwarz et al. 1993) as well as for a closed population (Mt, capture probability varies with time; cf. Otis et al. 1978). Because the sterlet is a migratory species (Holcik 1989), migration processes in and out of the sampling area cannot be excluded. Therefore, it can be assumed that an open population model is more suitable. However, sterlets can reach a relatively old age of approx. 25 years and the study took place over a period of four years, which means that mortality events can be neglected. Current data of the observed population suggests that recruitment processes do not play a role (Friedrich et al. 2014). In case of random migrations in and out of the sampled area (cf. Ratschan et al. 2017), migration processes can also be neglected (Kendall 1999). Therefore, the results of a closed model can be considered as plausible as well. In addition, the population size of the sterlets below Freudenau and the population size of the sterlets in the area of Jochenstein were calculated based on their genetic diversity. A total of 132 samples from Jochenstein and 37 samples from the area of the National Park from sterlets caught between 2014 and 2021 were genetically analysed. Additionally, 340 samples from previous studies from other Danube sections were used. Fish with signs of hybridization and partial Volga genotypes from uncontrolled stocking were excluded from the calculation. Two models for panmictic (random mating) and assortative mating (non-random mating) (Jones & Wang 2010) were calculated.

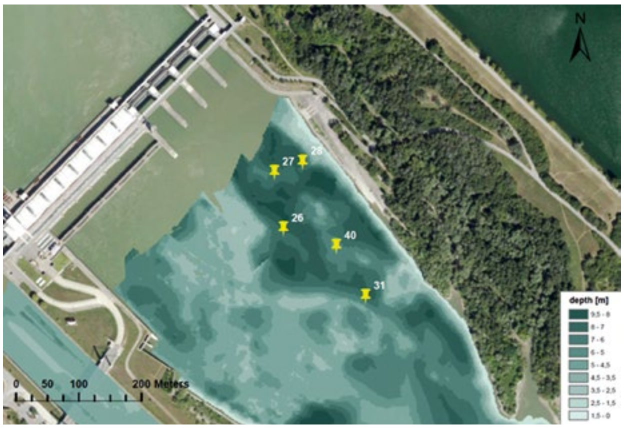

Figure 3. Hydrophone positions of the 2D- telemetry study

Results

Hatchery

Between 2017 and 2022 more than 238 000 juvenile fish were reared and released in the project areas. The hatching and rearing in Danube water differs due to temperature fluctuations, increasing turbidity during floods, etc. (Friedrich & Eichhorn in prep.) from commercial rearing under controlled conditions (cf. Chebanov et al. 2011). However, mortality rate at the various life stages was within the range of empirical values of commercial farms.

Habitat and migration monitoring.

Through the telemetry study, five different migration patterns could be distinguished. Wild sterlets showed the smallest migration ranges and were mainly detected below the HPP Freudenau together with a few stocked sterlets. Most of the stocked fish migrated immediately downstream after their release, whereas some migrated upstream again. Observed migrations could not be related to changes in temperature and discharge. The variety of migration patterns was interpreted as the individual ability to adapt to a new environment and explorative behaviour. Observed maximum and average migration distances of 100.7 km and 37.7 km (SD ± 27.7 km) and observed aggregations of sterlets below migration barriers, like the HPPs Freudenau and Gabčíkovo, highlight the need to restore longitudinal connectivity in the Upper Danube. The array in the tailwater of the HPP Freudenau showed that all fish used core areas between 3 732 m^2 and 4 739 m^2 and that the used habitat of individuals overlapped to some extent. The maximum number of encounters between two individuals was 331, increasing with water temperature (> 9 °C). On average, sterlets preferred depths of 9.7 m (SD ± 1.8 m), with no significant difference between day and night. The observed movement distance of individual fish within the array ranged from 786 m (SD ± 596 m) to 1 670 m (SD ± 788 m) per day.

Population monitoring

During 41 netfishing sessions, a total of 68 captures of 38 individual sterlets were made. Some fish were captured several times – up to five times – during the four-year study. The number of recaptures increased from no recaptures in 2018 to 16 recaptures in 2021. Figure 4 shows that the majority of all captured sterlets were females (n = 27, 71.1%), whereas only a small proportion could be identified as males (n = 7, 18.4%). The sex of four fish could not be clearly identified (10.5%). All individuals were adults. Table 1 shows the lengths and weights of the captured fish. Two sterlets had to be excluded from further analysis due to missing weight measurements. With a length of 800 ±

Release site	Larvae	3-5 cm	5-10 cm	10-15 cm	15-20 cm	20-30 cm	>30 cm	TOTAL
Wachau	17 500	28 700	4 650	1 869	910	1 369	821	55 819
Greifenstein-Freudenau	23 500	8 800	1220	880	382	1 218	234	36 234
Nationalpark Donau-Auen	34 000	51 700	10 827	1 918	1 908	2 948	1 048	104 349
Morava CZ	8 500	5 500	7 610	4 593	670	1 962	569	29 404
Morava AT	8 000	2 800	1 050	-	50	124	131	12 155
Marchfeldkanal	-	-	-	-	-	200	-	200
Asten	-	-	-	-	-	200	-	200
Traisen	-	-	-	-	-	253	50	303
Total	91 500	97 500	25 357	9 260	3 920	8 274	2 853	238 664

Table 1. Number of released juvenile sterlets from 2017 to 2021

62 mm and a mean weight of 3 294 ± 1 324 g, females were evidently larger and heavier than males (660 ± 73 mm, 1 350 ± 358 g). Mean length and weight of unidentified fish were 800 ± 114 mm and 2 850 ± 1 196 g.

The results of both population models were quite similar and overlapped to some extent. The population size of sterlets in the sampled area, estimated with the open population model, resulted in 53 individuals (95% confidence interval (CI) = 43-80) whilst the model for closed populations estimated 48 individuals (95% CI = 42-63) (Neuburg und Friedrich 2022). The population genetics for the sterlets downstream of Vienna resulted in 75 reproductive individuals (95%, CI = 46-146) based on a panmictic population and 57 individuals (95% CI= 34-110) based on an assortative population (Friedrich and Ludwig in prep.). Analyses from the population of Jochenstein showed a size of 99 reproductive individuals (95% CI= 74-136) in a panmictic population and 60 individuals in an assortative population (95% CI= 41 -85) (Friedrich & Ludwig in prep.).

Discussion

Due to the late sexual maturity of the sterlet (4 to 5 years for males, 5 to 6 years for females) and the challenges of sampling in the Danube, the long-term success

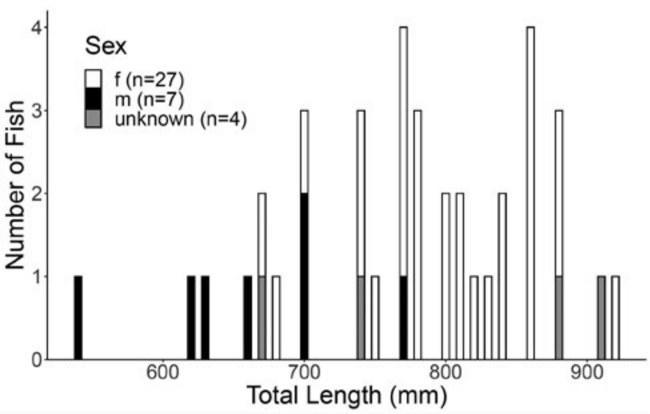

Figure 4. Length-frequency-diagram of caught sterlets

of implemented measures during the LIFE-sterlet project must be evaluated in detail after the project period. The rearing method in Danube water and the use of live food has proven to be promising. Moreover, successful rearing trials with other fish species as well as the mobility of the container imply a versatile use of the rearing system. The rearing and monitoring led to an important gain in knowledge concerning the autecology of the sterlet with regard to behaviour, sexual maturity, spawning season and migration patterns. The size limit for angling sterlets in some federal states in Austria of 40 to 50 cm is definitely too small, since sexual maturity is reached with 55 to 60 cm in males and 60 to 70 cm in females. The phototactic behaviour in the larval and post-larval phase as well as the results of the telemetry studies illustrate once again the relevance of upstream and downstream passage for sterlets and the availability of near-natural, river-typical habitats.

LIFE Boat 4 Sturgeon

The follow-up project LIFE Boat 4 Sturgeon builds upon the methods and results of the LIFE-Sterlet project. In the long term, the monitoring is to be continued and intensified to document the development of the population. Furthermore, an investigation along the whole Danube for possible residual populations, will be carried out. For all four remaining Danube sturgeon species, a genetically diverse captive broodstock of mature animals will be established in at least two locations (AT and HU). Those stocks will be maintained over the long-term to preserve the gene pool and to support the three anadromous species in the Lower Danube with genetically diverse, autochthonous and fit juveniles. In Austria, a floating rearing station in the Danube in the centre of Vienna will be built in addition to the existing LIFE-Sterlet hatchery container. Further reintroduction measures in the Upper Danube are based on the surveys along the Austrian Danube. Within the LIFE-Sterlet project, a total of 12 sterlet families could be established and a part of each family was kept as future broodstock. The mother fish stock of all species will be constantly expanded through different genotypes and the reproduction through a studbook enables the greatest possible genetic diversity of the offspring. The time horizon for the measurements extends over several years to decades due to the critical population sizes, existing negative influences and late sexual maturity, especially for the anadromous species. In parallel, the restoration of the habitats especially of the longitudinal continuum not only at the Iron Gates but also at upstream migration obstacles is indispensable.

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Development perspectives and management options for the ecology of the urban floodplain Lower Lobau

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Abstract

The Lower Lobau is an urban floodplain system, which was disconnected from the main channel of the Danube in the 1880s. In its present state, the area is dominated by groundwater-fed and back-flooded successional floodplain water bodies hosting a high biodiversity. The main threat for the system is that strong terrestrialization processes are prevailing, significantly accelerated by ongoing hydrologic alterations. To stop the ongoing loss of aquatic habitats and their associated community, different management concepts for a step-wise rehabilitation have been developed. In this article, we give an overview of the prognosis of these different management options and development perspectives for the system.

Introduction

Terrestrialization, or hydrarch succession, is a plant succession that starts in shallow water bodies and culminates in a forest. In natural floodplain water bodies, it is countered by rejuvenation due to dynamic geomorphic processes (scouring floods, channel migration; Ward et al. 2001). In regulated rivers, terrestrialization often remains the only ongoing geomorphic process and therefore floodplain management and restoration aim to reverse this trend of decreasing waterbody area (Schiemer et al. 1999). Successional communities are complex and diverse commu-

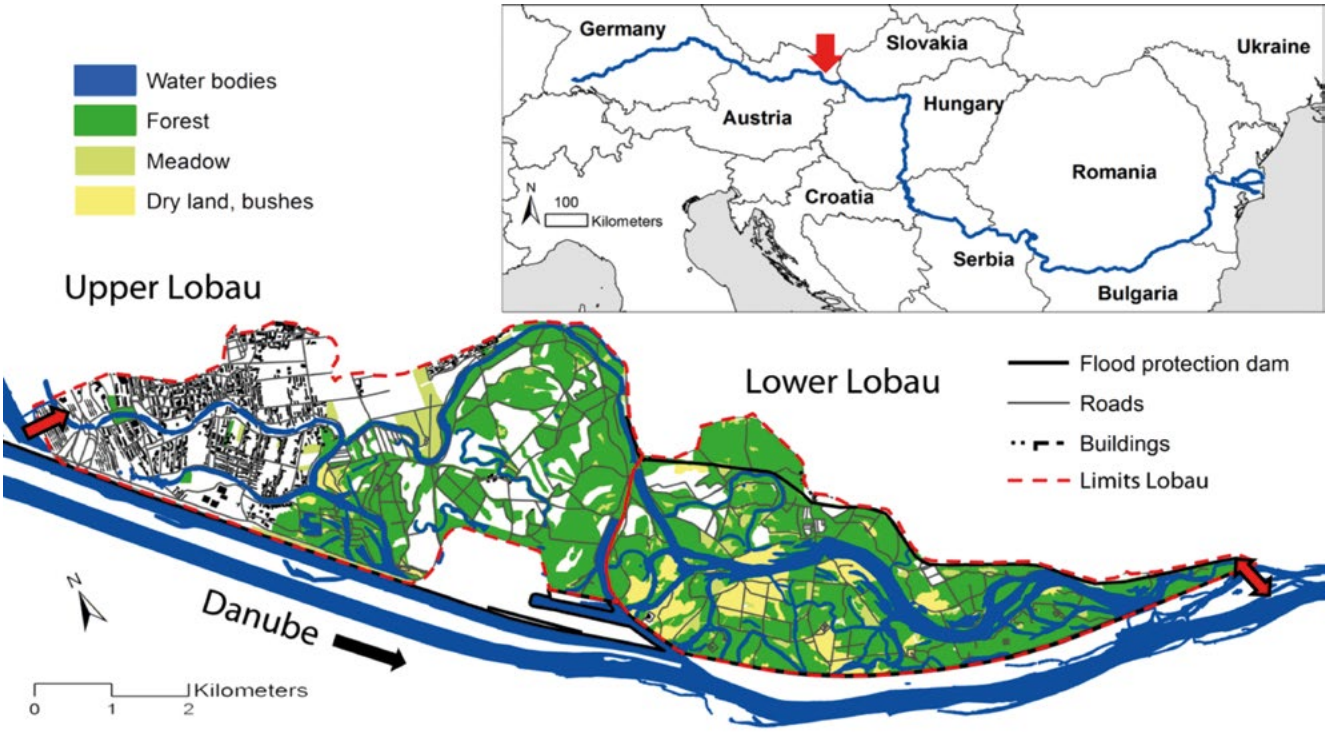

Figure 1. The floodplain system of the Lobau. Red arrows indicate the inflow/outflow area in the Lower Lobau and the inflow area of the water enhancement scheme of the Upper Lobau in its present state.

nities in transition and therefore, manipulations of succession require detailed planning based on scientific knowledge (Prach et al. 2007).

The Lower Lobau is an example of such a complex successional floodplain system. The former dynamic system was disconnected from the main channel of the Danube River by the construction of a flood protection dam in the early 1880s and thereafter, creating a system of groundwater-fed and back-flooded successional floodplain water bodies. These water bodies host a high biodiversity, including many species and habitat types protected by the Habitat Directive or Bern Convention, which led to the designation of the Lobau as a site of European and International importance (NATURA 2000, UNESCO Men and Biosphere Reserve, RAMSAR; Funk et al. 2013). Protection status was mainly designated for successional communities including a variety of macrophyte assemblages hosting many rare and endangered aquatic and semi-aquatic species (Barta et al. 2009). The main threat for the system in its present state is that the ongoing terrestrialization process is significantly accelerated by ongoing hydrologic alteration, a decrease in groundwater and surface water levels due to river bed incision of the main river and climate change related increase of periods with low precipitation and low water tables of the main river and the ground water. Enhanced inorganic sedimentation due to the impact of back-flooding of the system in combination with the lack of erosion further enhance the terrestrialzation process (Hohensinner et al. 2022; Reckendorfer et al. 2013).

This development was already recognized in the 1990s and since then, various management concepts for a step-wise rehabilitation of the Lobau floodplain have been developed (Trauner et al. 2016; Weigelhofer et al. 2013). In this article, we discuss the different development perspectives and management options targeting ̂to reduce, stop̂ or even partially reverse the enhanced terrestrialization prozesses in the system.

Past development and current state

The Lobau floodplain (*fig. 1*) is situated along the Austrian Danube, with large parts within the city borders of Vienna, and it is part of the 'Donau-Auen' Nationalpark. During the major river engineering phase between 1870 and 1885, this former dynamic floodplain was disconnected from the main channel by the construction of a flood protection levee. Nowadays, the floodplain can be separated into two subareas that differ considerably in their conditions. The upstream section, the 'Upper Lobau', is completely disconnected from flood events and is integrated into the settlement area of the City of Vienna. The downstream section, called 'Lower Lobau', is still affected by the flood regime of the Danube River by a downstream opening and has a widely natural land cover (Preiner et al. 2018).

Biodiversity and conservation

The Lower Lobau is of outstanding ecological value for its diverse macrophyte community and its associated animal communities (Barta et al. 2009; Janauer 2005). A total of 156 macrophyte species have been identified so far, 82 of them have a protection status according to the Austrian Red Lists (Weigelhofer et al. 2014). Particularly the smaller floodplain water bodies, separated from the larger oxbows, represent biodiversity hotspots hosting many rare and endangered aquatic species (Barta et al. 2009). These types of water bodies in the Lower Lobau are also of outstanding ecological value for rare and threatened amphibian species (Waringer-Löschenkohl et al. 2013; 1986). Within the national park, the isolated water bodies of the Lobau with sufficiently long permanence (water from March to at least August) are of special importance for the reproduction of important amphibian species such as Danube crested newt (*Triturus dobrogicus*), fire-bellied toad (*Bombina bombina*) or European common spadefoot (*Pelobates fuscus*). Furthermore, the late successional waterbody type is important for protected macroinvertebrate species including important protected dragonfly species (e.g., *Leucorrhinia pectoralis,* protected according to Habitats Directive; Weigelhofer et al. 2014). Rare, endangered and protected stagnophilic fish species can be found in less frequently connected (European bitterling, *Rhodeus amarus*) or completely isolated (e.g., weatherfish, *Misgurnus fossilis*) waterbodies (Funk et al. 2013; Schabuss & Reckendorfer 2006).

Rare and protected species in the Lower Lobau are mainly associated with the (late) successional communities of floodplain systems, which are at the same time also most threatened due to the ongoing enhanced terrestrialization processes. Due to the decreasing surface and groundwater tables in the Lobau, these smaller floodplain water bodies, separated from the larger oxbows, are continuously decreasing during the last years (Barta et al. 2009). Especially the communities of submerged hydrophytes are already endangered in their existence (Janauer & Strausz 2007; Schiemer et al. 1999).

Furthermore, with its extensive reed beds, the Lower Lobau is of specific importance for the reed-breeding species of waterbirds, which reach higher densities than in other side arm systems of the Nationalpark Donau-Auen (Frühauf & Sabathy 2006). The species of particular conservation relevance are, for example, the little bittern (*Ixobrychus minutus*) and the great reed warbler (*Acrocephalus arundinaceus,* Schulze & Schütz 2013).

Additionally, the large shallow waterbodies with extensive terrestrialization zones are also highly relevant for wading birds including different species of herons (e.g. *Ardea alba*) or swimming waterbirds including protected duck species (e.g. *Anas querquedula* or *Aythya ferina;* Frühauf & Sabathy 2006). Furthermore, the Danube floodplain east of Vienna is home to the only reproducing population of the European pond turtle (*Emys orbicularis*) in Austria, with about one third of the population located in the Lobau (Schindler et al. 2012), inhabiting also the larger waterbodies of the system.

The fish community of the Lower Lobau is dominated by widely distributed eurytopic fish species. In its present state, it does not serve as habitat for endangered rheophilic species (e.g. nase, *Chondrostoma nasus* and barbel, *Barbus barbus;* Schabuss & Reckendorfer 2006). Equally, other communities of the large water bodies of the Lobau are characterized by generalists with a wide range of ecological requirements. Regarding macroinvertebrates, the Lower Lobau has a specific relevance for a high number of dragonfly species. With a total of 46 recorded dragonfly species, the Lower Lobau is the most species-rich alluvial forest area in Austria (Schulze & Schneeweihs 2013). Dragonflies include the endangered species *Sympetrum meridionale,* the critically endangered species *Somatochlora flavomaculata,* and the endangered species *Orthetrum coerulescens,* amongst others.

Provisioning and cultural Ecosystem Services

In the Lower Lobau, provisioning and cultural ecosystem services evolved over the centuries. While the Upper Lobau, which is located closer to the city, is surrounded by settlements and a sought for recreation and leisure area since about one century, the Lower Lobau is less affected by urban development and human uses (Haidvogl 2019).

After 1918, forestry was a dominating use until the late 1970s. Forestry management changed in this period because of altered hydrological conditions after the Danube channelization. The proportion of hard wood tree species increased from approximately 8% in 1850 to 50% in 1940. However, typical trees such as willows, alder or poplar still kept their importance (Haidvogl 2019).

A powerful actor entered the area in the 1950s and 1960s, when plans to tap groundwater resources for urban drinking water supply south of Vienna failed. In addition, growing agricultural production in the region Marchfeld east of Vienna increased the demand for water. In the 1950s, water extraction started with small wells supplying agriculture. In 1958, groundwater areas were identified at a depth of 12 m that appeared suitable for drinking water supply. Two years later, an area of 10 km^2 was designated as drinking water protection zone. In 1964, construction of three wells started. For about two decades, these drinking water wells contributed significantly to the supply of the Viennese districts east of the Danube and Donaukanal, respectively. Since 1988, the main purpose is to secure water supply during peak demand and in case of maintenance work on the two main Viennese water pipelines (Haidvogl 2019).

Predictions for the future and scenarios for conservation and rehabilitation

During a 70-years period since 1938, 34% of the aquatic areas of the Lower Lobau were lost due to sedimentation and terrestrialization. Digital geo-referenced orthophotos were used to visually estimate the areal extension of water bodies in the floodplain from 1938 to 2009 (supplied by Bundesamt für Eich- und Vermessungswesen BEV, Nationalpark Donau-Auen, viadonau, and MA41; Reckendorfer

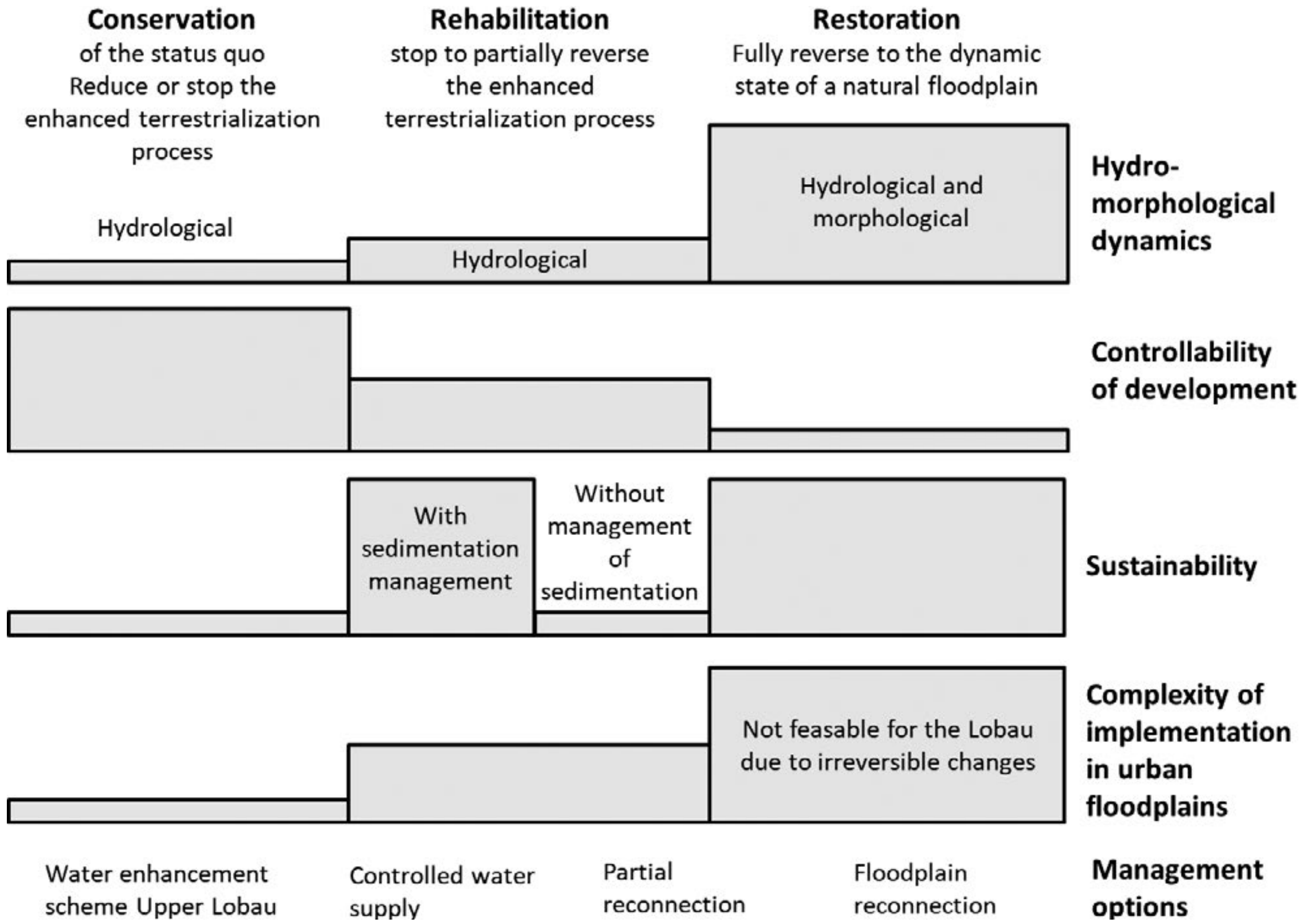

Figure 2. Overview of potential floodplain conservation, restoration and rehabilitation measures that were proposed and evaluated for the Lobau system. The size of the boxes increases with the match to the respective property (modified after Weigelhofer et al. 2013).

et al. 2011). The losses were significantly higher for small and shallow water bodies (70%) than for large and deeper parts of the side arm (30%) and they were also greater in the Upper Lobau than in the Lower Lobau. The estimated average sedimentation rates for this period ranged between 1 to 14 mm per year, with maxima of up to 28 mm per year (Reckendorfer et al. 2013). Predictions about the future development of floodplain water bodies in the Lobau are difficult. On the one hand, the incision of the Danube River, which was one major driver of the increasing terrestrialization during the last 20-30 years, was mitigated by regular gravel supply to the river channel (Habersack et al. 2013). On the other hand, more frequent low surface and subsurface water levels in the Danube and the adjacent floodplain are predicted for the future due to climate change induced shifts in the seasonal precipitation patterns (Hein et al. 2016). A sedimentation model showed high sedimentation rates of up to 46 cm of fine sediments until 2050 in shallow and low-flow water bodies near the downstream inlet of the Lower Lobau (Weigelhofer et al. 2015; Funk et al. 2014). In addition, both aquatic and terrestrial primary production will lead to further sedimentation of plant material (10-15 cm until 2050) in isolated water bodies. Thus, if no measures are taken in the future, further losses especially of small and shallow water bodies are certain to occur (Reckendorfer et al. 2013).

Since the 1980s, various management concepts for a step-wise rehabilitation of the Lobau floodplain have been developed (Trauner et al 2016; Weigelhofer et al. 2013). As a first management measure, a water enhancement scheme was started in the area of Upper Lobau in 2001. Water from large stagnant former Danube branches within the city borders of Vienna is discharged during the vegetation period (March to October; Weigelhofer et al. 2011; 2005; Funk et al. 2009). The discharge is restricted to a maximum of 1.5 m^3/s and depends on chemical, hygienic, and hydrological thresholds. The New Danube as source of the water enhancement scheme was preferred over the Danube main channel due to the better water quality in this artificial side channel.

For the Lower Lobau, different hydrological scenarios were developed and evaluated based on different quantitative and qualitative models since 2005 (*fig. 2*; Weigelhofer et al. 2020; 2005; Trauner et al. 2016; Funk et al. 2013; Reckendofer et al. 2013; Sanon et al. 2012). Besides a business-as-usual scenario without measures, they included two types of measures:

1. A controlled water supply with increased waterflow from the Upper Lobau or from alternative sources e.g. directly from the Danube, aiming to stop and partially reverse the enhanced terrestrialization by raising the surface and

groundwater levels in the floodplain, increasing the connectivity and the surface water exchange via the main side arm. In the most recent planning phase, a scenario with a controlled water supply of 3 m³/s from the Danube main stem was evaluated (Weigelhofer et al. 2020).

2. Different levels of re-connections with the Danube, including a dynamic discharge of the river into the main side arm of the floodplain. Besides the aim to stop and partially reverse the enhanced terrestrialization, this scenario type also aims at increasing the erosion in certain stretches and reducing the effect of sedimentation at least in parts of the system (Funk et al. 2013; Sanon et al. 2012).

Opportunities and risks

All evaluated management scenarios, except the business-as-usual scenario, have the potential to improve, stop or even reverse the hydrologically driven terrestrialization process, dependent on the amount of water entering into the system, i.e., an increase of the groundwater and surface water tables that reverses or stabilizes the human driven loss of water body area in the system (e.g. Weigelhofer et al. 2020).

The different management options also come together with some risks for the biodiversity and integrity of the system.

There is a risk for a loss of the diversity of small permanent to temporal, isolated water bodies by increasing the surface connectivity with the large main waterbodies. This may initiate a loss of heterogeneity, increase in nutrient levels and productivity, trophic state and consequently, loss of the sensitive community and dominance of more eurytopic species. This is a risk of both types of restoration measures (Weigelhofer et al. 2020; Funk et al. 2013) but according to Reckendorfer et al. (2013) especially relevant for the partial re-connection type where nutrient and sediment rich surface waters enter the system widely uncontrolled. In a controlled water supply scenario, the amount and quality of surface water that is supplied can be controlled and regulated as already shown for the Upper Lobau. A potential management solution for this issue is also a creation (excavation) of small isolated groundwater-fed water bodies that can compensate a potential loss of these types (Weigelhofer et al. 2020).

Further, there is a risk related to socio-economic demands in the system. Only the controlled water supply type of scenario is expected to fully preserve important socio-economic demands in the area such as drinking water supply, recreation or agriculture. Especially a full reconnection of the system would be in conflict with the socioeconomic demands, particularly for the potential for drinking water production, as the surface water influence impacts the quality of groundwater (Sanon et al. 2012). Therefore, a partial re-connection scenario with a dynamic, permanent discharge (depending on the respective water level of the Danube) and a controlled maximum discharge of 80 m³/s was developed to reduce this risk (Weigelhofer et al. 2020).

Sedimentation processes in the system are a further issue. Ongoing sedimentation can only be reversed, if the discharge in the system is high enough to allow erosion processes; this is only predicted for the re-connection type of measures, so with a controlled water supply enhanced terrestrialisation might continue (Weigelhofer et al. 2020; Funk et al. 2013). On the other hand, these erosion processes within a reconnection type measure come also with the risk that the successional stage of parts of the system are more strongly reversed than targeted, parts of the waterbodies might lose their current stagnotopic species rich community (Weigelhofer et al. 2020; Funk et al. 2013). A potential solution to reduce the impact of sedimentation within a controlled water supply scenario could also be a targeted excavation of water bodies with high sedimentation rates to reduce the already accumulated sediments.

Figure 3. View of an isolated oxbow in Untere Lobau (© Andrea Funk)

Therefore, most promising could be a stepwise adaptive management approach, closely monitoring the effects of controlled water supply, beginning with low amounts of nutrient and sediment poor water to reduce the described risks, then further increasing the supply and if the targeted reversion in succession is not achieved a partial re-connection can be implemented in a second step (Reckendorfer et al. 2013).

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Danube Landscapes – history, diversity, conflicts, identity, but no lobby!

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The International Association for Danube Research (IAD) is in many ways actively contributing to both the International Commission for the Protection of the Danube River (ICPDR) and European Macro-Regional Strategy for the Danube Region (EUSDR). The Sturgeon Action Plan after 2005 set the fundament for all further networks and has been established in a Danube Sturgeon Task Force (DSTF). The Danube Invasive Alien Species Network (DIAS) has been developed since 2014. Continuous cooperations between the Working Community of the Danube Region, the European Land and Soil Alliance (ELSA) and the IAD expert group Sustainable Development and Public Participation (IAD EG

Figure 1. Practical implementation of the European Landscape Convention in Czech Republic (© Harald Kutzenberger)

Figure 2. Sharing experience between botanical gardens Linz and Novi Sad (© Harald Kutzenberger)

SDPP) exist since 2012. Since 2020 a Danube Landscape Task Force has been set up within the EUSDR.

Do we forget about cultural Landscapes

'*Landscape* means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (ELC 2004: Article 1a). Cultural landscapes have never been static ecosystems but geographic mirrors of economic, technological and social conditions. Twenty years have passed since starting the implementation of the European Landscape Convention and 28 years of implementing the NATURA2000 network: these are milestones to have a look at the history and diversity of cultural landscapes in the Danube region, covering the total catchment.

What we consider that 'typical' in cultural landscapes is often connected to a specific period. Feudal and totalitarian political systems have left their traces over millennia as well as language and handcraft. Local geological and environmental resources brand cultural landscapes and create the strongest imprint on cultures and identity. The unleached population development of the last century has raised the pressure on landscapes and all their resources in an unprecedented dimension. Most conflicts in nature conservation and sustainable land use needs find their origin in this fact. Managing this continuous change in cultural landscapes needs practical implementation in every project in an integrated way comprising quality of life (human recreation etc.), diversity of life (species and habitats) and the fundaments of life (soil, water, climate).

Structure and identity of DL:TF

Cultural landscapes in their diverse structures and connections provide essential services and functions for our well-being. The Danube Landscapes Task Force (DL:TF) comprises an international and interdisciplinary network of experts from all Danube and Black Sea regions to cover both the diversity of the region and the scientific complexity of the topic. So, we chose a twofold identity of the DL:TF structure:

Figure 3. Integrated landscape management includes quality of life, diversity of life and fundaments of life (© Harald Kutzenberger)

- Regional structure: informal, decentral, interdisciplinary cooperation in lower, middle and upper Danube region with connection to the Black Sea region and the Alpine region
- Thematic structure: continuous cooperation of experts in academic activities, working groups, pool of experts with experience in a wide range of landscape relevant aspects including participation and implementation

An important part of the cooperation is the exchange between academic institutions and local initiatives to support the implementation of the European Landscape Convention (ELC), to encourage actors on policy and governmental level to raise awareness on the vulnerability of cultural landscapes and to contribute to the work of the macroregional EU strategy for the Danube region (EUSDR), especially the Priority Area 6 biodiversity, landscape, quality of soil and air.

DL:TF mission statement

Being aware that cultural landscapes are the expression of our cultures in interaction with the natural conditions, the Danube Landscapes:Task Force (DL:TF) promotes an improved coordination among actors in research, assessment, planning and management of cultural landscapes within the Danube and Black Sea Region. Politically independent, it brings together scientists, authorities and stakeholders and aims to raise the awareness on the vulnerability and crucial importance of cultural landscapes for the sustainable development in the Danube and Black Sea region. The members of DL:TF coordinate their activities to

- discuss the interactions of Danube cultural landscapes in the frame of the implementation of the EU Biodiversity strategy 2030 and the European Landscape Convention;
- prepare a strategy and work plan to efficiently tackle the issue of an integrated landscape protection and management in the Danube Black Sea Region, such as: characteristics and transformation trends of Danube landscapes, integrated planning tools; management and restoration; dissemination and awareness raising;
- support a holistic approach within a network of specific thematic regulations in the EU environmental and regional policies;
- foster an integrated perspective on landscapes in their cultural, recreational, historical, biological and climatical aspects;
- establish a scientific advisory board for landscape related topics within the EUSDR;
- consider and cooperate with existing European and global landscape networks and organizations;
- develop individual but coordinated local implementation projects in all parts of the Danube and Black Sea region, to connect the local partners and create a network of learning microregions;
- Award individuals and institutions within the area for special contributions of sustainable development in cultural landscapes
- explore options for cooperation and funding within the frames of the participating networks, institutions and other organisations and
- promote the transfer of knowhow and expertise to actors on all administrative level

in a transnational context in order to contribute to a sustainable and liveable future of the Danube and Black Sea Region.

Three regional conferences to foster implementation

A 3rd Danube Landscapes:Task Force Conference 2022 'Implementing the European Landscape Convention' has been held from 28th to 30th September 2022 in Austria on changing locations between Tulln, Krems, Linz and Traun. It was the first full face2face event and participants from eight countries could be welcomed. There are several common initiatives within the DL:TF network.

One common project takes care of the way to a Botanical Garden in Novi Sad, coordinated by long term IAD member Dragana Vukov. The common vision is a micro-cosmos of Danube landscapes in the historical ensemble of Petrovaradin. Botanical gardens can be much more than a collection of plants: awareness raising on eco-systems, climate and soil protection and of course, cultural landscapes.

A new initiative prepares strategies for the restoration of green infrastructure in Ukraine in war affected areas. The damage is comparable to the hurricane villages in Czech Republic last year, but on a huge scale. Our Czech colleagues Alena Salasova and Petra Malá share experience how to prepare together with Oksana Manturova and Olena Lietytska from IAD Ukraine.

On regional level, Austria is one of the last countries to ratify the ELC within Danube region. Negative results of the neglection of landscape can be seen more and more obvious in Austrian municipalities in daily decisions. The coordination team continuously reminds the responsible authorities of the Austrian government to set action in the ratification process.

Perspective

Within a Danube Landscapes:Task Force an interdisciplinary network of experts with practical experience is developing as an exchange platform between academic institutions and local initiatives to support the implementation of the European Landscape Convention (ELC), to encourage actors on policy and governmental level to raise awareness on the vulnerability of cultural landscapes and to contribute to the work of the macroregional EU strategy for the Danube region (EUSDR), especially the Priority Area 6 biodiversity, landscape, quality of soil and air, and EUSDR PA10, Institutional capacity and cooperation in Danube Region. Cultural landscapes are often in a trap between institutional weakness and contradicting sectoral laws.

Promote measures to enable fish migration in the Danube River Basin

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In autumn 2021, the Priority Area 4 (PA4), Water Quality, of the European Strategy for the Danube Region (EUSDR) has published a new brochure on ‘Promoting Measures to enable Fish Migration in the Danube River Basin’. The EUSDR PA4 puts a strong emphasis on the protection of water resources and one of the seven targeted actions aims to promote measures to enable fish migration in the Danube River Basin.

PA 4, Water quality, aims to promote measures towards reducing knowledge deficits and to

- raise broad public awareness and political commitment for the Danube sturgeons as flagship species for the Danube River Basin and for the ecosystems and biodiversity of the Danube River basin as a whole,
- foster sturgeon conservation activities including protection of habitats, restoration of fish migration routes and ex-situ conservation measures,
- close knowledge gaps concerning monitoring of pressures and planning of measures for fish migration.

The decline of migratory fish populations in the Danube River Basin started centuries ago due to overfishing, and their vulnerability was increased by the large river regulation schemes, hydropower utilization, pollution and shipping from the 19th century onwards. The current environmental status of the Danube and its major tributaries is not satisfactory with respect to the requirements of the long- and medium-migratory fish species.

Migratory fish are particularly affected by fragmentation and destruction of river habitats, as they are prevented from movements between their spawning grounds and other core habitats, which are essential for their long-term survival and recovery. Blocking migration routes with river control facilities is the leading cause of their down-trending population dynamics.

The functionality of ecological corridors is a fundamental conservation priority in a river system, which can be ensured by the following measures: 1) improving the physical connectivity by mitigation or the removal of migration barriers, 2) restoration or maintaining core habitats for fish and 3) enhancing or sustaining viable fish populations by supportive programmes for rebuilding population structure and restoring natural reproductive potential.

A variety of passage facilities can be installed at river barriers for the restoration of connectivity of fragmented rivers. Despite the cost of building these structures, there is not enough information about their functionality and overall success in restoring the ecological corridor. Surmountability of most of the fish passes is usually incomplete, and accumulation of migratory fish is often observed below obstacles. Tagging, mark-recapture, fish pass trap and telemetry tracking of fish movement are informative methods for assessing the overall effectiveness of fish passages.

Biological and engineering expertise is now available to build and operate fish passes, however more detailed biological information is needed about migratory behaviour of the Danube fish, above all sturgeons. The swimming ability of target fish species varies. Understanding of complex interacting factors of fish migration and proper knowledge of swimming performance is crucial for designing effective fish passage systems.

The cumulative effect of a series of limited efficiency fish passes may be very significant. The importance of monitoring is particularly apparent in the case of rivers where multiple facilities operate to support fish migration. Long-term monitoring of fish migration provides information about the effectiveness of facilities providing connectivity and function of ecological corridors.

The mortality of fish migrating downward is confirmed by several surveys at hydropower plants. Migrating fishes are often not likely to be successful in overcoming the numerous obstructions in sufficient quantities to maintain populations unless mitigating measures are taken. A variety of downstream protection facilities have been used to guide fish away from turbine intakes and transport them to the tailrace downstream of the power station.

The conservation of migratory fish species and the enhancement of their populations require a long-term, well-funded program of fish pass developments and constructions, improvements to dam operation, and removal of barriers wherever possible in the Danube River Basin. Governments are obliged to comply with international agreements such as the Convention of Biological Diversity (CBD), the Convention on Migratory Species (CMS), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention, etc. and regional regulations such as the Habitats Directive, Water Framework Directive (WFD), EUSDR, etc. These frameworks can therefore be used actively to promote the restoration of fluvial ecological corridors. The strategies and action plans for the conservation of migratory fish can be successfully implemented through strong international cooperation. Development of national organisations for research of fish migration would be also important for the success of extensive international cooperation.

References and links:

This brochure can be downloaded here:
https://dunaregiostrategia.kormany.hu/download/8/33/e2000/EUSDR_digital_oldalpar.pdf

The Estuarine Ecological Knowledge Network Makes Progress: International Project Sites and Potential Ways Forward

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The Estuarine Ecological Knowledge Network (EEKN) brings together scientists and coastal fishing communities in seeking new ways forward for Earth's major river deltas and estuaries, including the Mississippi (United States), Rio Grande (United States), Danube (Romania/Ukraine), Ganges (India/Bangladesh), Niger (Nigeria), and Mekong (Vietnam) river deltas, and the Patos Lagoon (Brazil). Such environments are universally understood as crucial for the biological productivity of oceans and they are home to hundreds of millions of human inhabitants, many of whom directly depend on that marine richness in terms of the operation of their socioeconomic systems. As human-induced climate change and its consequences for Earth's oceans and coastlines increases, estuarine ecosystems are particularly threatened by problems such as sea-level rise, coastal erosion, saltwater intrusion, and increased impacts from tropical storms. These problems are often amplified by human dynamics of environmental degradation, including overfishing, pollution, and large-scale landscape modification projects. The EEKN is designed to enhance communication and cooperation between fishing communities, scientists, and policy makers in learning about the complexity of both ecological and socioeconomic systems in estuaries and deltas, and in developing more effective policy for managing fisheries, protecting and restoring coastlines, and increasing the resilience of coastal communities.

The Danube Delta was selected as a case study site in this truly transcontinental project because it is one of the global ichthyo-diversity hotspots, including numerous endemic, rare, and important species both of conservation and economic importance. A specific unique complex of ecosystems also plays a key role for the Danube River and Black Sea ichthyofauna through its function as buffer and shelter as well as a transitional feeding and reproduction area.

Due to its opportunities for international participation and collaboration the EEKN’s group of project partners covers five continents and eight countries, covering some of Earth’s most important marine environments. However, the EEKN’s project partnerships are intended to expand to the innumerable estuarine contexts – both large and small – not already included among the project sites. In addition, while the project group views the starting working steps as essential pilot research, the long-term goal is to promote collaboration between fishing communities, scientists, and policy makers across the international project sites. It is assumed that effective strategies and novel scientific knowledge will begin to emerge within local networks and spread between international project sites.

For further information and details on the project team as well as on the progress of the project please visit
https://www.eekn.org/.

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International Association for Danube Research (IAD)

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Hydrological catchment of the River Danube

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