ISSN 2070-1292

danube news

International Association for Danube Research (IAD)

In a side arm of the Danube Delta, May 2024 (© Bernd Cyffka)

Content

Danube News
No. 50

Showcasing the state of habitats across realms in the Danube-Carpathian region – setting the scene for improved connectivity between freshwater and terrestrial habitats

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DOI: 10.5281/zenodo.14215525

Abstract

Human activities have significantly altered our planet, leading to a decline in biodiversity with freshwater-related habitats being particularly affected. These habitats provide essential ecosystem services such as water retention and erosion control. As part of the EU project 'Natura Connect', this article summarizes the initial results of a case study on the distribution and condition of protected freshwater-related habitats in the Danube-Carpathian Region. The study reveals that many habitats and species in this region are in poor or inadequate condition although protected areas, like Natura 2000, are crucial for maintaining biodiversity and ecological functionality. This case study highlights the urgent need for coordinated conservation efforts and effective management strategies to address the complex challenges facing these ecosystems.

Introduction

Human activities have significantly altered our planet (Richardson et al. 2023), leading to a decline in biodiversity to the extent that we now witness a sixth mass extinction (Cowie et al. 2022). Nowhere is the biodiversity crisis more pronounced than in freshwater and wetland habitats (WWF 2024). Globally, these ecosystems – including fens, bogs and mires, floodplain forests, and wet meadows – are threatened by numerous anthropogenic stressors (EEA 2024a), affecting their functioning (Abell et al. 2011; He et al. 2023). Despite covering a small portion of our planet, freshwater and wetland habitats exhibit high biodiversity (Tickner et al. 2020). Transition zones between land and freshwater ecosystems, characterized by specific hydrological, geological, edaphic, and biotic conditions, are particularly influenced by the water cycle and land use in the surrounding catchment areas (Abell et al. 2011; Weigelhofer et al. 2020). Depending on their ecological functionality, these habitats offer a wide range of ecosystem services, such as water retention, erosion control, and nutrient reduction in water bodies (Funk et al. 2019).

As part of the EU Horizon Europe project 'Natura Connect' (https://naturaconnect.eu/), this article summarizes the first results of a case study on the condition and distribution of freshwater-related and wetland habitats and their species in the Danube-Carpathian Region (DCR). Based on our analyses, freshwater-related and wetland habitats will be prioritized in the DCR to improve and restore the connectivity of land- and water-related ecosystems. Protected areas play a crucial role here, essential for maintaining biodiversity and ecological functionality and protecting vital ecosystem services (Hermoso et al. 2016; Perosa et al. 2021). In addition to national protected areas, Europe has a transnational network of protected areas of Natura 2000 sites within the EU and Emerald sites outside the EU (EEA 2019). These areas, along with ecologically valuable but currently unprotected habitats are analyzed here together with various stressors affecting these species and habitats.

Study Area: Danube-Carpathian Region

The study area encompasses the entire Danube-Carpathian Region (DCR), combining the management areas of the International Commission for the Protection of the Danube River (ICPDR) and the Carpathian Convention (CC). The 839,140 km^2 area extends from the source of the Danube in the Black Forest (Germany) to its mouth in the Black Sea (Romania, Ukraine). Of this, 26% belong to the Carpathian Region, and 96% to the Danube River Basin, which includes parts of the Carpathian Region *(fig. 1)*. The project area includes five biogeographical regions: Continental (49.40%), Alpine (26.12%), Pannonian (18.02%), Steppe (5.84%), and Black Sea (0.25%) (see also fig. 3 in the results section). The DCR includes parts of 11 EU member states (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland, Romania, Slovakia, and Slovenia) and 9 non-EU countries (Albania, Bosnia and Herzegovina, Kosovo, Moldova, Montenegro, North Macedonia, Serbia, Switzerland, and Ukraine) *(fig. 1)*.

Data on protected areas, habitats, and species

Initially, a geodatabase was built by collecting relevant datasets. Most datasets were not available for the entire project area, such as data from the EU Copernicus program (e.g., CORINE Landcover, Copernicus Riparian Zones) were only available for countries that are members of or collaborate with the European Environment Agency (EEA) (Copernicus Land Monitoring Service 2024). In the DCR, this includes all countries except Moldova and Ukraine. Data on Natura 2000 sites and data from reports under Article 17 of the EU Habitats Directive (HD) (European Union 1992), and Article 12 of the EU Birds Directive (BD) (European Union 2009) were only available for EU countries. Therefore, most of the

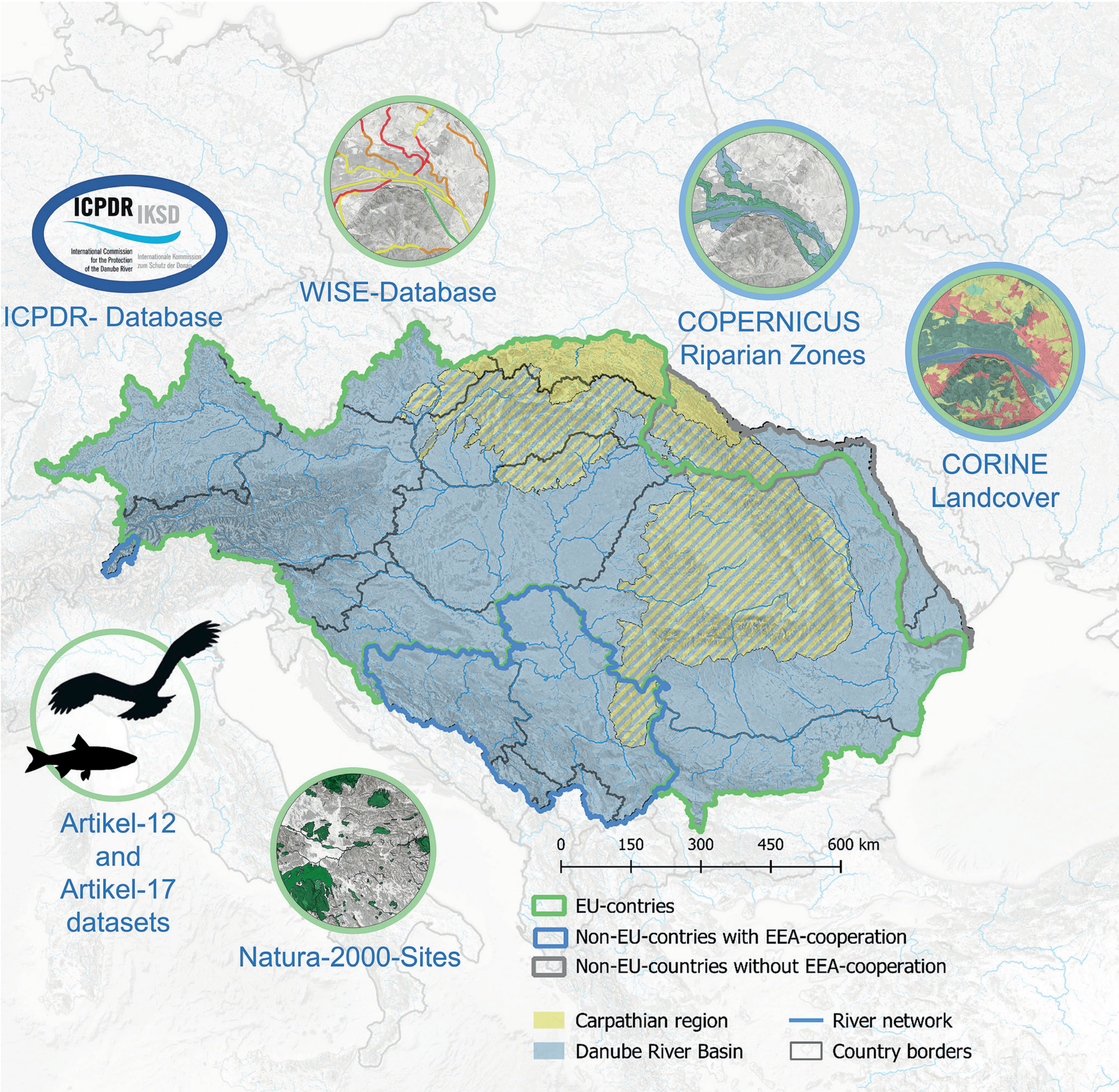

Figure 1. Study area with administrative boundaries and indicting the areas of the Danube River Basin and the Carpathian region (adapted from Schinegger et al. 2024).

analyses presented here refer to the EU member states in the study area (indicated by 'DCR-EU').

To analyze the DCR's coverage by protected areas, we overlaid the spatial dataset of Natura 2000 sites (EEA 2022) with the DCR-EU. For non-EU countries, Emerald sites in the 'Emerald Network of Areas of Special Conservation Interest' protected under the Bern Convention were used (EEA 2024b). For this calculation, overlaps of Natura 2000 sites protected under the HD and those protected under the BD were dissolved. All habitat types listed in Annex I of the HD occurring in the DCR were initially extracted. In a further step, habitat types in the categories 'standing waters,' 'flowing waters,' 'wet meadows,' 'mires, bogs and fens,' and 'wet forests' were selected. Similarly, species reported under Article 17 of the HD (Annex II, Annex IV, and Annex V) were intersected with the study area to determine their occurrence in the DCR-EU. Only species 'exclusively' or 'preferably' associated with freshwater and wetland habitats were selected.

To assess the condition of freshwater-related and wetland habitats, the conservation status parameter 'Structure and Functions' from the reports under Article 17 of the HD was used. This parameter describes the quality of specific occurrences of habitat types, aggregated by biogeographical regions, in terms of their species communities, structures, and biotic and abiotic factors. Similarly, the 'Habitat for the Species' parameter can be used for non-bird species. This parameter assesses the quantity and quality of habitats. Both assessments were available in the categories favourable (FV), unfavourable-inadequate (U1), unfavourable-bad (U2), or unknown (XX) for the biogeographical regions of the EU member states. These assessments were extracted for all biogeographical regions overlapping with the DCR. For the presentation of species habitat assessments, the assessments were summed up by species groups: fish, mammals, invertebrates, amphibians, reptiles, and plants. As there is no similar parameter available in the BD, bird species were not included in this analysis.

Results

Natura 2000 and Emerald Sites in the DCR

Overall, 19% of the DCR area was protected by Natura 2000 or Emerald sites. In the DCR-EU, the coverage of the 3,823 Natura 2000 sites, protected under the Birds or HD or both, was approximately 22% of the area, while outside the EU, 169 Emerald sites covered 11% of the area. Of the 3,823 partially overlapping Natura 2000 sites, 480 were designated under the BD, and 3,267 under the HD. In 76 sites, the boundaries are identical and thus protected by both directives.

Condition of Habitat Types and Species in the DCR-EU Regions

The condition of freshwater and wetland habitats was predominantly bad (U2), inadequate (U1), or unknown (XX) in the Alpine, Continental, and Pannonian regions. In the Alpine region, 16% of habitats were classified as bad (U2), 30% as inadequate (U1), 34% as unknown (XX), and only 20% as favourable (FV). Similarly, the classification of habitats in the Continental (U1: 31.0%; U2: 36.7%; XX: 14.6%; FV: 17.7%) and Pannonian regions (U1: 37.5%; U2: 42.9%; XX: 3.6%; FV: 16.1%) was predominantly unfavourable. These three regions cover about 94% of the study area, while the Steppe and Black Sea regions together cover only about 6%. In these two regions, the condition of habitat types was better. The poor or missing assessment of the condition of flowing waters, bogs, fens and mires in the Alpine and Continental regions was particularly striking. The assessment of standing waters was better in the Alpine region but predominantly bad and inadequate in the Continental and Pannonian regions. The classification of wet forests and meadows was also predominantly bad, inadequate, or unknown in most regions. The breakdown of habitat conditions by regions and habitat types or habitat type groups is presented in table 1.

Habitat-Type	Habitat-Code	ALP	CON	PAN	STE	BLS
	3130	FV	U1	U2	FV	FV
	3140	U1	U2	U1	FV	FV
	3150	XX	U2	U1	FV	XX
Standing waters	3160	FV	U1	U1	FV	
	3180	U1	FV			
	3190	FV	U2			
	31A0			U2		

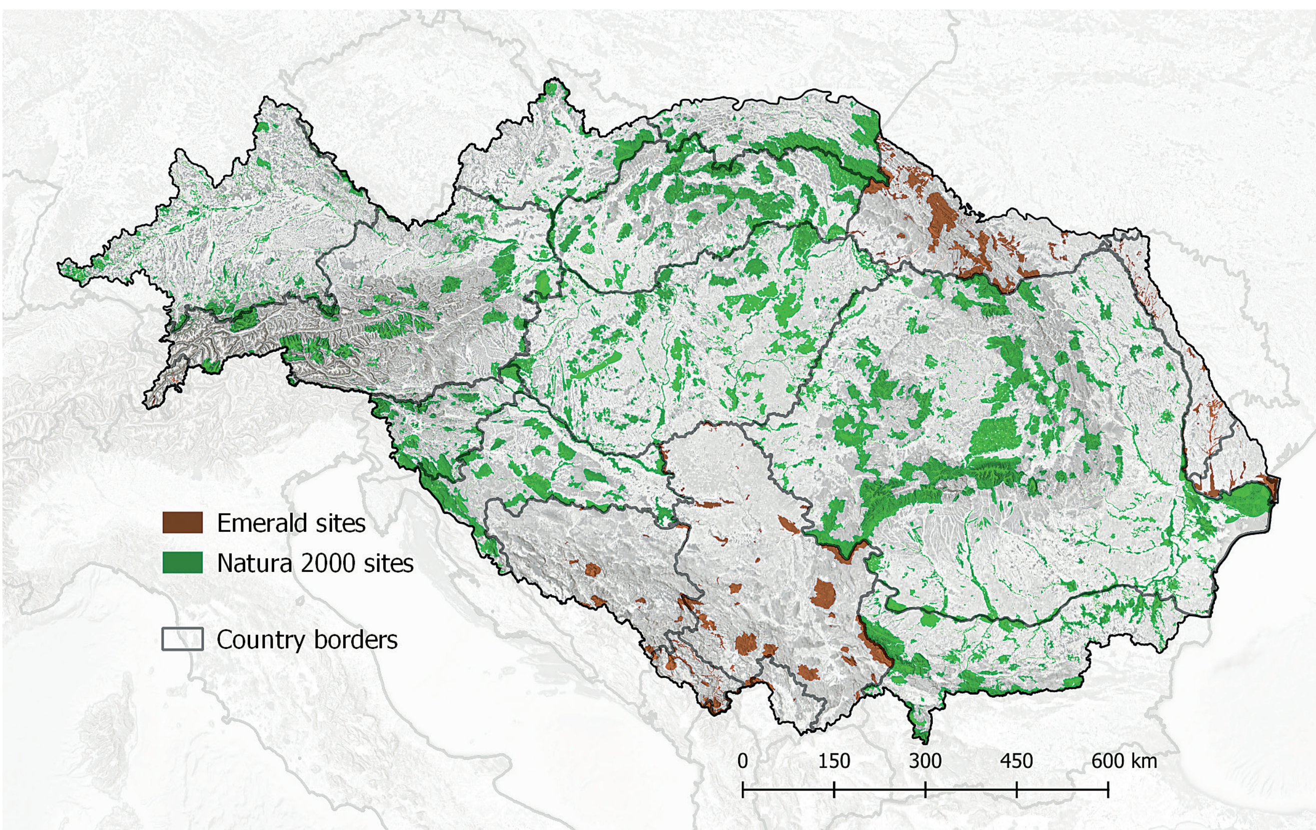

Figure 2. Natura 2000 and Emerald sites located in the study area

Habitat-Type	Habitat-Code	ALP	CON	PAN	STE	BLS
	3220	U1	U1			
	3230	U2	U2			
	3240	XX	U1			
Running waters	3260	U1	U1	FV	FV	U1
	3270	XX	U1	FV	FV	FV
	32A0	U1	U1			
	1310		U1		FV	XX
	1340	FV	XX	U1		
	1530		XX	U1	FV	XX
Wet meadows	6410	U2	U2	U2	FV	FV
	6420	U2	U2			U1
	6440	FV	U2	U2	FV	FV
	7110	U2	U1	U2		
	7120	U2	U2			
	7130	U2				
	7140	U1	U1	U2		
Mires, bogs & fens	7150	XX	XX			
	7210	XX	U1	FV		
	7220	XX	U1	FV		XX
	7230	XX	U2	U2		
	7240	U1	XX			
	91D0	XX	U1	U1		
	9,10E+01	U2	U2	U2		FV
Wet forests	91F0	U2	U2	U2	U1	FV
	92A0	XX	U1	U1	FV	FV
	92D0	XX	FV		XX	XX

Table 1. Status of habitat types in the Alpine (ALP), Continental (CON), Pannonian (PAN), Steppe (STE) and Black Sea (BLS) regions (adapted from Schinegger et al. 2024).

Condition of Species Habitats in the DCR-EU Regions

Most species of the HD that are living in freshwater and wetland habitats show an inadequate, bad, or unknown status of the conservation status parameter 'Habitat for the species' in most regions. In the Continental region, only 29% of species are classified as favourable (FV), while 46% are inadequate (U1), 14% are bad (U2), and 11% are unknown (XX). Similarly, the classification in the Alpine region is (FV: 24%; U1: 8%; U2: 52%; XX: 16%). In the Pannonian (FV: 44%; U1: 6%; U2: 46%; XX: 3%), Steppe (FV: 51%; U1: 4%; U2: 34%; XX: 11%), and Black Sea regions (FV: 61%; U1: 4%; U2: 18%; XX: 18%), the classification is more positive. A detailed classification of the individual species groups in the respective regions is shown in figure 2.

Discussion

Our analyses of the condition of species and habitats under the HD in freshwater and wetland habitats in the DCR highlighted the alarming biodiversity situation in this area, which is severely threatened by human impacts (Funk et al. 2019). In the DCR-EU, the majority of analyzed species with a focus on freshwater and wetland habitats showed inadequate, bad, or unknown conditions for different parameters of the conservation status in most regions, comparable to the conclusions of Sommerwerk et al. (2022). Our analyses demonstrated the urgency for better implementation of the Natura 2000 management, which in first places requires specific, concrete and verifiable conservation objectives (Ellmauer & Suske 2024). A series of infringement and legal proceedings against EU member states in the DCR region suggests that the Natura 2000 network in the study area insufficiently contributes to the maintenance or restoration of favourable conservation status, consistent with the findings of Acreman et al. (2020). Therefore, our project aims to prioritize the conservation of freshwater and wetland habitats in the DCR to improve the connectivity of land and water ecosystems, for example, by identifying ecologically valuable areas that are not yet protected.

Despite some limitations, our work provides initial large-scale insights into the condition of species and habitats under the HD in the DCR and potentially offers new information for conservation and catchment management. In this context, we particularly highlight the need for even more cross-border cooperation and planning to adequately address the transnational challenges of protecting and restoring freshwater and wetland habitats. This includes considering socio-economic factors and cross-sectoral goals (Izakovičová et al. 2020), as the habitats we studied in the DCR-EU also provide a variety of ecosystem services for human well-being, such as the provision of green and blue infrastructure (Perosa et al. 2021).

Integrated strategies that consider various aspects of conservation, land use and water management are essential to ensure that restoration measures can restore the ecological integrity of freshwater and wetland habitats while contributing

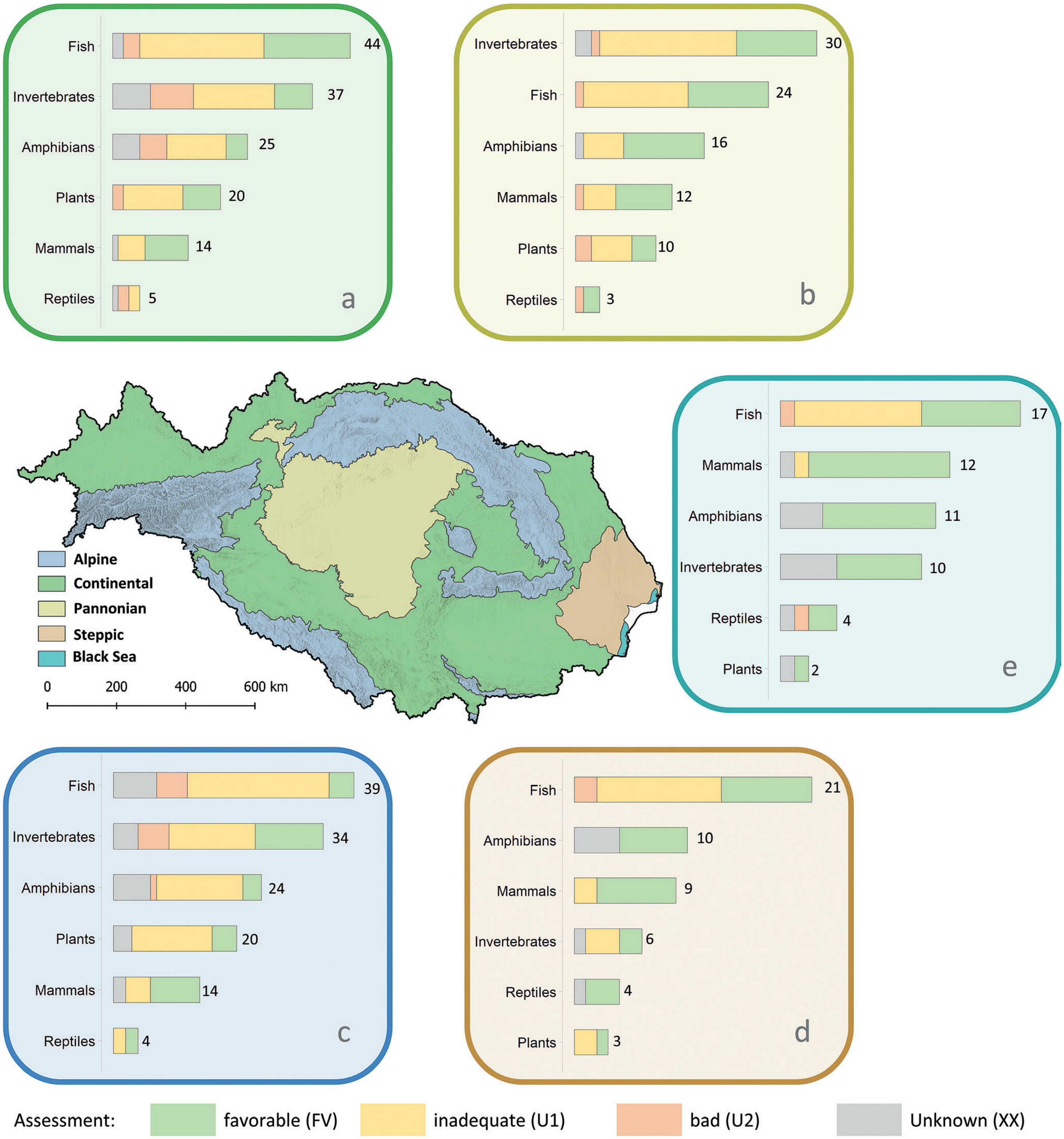

Figure 3. Status of structures and functions of the species habitats in the Continental (a), Pannonian (b), Alpine (c), Steppe (d) and Black Sea (e) regions. The species are here grouped into taxonomical groups and summed up (adapted from Schinegger et al. 2024).

to the region's sustainable development (Trovato et al. 2021). For example, nature-based solutions (NbS; Perosa et al. 2021) through the restoration of floodplains and flood areas can make habitats accessible to various species and protect humans from flooding (Stoffers et al. 2022).

Accordingly, solid political measures at transnational and national levels are required. Priority topics include strategic conservation planning, integrated water resource management, and new technologies for monitoring affected ecosystems (van Rees et al. 2021). This includes the existence of cross-border, well-designed research and monitoring programs and the collection of new, uniform spatial and temporal data across a broader spectrum of taxonomic groups, covering different realms and ecological processes, for example, using historical data and remote sensing-based analyses (Acreman et al. 2020; Erös et al. 2023).

In conclusion, protecting and restoring freshwater and wetland habitats in the DCR are critical for maintaining biodiversity and ecosystem services. Our study highlights the urgent need for coordinated conservation efforts and effective management strategies to address the complex challenges facing these vital ecosystems.

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The history of the WWF Floodplain Reserve Marchegg: Land use change along a border section of the Morava River

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DOI: 10.5281/zenodo.14215574

Abstract

The Morava River is a tributary of the Upper Danube and one of the largest Austrian lowland rivers. Its floodplains were once intensively used for agriculture and forestry. In the first decades of the 20th century, land use transformation and intensification processes started, comparable to other Danube tributaries. However, the political divide between East and West made the area a border region along the Iron Curtain and slowed down this development. Already in 1970, the section became a WWF nature protection reserve, and since 1989, the Morava floodplains have been part of the European Green Belt.

Introduction

The Morava River is a central European lowland river and one of the larger tributaries of the Danube (*fig. 1*). The lowest section forms the border between Austria and Slowakia. Here, the river and its adjacent floodplains are part of the European Green Belt, a nature protection programme focusing on the former border region between Western and Eastern Europe. Especially between the Austrian communes Marchegg and Zwerndorf, extensive floodplains have been preserved. Although these

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are located 14 to 28 kilometers upstream of the mouth of the Morava at the Danube, they were – and still are – surprisingly closely linked to the Danube's runoff. The interplay of Danube and Morava floods influenced not only the lower Morava, but also the Danube itself. Depending on the Morava's water level, the Danube's backwater extended upstream as far as Marchegg, Zwerndorf or even Dürnkrut during floods. If both rivers were in flood simultaneously, catastrophic deluges were inevitable (Weber-Ebenhof 1894). To understand the river morphological development of the once intensively meandering course of the Morava and the associated possibilities of human use in the floodplain, the hydromorphological influence of the Danube far downstream must also be considered.

Although a project to regulate the Morava had already been agreed with the Hungarian government in 1898, hydraulic works on the estuary section upstream of the Danube did not begin until 1911 (Benz 2019). The regulation project aimed to improve the flood discharge capacity of the Morava by significantly straightening its course while at the same time preventing large-scale flooding of the surrounding area. To this end, massive dam systems were built on both sides of the straightened river course, cutting through the former floodplain. However, due to the two world wars, it was to take until the 1960s before the construction programme could be completed. Additional regulation measures were carried out until the end of the 1970s (Hohensinner 2022).

The Austrian Morava floodplains were utilised for many centuries. The forests provided wood, litter, resin, and berries, and the landowners hunted game. Large areas were cleared and served the neighbouring communities as fields, meadows or pastures. Settlements such as Marchegg or Zwerndorf on the Austrian side or Vysoka pri Morave on the Slovakian side were built close to the river on old, higher river terraces (Jelem 1975). In contrast to many rivers where the floodplains have disappeared, large areas remained on the Morava between Marchegg and Zwerndorf that are still flooded today and are valuable from a nature conservation and ecological point of view. The WWF Marchegg floodplain

Figure 1. The location of the Morava River within the Danube catchment (see white insert and orange/red line; the red line indicates the location of the study site)

reserve was therefore established here in 1970. However, as a recent study showed, the land use history of this area is more complex and involves periods with more intensive agriculture than assumed at first sight (Haidvogl & Sauer 2022).

Pre-industrial patterns of land use around 1820

The spatial extent and distribution of agricultural land in the Morava floodplains can be reconstructed in detail using historical maps from the 19th century onwards. The location of the fields, meadows and pastures in the vicinity of the March and in the three Austrian March communities of Marchegg, Baumgarten and Zwerndorf shows a typical pre-industrial land use pattern (Haidvogl 2010). Around 1820, less than 3% of the land near the river was cultivated as fields and, except for Zwerndorf, these were mainly located around the historic settlement centres (*fig. 2*). In the entire municipalities, however, the proportion was more than 41%. The fields were preferably located at a greater distance from the Morava or on elevated areas, the so-called 'Parzen', remnants of older terraces (Umweltbundesamt 1999). Around 1820, the fields in all three municipalities were farmed according to the classic three-field system. The typical cereals cultivated were wheat, barley, rye and oats. Wheat and barley were sold, while rye and oats were mainly produced for the farmers´ use in fields with poorer soil quality and lower yields. In contrast to other regions of Austria, the utilisation of fallow land in the form of green fodder cultivation had not yet been introduced along the Morava around 1820. However, cattle were sometimes brought here to graze. In the crop fields in frequently flooded areas and near the Morava or the Maritz water system, the soils were described as 'shallow and weak'. After flooding, water often remained here for a long time. This sometimes spoilt the seed, as did the fine sediments deposited during flooding. In Marchegg, even the most productive farmland was regularly flooded, damaged by ice drifts or affected by heavy summer rains.

Farmers sometimes planted maize to compensate for the seeds that were destroyed if there was flooding or ice in the spring. In contrast to the winter and summer cereals, typically planted in September after the harvest or in March, this crop can also be planted in April and May, as it requires higher temperatures to germinate. The Marchegg estate also cultivated potatoes on a large scale. These were primarily used to make brandy, and the unusable leftovers were used as fodder for the oxen kept by the estate.

Around 1820, there was a considerable amount of grassland near the marshes. In total, 45% of the land in the surveyed area fell into this category, while the proportion was less than 37% in the entire three villages. Flooding and ice flows in the Morava and Maritz rivers also affected the grassland used as meadows or pastures. As a result, the areas silted up, and the grass harvest often failed utterly. Pastures were used intensively, especially for sheep and pigs. Cows were also regularly taken to pasture and oxen and horses, at least

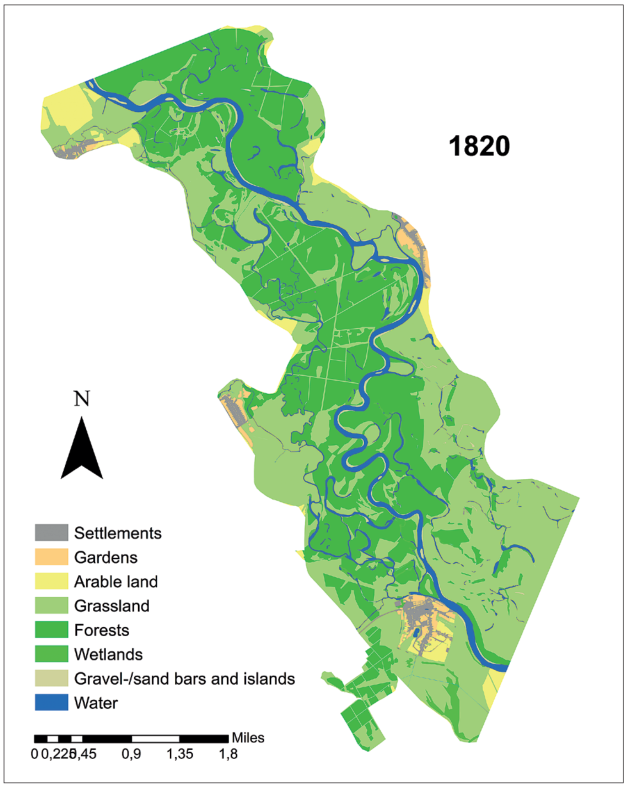

Figure 2. Land use in the Morava floodplains between Zwerndorf and Marchegg

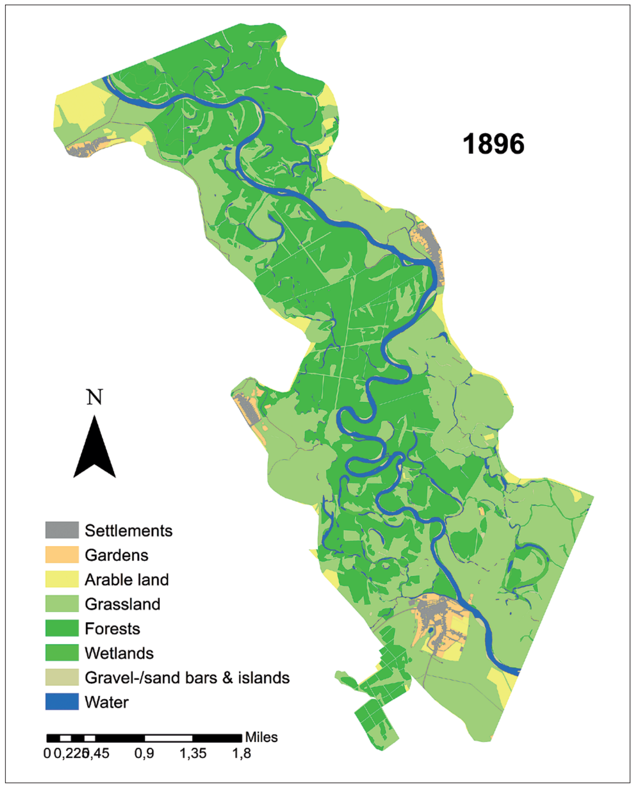

Figure 3. Land use in the Morava floodplains between Zwerndorf and Marchegg 1896

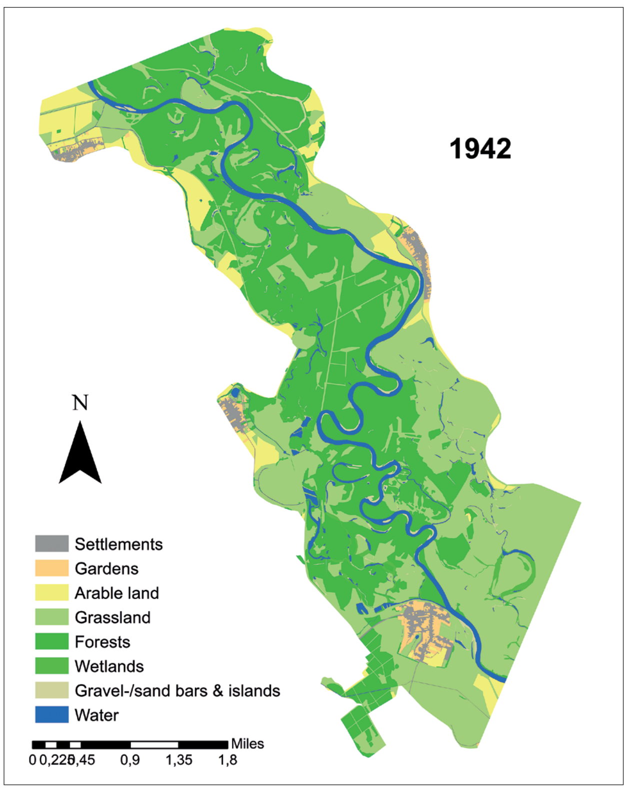

Figure 4. Land use in the Morava floodplains between Zwerndorf and Marchegg 1942

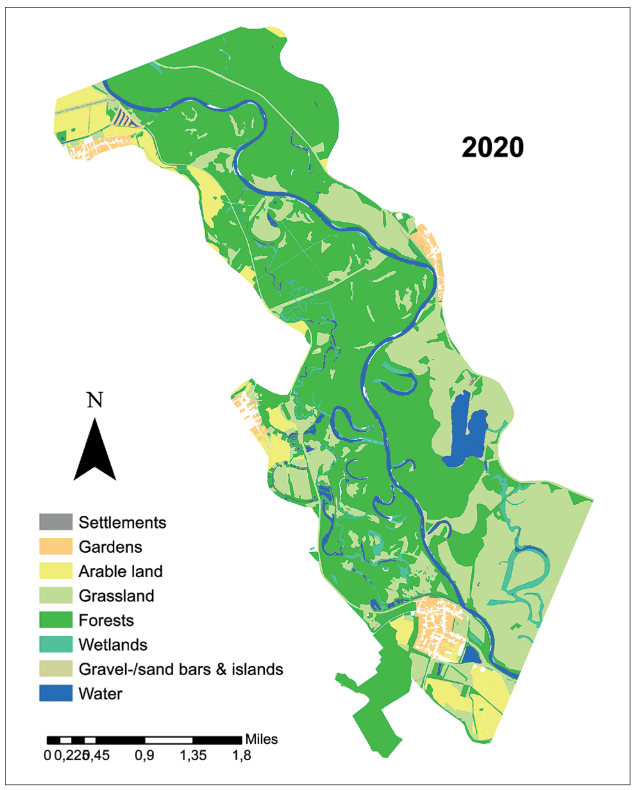

Figure 5. Land use in the Morava floodplains between Zwerndorf and Marchegg 2020

on Sundays and public holidays when they were not needed for work. The grazing areas did not cover the demand, so the animals were also driven onto the fallow fields or harvested fields. The lack of pasture was particularly noticeable in Zwerndorf. Stable feeding, already common in all three communities around 1820, was, therefore, not only a means of collecting livestock manure more efficiently as fertiliser, but it was also necessary to provide the cattle with sufficient food. Areas where reeds grew were also utilised. The reeds were used to cover the roofs and, like wood, were used as fuel.

Large areas of (floodplain) woodland remained. These were found on a total of 40% of the analysed area, while in the entire municipalities of Marchegg, Baumgarten and Zwerndorf they wonly accounted for about 13%. Willows, aspens and black poplars dominated in the alluvial forests of Baumgarten, but elms and oaks were also found. A large proportion of the wood was used locally as fuel. However, some larger oaks remained as individual trees. Historical sources document typical successional stages of the alluvial forests. At some sites, silver poplar dominated the stand. In Marchegg and Zwerndorf the alluvial forests were composed of willow, silver and black poplar, aspen, black alder, maple, oak and elm. Birch trees also occurred and were utilised. Except for the oaks, which were used as timber and lumber, the trees were also used as fuel in Marchegg and Zwerndorf.

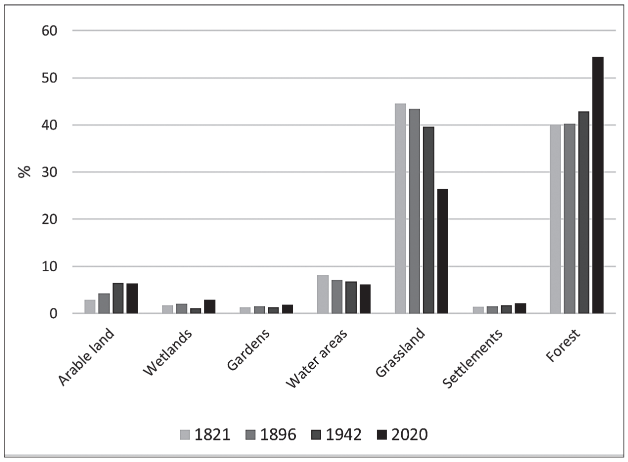

Figure 6. Overview of land use change in the Morava floodplains between Zwerndorf and Marchegg

Land use at the beginning of industrialisation

On several Austrian rivers, the framework conditions for land use in floodplains changed around 1900 due to regulation or drainage. However, along the Morava fluvial processes and, thus, the framework conditions for agriculture and forestry changed little. Pre-industrial practices were preserved mainly here. With only a moderate increase in the productivity of the grain fields, one of the most important triggers for changes in land use was the development of population figures. In Marchegg, around 1,100 people lived in 1830, around 1,800 in 1870 and by 1900, the number had risen by a further 1,000 people to around 2,750 (NÖLA 1828, Statistik Austria 2021). Consequently, in the floodplains between Marchegg and Zwerndorf the settlement areas increased from around 44 ha to almost 50 ha between 1821 and 1896. This growth affected the Austrian municipalities of Marchegg, Baumgarten and Zwerndorf as well as Vysoka pri Morave on the Slovakian side. It occurred around the historic settlement centres, primarily on former grassland and garden areas (*fig. 3*).

Figure 7. In the WWF Floodplain Reserve Marchegg open grasslands as part of the former cultural landscape are preserved (© Michael Stelzhammer)

Figure 8. Disconnected meander in the Morava floodplains (© Severin Hohensinner)

During the same period, the arable land in the Morava floodplains of Marchegg, Baumgarten, Zwerndorf and Vysoka pri Morave grew from 90 to 134 ha. They were mainly created in the vicinity of settlements or on the edges of the area studied, for example, on land classified as gardens, grassland or woodland in 1821. Even in today's WWF floodplain reserve, some forests were cleared in favour of fields and meadows. The reduction in grassland from 1,417 to 1,380 ha was small in absolute terms, but there were larger-scale shifts in location, meaning that the change in land use was considerably more significant. The reduction was, among others, due to the declining demand for pastureland because of more frequent livestock stabling and a general change in livestock farming. Some exceptionally wet pastures and meadows were no longer farmed until 1896. In other places, new grassland was created, mainly in woodland. The inhabitants sometimes established new fields and settlement areas on the abandoned grassland.

The total area of woodland had changed little until around 1900. However, even here, the absolute figures conceal more significant transformations, as almost a tenth of the woodland in 1896 was still being used as meadows and pastures in 1821.

The trends in land use development of the 19th century continued in the first decades of the 20th century. The municipalities continued to record rising population figures associated with an ever-increasing number of buildings and settlement areas. The latter grew to 56 ha by the 1940s *(fig. 4)*. Arable land continued to increase, from 134 ha in 1896 to more than 206 ha in 1942, with new arable land cultivated primarily on former grassland. In Marchegg, fields located directly in the town were converted into gardens. Grassland continued to decline in the first decades of the 20th century. Apart from fields, new forests were created in many of these areas. These expanded until 1942 – including along the River March.

New drainage projects were carried out in the March floodplains at the beginning of the 20th century to improve agricultural productivity. A project was negotiated in Baumgarten, Zwerndorf, Oberweiden and Stripfing in 1904 and construction began in 1907. This project also included regulating the section of the Mühlbach running east of Baumgarten (Sümecz 2017).

The Morava floodplains as part of the 'European Green Belt' and nature conservation as a guiding principle for the management

After World War II, industrialisation gradually came to dominate agriculture. Machines gradually replaced human and animal labour. The large-scale production of maize replaced fodder legumes. Transport infrastructures were improved, and agricultural land ameliorated. Under the slogan of the 10th federal state, the Austrian administration initiated a systematic drainage of wetlands and bogs, which also affected the floodplains in connection with water regulation and flood protection (Ramsauer 1948).

As the Morava floodplains had been a border region between Austria and Slovakia since 1918, they were far less affected by these developments than most of the Austrian agricultural land. The proportion of arable land remained largely the same the investigated villages. However, their locations had shifted by 2020 (*fig. 4*). More than 20% of these areas were still forested in 1942, and 15% were ploughed as grassland. Grassland was converted into cereal fields, especially in the south of Marchegg. In contrast, the fields in the Slovakian floodplains almost entirely disappeared by 2020 (*fig. 5 and 6*).

The settlements in the analysed area grew from 56 to 68 ha between 1942 and 2020. The new areas mainly expanded around the historic centres. With a few exceptions, urban sprawl did not affect the Morava floodplains. Outside the floodplains, however, such processes did occur.

The most obvious change was the increase in forests in the second half of the 20th century. At around 1,730 ha, this land use type reached its most considerable extent since the 1820s. On the one hand, this expansion affected the area of today's WWF floodplain reserve, where the forest areas grew from 800 to 913 ha. However, this applied far more to the area outside the reserve, where the forests increased from 564 ha in 1942 to 818 ha in 2020, mainly on former grassland.

The two land use maps from 1942 and 2020 (*fig. 4 and 5*) show further developments in the second half of the 20th century: Single patches of forests as well as arable land and grassland were much larger due to rezoning plans following Austrian agricultural policy after the World War II. Pre-industrial plot divisions with small-scale utilisation structures were abandoned in favour of more efficient land cultivation with machines.

From 1970 onwards, most of the Morava floodplains studied here came under the care of the WWF. Since then, this area has been managed according to nature conservation principles as the Marchegg floodplain reserve (WWF 2022).

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The EU Mission ‘Restore our Ocean and Waters’ and its Danube & Black Sea Lighthouse coordinated by the EcoDaLLi Project

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Background

Around 75% of the Earth's surface is covered by oceans, seas and inland waters. They play a crucial role in the Earth's global ecosystem; their protection is fundamental to our future. Unfortunately, our oceans and waters are under serious threat from pollution, overfishing, unsustainable tourism and inappropriate land use. In addition, the consequences of the climate crisis, such as floods, droughts, rising temperatures, rising sea levels and heatwaves, are putting considerable pressure on water systems. One of the consequences of this is the loss of valuable biodiversity in water systems all over the world.

Restoration and full exploration of European marine and freshwater ecosystems by 2030

For this reason, the European Commission has launched a dedicated mission: The EU Mission ‘Restore our Ocean and Waters by 2030’. It aims to contribute to the restoration, protection and full exploration of European marine and

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freshwater ecosystems by 2030. Specifically, the objectives and three priorities of the Mission Ocean & Waters are: (1) protecting and restoring marine and freshwater ecosystems and their biodiversity, (2) preventing and reducing water pollution, and (3) creating a carbon-neutral and circular blue economy. The mission thus also supports the political goals of the Green Deal and is divided into two phases: Potential solutions demonstrated in a first phase (2021-2025) will be scaled up and replicated across the EU in the second phase (2026-2030). Implementation at regional, local and municipal levels is crucial to the success of the Mission; research and innovation also have an important contribution to make.

Lighthouses within the EU Mission 'Restore our Ocean and Waters'

In order to achieve the ambitious goals, four Lighthouse areas have been created in four large EU sea and river basins. These Lighthouses bundle the activities of the Mission and are sites for the piloting, demonstration, development and deployment of innovative solutions. Each area has been assigned one of the four main objectives of the Mission Ocean & Waters (*fig. 1*): Thus, the Mediterranean Sea Basin Lighthouse is dedicated to the prevention and reduction of water pollution; the Baltic & North Sea Basin Lighthouse to a sustainable blue economy that is climate neutral and circular. The protection and restoration of marine and freshwater ecosystems and biodiversity are central themes of the Danube River Basin Lighthouse with connections to the Black Sea and the Atlantic & Arctic Basin Lighthouse.

'If you would like to support the EU Mission Ocean & Waters and its Danube & Black Sea Lighthouse, you can submit actions that contribute to its objectives through the Mission Charter. By doing so, you send a clear message to European institutions about the important work being done in the Danube region. Mission Charter actions can take many forms, including supporting research and innovation, sharing knowledge, deploying solutions, providing education, or engaging citizens in ecosystem protection – ultimately contributing to a healthier Danube River Basin. Every contribution matters. Submit your actions here:
https://ec.europa.eu/eusurvey/runner/MissionOceanWatersCharter.'

Elements for implementing the Mission objectives

Horizon Europe-funded projects are essential for achieving the Mission's objectives. Each of the four Lighthouses is coordinated by a Coordination and Support Action (CSA) project and is accompanied by Innovation Action (IA) and Research and Innovation Action (RIA) projects. In addition, there are also cross-lighthouse projects that contribute to the objectives of the Mission. The 'Digital Twin Ocean', a virtual representation of the ocean that combines ocean observations, artificial intelligence and advanced modeling on high-performance computers, and the 'Mission Charter' are also of great importance for the implementation of the Mission objectives. The Mission Charter unites stakeholders and provides tools, services, and best practices, while quantifying the Mission's impact and success.

Figure 1. Four Lighthouses of the EU Mission 'Restore our Ocean and Waters' and their assigned main objectives.

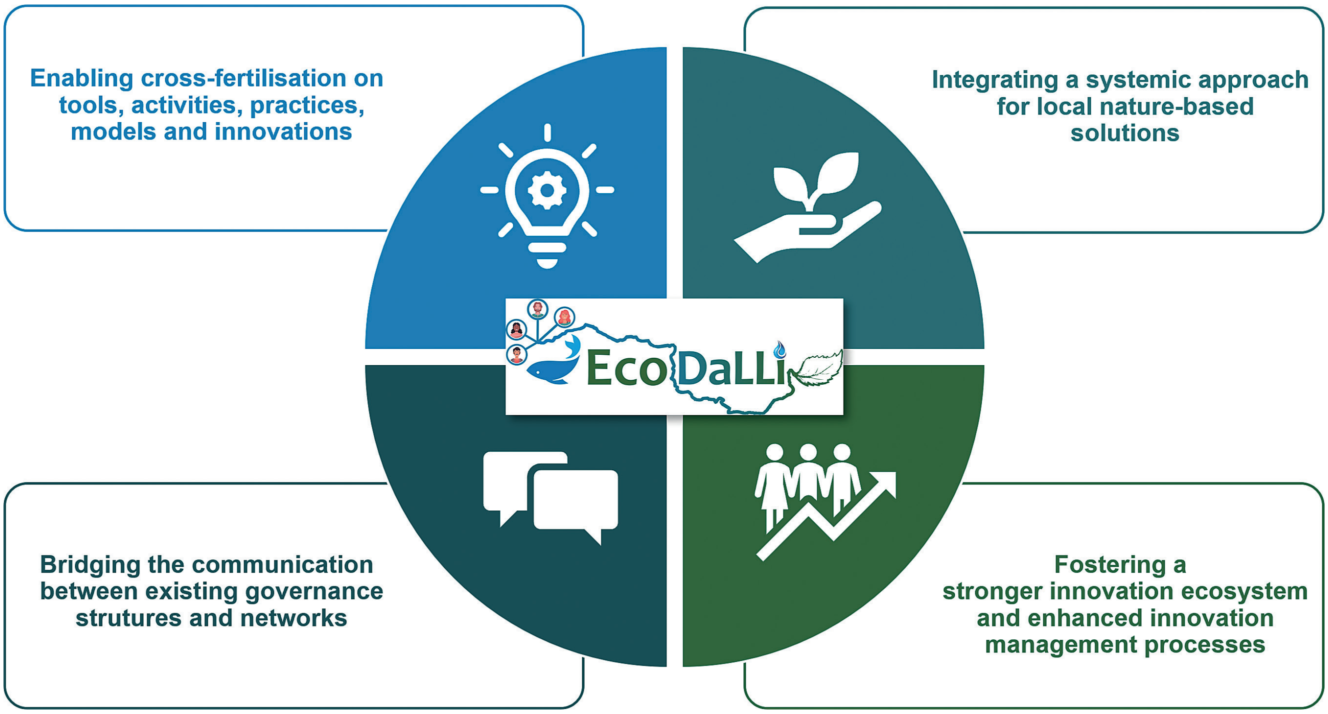

Figure 2. Main goals of the EcoDaLLi project as CSA of the Danube & Black Sea Lighthouse.

Projects within the Danube & Black Sea Lighthouse

The Danube & Black Sea Lighthouse is one of the four Lighthouses in the Mission Ocean & Waters. It currently comprises seven projects: EcoDaLLi as CSA and six IAs: DANUBE4all, DALIA, DaWetRest, Restore4Life, SUNDANSE and iNNO SED. While the DANUBE4all and DALIA projects are dedicated to the restoration of the Danube river, DaWetRest and Restore4Life are committed to the revitalization of climatically valuable wetlands. SUNDANSE and iNNO SED both focus on sediment management in the Danube & Black Sea basin. EcoDaLLi as a CSA works closely not only with the other Lighthouse areas and associated projects, but also with all key stakeholders and governance structures relevant to the Mission. The projects are funded by the EU with a total of 52.3 million euros under Horizon Europe.

Figure 3. Participants of the workshop ‘Strengthening the Danube Innovation Ecosystem’ in Ulm, Germany, organized by EcoDaLLi in cooperation with Priority Area 8, Competitiveness of Enterprises, of the EU Strategy for the Danube Region.

The EcoDaLLi project

EcoDaLLi (2023-2026) stands for 'ECOsystem-based governance with Danube lighthouse Living Lab for sustainable Innovation processes'. Coordinated by Steinbeis Europa Zentrum (SEZ) in Germany, the project brings together 17 partners and one associated partner from eleven countries. Through a network of Living Labs, EcoDaLLi strengthens collaboration between stakeholders, driving the development and implementation of innovative, sustainable solutions for the Danube and its delta. The project aims to build a robust innovation ecosystem, supporting the ecological restoration, protection and conservation of the Danube basin and its delta.

EcoDaLLi's concept and achievements

EcoDaLLi is built around four key objectives that guide its mission to support sustainable innovation in the Danube basin. These goals, illustrated in figure 2, focus on promoting collaboration, integrating nature-based solutions, and strengthening the region's governance and innovation ecosystem. Through these efforts, EcoDaLLi aims to enhance ecological restoration and support the long-term health of the Danube basin.

Key achievements of the project so far include the development of a nature-based solutions methodology and a best-practice catalog, which is designed to support the implementation of sustainable approaches across the Danube region. EcoDaLLi has also launched a Danube Innovation Community through stakeholder engagement workshops and Living Labs (*fig. 3*), facilitating collaboration among various stakeholders. Additionally, the project has established the EcoDaLLi portal, which serves as a repository for all project results (https://portal.ecodalli.eu/). A Danube & Black Sea Lighthouse Roadmap provides the framework for close cooperation between the Lighthouse projects to ensure effectiveness in working towards the shared goal: reaching the targets set by the Mission for the Danube & Black Sea Lighthouse.

Looking ahead to the project's completion in June 2026, EcoDaLLi will focus on capacity-building activities for stakeholders, offering targeted trainings to help scale up innovations demonstrated in the Danube & Black Sea Lighthouse. The project will also develop a Danube Innovation Action Plan, which will integrate its key outputs to ensure they are reflected in long-term governance policies. This plan will not only support entrepreneurship in the Danube basin but also foster cross-border cooperation, contribute to a healthier environment, and further strengthen the innovation ecosystem. Through these efforts, EcoDaLLi will facilitate shape strategies and policies that drive progress towards the overarching goals of the Mission Ocean & Waters.

Hands-On Science: IAD Summer School in the Danube Delta, 2024

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Abstract

By the end of August 2024, more than 20 student applicants nominated by IAD national representatives and 13 IAD expert group leaders and lecturers attended a one-week IAD Summer School in the Danube Delta. Ten students were from Romania and Austria, while another twelve came from Bulgaria, Hungary, Serbia, Ukraine and Slovakia. The summer school focused on microplastics, along with wetland biodiversity and nature conservation, reed management, and landscape development in the context of climate warming mitigation. Lecturers, who volunteered their time, represented many IAD countries and shared their expertise in diverse scientific fields, including microbiology, biota field surveys, reed management, wetland landscape planning, nature conservation, and climate research, as well as environmental education. This project was financed by the 'Executive Agency for Higher Education, Research, Development and Innovation Funding' Romania and IAD.

Excursion Details

Danube Delta Scientific Summer School aimed to create a friendly and open atmosphere for students and lecturers, sharing scientific practice in the floodplain and scientific discussions at 'round tables'. This was in line with the mission statement of IAD, to foster space for scientific collaboration and mutual exchange. IAD, as vital scientific network, is dedicated to a better understanding and protection of the Danube River and its catchment. By connecting with fellow participants and experts during IAD scientific summer school, we aimed to strengthen a better understanding of the many vital Danube Delta ecosystems, a unique area of 6,264.03 km² biosphere reserve established in 1998 under UNESCO's Programme on Man and the Biosphere and shared by Romania and Ukraine.

The lecturers have brought in their broad and deep expertise in aquatic sciences, while the students, many of whom are PhD candidates, also offered specialized knowledge backgrounds. This diverse mix of participants from various Danubian countries promises a rich learning experience. Thus, we had meaningful and stimulating discussions about former collaboration and joint projects and shared discoveries as we explored the fascinating world of the Danube Delta together. The photo figure 1 A shows the whole group of participants of this summer school in front of the small

Figure 1. *Group photo of the summer school participants, B-C: Students identifying biota, B: European green toad, Bufo viridis, C: Salt marsh plant, Salicornia; D: Insect Mantis. (Photo A: Dragos Balaican; B-D: Polina K. Nikova)*

Figure 2. *A: The five-to-ten-minute stimulating talk and discussion at round tables after dinner. B-C: Thematic excursion to the study areas of the project DaWetRest (Caraorman and Seaside Cordon). B: The floating reed islands, some as large as entire cities, impressed the participants of the summer school. C: Dr. Alexandru Cătălin Doroşencu, as IAD summer school lecturer, presented his extensive lexical knowledge of the ecological background and the specifics of the sites, landscapes, and biota in the delta. D: Zonation of riparian vegetation of floating aquatic plants (Nymphaea alba) and reed beds (Typha). (Photo A, D: Polina K. Nikova; B, C: Katrin Teubner)*

Figure 3. Thematic excursion to the Periprava area and Letea Forest. A: Pelicans in the sky above the sand dune area. B: Abandoned traditional houses in the village Letea, C: Endangered plant species of sand dunes, Ephedra distachya , D: Visiting saline vegetation (Photo A, B: Polina K. Nikova; C,D: Katrin Teubner)

Figure 4. 'BeachCleanUp', collecting macroplastics and other waste on a natural beach section of the Black Sea near Sulina. A: Sand dunes and coastal vegetation by the sea. B: Searching for waste on the beach. C, D: The amount of waste collected by two groups within three hours each. (Photo A, B: Katrin Teubner, C, D: Dragos Balaican)

harbor in Sulina, furthermore, figures 1-4 document main activities during this summer school.

The expertise of the IAD lecturers ranged from terrestrial observations in floodplains to aquatic microbiology and plastic pollution. When lecturers introduced theirself, they focused on one of three main topics during IAD summer school, terrestrial or aquatic issues or plastics as follows:

1. Terrestrial issues: Diversity of floodplain habitats in the Danube Delta, with focus on terrestrial systems

Prof. Bernd Cyffka (Germany) presented online a welcome speech for this summer school, and also about the mission and history of IAD

Dr. Eng. Iulian Nichersu (Romania) introduced to the IAD summer school at Danube Delta National Institute (DDNI) and referred, among others to 'Floodplain Reconnection & Delta Wetland Conservation'.

Dr. Thomas Zechmeister (Austria) contributed to 'Wetland monitoring & conservation, Reed management, Saline lakes and soda pans, Biodiversity of Moths and Butterflies'.

Dr. Alexandru Cătălin Doroşencu (Romania) introduced to the Delta ecosystems in general, with focus on 'Bird Monitoring & Conservation Strategies in the Danube Delta' *(fig. 2 C)*.

Prof. Dr. Dušanka Cvijanović (Serbia) provided scientific background of 'Wetland monitoring and conservation'.

Dr. Werner Lazowski (Austria) introduced to aspects of 'Botanical surveys, Floodplain vegetation, wetland conservation'.

Mag. Dragos Balaican (Romania) did an introduction on utilizing Chorematic Focus Maps for 'Water Energy Food Nexus in urbanizing wetlands in Danube Delta'.

2. Water issues: Diversity of floodplain habitats in the Danube Delta, focusing on channels and lakes

Prof. Martin Dokulil (Austria) with focus on Phytoplankton, Freshwater Ecology, Impact of global warming on aquatic systems contributed to the topic 'Global warming & Delta Ecosystems'.

Prof. Vera Istvánovics (Hungary) outlined about 'Eutrophication & Delta Ecosystems', which was most stimulating for discussions about the future of the Danube Delta ecosystems.

Dr. Adrian Burada (Romania) provided insights to his research field of 'Environmental Impact Assessments and Water Quality in the Danube Delta'.

Eng. Matei Simionov outlined to 'Hydraulic parameters measurements & Hydraulic Modeling in the Danube Delta'.

PD Dr. Katrin Teubner focused on 'Water quality and macrophytes in Delta Ecosystems'.

Dr. Markus Weinbauer emphasized the many facets of microbiology in coastal areas with focus on 'Viruses und microorganisms & Delta Ecosystems'.

3. Macroplastic and microplastic issues: Detecting plastic and effective strategies to prevent and mitigate this pollution.

Dr. Eng. Cristina Despina presented a comprehensive outline about 'Microplastic Pollution in the Danube Delta'.

In addition to this, as mentioned before, advanced students contributed to issues, as Polina K. Nikova (Bulgaria) to the identification of invasive species, Gergely Tikász (Hungary) by a detailed presentation using AI methods for detecting macroplastics to reduce waste degrading ecosystems, and Nikola Bobchev to methods analysing microplastics.

After the Visit and welcome speech at the Danube Delta National Institute in Tulcea we traveled by boat to Sulina. It was, all in all, a dense program with limited time in the Delta identifying biota diversity of ecosystems among other Delta issues (*fig. 1 B-D*). The two whole-day excursions were the boat trip to the Periprava area and Letea Forest (*fig. 2*) and visiting the study areas of the project DaWetRest (Caraorman and Seaside Cordon, *fig. 3*). Another day was dedicated to plastic collection at a natural coastal area near Sulina, focusing on identifying the types and quantities of macroplastics and other waste (*fig. 4 A, B*). The participants were divided into two groups for this activity. The volume of waste collected by late morning is shown in figure 4 C, D.

The four 'round table' discussions after dinner (*fig. 2 A*) were about 1: scientific publishing – presenting research results in scientific journals, at conferences, and using other science platforms, 2: 'terrestrial issues', 3: 'water issues' and 4: 'macro and microplastics'. Most stimulating for students, for example, was the discussion about the validity and the limits of using artificial intelligence in research, especially in the context of scientific publishing.

Outlook: Several participants of the summer school are still in contact. Some are exchanging ideas about potential publications arising from practical work during summer school excursions, comparing sampling results from the Delta with other wetland areas. The potential topics preparing publications are 'The Danube Delta and Its Ecosystem Diversity and Threats to the Ecosystem Diversity in the Danube Delta (Review)', 'Modern Monitoring of Floodplain Forests Vegetation in the Danube: NDMI and Conservation Efforts', 'Tracing Pollution Pathways: Industrial, Agricultural, and Urban Impacts on the Coastal Area between Sulina and Sf. Gheorghe', 'Sustainable Food Systems: Addressing Microplastic Pollution in the Danube Delta's Aquatic Food Chain' and 'Structural Diversity of underwater vegetation habitats: Bio-Mass vs Bio-Surface Ratios of macrophyte species'. Furthermore, several lecturers from this summer school will continue their collaboration in approved joint research projects along the Danube River starting in 2025.

Dr. Artem Liashenko †

With great sadness, we announce that our colleague, Dr. Artem Liashenko, Deputy Director of the Institute of Hydrobiology Kyiv, National Academy of Sciences of Ukraine, has passed away.

Involved in IAD cooperation for over 30 years and IAD National Representative of Ukraine since 2012, his research interest was focused on benthic invertebrates, water quality, assessment of ecosystem status and biodiversity conservation. He participated in numerous national and international projects, being involved since 1981 in national investigations of Ukrainian ecosystems such as Dnieper, Dniester, Bug, as well as in transnational research cooperation on rivers Danube, Prut, Tisa, Danube Delta and the adjacent estuaries, etc.

For many years, he was the Head of the Danube Research Laboratory, participating in international projects aiming to enhance knowledge exchange and contribute to methods harmonization in aquatic investigations. An example of IAD cooperation project was carried out between 2005-2007 in the Danube Delta in the frame of the SCOPES program, funded by the Swiss National Science Foundation, where the aquatic ecosystems in the Romanian and Ukrainian sides of the delta were jointly studied, allowing methods intercalibration and inter-comparability of results. Additional examples include the inter-academic exchanges between the research institutes belonging to the Academies of Sciences in Romania, Bulgaria and Ukraine, facilitating research exchange and joint investigations of selected waterbodies. He was also interested in environmental education, training young colleagues in limnology science and fieldwork, communicating the output of scientific research at many international conferences, and translating and disseminating an IAD children's book in Ukrainian language. In 2022, on behalf of IHK, he should have been the lead organizer of the IAD conference in Kyiv, but unfortunately, this plan was stopped by the Russian invasion in Ukraine. And now, all the plans we made with Artem to continue the transnational cooperation and launch new research projects were stopped by his death.

He was a dedicated scientist, his activity comprising over 200 scientific publications, including articles in top-rated international journals, monographs, and invention patents. However, besides being a good scientist, he was also a great colleague, a cheerful and friendly person, and a mentor for younger generations of Ukrainian limnologists. May his soul rest in peace, we will surely miss him!

The IAD Presidium

45th IAD Conference 2025

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Sofia / Bulgaria
April 9 to 11, 2025

Innovative solutions and cooperation to protect and restore biodiversity and ecosystems in the Danube River Basin

April 9–11, 2025
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Details in due course on the IAD homepage!

ISSN 2070-1292

danube news

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Catchment of the River Danube

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Layout:

M. Diener, info@diener-grafics.ch

Printing:

Druckwerk24, Wolfgang Rückel
Eisengasse C125,
D-86633 Neuburg a.d. Donau