

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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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 km² 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

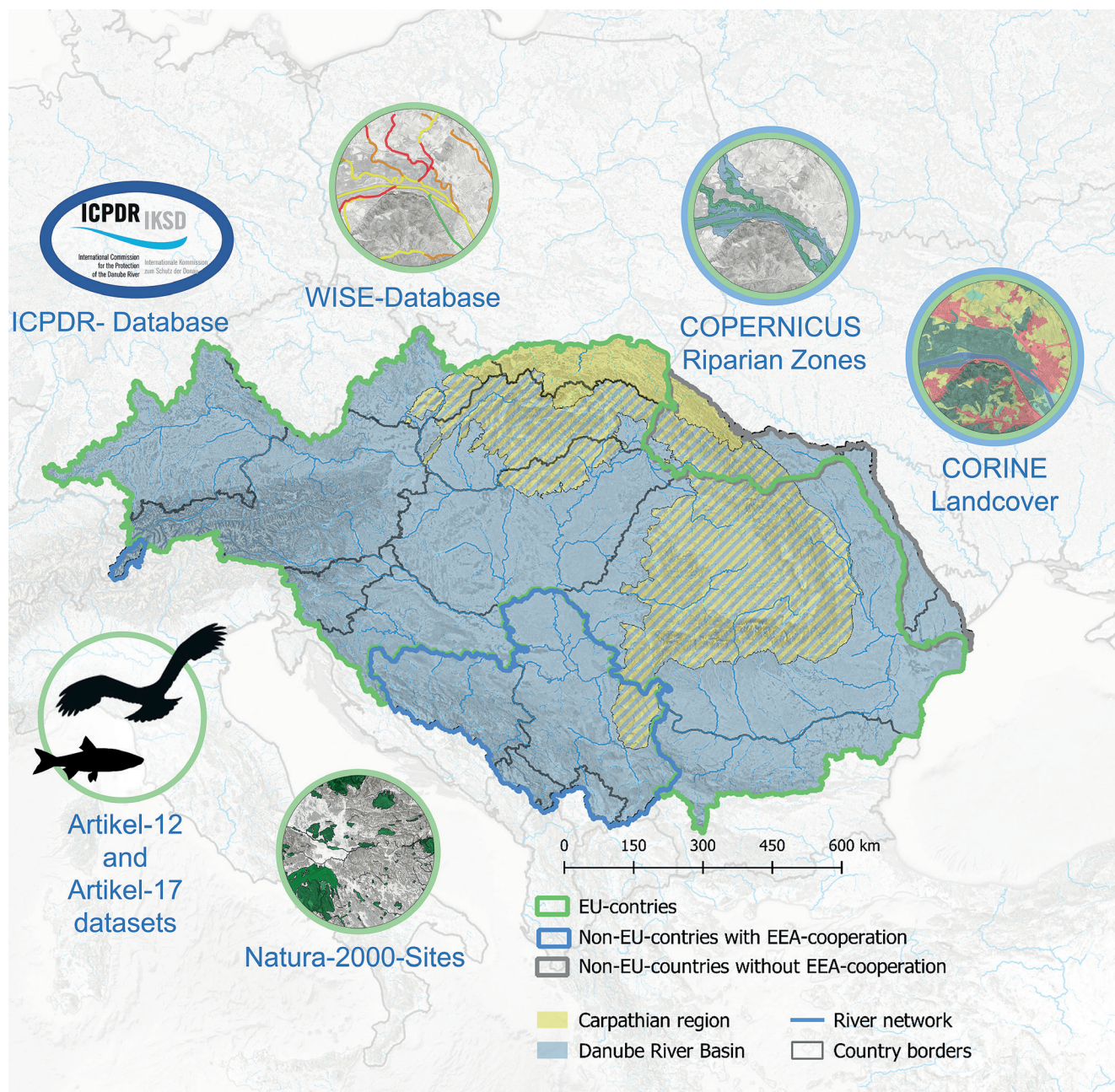


Figure 1. Study area with administrative boundaries and indicating the areas of the Danube River Basin and the Carpathian region (adapted from Schinegger et al. 2024).

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
Standing waters	3130	FV	U1	U2	FV	FV
	3140	U1	U2	U1	FV	FV
	3150	XX	U2	U1	FV	XX
	3160	FV	U1	U1	FV	
	3180	U1	FV			
	3190	FV	U2			
	31A0			U2		

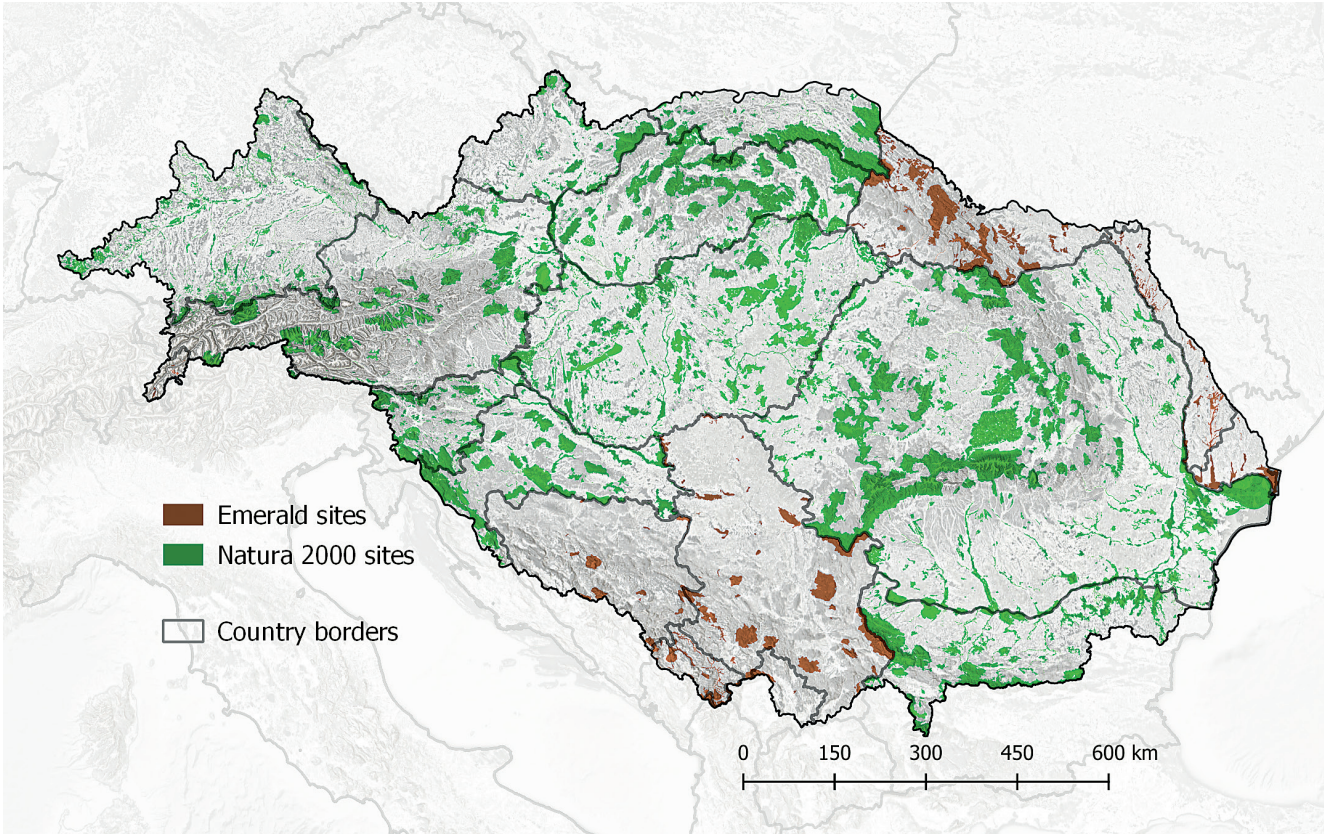


Figure 2. Natura 2000 and Emerald sites located in the study area

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

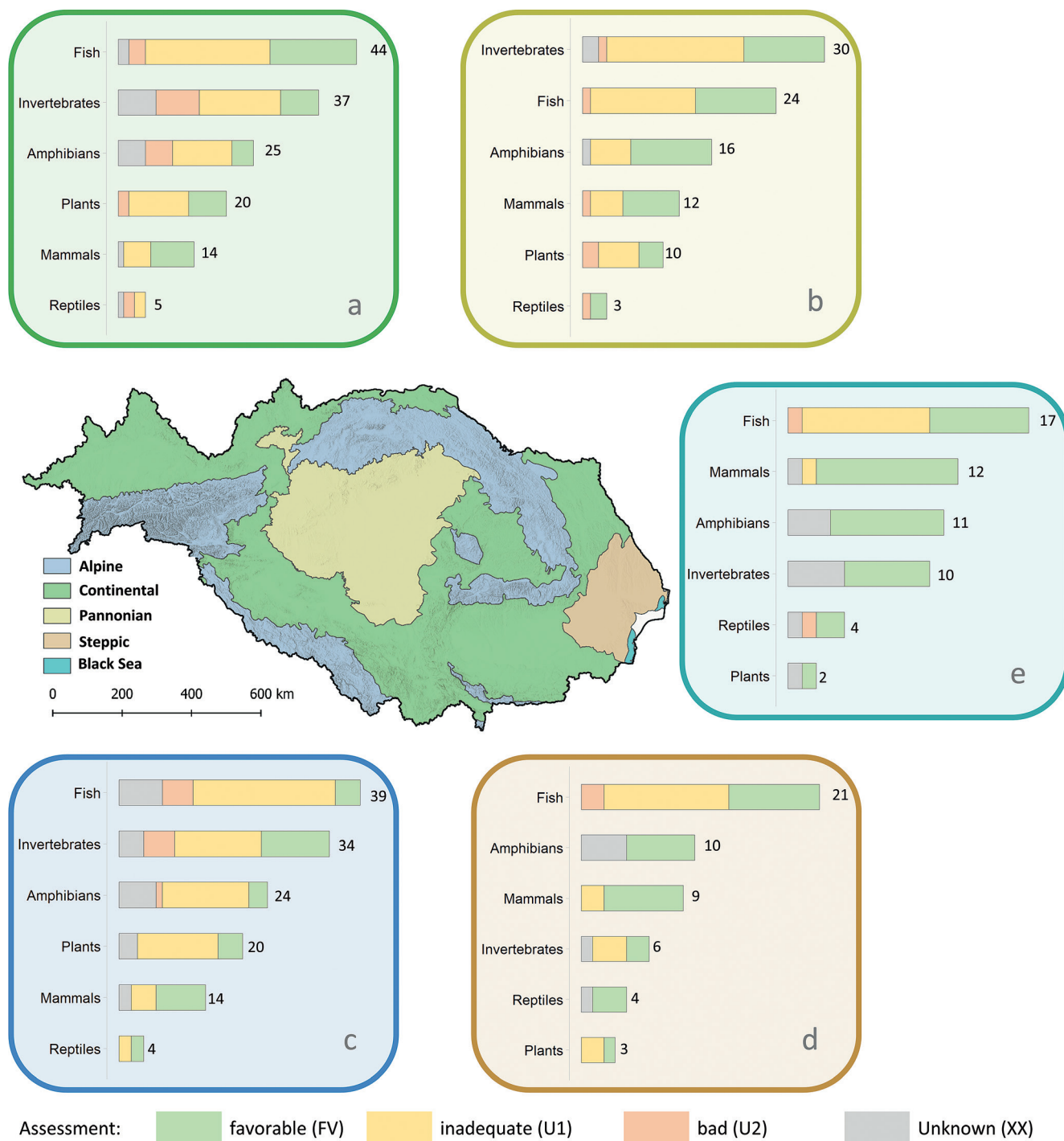


Figure 3. Status of structures and functions of the species habitats in the Continental (a), Pannonian (b), Alpine (c), Steppe (d) and Black Sea (e) regions. The species are here grouped into taxonomical groups and summed up (adapted from Schinegger et al. 2024).

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 pro-

grams 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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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 Slovakia. 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