Restoration of the Danube River Basin for ecosystems and people from mountains to coast

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Connectivity assessment for fish in the Danube River basin

International conference on protecting and restoring free-flowing rivers in Europe, Groningen, Netherlands

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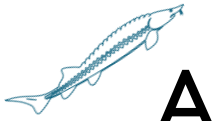
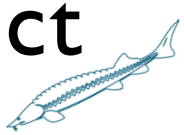
AGENDA

- About Danube4All
- Defining connectivity
- Technique used
- Challenges and Solutions
- Demonstration



About the Danube4All project



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14

48

Ambition

Development of a strategic **Danube Basin Restoration Action Plan**.

Objectives

Scientific, social and economic collaboration that integrates:

- Ecological status and biodiversity improvement and ecosystem connectivity
- Flood and drought risk reduction
- Enhancement of sediment continuity
- Economic interests
- Inhabitants' interests and Citizen Science

DEFINING CONNECTIVITIES

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Free-flowing river

"The 25 000 km of free-flowing rivers is intuitively easy to understand: it suggests rivers (and lakes) in a natural state, undisturbed in their natural functions, unhindered by artificial barriers."

"However, there is no established consensus as to what criteria would define a free-flowing river that could count towards the EU target. Similarly, **a ready-to-use indicator to measure free-flowing rivers currently does not exist**."

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Connectivity dimensions

Connectivity - Type

- Longitudinal
- Lateral
- Vertical
- Temporal

Connectivity - Aspect

- Flow
- Sediment
- Biota
- Physicochemical
- Nutrient

AI-generated image

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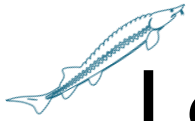
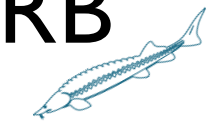


Longitudinal connectivity for fish in the DRB



TECHNIQUE USED

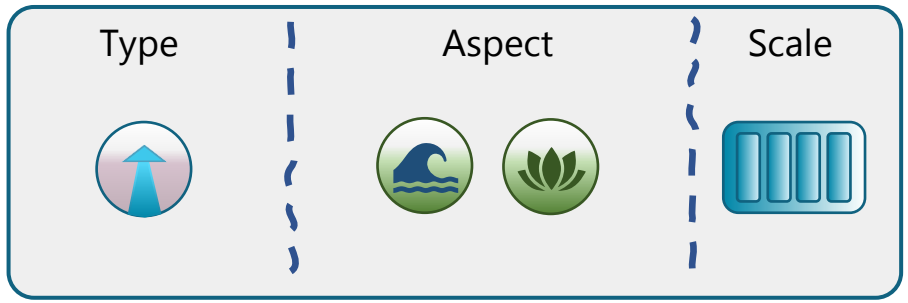
Riverconn (R package)

Notes

Tool that calculates longitudinal connectivity indices following several methods;

https://damianobaldan.github.io/riverconn_tutorial/

Connectivity



Data requirements

River network, habitat suitability, location and passability of the barriers

0.0 – 1.0

complete blockage – fully passable for fish

Index name	Reference	Index type	Weight	c_{ij}	B_{ij}
Dendritic Connectivity Index (DCI)	Cote et al. (2009)	CCI	Reach length	Symmetric passabilities	No
Population Connectivity Index (PCI)	Rodeles et al. (2021)	CCI	Reach length	Symmetric passabilities	Exponential symmetric dispersal kernel
Probability of Connectivity (PC)	Pascual-Hortal and Saura (2006)	CCI	Reach/Habitat Area	No	Exponential symmetric dispersal kernel
Integral Index of Connectivity (IIC)	Pascual-Hortal and Saura (2006)	CCI	Reach/Habitat area	No	Binary symmetric dispersal probabilities
Volume-based River Connectivity Index (RCI_{VOL})	Grill et al. (2014)	CCI	Reach volume	Symmetric passabilities	No
River Class Connectivity Index (RCI_{CLASS})	Grill et al. (2014)	CCI	Reach volume, unique reach classes	Symmetric passabilities	No
River Migration Connectivity Index (RCI_{RANGE})	Grill et al. (2014)	CCI	Potential number of migratory fish species	Symmetric passabilities	No
Stream Continuity Index (SCI)	Shao et al. (2020)	CCI	Stream order, reach length	Symmetric passabilities	No
Dendritic Connectivity Index for diadromous fish (DCId)	Cote et al. (2009)	RFI	Reach length	Symmetric passabilities	No
Breeding Area Connectivity Index (BACI)	Rodeles et al. (2019)	CCI	Habitat area	Binary passabilities	No
Residual Core Length (RCL)	Fuller et al. (2015)	CCI	Reach length	Binary passabilities	No
Catchment Area Fragmentation Index (CAFI)	Jumani et al. (2022)	BFI	Barrier upstream area	Symmetric passabilities	No
Catchment Area Rainfall Fragmentation Index (CARFI)	Jumani et al. (2022)	BFI	Barrier upstream precipitation	Symmetric passabilities	No

Table 1. Examples of connectivity indices that can be calculated with 'riverconn'. Index type refers to the typologies introduced in this paper. CCI: Catchment Fragmentation Index, RFI: Reach Fragmentation Index, BFI: Barrier Fragmentation Index.

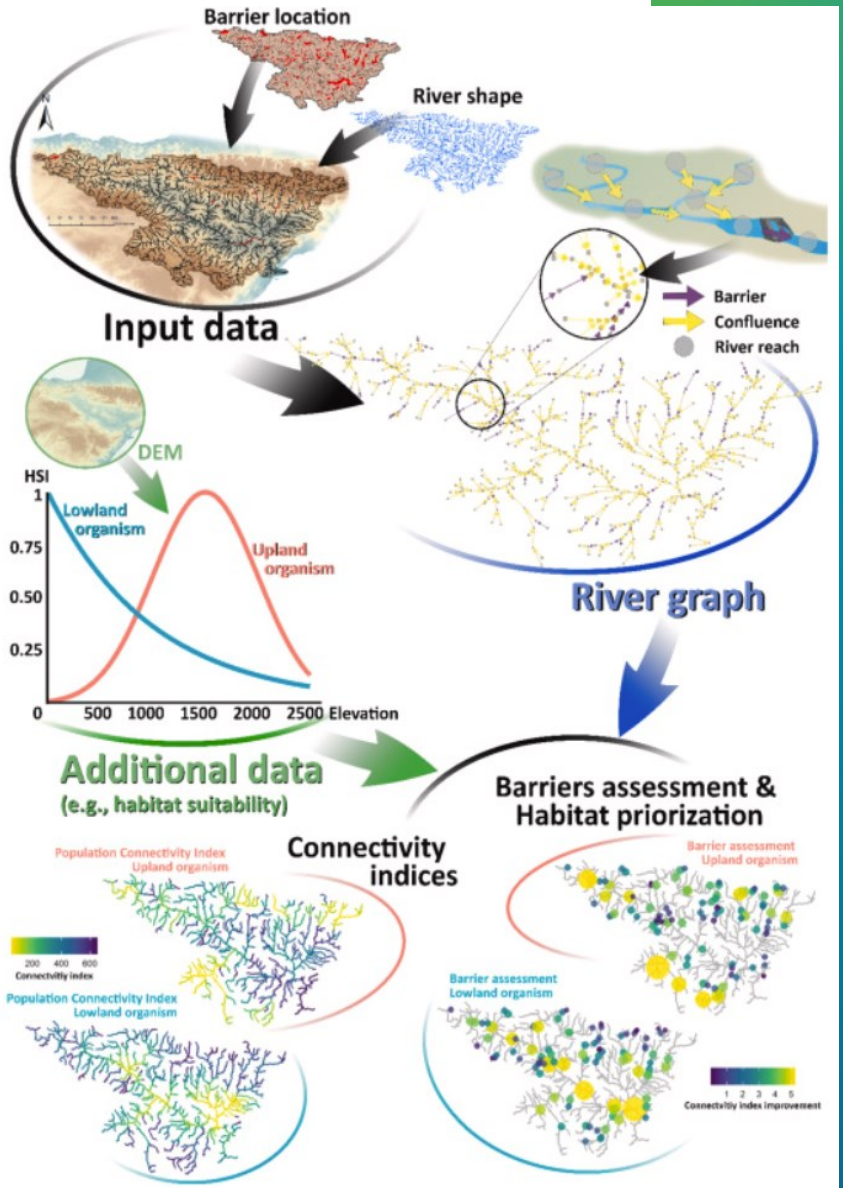


Fig. 1. Package workflow. DEM: Digital Elevation Model; HSI: Habitat Suitability Index.

Baldan, D., Cunillera-Montcusí, D., Funk, A., & Hein, T. (2022). Introducing 'riverconn': an R package to assess river connectivity indices. Environmental Modelling & Software, 156, 105470. https://doi.org/10.1016/j.envsoft.2022.105470

Riverconn (R package)

Notes

DCI: Assess connectivity based on expected probability of organism being able to move freely between two random points of the network.

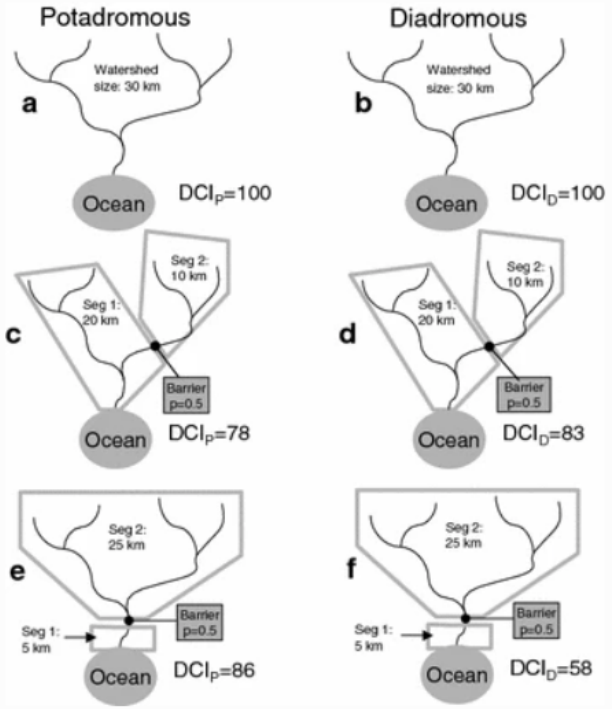
https://damianobaldan.github.io/riverconn_tutorial/

Connectivity

Data requirements

Number, passability, and location of barriers, river network

Fig. 1



Components of the Dendritic Connectivity Index (DCI). In systems with no barriers, the system is fully connected and the DCI has a maximum value of 100 for both life histories considered: potadromous (**a**) and diadromous (**b**). The introduction of a single barrier creates two stream sections, and the DCI is based on both the sizes (total channel lengths) of the resulting sections, the permeability of the barrier in both upstream and downstream directions (in this case, the product of the two permeabilities = 0.5) and in the diadromous case, the location relative to the downstream end (represented by the ocean) of the system (**b**, **c**). Changing the barrier location to create a greater inequality in stream section sizes results in a more connected system (higher DCI) for the potadromous life history (**e**), and moving the barrier closer to the ocean significantly reduces connectivity (lower DCI) for the diadromous life history (**f**)

Cote, D., Kehler, D.G., Bourne, C. et al. A new measure of longitudinal connectivity for stream networks. Landscape Ecol 24, 101–113 (2009). https://doi.org/10.1007/s10980-008-9283-y

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Longitudinal connectivity for fish in the DRB

CHALLENGES AND SOLUTIONS

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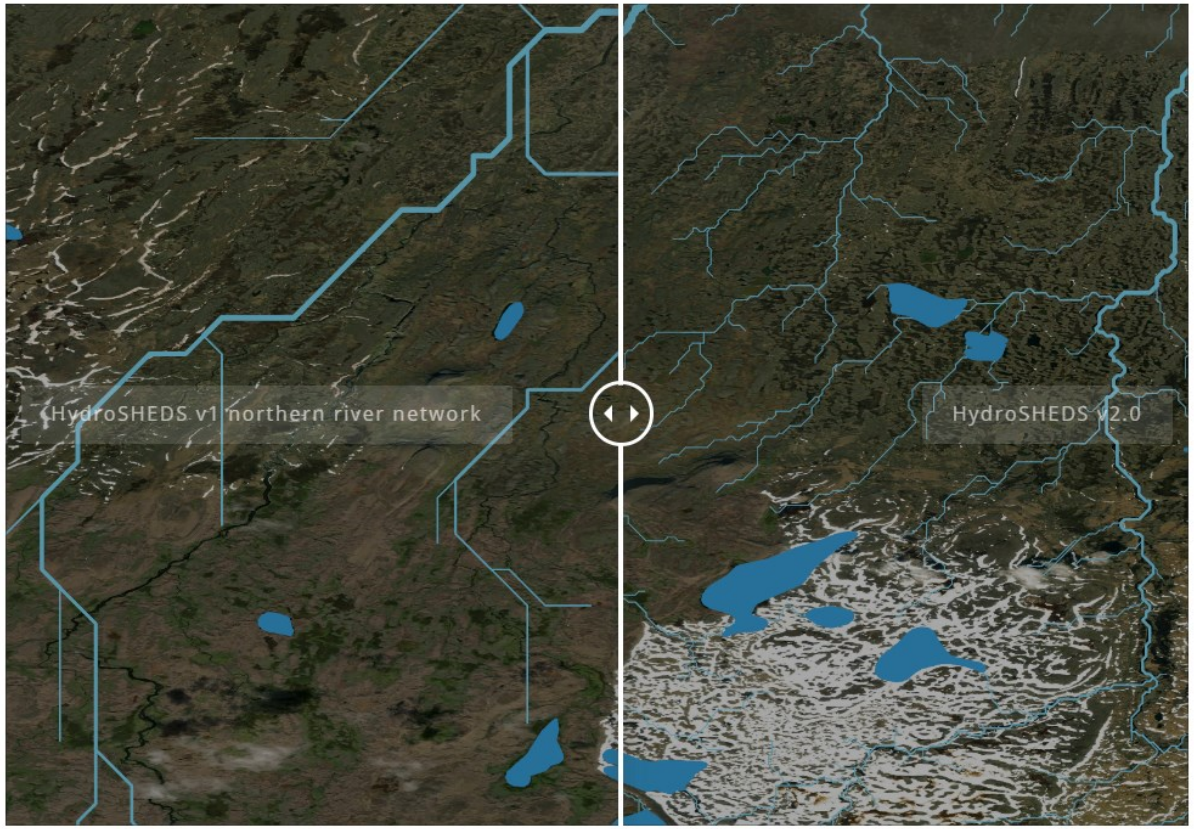
Challenges and solutions

RIVER NETWORK: ▶ HYDROSHED

Concerns and Solutions

- Inconsistent datasets (National, International & EU databases)
- Simplified (but consistent) dataset
  - Unrealistic layout on microscale
  - No islands, or branches, side arms included
- ICPDR evaluation criteria has been followed for tributary selection (>4000 km^2)



The left image depicts the HydroSHEDS v1 river network (produced in northern regions from coarser HYDRO1k elevation data) and the right image depicts the HydroSHEDS v2 preliminary river network (produced at 90 m resolution). Slide to compare the two river networks.

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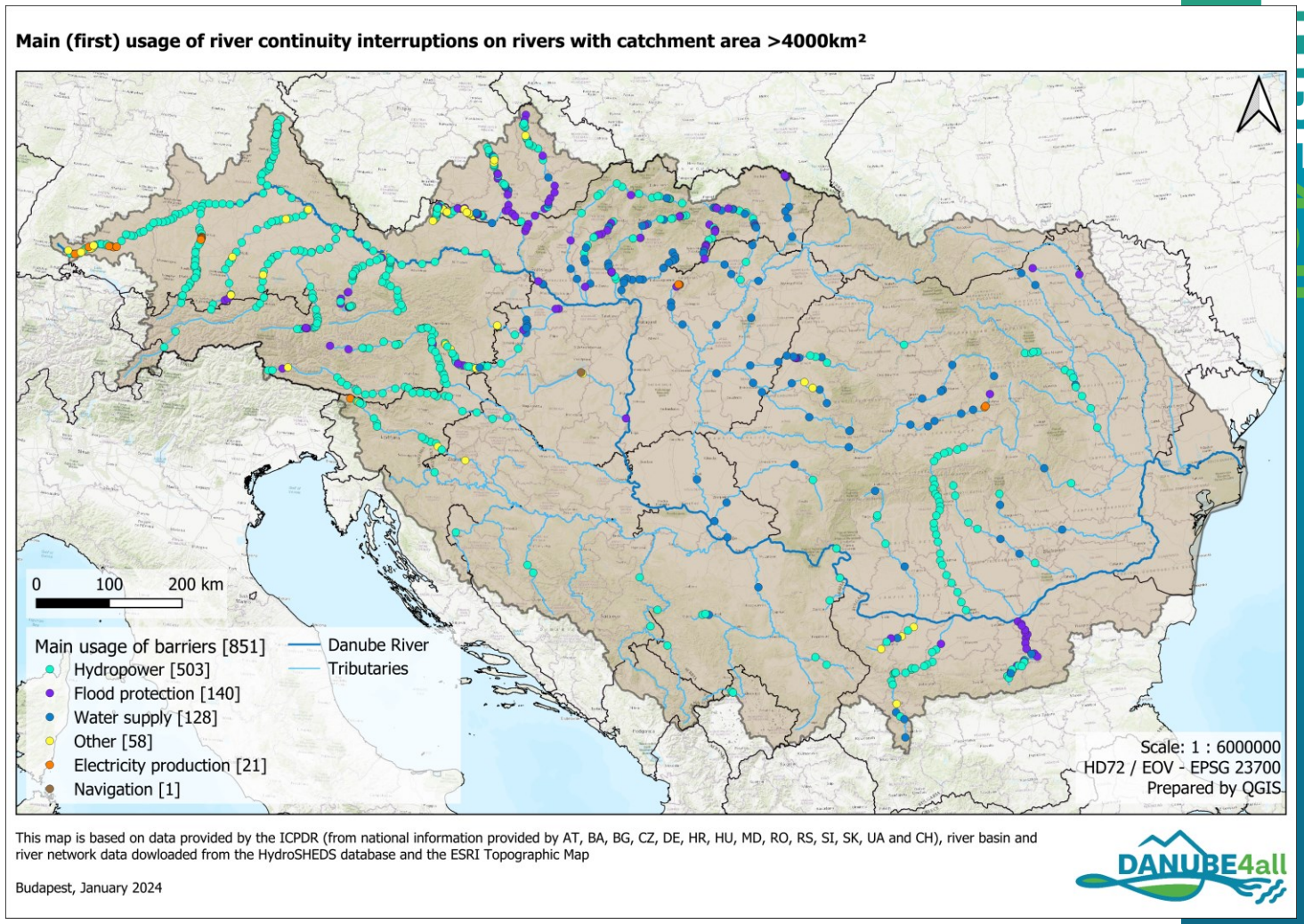
Challenges and solutions

BARRIER DATABASE:

Concerns and Solutions

- Incomplete datasets (e.g.: AMBER)
- Not only dams, but weirs, groynes, sills also found in some databases
- Passability assessment are mostly unknown
- **ICPDR** dataset provide a good basis



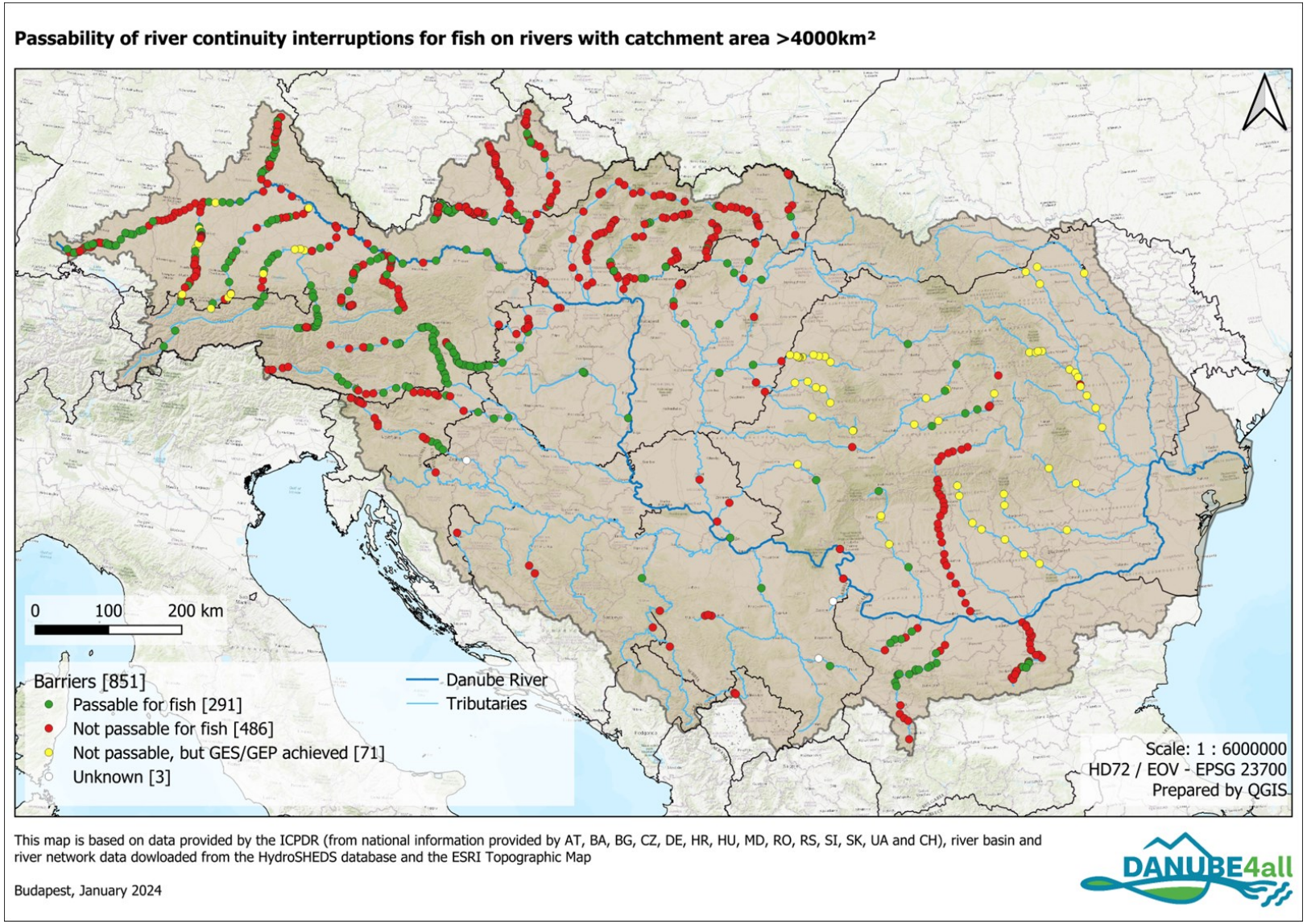
Challenges and solutions

BARRIER DATABASE:

ICPDR database:

- Access to the reported barriers and their binary passability from the countries

- Looking for a more qualitative assessment



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Challenges and solutions

Passability evaluation:

Rapid Barrier Assessment

- Based on the method presented by:

  King, S., O'Hanley, J.R., Newbold, L.R., Kemp, P.S. and Diebel, M.W. (2017), A toolkit for optimizing fish passage barrier mitigation actions. Appl Ecol, 54: 599-611. https://doi.org/10.1111/1365-2664.12706

Qualitative assessment	Assigned **passability** value
Complete barrier to fish passage	**0.0**
Passable to a small proportion of fish or passable only for short periods of time	**0.3**
Passable to a high proportion of fish or for long periods of time	**0.6**
A fully passable barrier	**1.0**

- Set up passability profiles for barriers based on their selected characteristics:

$$\mathrm{p_{dir}} = \frac{\sum p_{dir,i} * p_{dir,w_i}}{n}$$

- Where

  $\mathrm{p_{dir}}$ - passability value per direction (upstream or downstream)

  $\mathrm{p_{dir,}}_{i}$ - assigned pre-passability value per characteristic parameter *i*

  $\mathrm{p_{dir,w_i}}$ - weight of assigned pre-passability value for characteristic parameter *i*

  n – total number of characteristics

Barrier characteristics from the ICPDR dataset:

- Barrier type
- Barrier height
- Is it equipped with fish aid facility or not
- Main usage of barriers

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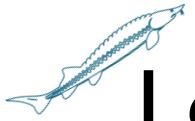

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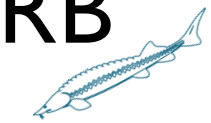
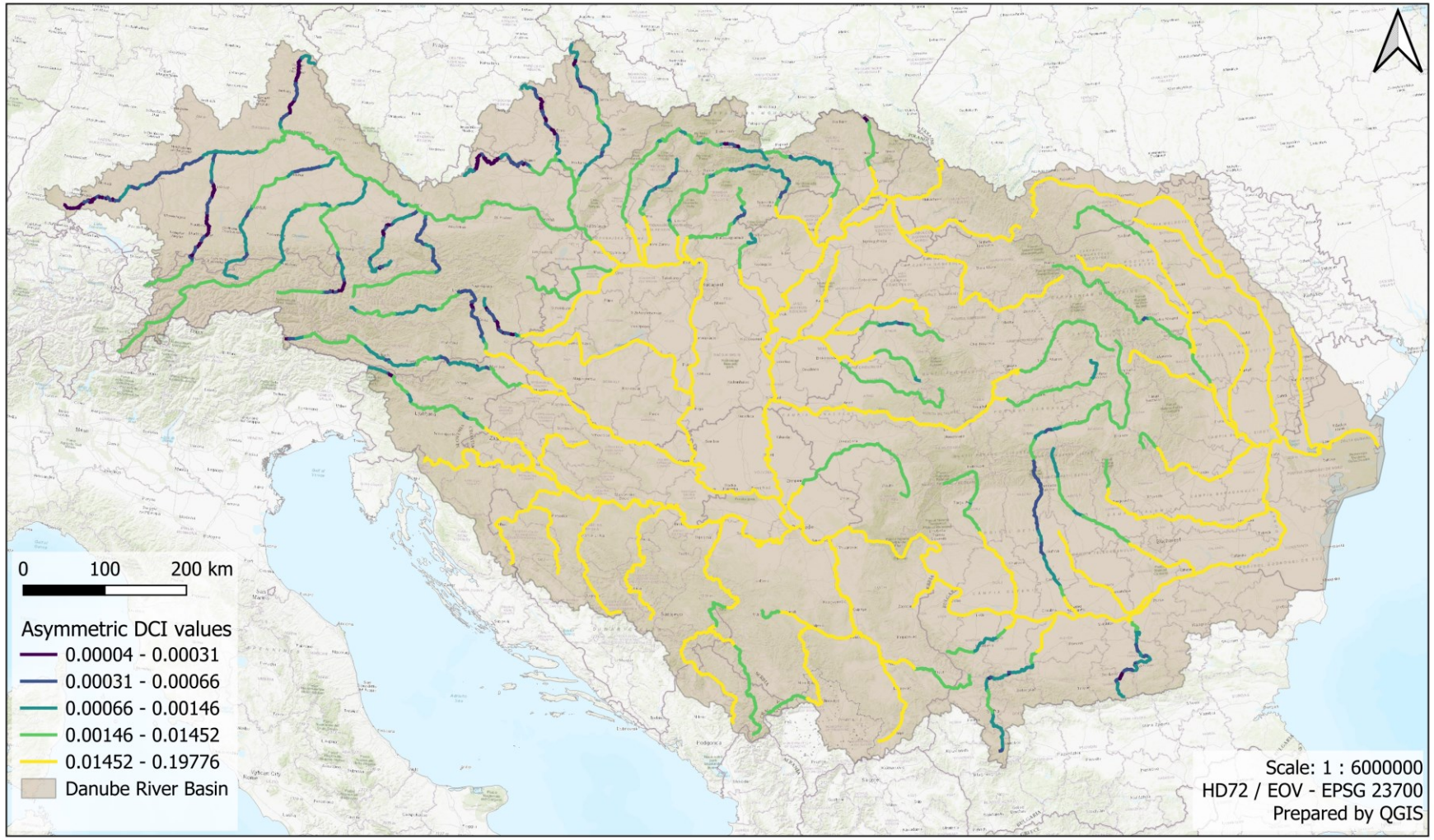


DEMONSTRATION and beyond

Longitudinal connectivity evaluation for fish

Asymmetric DCI of barriers of the Danube River Basin, based on calculated downstream and upstream passability values (River continuity interruptions investigated on rivers with catchment area >4000km²)



Better conditions

This map is based on data provided by the ICPDR (from national information provided by AT, BA, BG, CZ, DE, HR, HU, MD, RO, RS, SI, SK, UA and CH), river basin and river network data dowloaded from the HydroSHEDS database and the ESRI Topographic Map

Budapest, February 2024

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Longitudinal connectivity evaluation for fish

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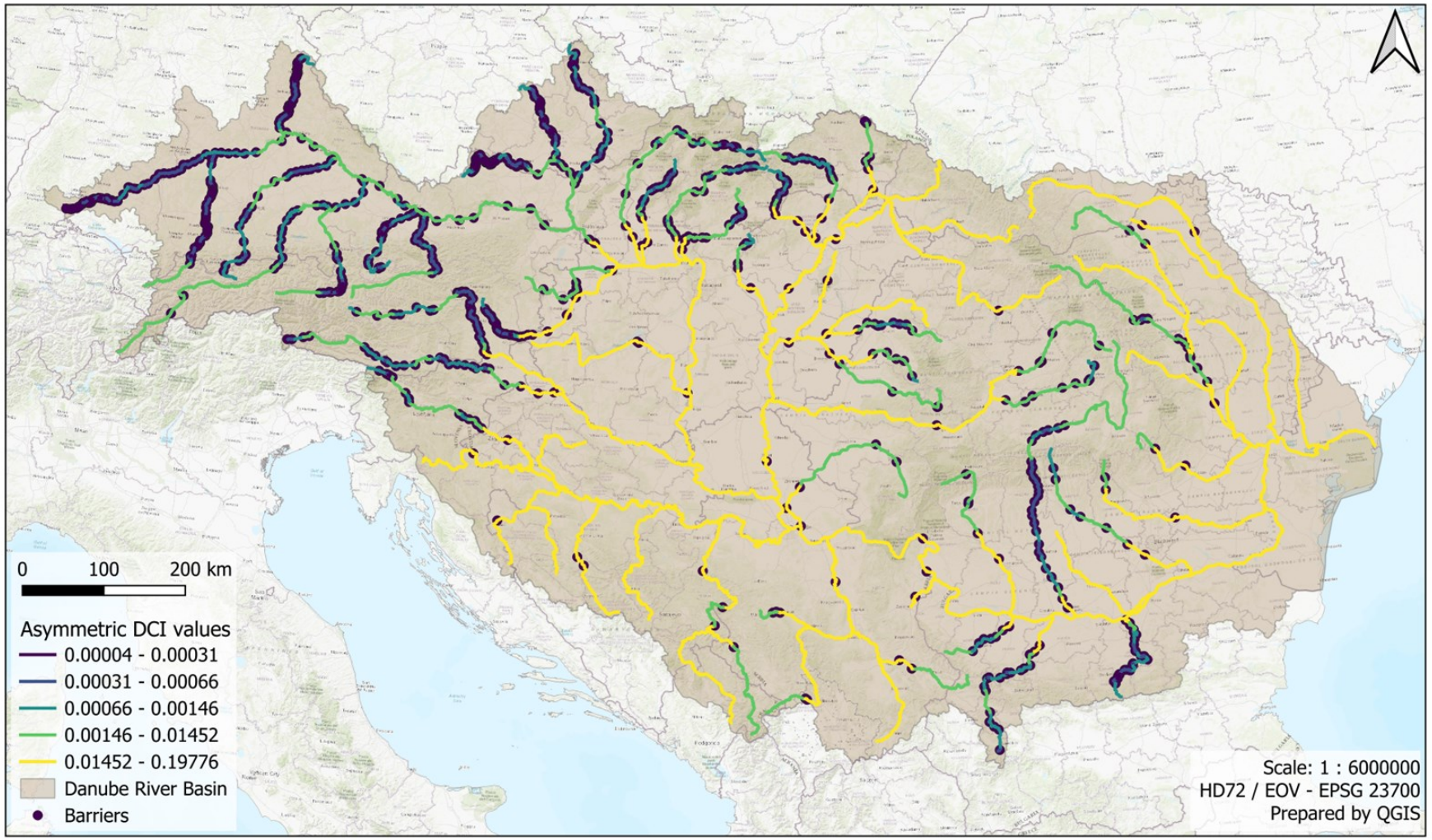

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Budapest, February 2024

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Thank you!

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