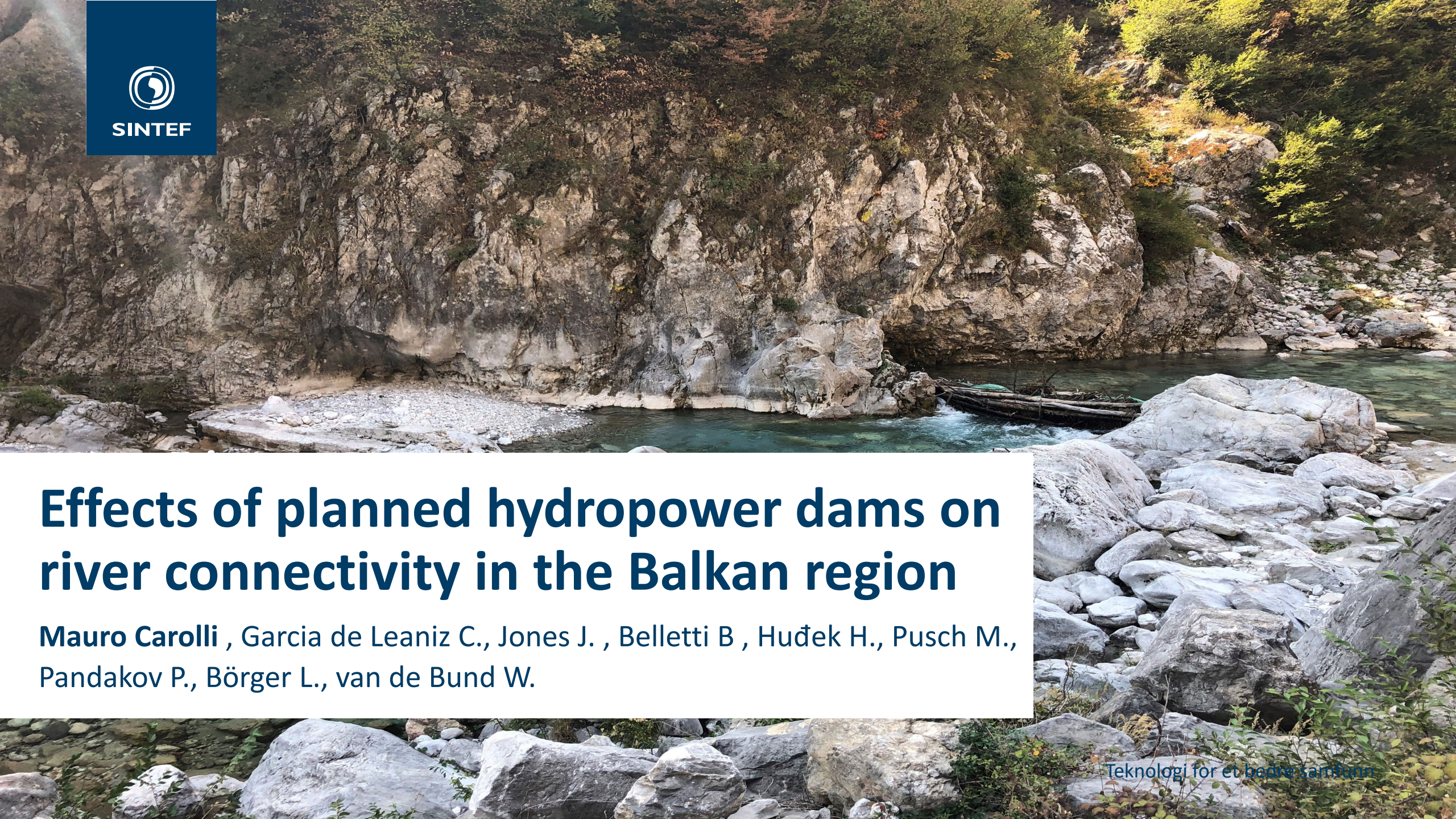


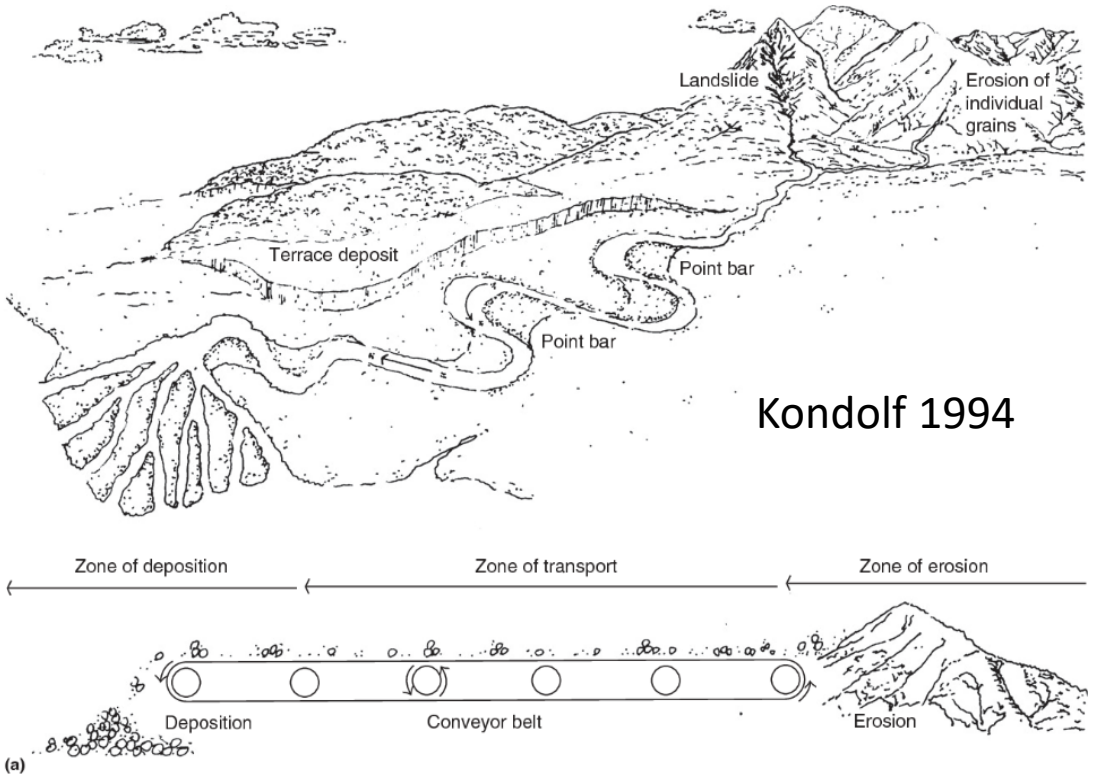
Effects of planned hydropower dams on river connectivity in the Balkan region

Mauro Carolli , Garcia de Leaniz C., Jones J. , Belletti B , Huđek H., Pusch M., Pandakov P., Börger L., van de Bund W.

Teknologi for et bedre samfunn

Connectivity and fragmentation

- Rivers are ecosystem with high biodiversity
- Natural rivers processes depend on the flow of water and sediments



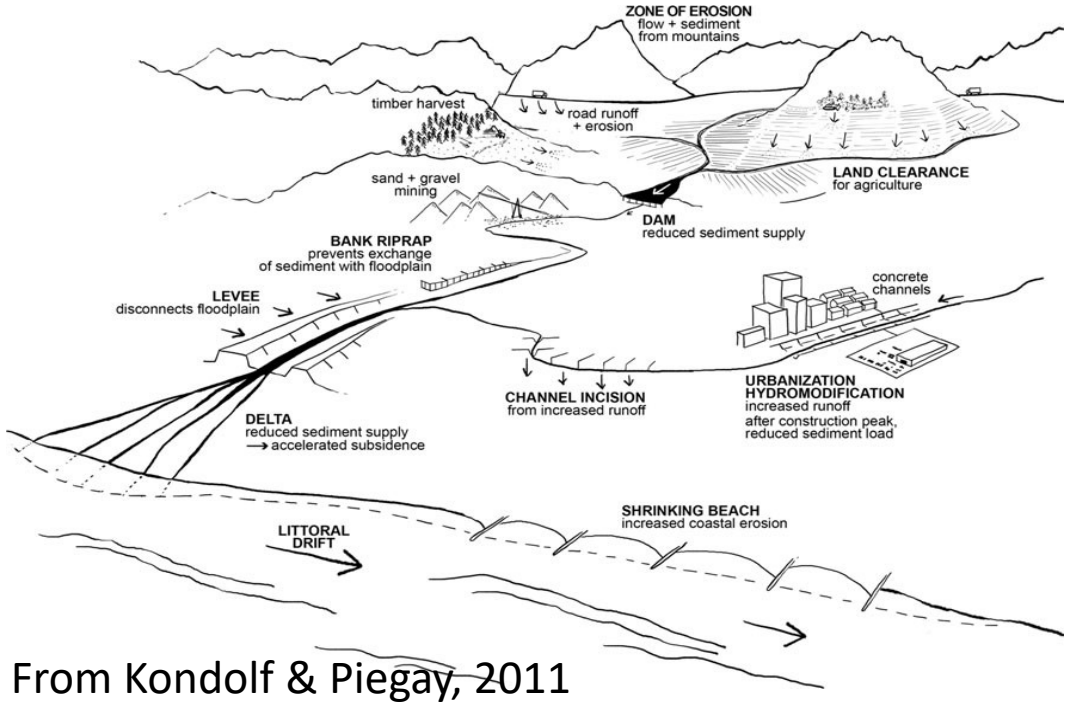
Kondolf 1994

Connectivity and fragmentation

- Rivers are ecosystem with high biodiversity
- Natural rivers processes depend on the flow of water and sediments
- Rivers provide a large range of ecosystem services to the human activities:
  - Navigation
  - Water supply
  - Recreational activities
  - Hydropower

Connectivity and fragmentation

- Many activities requires the construction of barriers
- Barriers increase river fragmentation
  - Decrease connectivity
  - Modifies natural processes
- Research questions:
  - How many barriers?
  - Where?
  - Which type?



From Kondolf & Piegay, 2011

The AMBER project

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689682.

- The AMBER project conducted the assessment of river connectivity at the European scale
- Cross-referenced barrier records from 120 databases from 36 countries
- Barriers grouped in 7 different types

The AMBER project

- The AMBER project conducted the assessment of river connectivity at the European scale
- Cross-referenced barrier records from 120 databases from 36 countries
- Barriers grouped in 7 different types

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689682.

The AMBER project

- The AMBER project conducted the assessment of river connectivity at the European scale
- Cross-referenced barrier records from 120 databases from 36 countries
- Barriers grouped in 7 different types
- Total reported barriers: 630,000
- Correction factor based on:
  - Ground-truthing the databases (147 rivers surveyed across 26 countries, 2,715 km)
  - Modelling barrier density (Random forest based on anthropic and environmental predictors)
- Corrected number: 1,210,000 - barriers are twice than reported
- European barriers density 0.38 n/km - corrected 0.74 n/km

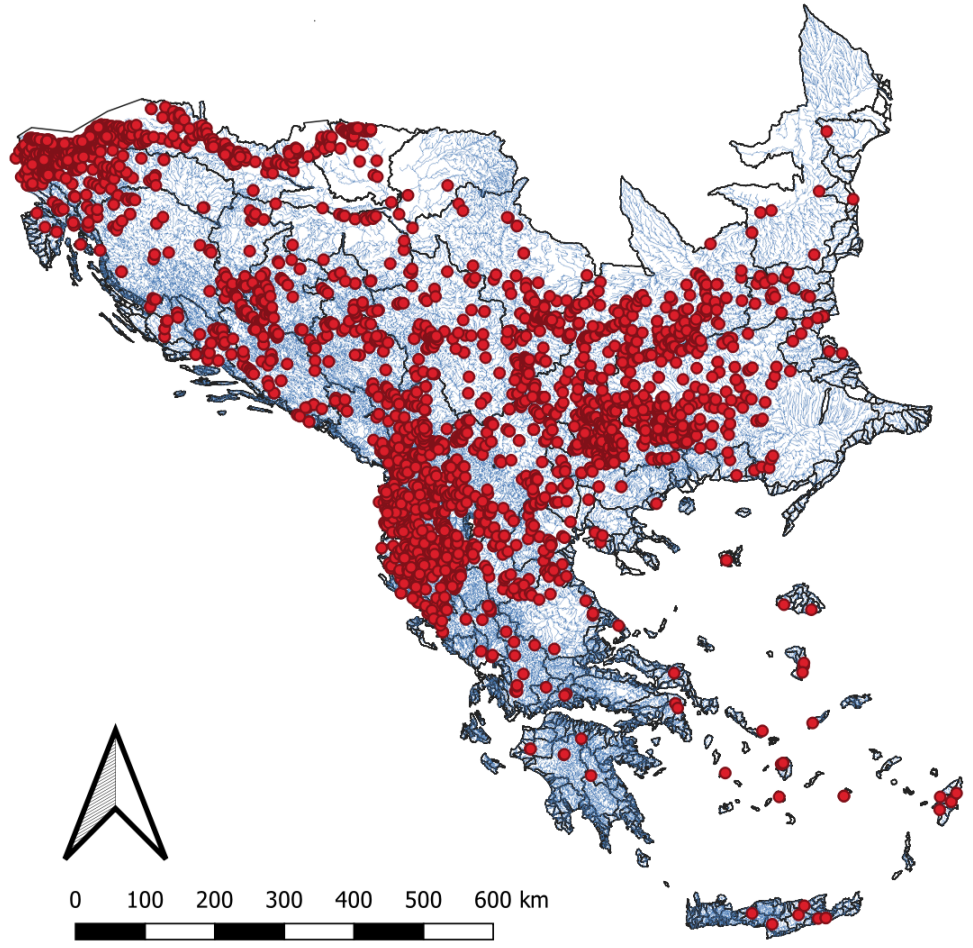
- Further info:
  - AMBER Atlas https://amber.international/
  - Belletti et al. 'More than One Million Barriers Fragment Europe's Rivers'. Nature 588, no. 7838 (17 December 2020): 436–41. https://doi.org/10.1038/s41586-020-3005-2.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689682.

Focus on the Balkan region

- Balkan river network: 250,000 km
- High diversity: from headwaters to European largest river (Danube River)
- Biodiversity hot-spot
- Home of the last Europe free-flowing rivers ?
- 3181 existing barriers of any type

	Length surveyed (km)	Barriers in the Atlas	Barriers in field	Minimum error	Maximum error	Average Atlas barrier density (n/km)
Total	629	33	220	40% (Slovenia)	98% (Albania)	0.01 (0.33)



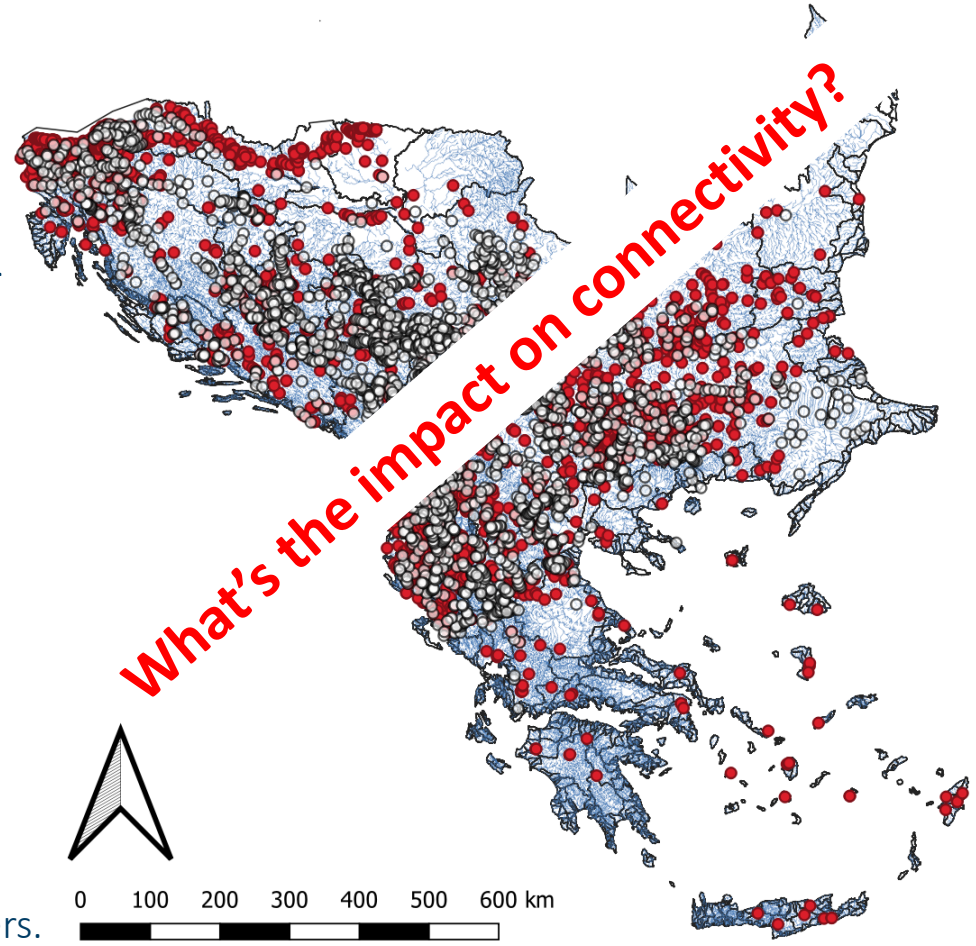
Corrected: 83,017 barriers

Europe avg: 0.74 n/km

The hydropower development

- Large unexploited hydropower potential
- 2983 new projects in the area
  - Data from Schwarz, 2019; integration with data from other datasets

	Number of barriers	Total installed capacity (MW)	% small plants (≤10 MW)	% large plants (>10 MW)
Total	2983	29,048	90.85 (2698)	9.15 (285)



Schwarz, U., 2019. Hydropower pressure on European rivers: the story in numbers. WWF, RiverWatch, EuroNatur, GEOTA, p. 40.

Quantifying fragmentation

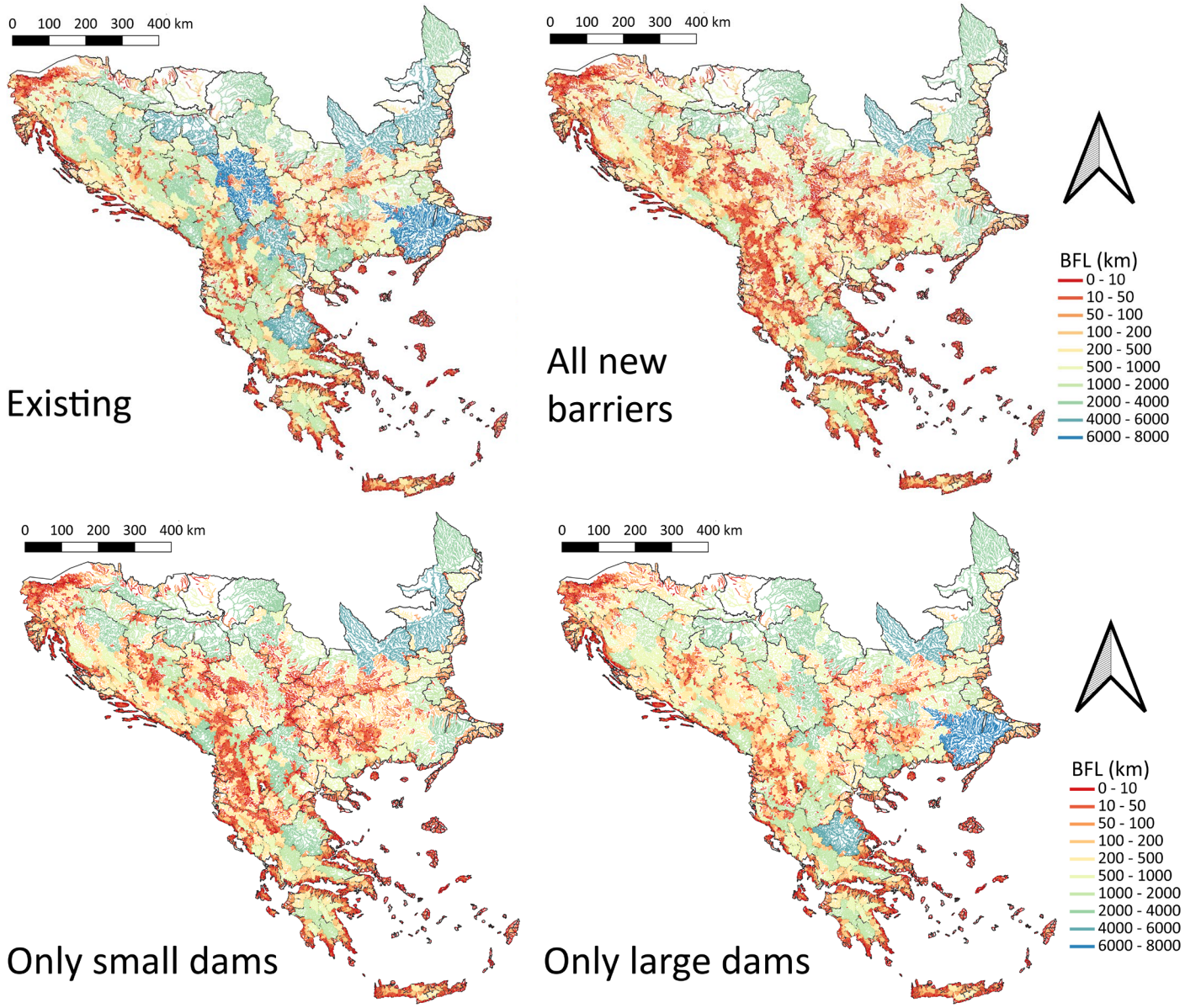
- Different metrics to quantify river fragmentation
  1. **Barrier Free Length (BFL)** is the length between pairs of consecutive barriers
  2. $\mathrm{l_{Max}}$ is the length of the longest barrier-free segment in each basin
  3. $\mathrm{BFL_{Max}} = \frac{\mathrm{l_{Max}}}{\mathrm{L}} * 100$ is the standardised longest barrier-free segment for each basin
  4. $\mathrm{DCI_p} = \sum_{i=1}^{n} \frac{l_i^2}{L^2} * 100$ dendritic connectivity index for potadromous species

- Comparing existing with future conditions in different scenarios:
  - Existing barriers (reference scenario)
  - All new barriers
  - Only large dams (> 10 MW installed capacity)
  - Only small dams (< 10 MW installed capacity)

BFL

- River network is already fragmented
- Decrease in all the scenarios
- The Adriatic catchments are more affected
- Compared to large dams, small dams have a larger effect

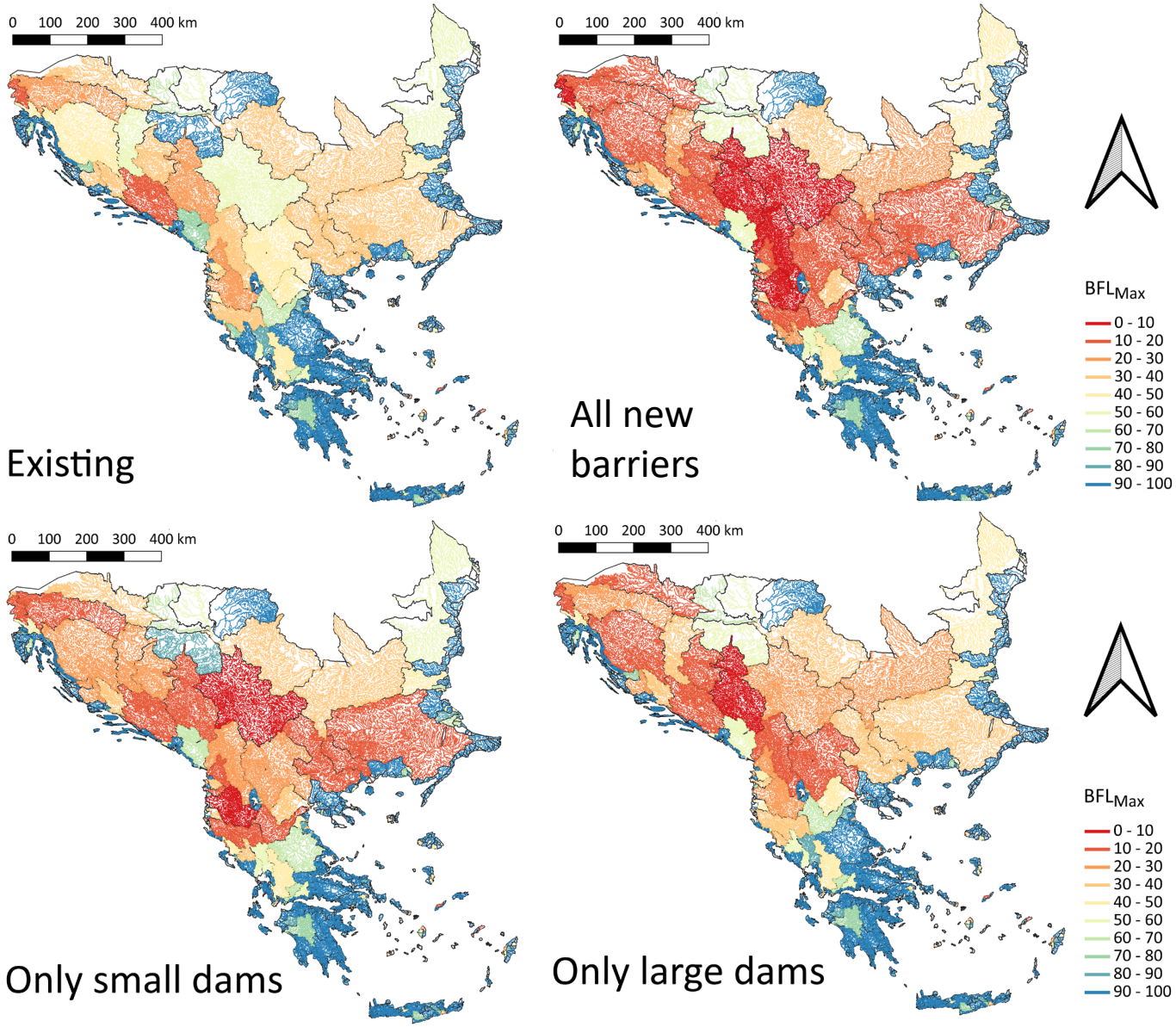
Scenario	Existing	All	Only small	Only large
BFL [km]	78.4 (360.0)	41.4 (164.7)	42.8 (188.6)	71.9 (274.3)



BFL_{MAX}

- One value for each catchment
- Decrease in each scenario
- Adriatic catchments and catchment in Bulgaria more impacted

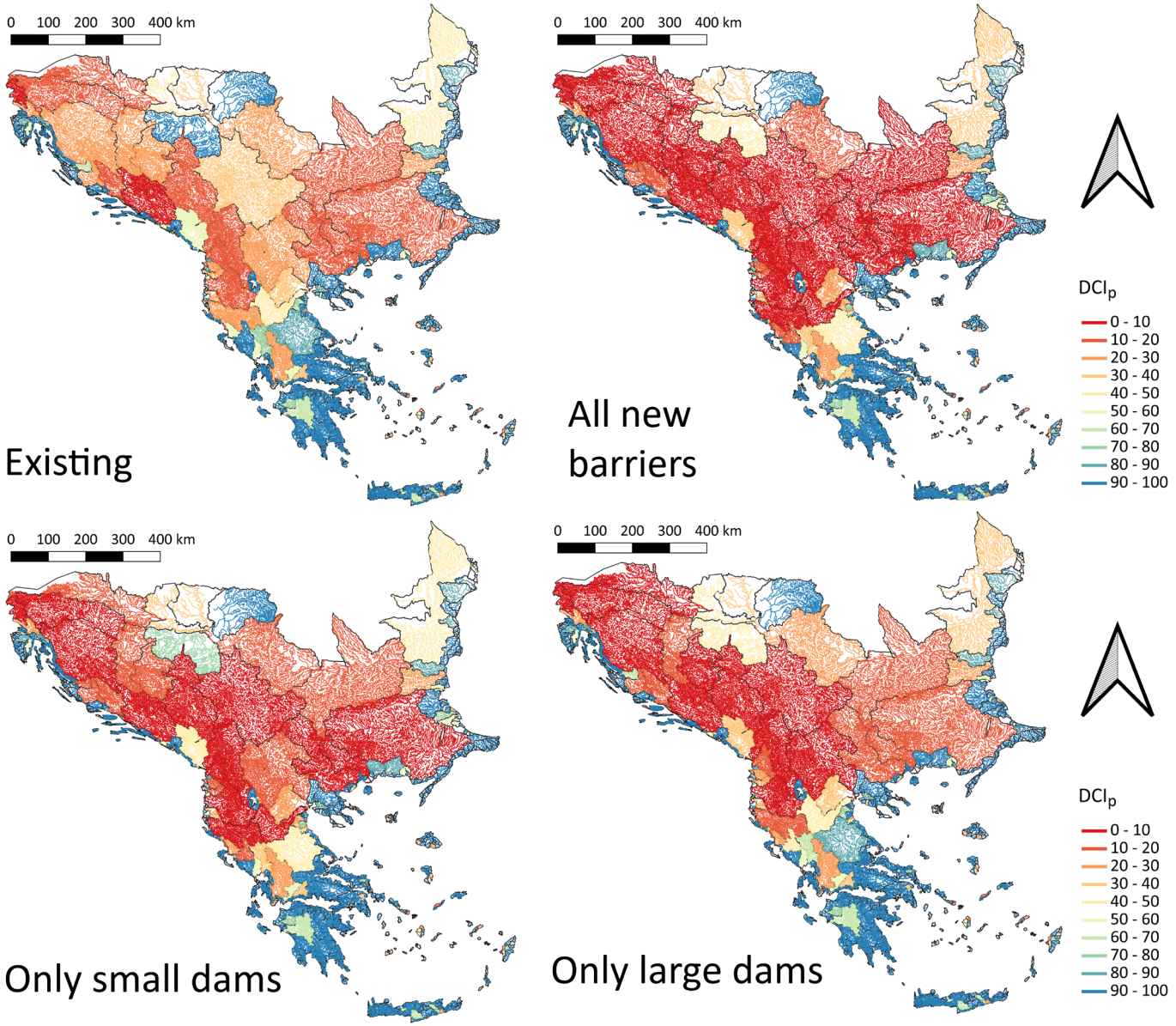
Scenario	Existing	All	Only small	Only large
l_{Max} [km]	801 (1465)	466 (816)	549 (964)	610 (1089)
BFL_{Max} [%]	61.7 (27.7)	53.8 (28.6)	55.4 (27.6)	59.7 (28.7)



DCI_p

- Decrease in each scenario
- Smaller difference between small and large dams scenarios

Scenario	Existing	All	Only small	Only large
DCI_p [%]	53.6 (31.2)	43.9 (29.9)	45.0 (29.6)	50.4 (31.8)



Results

- BFL, BFL_{Max}, DCI_p in the future scenarios are statistically different from reference scenarios (ANOVA Kruskal-Wallis and Friedman, $p < 0.001$)

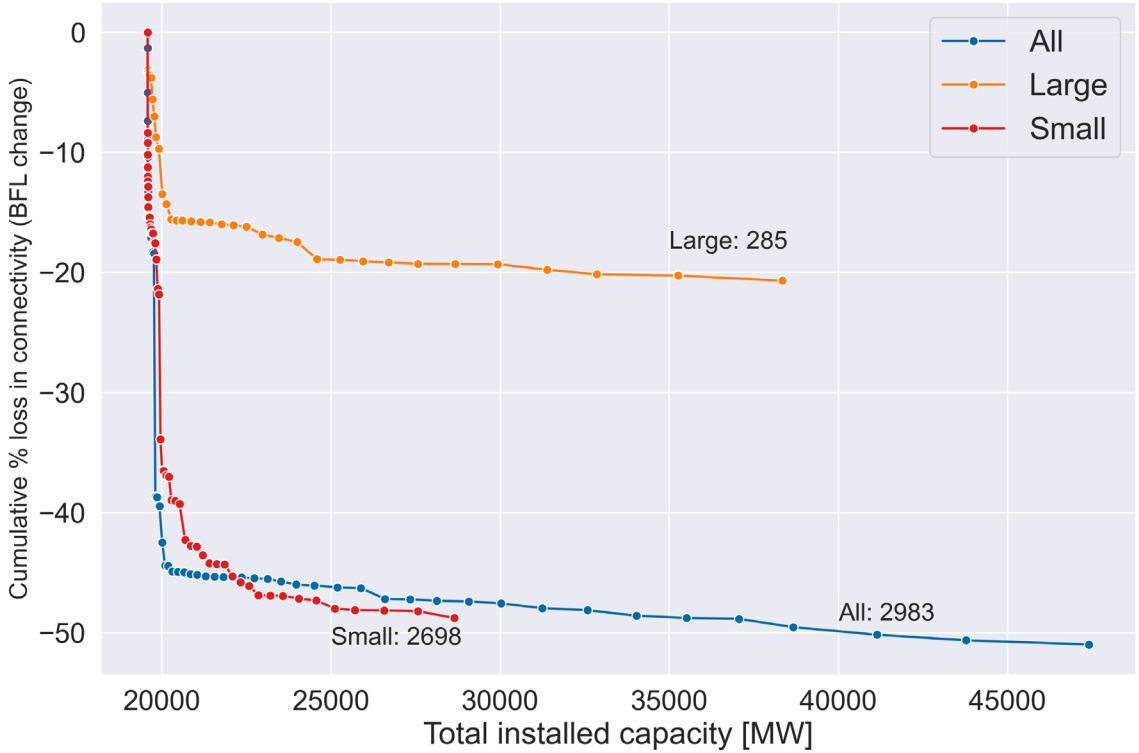
- The river network is already fragmented BUT
- All future scenarios will increase river fragmentation (decrease connectivity)
- Some areas are more impacted than others
- Small dams have a larger and more widespread effect
  - They are 90% of the new barriers
- What is the effect of the barriers in relation to installed capacity?

Trade-off: connectivity and hydropower

- BFL loss vs total installed capacity, cumulated for each scenario
  - Y axis is negative
  - Total installed capacity equal to the current capacity plus the planned capacity

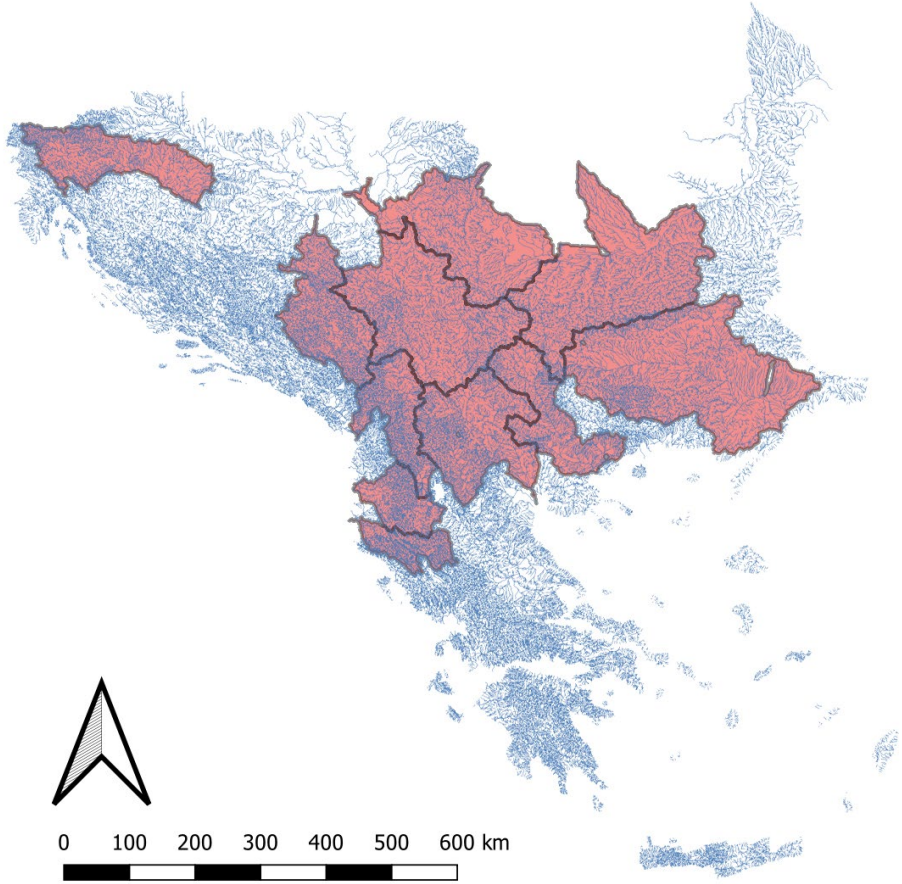
Scenario	All	Only small	Only large
N barriers	2983	2698	285
Production [MW]	27833	9061 (33%)	18772 (67%)
Connectivity [%]	-51%	-48.8%	-20.7%

- Higher resolution: some barriers have a large effect vs a small contribution to the production



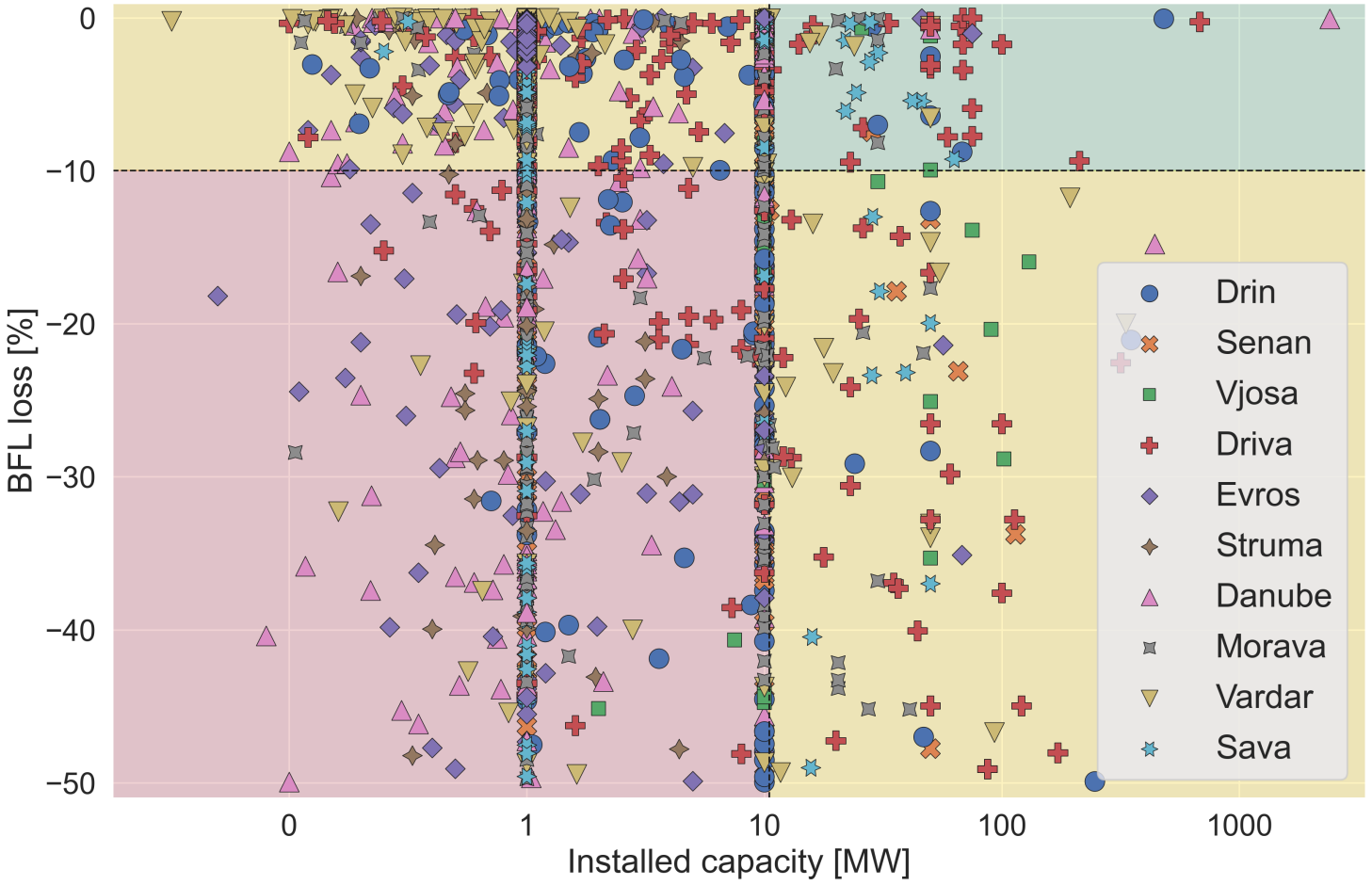
Trade-off: connectivity and hydropower

- Hydropower development in 61 basins
- 70% (2036) new barriers are in 10 basins
- Area is 43% of the total
- 148 large plants, 1281 plants ≤1 MW



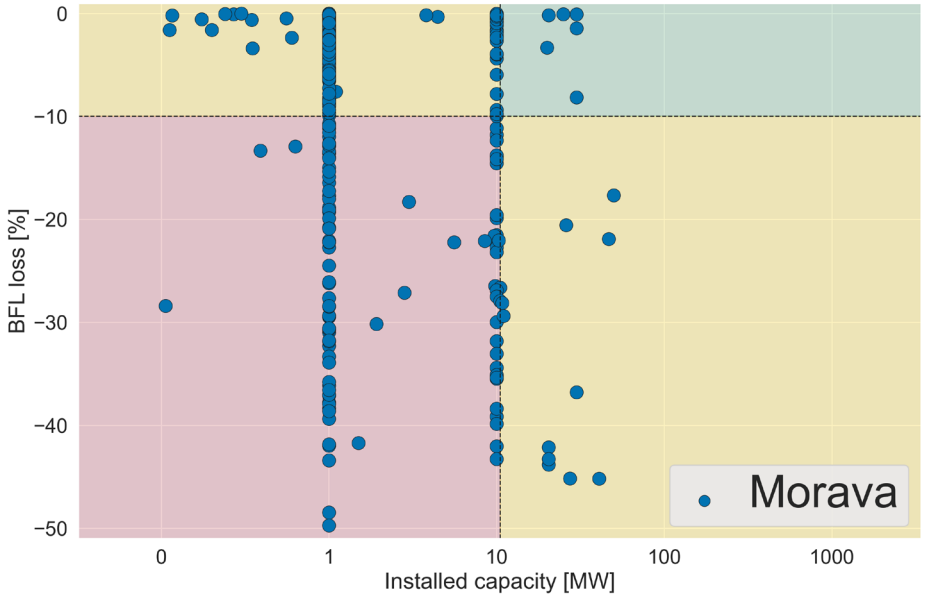
Trade-off: connectivity and hydropower

- Hydropower development in 61 basins
- 70% (2036) new barriers are in 10 basins
- Area is 43% of the total
- 148 large plants, 1281 plants ≤1 MW
- BFL loss vs installed capacity
  - Yellow areas: low impact - low production OR high impact - high production
  - Red area: high impact - low production
  - Green area: low impact – high production
- Prioritize projects in the green area



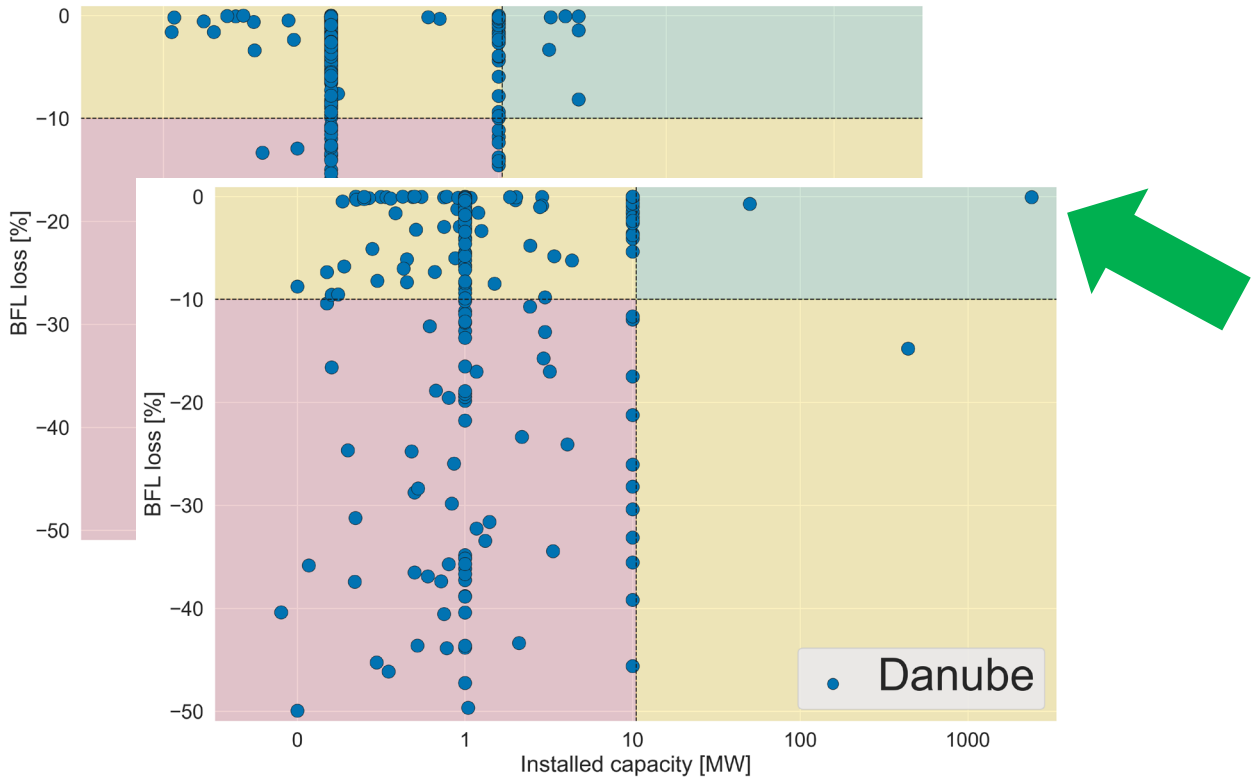
In detail

- Morava catchment
  - 535 projects
  - 442 projects ≤1 MW
  - 6 green, 20 high production



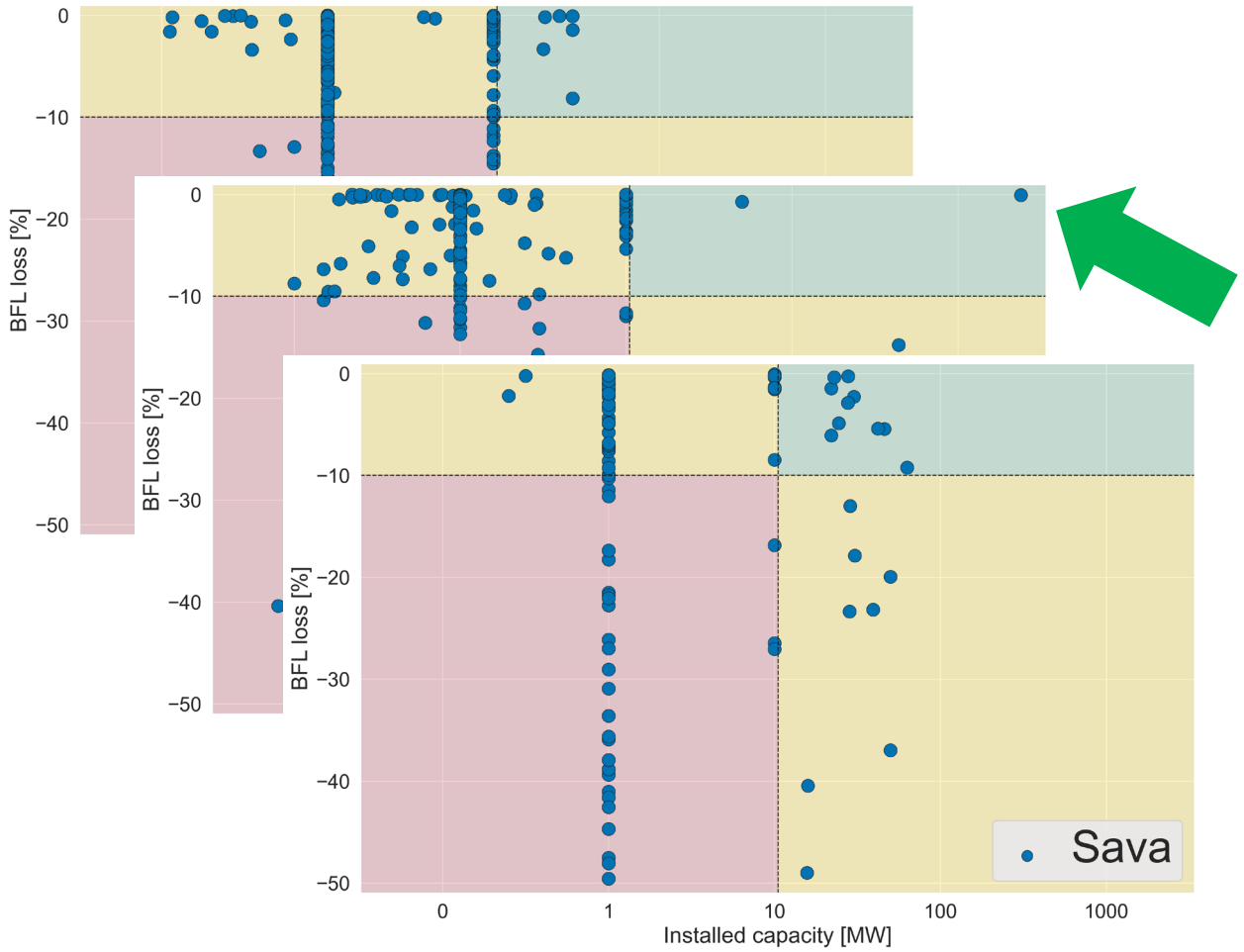
In detail

- Morava catchment
  - 535 projects
  - 442 projects ≤1 MW
  - 6 green, 20 high production
- Danube catchment
  - 228 projects
  - 169 projects ≤1 MW
  - 2 green, 3 high production



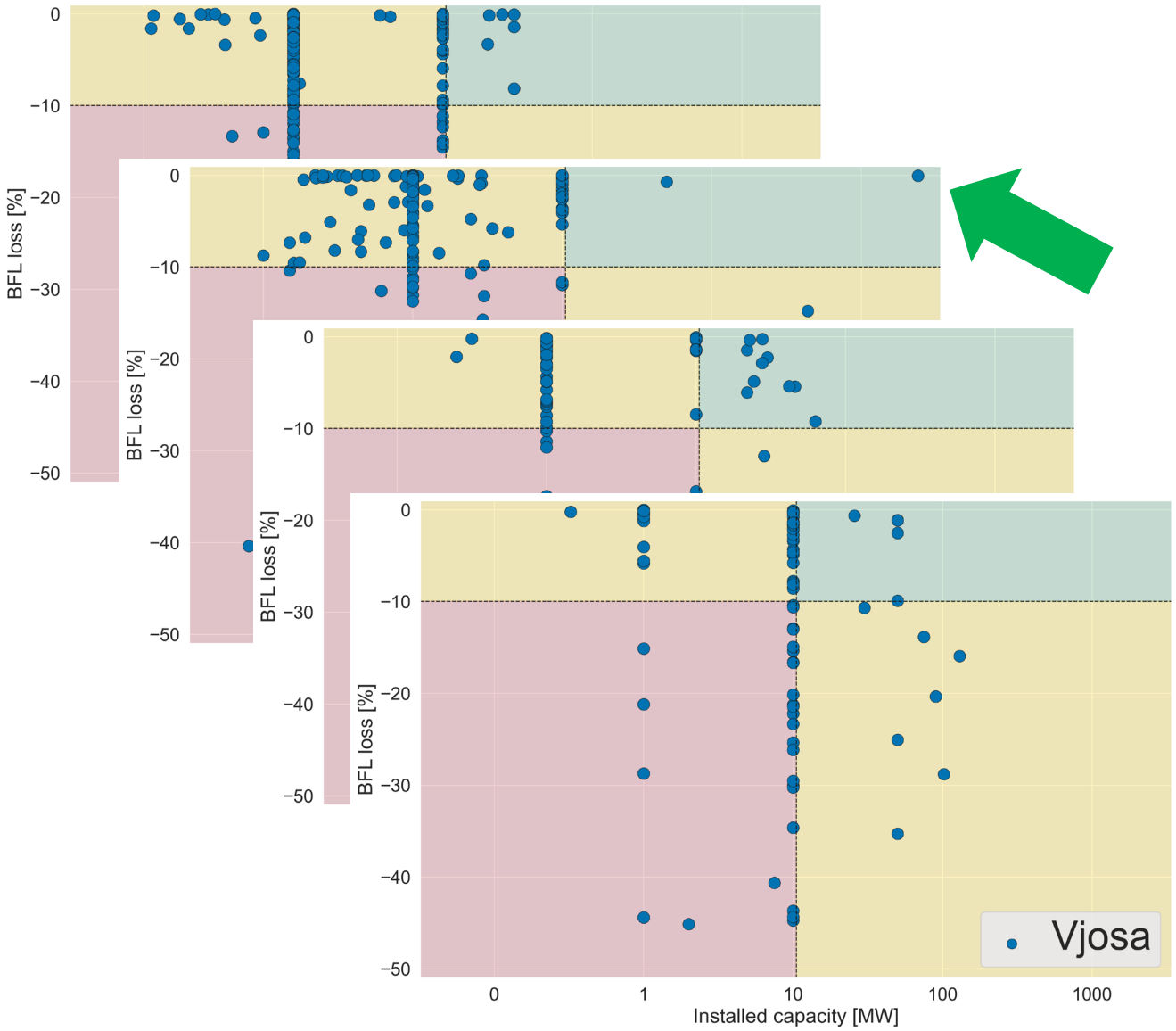
In detail

- Morava catchment
  - 535 projects
  - 442 projects ≤1 MW
  - 6 green, 20 high production
- Danube catchment
  - 228 projects
  - 169 projects ≤1 MW
  - 2 green, 3 high production
- Sava catchment
  - 104 projects
  - 75 projects ≤1 MW
  - 10 green, 18 high production



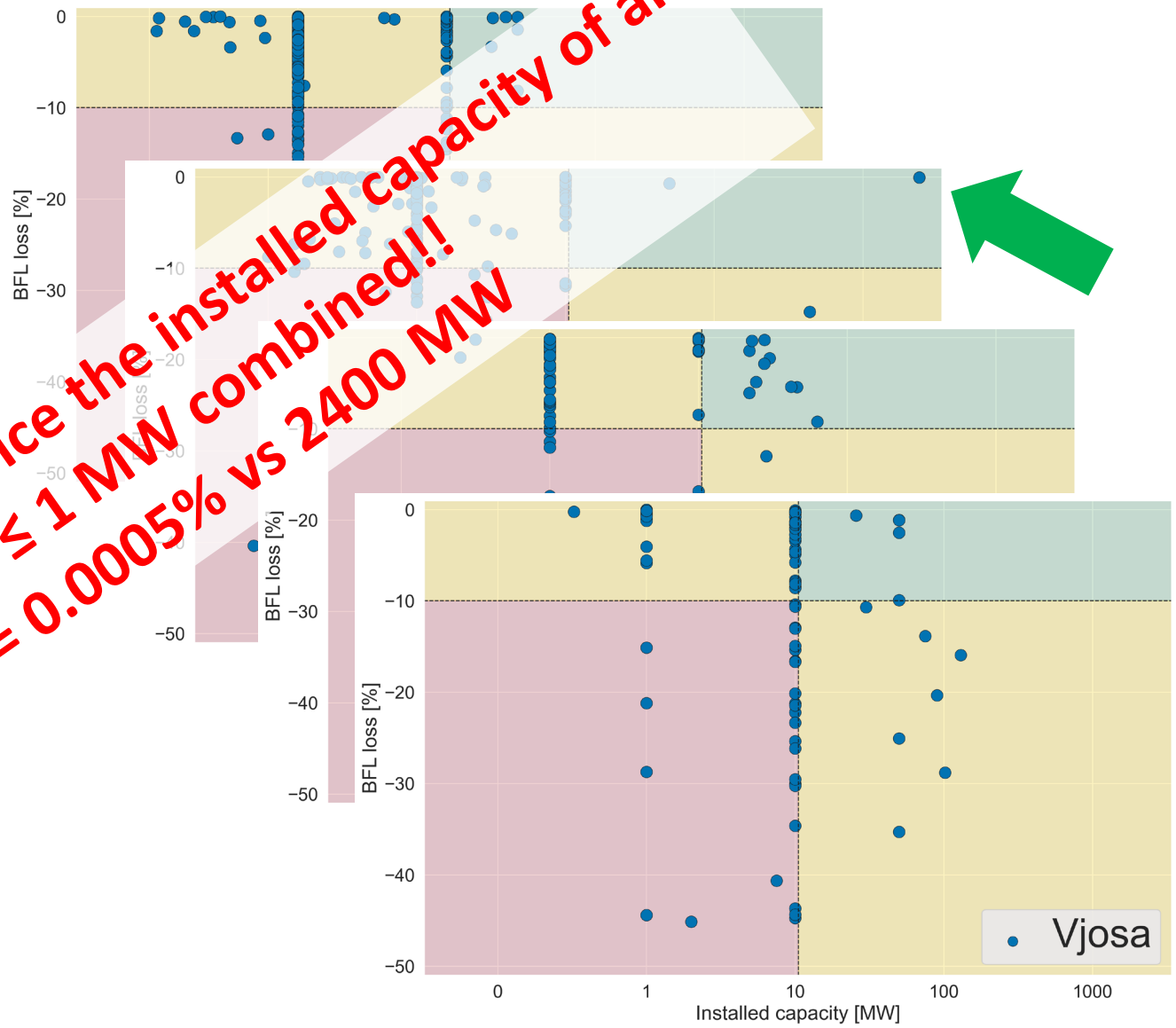
In detail

- Morava catchment
  - 535 projects
  - 442 projects ≤1 MW
  - 6 green, 20 high production
- Danube catchment
  - 228 projects
  - 169 projects ≤1 MW
  - 2 green, 3 high production
- Sava catchment
  - 104 projects
  - 75 projects ≤1 MW
  - 10 green, 18 high production
- Vjosa catchment
  - 99 projects
  - 3 green, 10 high production



In detail

- Morava catchment
  - 535 projects
  - 442 projects ≤1 MW
  - 6 green, 20 high production
- Danube catchment
  - 228 projects
  - 169 projects ≤1 MW
  - 2 green, 3 high production
- Sava catchment
  - 104 projects
  - 75 projects ≤1 MW
  - 10 green, 18 high production
- Vjosa catchment
  - 99 projects
  - 3 green, 10 high production



One pumping project twice the installed capacity of all the plants ≤ 1 MW combined!!
BFL Loss = 0.0005% vs 2400 MW

Limits of the approach

- Analysis only on longitudinal connectivity
  - no information about lateral or vertical
- Did not include barriers passability
- Underestimation of the effect of the existing barriers
  - Estimation of “how many they might be” but not “where they are”
- Large dams have a high production and minor effects on fragmentation, but a huge impact on flow regime, sediment regime, habitat
  - Might encounter strong opposition by local communities (see the movie “Blue heart – the fight for Europe’s last wild rivers”)
- Effects of large dams is well-studied, small dams are less investigated
- Cumulative ecological effect of small dams might be more harmful than larger dams
- Effects are case-specific

Conclusions

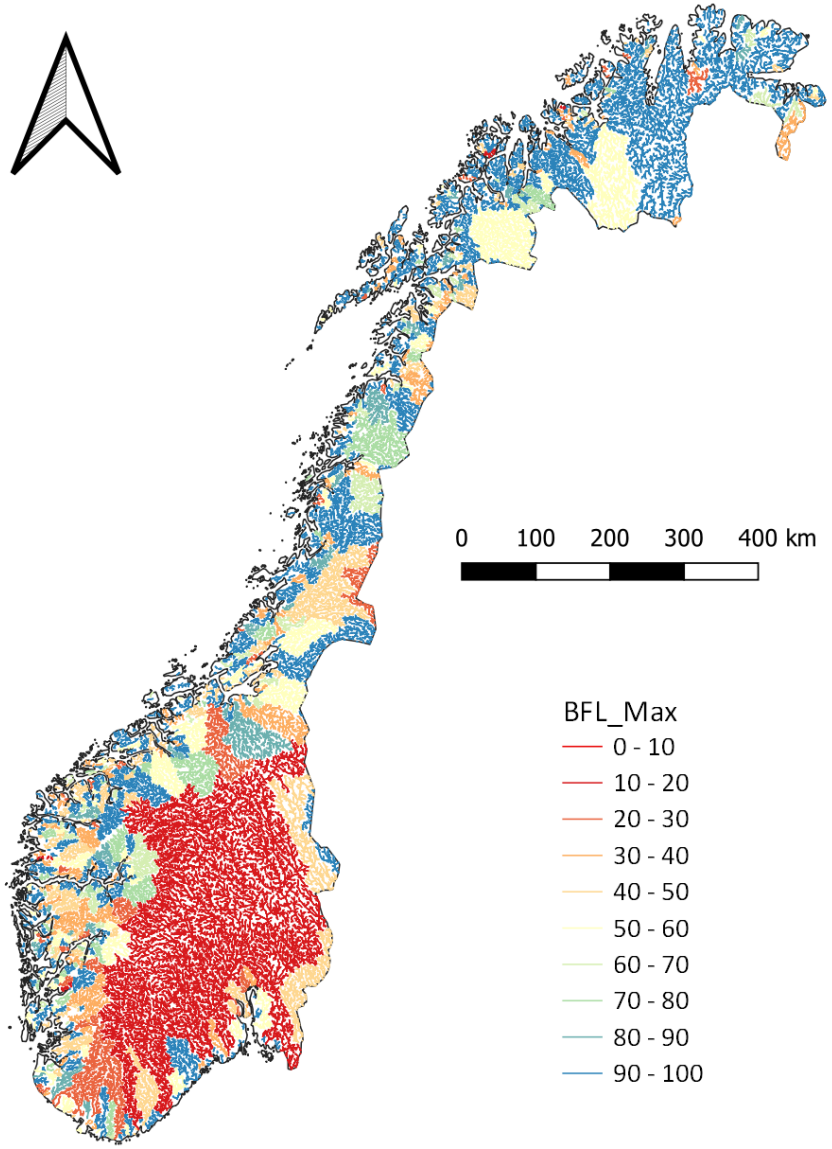
- Most of the planned projects in the Balkan region are small plants
- Small contribution to the production, major impact on river fragmentation
- Trade-off analysis assists in identifying projects to prioritize: prefer projects with high production - low impact
- Conflict with the EU directives (for the countries complying with the WFD and the EU Taxonomy)
- Case –specific effects: perform SEA and EIA for hydropower projects, not mandatory in all the countries in the area

Barriers in Norway

- 3980 barriers (corrected 9045) – Error 56%
- Preliminary analysis
  - Red catchments: Glomma, Drammenselva

Open questions

- Many dams built on existing natural lakes
  - Which contribute to fragmentation?
- Distance of the barrier from the river mouth
  - Barriers in the headwaters have minor impacts on migratory species?
- Sediment supply and transport
  - Lower compared to the Balkans: what's the influences of barriers on Norwegian rivers morphology?



For more information:

Science of the Total Environment 871 (2023) 161940

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Impacts of existing and planned hydropower dams on river fragmentation in the Balkan Region

Mauro Carolli [a], Carlos Garcia de Leaniz [b,*], Joshua Jones [b,1], Barbara Belletti [c,2], Helena Huđek [d], Martin Pusch [d], Pencho Pandakov [e], Luca Börger [b], Wouter van de Bund [f]

Article

More than one million barriers fragment Europe's rivers

https://doi.org/10.1038/s41586-020-3005-2

Received: 28 June 2020

Accepted: 26 October 2020

Published online: 16 December 2020

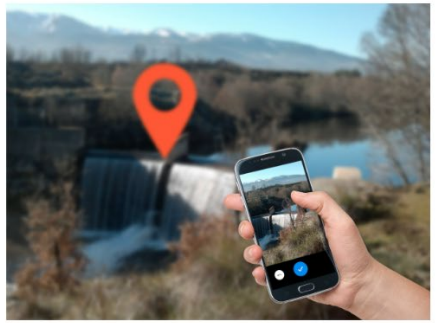
Check for updates

Barbara Belletti[1,29], Carlos Garcia de Leaniz[2]✉, Joshua Jones[2], Simone Bizzi[1,30], Luca Börger[2], Gilles Segura[3,4], Andrea Castelletti[1], Wouter van de Bund[5]✉, Kim Aarestrup[6], James Barry[7], Kamila Belka[8], Arjan Berkhuysen[9], Kim Birnie-Gauvin[6], Martina Bussettini[10], Mauro Carolli[11], Sofia Consuegra[2], Eduardo Dopico[12], Tim Feierfeil[13], Sara Fernández[12], Pao Fernandez Garrido[9], Eva Garcia-Vazquez[12], Sara Garrido[14], Guillermo Giannico[15], Peter Gough[9], Niels Jepsen[6], Peter E. Jones[2], Paul Kemp[16], Jim Kerr[16], James King[7], Małgorzata Łapińska[8,17], Gloria Lázaro[14], Martyn C. Lucas[18], Lucio Marcello[19], Patrick Martin[3], Phillip McGinnity[20,21], Jesse O'Hanley[22], Rosa Olivo del Amo[9,31], Piotr Parasiewicz[23], Martin Pusch[11], Gonzalo Rincon[24], Cesar Rodriguez[14], Joshua Royte[25], Claus Till Schneider[26], Jeroen S. Tummers[18], Sergio Vallesi[18,32], Andrew Vowles[16], Eric Verspoor[19], Herman Wanningen[9], Karl M. Wantzen[27,33], Laura Wildman[28] & Maciej Zalewski[8]

The Barrier Tracker App

With the app, called "Barrier tracker", you can record new barriers into a database. Using the app in the helps with gathering of more data and greater spatial coverage of records than would have been possible using conventional surveys. Typical data gathered includes a photo of the barrier, the location of the barrier and the height of the barrier.

Download on the App Store | GET IT ON Google Play



Search for «AMBER barrier tracker»

Carolli, M., Garcia de Leaniz C., Jones J., Belletti B., Huđek H., Pusch M., Pandakov P., Börger L., and van de Bund W. 'Impacts of Existing and Planned Hydropower Dams on River Fragmentation in the Balkan Region'. Science of The Total Environment 871 161940. https://doi.org/10.1016/j.scitotenv.2023.161940.

Belletti, Barbara, Carlos Garcia de Leaniz, Joshua Jones, Simone Bizzi, Luca Börger, Gilles Segura, Andrea Castelletti, et al. 'More than One Million Barriers Fragment Europe's Rivers'. Nature 588, no. 7838 (17 December 2020): 436–41. https://doi.org/10.1038/s41586-020-3005-2.

SINTEF

Thank you for the attention