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

D2.6. Simulation and modelling methodology with indicators ('habitat stress days') for management scenario comparisons.

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History of changes

Version	Date	Changes	Pages
1.0	22 March 2019		

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Executive summary

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Rivers are “arteries of life” connecting aquatic and terrestrial environments of our planet. These communication and transportation pathways are very frequently blocked and disturbed by human activities that create physical and chemical barriers. The European Barrier Atlas prepared by the AMBER project documents the magnitude of this impact using the example of physical barriers such as dams or weirs. The impact of these features is not only related to blocking up- and downstream migration, but also to the modification of adjacent habitats. Due to the number of such barriers averaging one dam every river kilometer, this causes massive alteration of flora and fauna composition. These changes are caused by the change of spatio-temporal habitat availability and structure. Within the MesoHABSIM habitat simulation approach we developed appropriate indicators of habitat quantity, structure and temporal shortages, creating so called Habitat Stress Days. The indices are applied to compare alternative dam management scenarios, also taking into account expected climate change driven modification of flows with the help of the Restoration Alternative Analysis diagram. Such diagrams indicate the expected habitat impacts in Euclidian space. The tool is demonstrated using the example of a small barrier on the low gradient River Mienia in Poland.



Authors

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Contributing Authors: Zbigniew Kaczkowski (ERCE), Mikołaj Piniewski (WULS), Iwona Pinskiwar (Warsaw Politechnic).

Contents

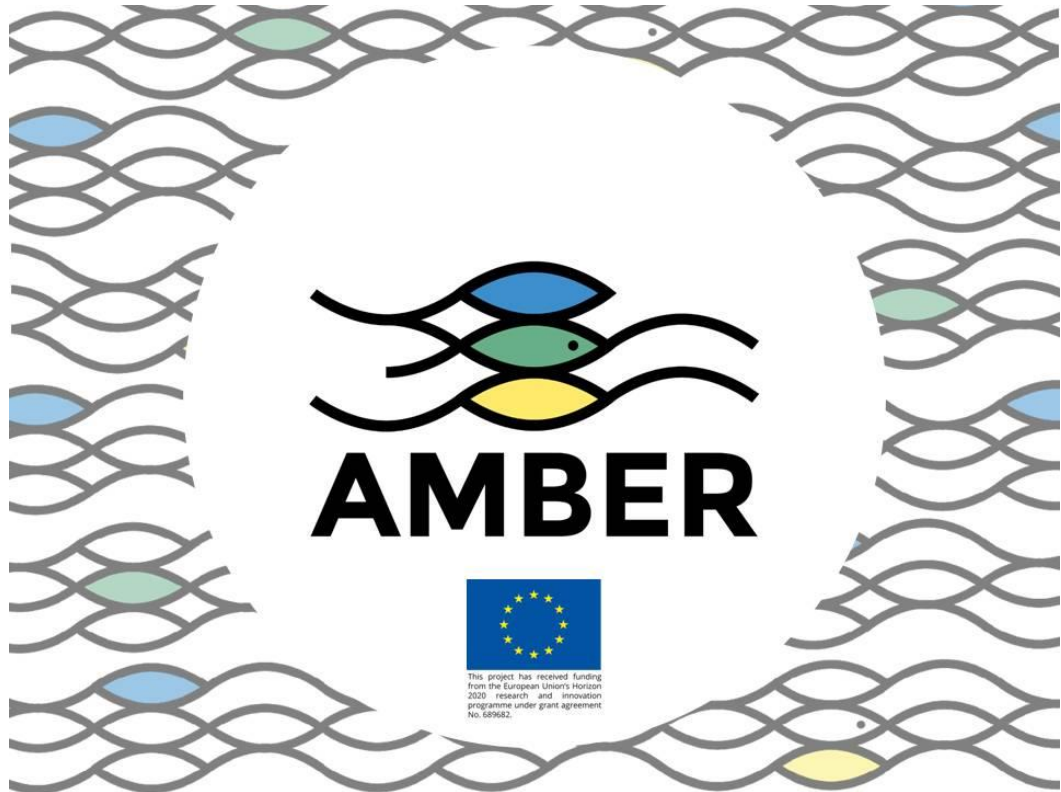
1. Software information	3
2. Introduction	4
3. Methodology slideshow	14
References	37



1. Software information

The core software applied for the presented MesoHABSIM analysis is Sim-Stream 8.0 by the Rushing Rivers Institute, www.Sim-Stream.org.

2. Introduction



2



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D2.6. Simulation and modelling methodology with indicators ('habitat stress days') for management scenario comparisons

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Editors

Piotr Parasiewicz (SSIPI), Paweł Prus (SSIPI), Katarzyna Suska (SSIPI), Kamila Belka (ERCE), Małgorzata Lapinska (ERCE), Mikołaj Adamczyk (SSIPI)

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Executive summary

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Barrier impact on up- and downstream habitats are evaluated with habitat simulation model MesoHABSIM and indicators of habitat quantity, structure and temporal deficits (Habitat Stress Days). The indices are applied to compare climate change driven management scenarios with help of Restoration Alternative Analysis diagram, which allows to plot the expected habitat impacts in Euclidian space. The tool is demonstrated using the example of small barrier on low gradient Mienia River in Poland.



Figure 1. Slides 1-3. About AMBER (<https://amber.international/about/>). Improving stream connectivity has been flagged as one of the priorities for more efficient stream restoration. To achieve 'good status' under the Water Framework Directive (WFD), one of the major challenges is the fragmentation of stream habitats. This fragmentation is mainly caused by tens of thousands of man-made barriers, many of which are old and no longer in use.

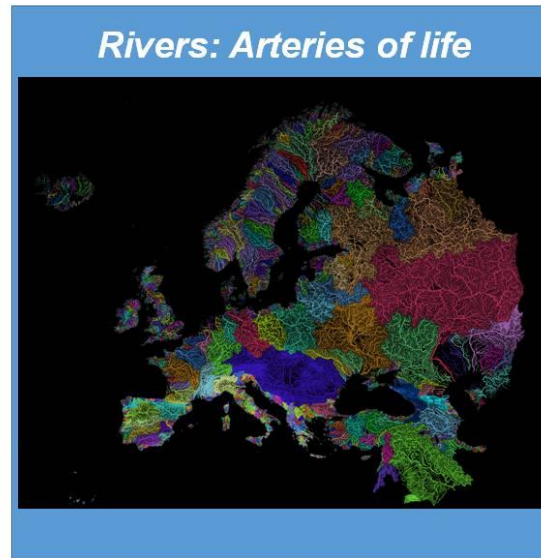
This project seeks to apply adaptive management to the operation of dams and barriers in European rivers to achieve a more efficient restoration of stream connectivity and address impacts caused by river fragmentation.

We target the main limitations of current stream restoration efforts to achieve more effective restoration of river ecosystems that is compatible with other water uses. This will improve the energy-generation security, help protect jobs, and boost European competitiveness, particularly in rural economies.

AMBER will have beneficial effects on the restoration of freshwater flora and fauna. The project will serve to protect global biodiversity in running waters by decreasing river fragmentation, promoting habitat connectivity, and evaluating the merits of different restoration actions through several quantified targets. The presentation will be available with audio commentary on the AMBER website <https://amber.international/>.

European Rivers systems

- Connecting continents with oceans
- Biological distribution pathways
 - transportation
 - communication
 - processess

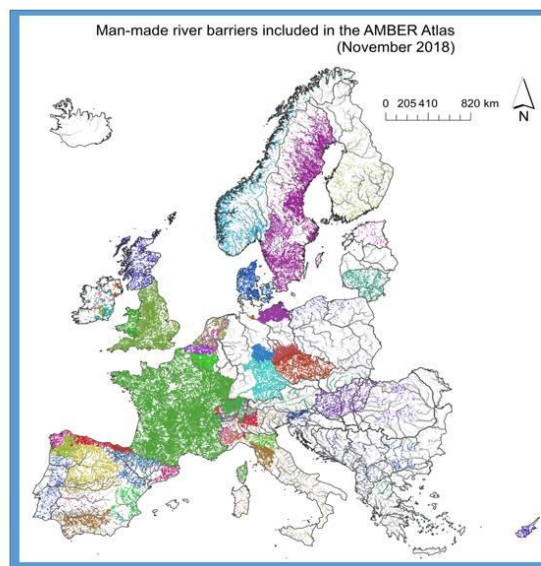


www.dailymail.co.uk/sciencetech/article-6511869/Fascinating-new-map-shows-river-basin-globe-different-colour.html

Figure 2. Slide 4. Rivers serve as distribution pathways for life entering from the ocean on the continents. Like blood vessels in our bodies, rivers distribute nutrients up- and downstream and provide living space for numerous plants and animals. Here we can see just how prominent they are within our landscape. We also depend on them for many of our resources: water, fish, recreational opportunities, birdlife, and so much more.

Barriers on European Rivers

- **400.000** recorded in AMBER ATLAS (status Nov 2018)



SOURCE: AMBER project

Figure 3. Slide 5. Unfortunately, human activities clogged these pathways by the construction of millions of dams and barriers. We had estimated that there is a “barrier every river kilometer”. In its current, as yet incomplete, version the AMBER Barriers Atlas includes over 400 000 barriers.

Types of barriers in AMBER project

BARIER DESCRIPTION		PICTURE
	Dam - a barrier that blocks or constrains the flow of water and raises the water level with permanent ponding.	
	Weir - a barrier aimed at regulating flow conditions and water levels.	
	Sluice - a movable barrier aimed at controlling water levels and flow rates in rivers and streams.	
	Culvert - a structure aimed at carrying a stream or river under an obstruction.	
	Ford - a structure in a river or stream which creates a shallow place for crossing the river or stream by wading or in a vehicle.	
	Ramp - a ramp or a bed sill is a structure aimed at stabilizing the channel bed and reducing erosion; it is recognizable by its stairway-like shape.	

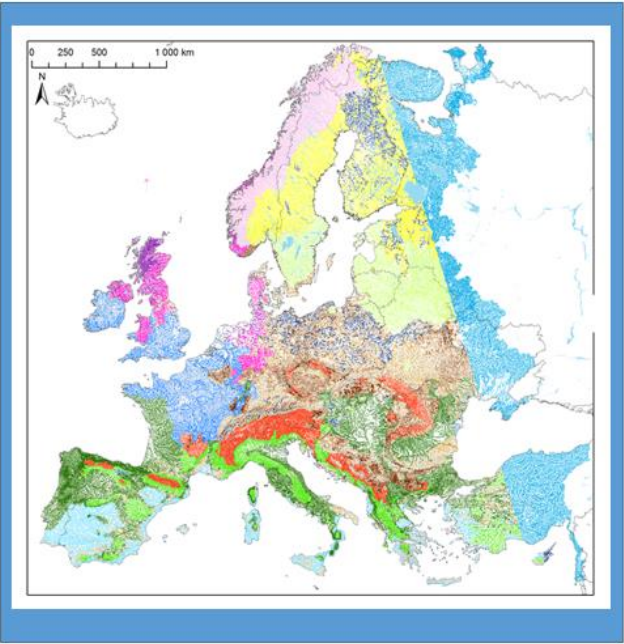
Phot. AMBER, ERCE

Figure 4. Slide 6. We consider here all barriers that limit migration of the fauna up and downstream. The slide presents the types of barriers identified in the AMBER project. The impact of those barriers on river ecosystems is not uniform, as some of them have a much stonger effect on the aquatic communities than others.

7

European rivers classified into Fish Community Macrohabitat types (FCMacHT)

- 1 Highland, medium sediment rivers
- 2 Mountain, Alpine and subalpine rivers
- 3 Central European lowland, medium sediment rivers
- 4 Central European lowland, large-medium sediment rivers
- 5 Highland and lowland, large-medium sediment rivers
- 6 Boreal large-medium sediment rivers
- 7 Boreal lowland rivers
- 8 Mediterranean mountain and upland rivers
- 9 South European highland
- 10 Mediterranean lowland rivers
- 11 Western European and Atlantic rivers
- 12 Lowland medium sediment and organic rivers
- 13 Boreal-Atlantic large-medium sediment rivers
- 14 Atlantic medium-large sediment rivers
- 15 North Atlantic lowland, medium-large sediment rivers
- all other rivers



(AMBER D2.2, VERSION 3.0).

Figure 5. Slide 7. Impact also depends on the aquatic fauna living in rivers, which is also not uniform across the Europe. Scientists from the AMBER project developed a map of Fish Community

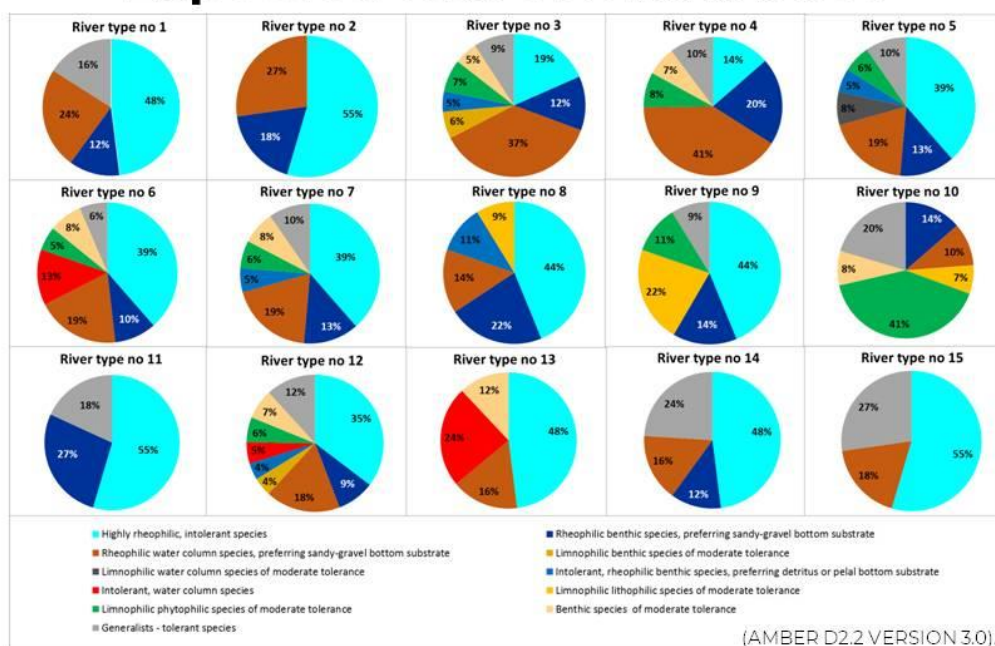
MacroHabitat Types. These are river sections with a specific fish community structure. Fish serve here as indicator organisms.

Data sources: [źródło danych o rybach], Catchment Characterisation and Modelling River and Catchment Database, version 2.1 (CCM21) (Vogt, J.V. et al., 2007), European Soil Database v2.0 (ESDB v 2.0; Panos, 2006), IHME1500 - International Hydrogeological Map of Europe 1:1,500,000, Environmental Stratification of Europe version 8: Metzger, Marc J. (2018). The Environmental Stratification of Europe, [dataset]. University of Edinburgh. <https://doi.org/10.7488/ds/2356>, Water Information System for Europe Water Framework Directive (WISE WFD) database (EEA, 2017).

Expected fish communities

8

11 Fish guilds proportions
for each of 15 FCMacHT



15 European Rivers Macrohabitat types (FCMacHT)

1 Highland, medium sediment rivers	6 Boreal large-medium sediment rivers	11 Western European and Atlantic rivers
2 Mountain, Alpine and subalpine rivers	7 Boreal lowland rivers	12 Lowland medium sediment and organic rivers
3 Central European lowland, medium sediment rivers	8 Mediterranean mountain and upland rivers	13 Boreal-Atlantic large-medium sediment rivers
4 Central European lowland, large-medium sediment rivers	9 Mediterranean highland rivers	14 Atlantic medium-large sediment rivers
5 Highland and lowland, large-medium sediment rivers	10 Mediterranean lowland rivers	15 North Atlantic lowland, medium-large sediment rivers

Figure 6. Slide 8. This slide presents proportions of fish habitat use guilds (i.e. groups of species using the same habitats) expected in each macrohabitat type.

Fish migration blocked

- altered or stopped fish upstream migration
- fish mortality:
 - dewatering
 - turbines



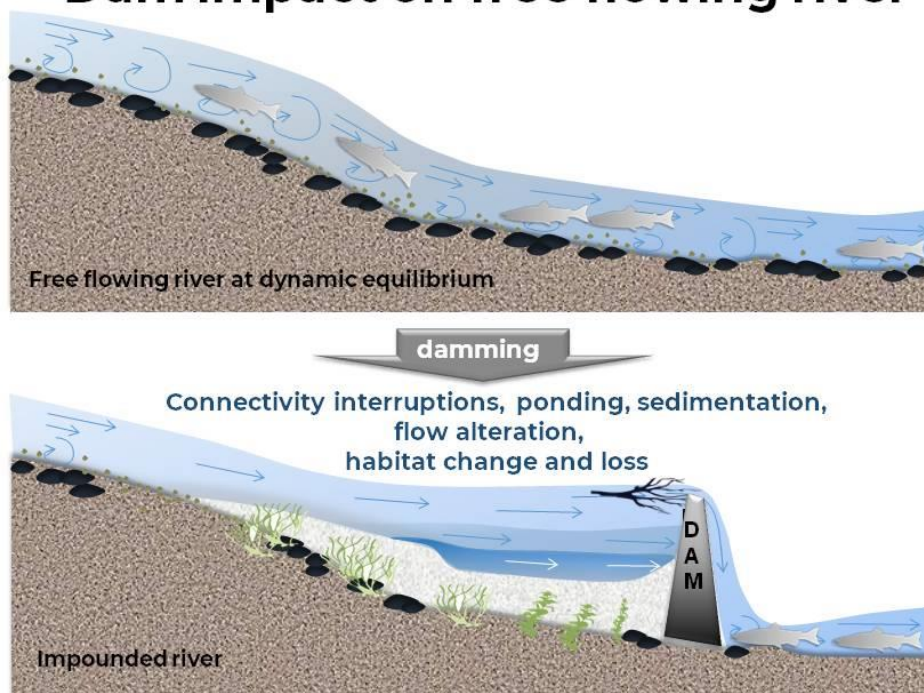
Phot. P. Prus, M. Adamczyk SSIRI



Figure 7. Slide 9. Most known impacts on fish are blockage of fish migration and mortality at turbines.

10

Dam impact on free flowing river



Modified from L. Wildman - The Effects of Dams on Floodplain Function

Figure 8. Slide 10. In general, barriers do not only affect the fish migration but also modify adjacent habitats. Upstream sections are impounded and downstream have disturbed flow patterns.

Dam impact on upstream habitat

- higher depth
- low velocity
- substrate siltation
- high temperature
- low oxygen
- eutrophication
- vegetation shift
- benthos shift

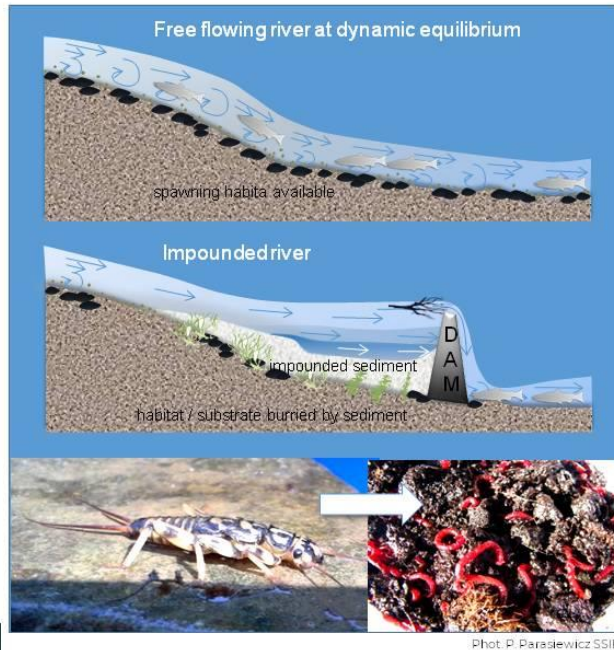
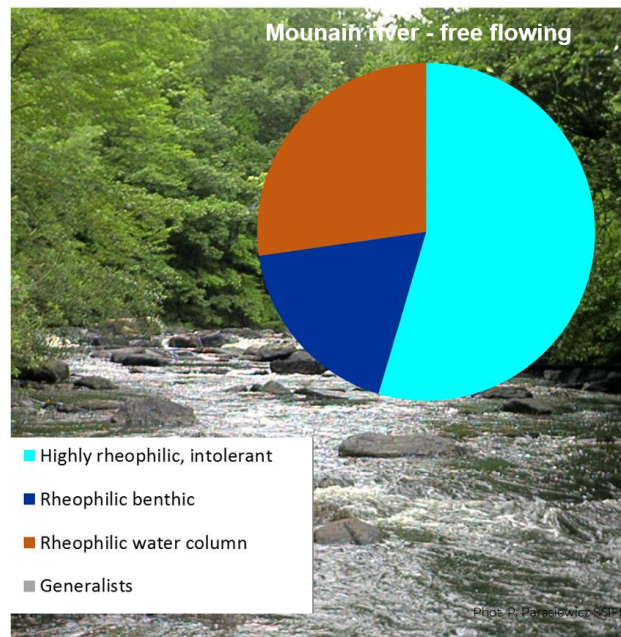


Figure 9. Slide 11. The impoundments increase water depth and slow water flow, causing siltation, lower oxygenation, higher temperature and eutrophication. Biological effects are shifts in vegetation patterns and benthic communities.

Upstream

- rheophilic fish guilds in undisturbed river



Upstream

- rheophilic fish guilds in undisturbed river



- change of lotic into lentic habitats
- altered fish community
- generalists - tolerant fish in impounded river

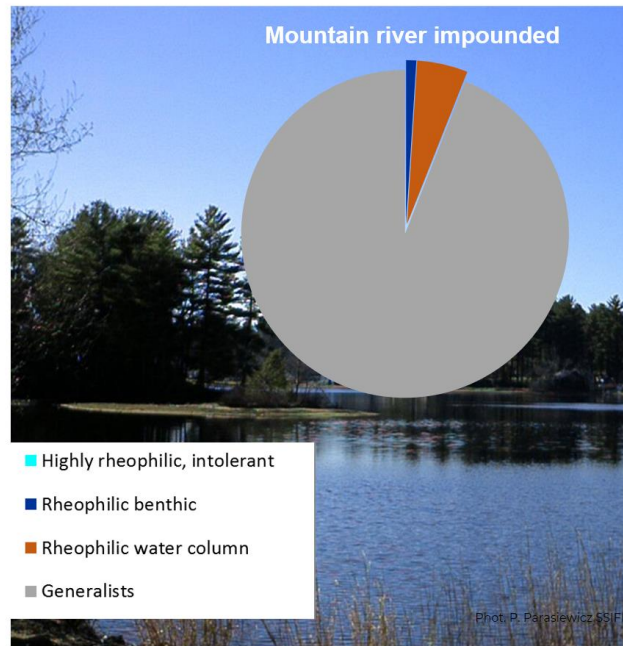


Figure 10. Slide 12. Impounding of free flowing rivers changes habitat conditions in the impoundment so far that the structure of the fish community is changing from fish using fast flowing habitat (i.e. river fish) to more generalists (i.e. pond fish).

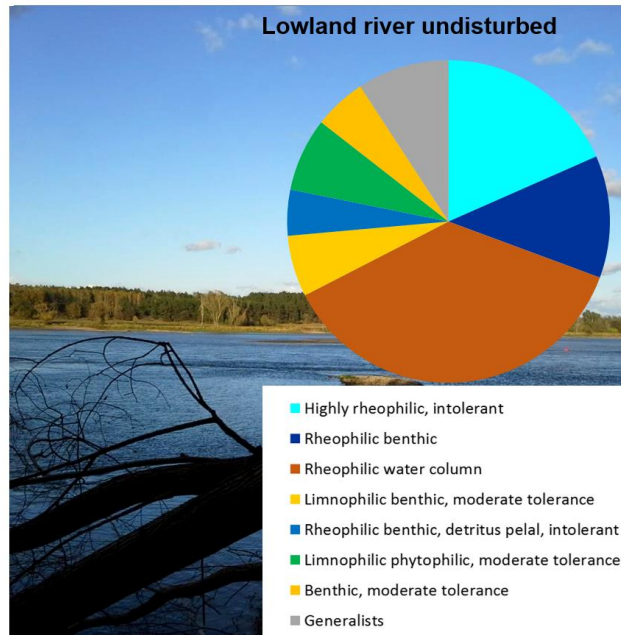
Dam impact on downstream habitat

- flow regime
 - fluctuations:
 - depth
 - velocity
 - temperature
- blocked sediment
 - riverbed erosion
- migration blocked
- fish mortality (dewatering)



Figure 11. Slide 13. Downstream effects include change of flow regime that frequently cause erratic fluctuations of flow velocity, depth and temperature. Sediment deficits lead to riverbed erosion. Due to blocked fish migrations, we can expect increased density of some species as well as mortality due to dewatering of the riverbed.

Downstream



14

Downstream

- change of habitat quality and stability
- rapid bottom erosion



- altered fish community

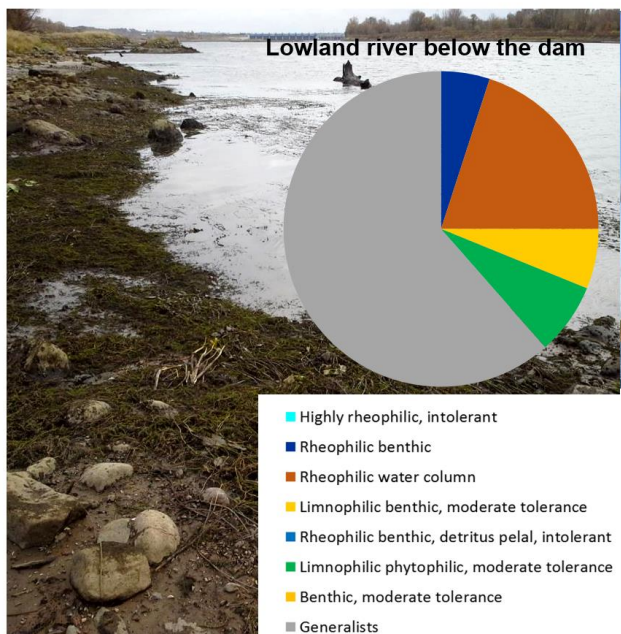


Figure 12. Slide 14. In downstream areas, fish community structure changes in direct consequence of habitat alteration, leading again to an increase of more generalist species, which are more resistant to the changes.

Investigating and mitigating impact of barriers

- Define habitat changes up- and downstream
- Develop mitigation scenarios
- Compare and select



Phot. ERCE, K. Susuła, P. Paradowski SSiFI

Figure 13. Slide 15. Consequently, to fully understand the impact of dams on riverine ecosystems and determine the best management actions we need to investigate change of habitats adjacent to the barrier.

3. Methodology slideshow

What habitat changes?

- Alteration of habitat structure
- Reduction of habitat area
- Temporary habitat deficits

Habitat simulation models are appropriate tool for this purpose

16

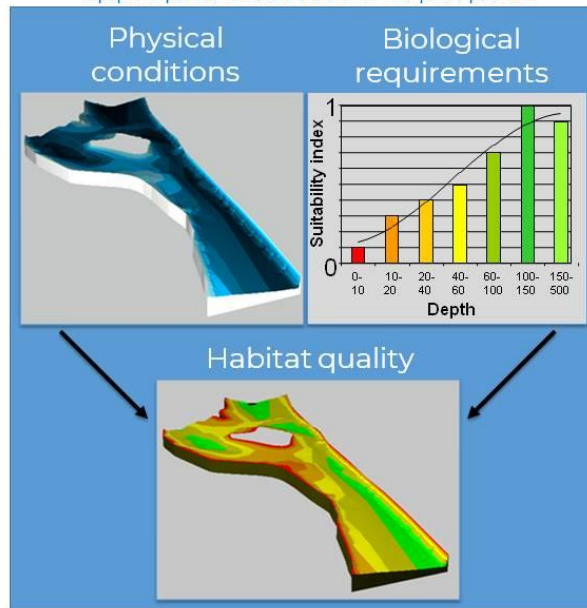


Figure 14. Slide 16. As visible from the analysis, there are major factors to be considered when performing such analysis. These are change in habitat structure and spatio-temporal alteration of habitat availability. Habitat simulation models allow such analyses. These are tools that create a computer model of the riverbed structure and a mathematical model describing the ways in which fish (or other animals) use their habitat (s.c. Preferences). The preferences are applied to validate the riverbed structure and hydraulics in terms of habitat suitability. Eventually the models quantify the amount of suitable habitat as suitable areas. In combination with hydrological time series analysis, all the above parameters can be determined.

Restoration Alternatives Analysis (RAA)

Comparing scenarios

- Represents possible scenarios in Euclidian space
- The data for the diagram obtained with habitat model

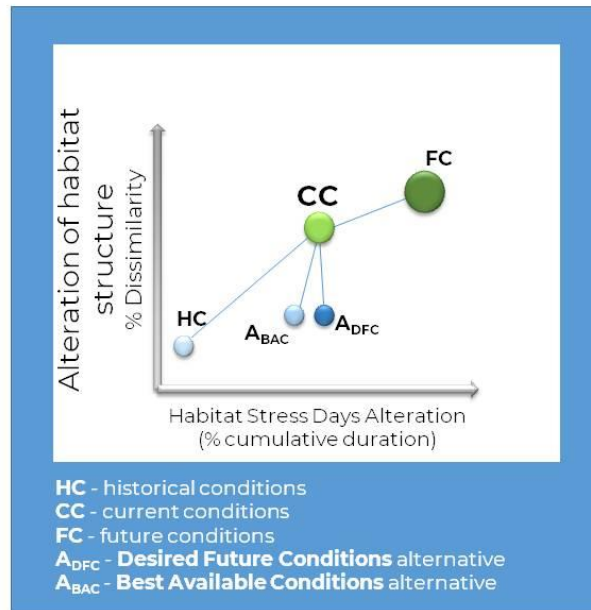


Figure 15. Slide 17. The results can be plotted for a variety of scenarios on the Restoration Alternatives Analysis (RAA) diagram. The historical, current and future condition can be plotted together with restoration alternatives. The closer to the origin of the diagram the lower the habitat impact of the scenario.

How to calculate 3 components of the diagram?

1. **Alteration of Habitat Structure**
2. **Alteration of Habitat Stress Days**
3. **Unsuitable Habitat Area**

Figure 16. Slide 18. Now we will demonstrate how to calculate the three components necessary to draw RAA diagrams: Alteration of Habitat Structure, Alteration of Habitat Stress Days and Unsuitable Habitat Area. First in general terms and then using the River Mienia in Poland as an example.

Select habitat simulation model

- MesoHABSIM is well suited for landscape level analysis.
- Evaluates geomorphic units
- Analyses entire aquatic communities

MesoHABSIM MODEL

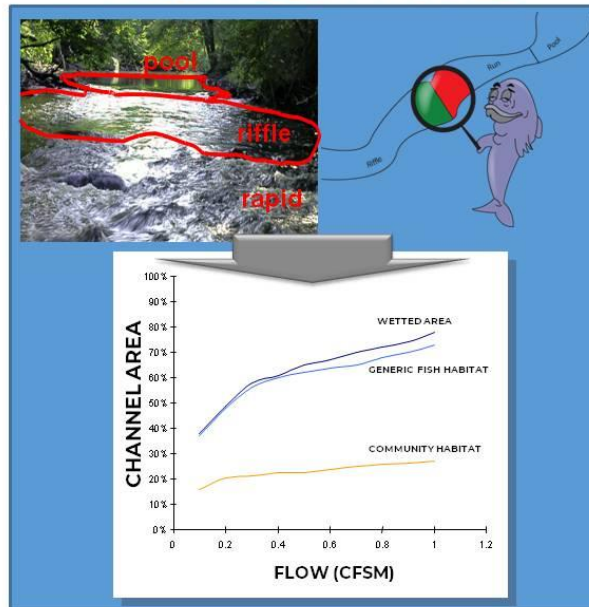


Figure 17. Slide 19. There are a number of habitat models available. Our model of choice is the MesoHABSIM habitat model, considered the best for this purpose. MesoHABSIM investigates riverbed structure and hydraulics at the scale of geomorphic units (riffles, pools, etc). Biological data is analyzed at a same scale. The model has also well-developed approaches to investigate habitats for entire aquatic communities and perform sophisticated time series analysis. Mesohabitats correspond in size and location to geomorphic or hydraulic units. Therefore, it offers a robust link between available geomorphic classification frameworks such as developed in REFORM project and ecohydraulic tools.

MesoHABSIM MODEL

Collect necessary data to create habitat map

- Mapping with help of drones
hydromorphological units (HMU-s) such as riffles or runs



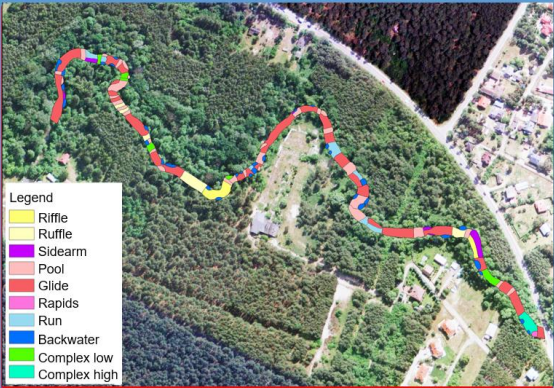
Phot. K.Suska SSIFI



MesoHABSIM MODEL

Collect necessary data to create habitat map

- Mapping with help of drones
hydromorphological units (HMU-s) such as riffles or runs



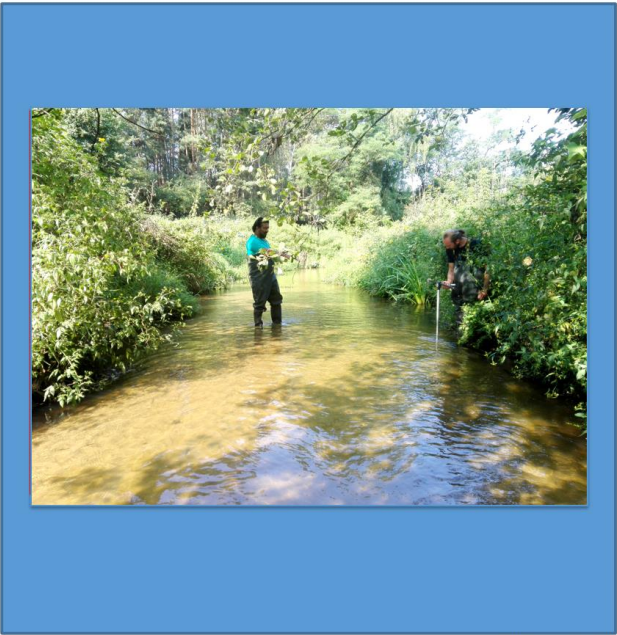
Phot. K.Suska SSIFI



MesoHABSIM MODEL

Collect necessary data to create habitat map

- **Mapping with help of drones**
hydromorphological units (HMU-s) such as riffles or runs
- **Measure**
 - depth
 - velocity
 - substrate
 - UAV photos



Phot. K.Suska SSIFI



Figure 18. Slide 20. The first step in model development is to gather the data necessary to create habitat maps. This consists of drone-supported mapping of hydromorphological units with attributes relevant for fish habitats and on-the-ground measurement of river hydraulics at multiple flows.

MesoHABSIM MODEL

Evaluating habitat

- Suitability criteria for physical attributes are defined
- Suitability criteria are species guilds specific

Habitat suitability					
Fish Guild	Depth [m]	Velocity [m s ⁻¹]	Substrate type (Choriotope)	HMU Type	Cover
Rheophilic water column	0.5-4.0	0.15-0.7	mesolithal, microlithal, psammal, akal, debris, xylal	run, fast run, pool, plunge-pool, backwater, riffle	boulders, undercut banks, woody debris, canopy shading

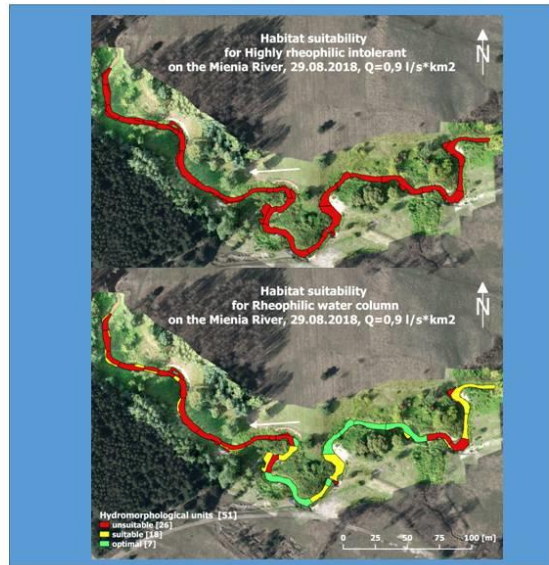


Figure 19. Slide 21. The biological model is established with help of literature analysis as sc. Conditional Habitat Suitability Criteria. Preferable ranges of depth and velocity, selected substrates and cover attributes are defined for every fish species habitat use guild.

MesoHABSIM MODEL

Habitat maps

- depending on how many criteria are fulfilled HMU's are
 - Unsuitable (red)
 - Suitable (yellow)
 - Optimal (green)
- Suitability criteria are applied to HMU maps
- Habitat area changes with flows



Author: K. Suska SSIF



Figure 20. Slide 22. Habitat maps are created for every guild, distinguishing areas of suitable and not suitable habitats, which are determined by applying the suitability criteria to mapped units. Due to the dynamic nature of hydromorphological units, the habitat suitability changes with flow causing an increase or decrease of suitable area.

MesoHABSIM MODEL

Rating curves

Represent

- how much of riverbed area is a suitable habitat for species guilds
- Suitable area proportion changes with river flow

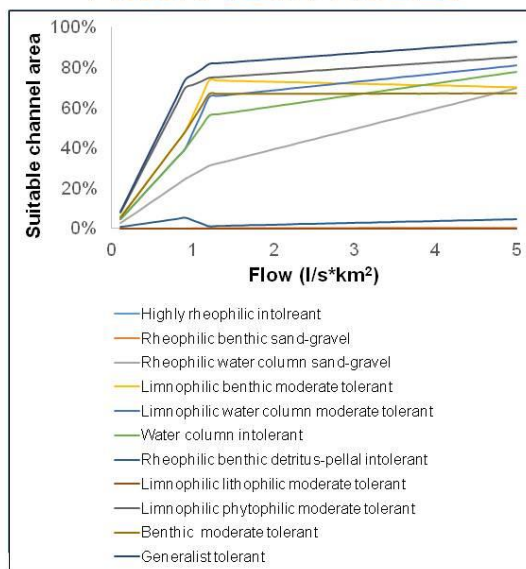
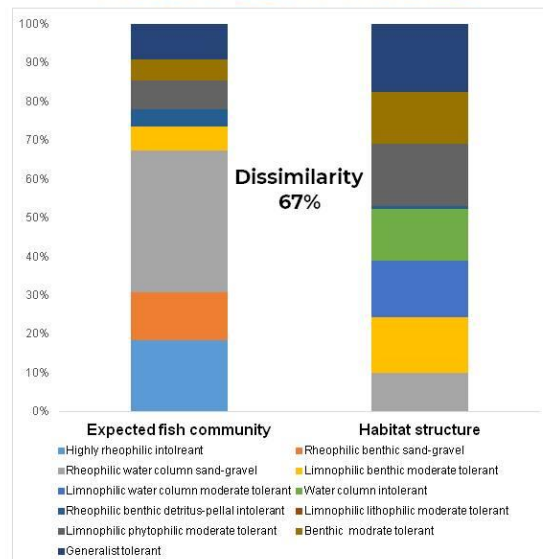


Figure 21. Slide 23. The change in habitat area is then demonstrated in the form of habitat flow rating curves showing how much of channel area (CA) is suitable for each species guild at each flow.

Community habitat structure at median low flow

- Can be compared with expected fish community structure or between scenarios
- Dissimilarity index shows summarized % of difference between classes

MesoHABSIM MODEL



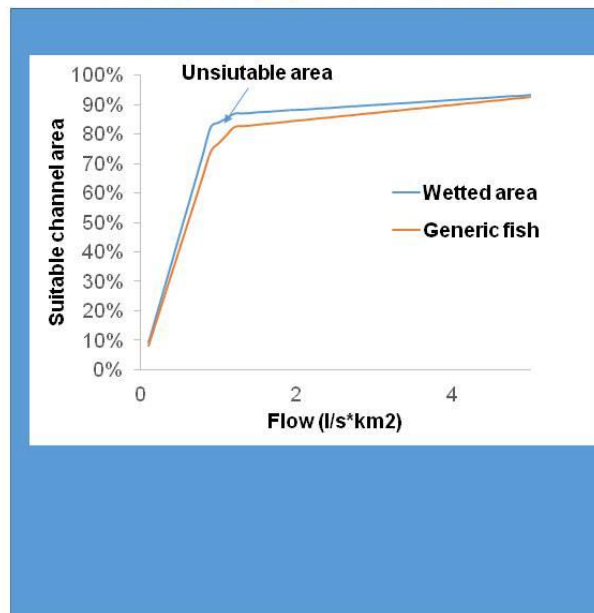
Y Axis of RAA

Figure 22. Slide 24. The area under each curve at one selected flow (usually median i.e. most frequent flow) can be plotted in habitat structure diagrams. In this way, two scenarios can be compared by calculating distribution dissimilarity index. Here we see the comparison of expected fish community structure and observed habitat structure (which may also serve a selection of restoration scenarios). Dissimilarity of habitat structure between scenarios is one of the components of the RAA diagram plotted on the Y-axis.

Habitat Quantity

- Generic Fish habitat is habitat area that is suitable to at least one of the species in fish community
- Unsuitable area can be measured between the wetted area and Generic Fish habitat area

MesoHABSIM MODEL



Size of the bubble on RAA

Figure 23. Slide 25. To determine the unsuitable area, habitat can be expressed as a generic fish habitat rating curve, which represents the entire habitat available for all members of the community.

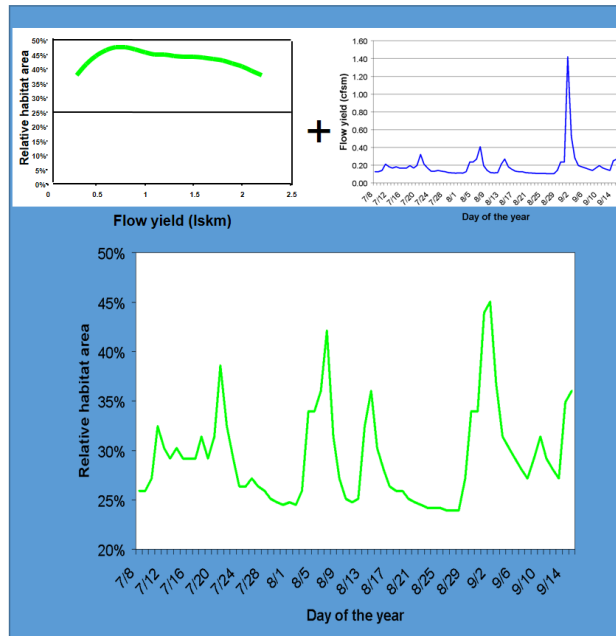
The difference between this rating curve and one representing entire wetted area, defines habitats not preferable by fish. It is the second component of the RAA diagram presented as a size of the circle representing a scenario.

26

Time series analysis

- Community rating curve + hydrograph = habitograph (habitat area change in time series)

MesoHABSIM MODEL

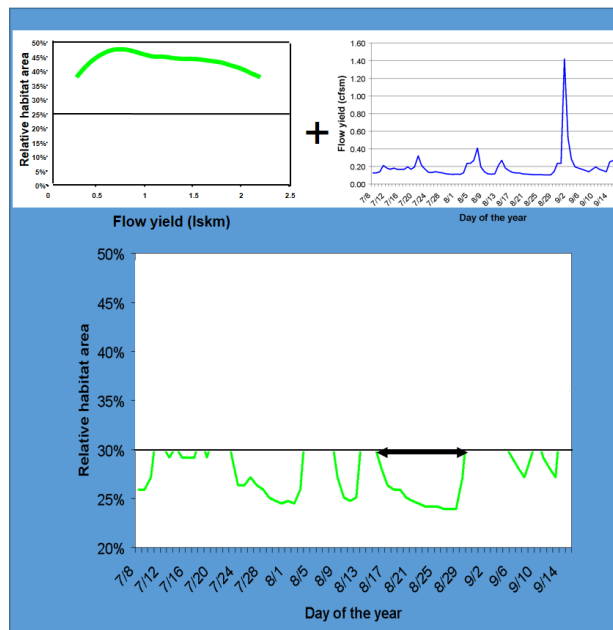


26

Time series analysis

- Community rating curve + hydrograph = habitograph (habitat area change in time series)
- Analysis of duration of events with habitat area below a threshold (one, then many thresholds)

MesoHABSIM MODEL



MesoHABSIM MODEL

Time series analysis

- Community rating curve + hydrograph = habitograph (habitat area change in time series)
- Analysis of duration of events with habitat area below a threshold (one, then many thresholds)

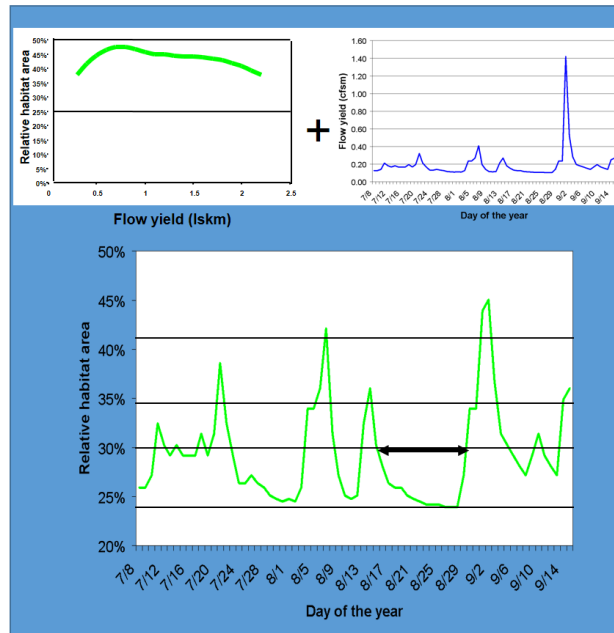


Figure 24. Slide 26. To define the third component of the RAA diagram habitat time series, analysis is needed. Habitat time series are created by using the community rating curve to translate flows of the long term daily flow time series into habitat time series (habitograph). Habitat stress occurs when deficits in habitat availability occur for persistent amount of time. To identify habitat stress days, we first need to determine the continuous duration of all events when habitat is below a threshold value. When the threshold is low such events are rare, and when it is high then they are quite common. Subsequently, duration frequency analysis identifies both rare and persistent events that can be considered as causing habitat stress.

Uniform Continuous Under Threshold (UCUT)

- The habitat deficit durations are plotted on cumulative duration diagram from longest to shortest.
- The steeper the curve the less change in frequency between event durations
- The more events of the same duration the flatter the curve
- The lowest critical point - > transition to persistent duration



MesoHABSIM MODEL

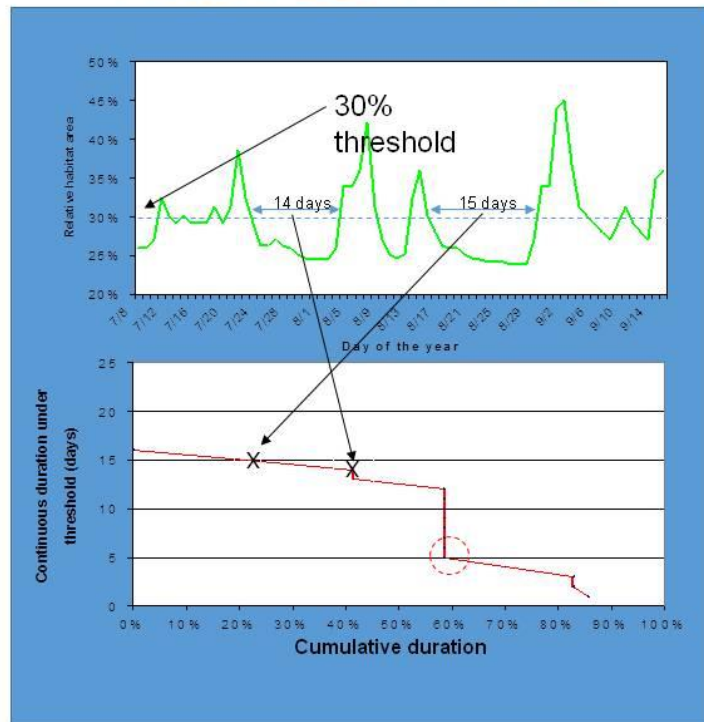


Figure 25. Slide 27. To perform duration frequency analysis, the continuous under threshold durations are plotted on a cumulative duration frequency diagram. The x-axis represents the relative duration of the entire period (e.g. summer) and y-axis the continuous duration of the under threshold event. The longest event is plotted first - in the presented case, it is 15 days on the y and 20% on the x axis (15 days makes 20% of the entire period). Then sum of length of the next shorter event (14 days) is added and connected with a line. If the events do not occur (e.g. 13 days) the line drops vertically. If many events of the same length occur, the line flattens out. Beginning with the shortest duration (bottom of diagram) a point can be observed in which the curve rapidly steepens. This critical point of the curve is considered a transition to persistent durations.

UCUT curves for many thresholds and long term data - interpretation

Rare events

(brown field):

- densely distributed curves in left lower corner - below red line
- catastrophic duration i.e. with 10 years recurrence interval

Typical events

(dark green field):

- densely distributed curves to the right
- Shorter than persistent (below critical points on key curves)

Persistent events

(light green field):

- Above the lowest critical point of rare and typical curve
- Shorter than catastrophic

MesoHABSIM MODEL

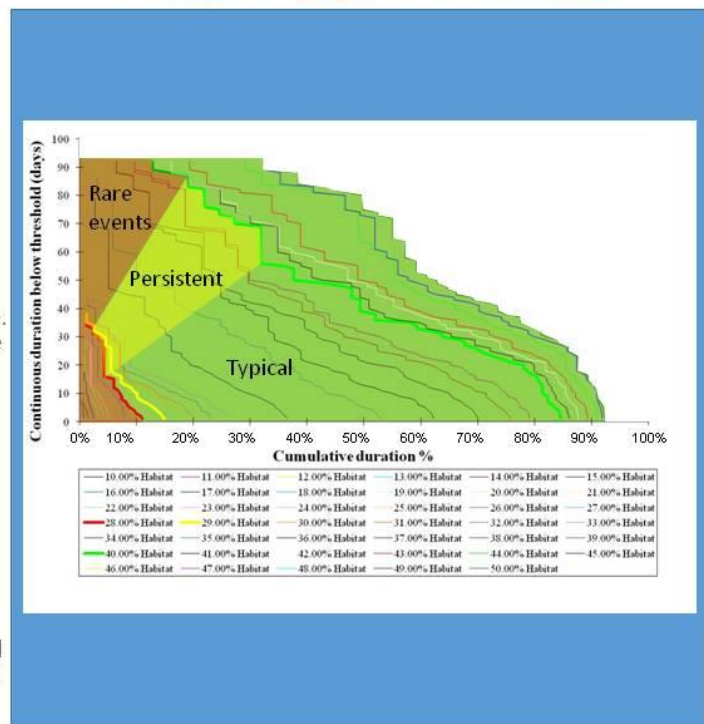


Figure 26. Slide 28. When multiple UCUT curves, each representing different thresholds, are plotted on one diagram, a pattern can be observed in the lower left corner of the diagram. Here the curves for low habitat thresholds are located. The spacing between the curves is at first very small and then increases rapidly as we move to the right. This is considered to be a transition value from rare events and the highest of the densely packed curves is called the rare habitat threshold. Similar pattern can be observed at the other side of the diagram for very high thresholds, the lowest of which is selected as a transition to common events. The critical points on both curves indicate transition to persistent events. One more value is plotted on each of the two curves: a duration that did not occur more frequently than every 10 years. This is considered a transition to events of catastrophic duration. As indicated on the diagram, we can then classify events into typical, persistent and catastrophic.

MesoHABSIM MODEL

Habitat stress days

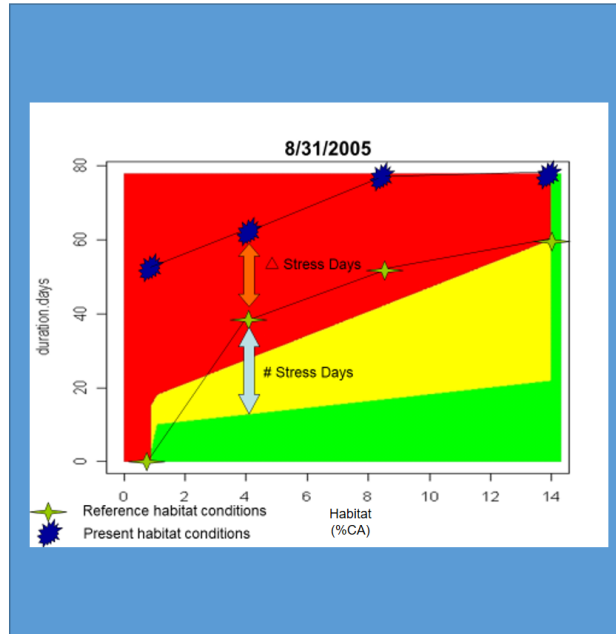


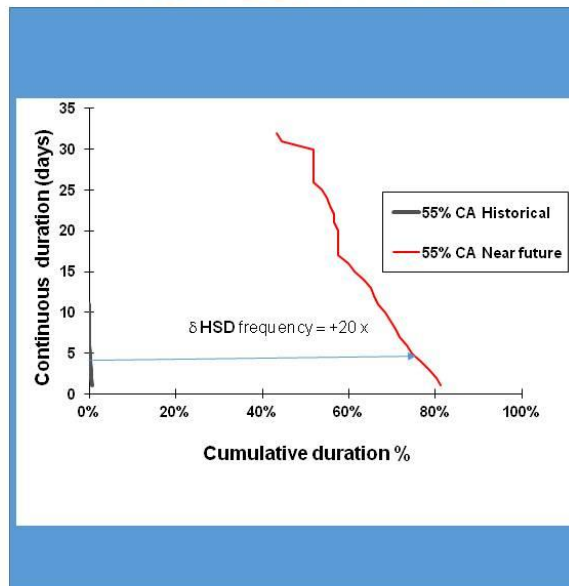
Figure 27. Slide 29. All non-typical events are considered to be stressful from the moment when habitat deficit duration is exceeding the duration of typical events. The number of days of this exceedance is called a number of habitat stress days (HSD). When comparing different scenarios we can measure change in HSD as an impact indicator.

30

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Alteration of Habitat stress days (HSD)

- Comparing rare UCUT curves between scenarios
 - measured as frequency increase of rare-persistent habitat threshold (*shift of the critical point to the right*)
- Metric for scenario comparison



X Axis of RAA

Figure 28. Slide 30. Alteration of habitat stress days in the long term habitat time series can be measured on the UCUT diagram by plotting rare thresholds for both scenarios. The distance between the critical points on the curves indicate the frequency change of persistent events. It is expressed as a ratio of HSD from reference scenario. In the above diagram the frequency increase is 2000% of the

original, hence the habitat area will be under this threshold for a persistent amount of time about 20 times more frequent. This may be considered deleterious to the investigated fauna and could cause a shift in community structure by promoting more flexible and resilient species. This value is plotted on the x-axis of the RAA diagram.

31

Restoration Alternative analysis (RAA diagram)

- Represents possible scenarios in Euclidian space
- Circle size represents unsuitable area
- The closer to origin the less impact

MesoHABSIM MODEL

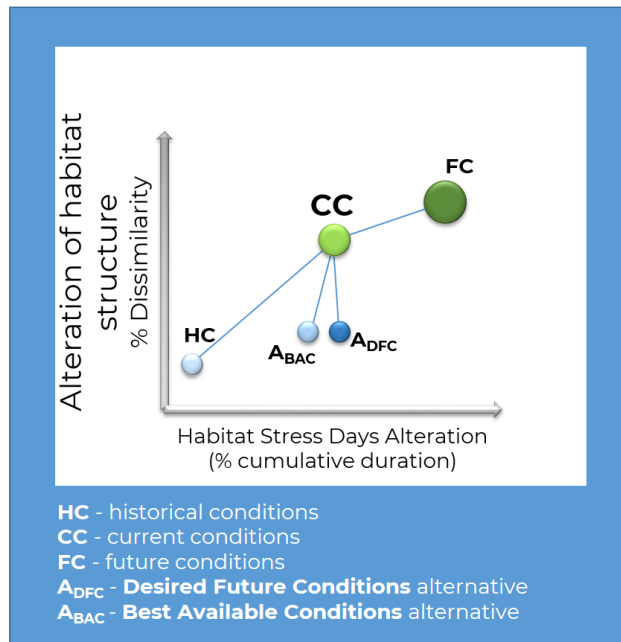
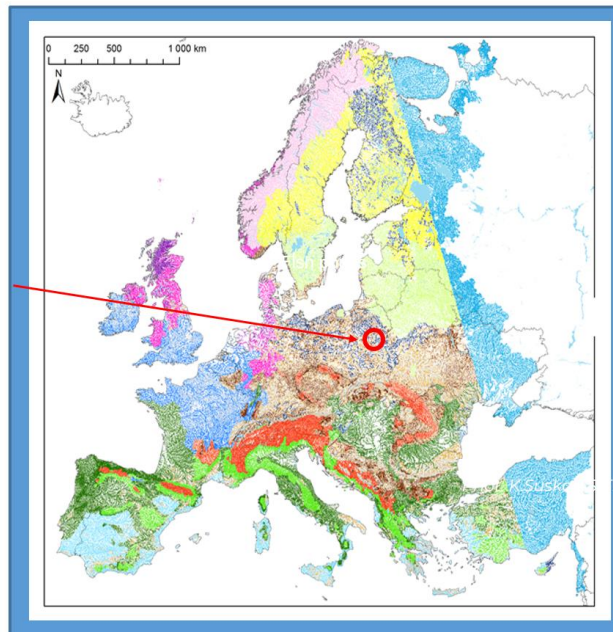


Figure 29. Slide 31. This slide represents a comparison of hypothetical scenarios on an RAA diagram. The closer the scenario is to the origin of the diagram, the lower the impact and the better the scenario.

Example of application: Mienia River (Central Poland)

- Watershed Area 256 km²
- Stream Order 1-3 (Strahler)
- Siliceous surficial geology
- Low gradient, sandy bottom
- Average width 5 m
- Has many small barriers and a dam to supply water for fish farm
- No fish passage

MesoHABSIM MODEL

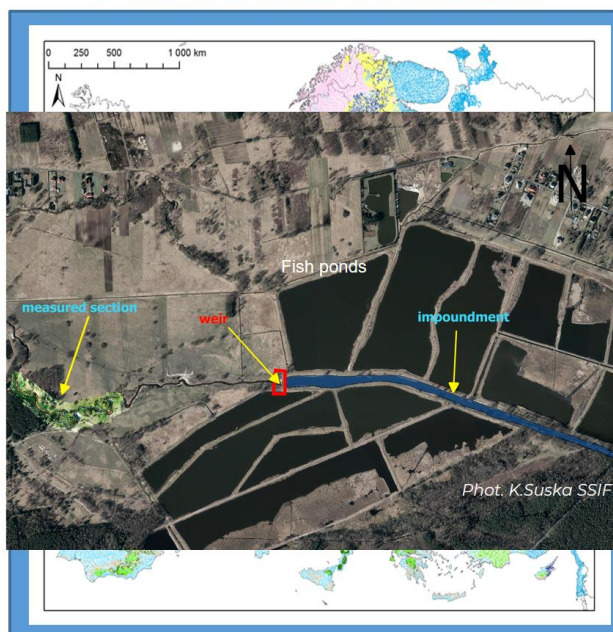


UAV Phot. K. Suska SSIFI

Example of application: Mienia River (Central Poland)

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- Average width 5 m
- Has many small barriers and a dam to supply water for fish farm
- No fish passage

MesoHABSIM MODEL



UAV Phot. K. Suska SSIFI

Figure 30. Slide 32. Now we will demonstrate the application of the above concept using habitat data collected on the River Mienia in Central Poland. This is a small lowland stream, a tributary of the River Świder, which flows into the River Vistula. In its lower section, the River Mienia flows through a conservation area, but further upstream it has been modified with the purpose of agricultural irrigation. It therefore has a number of small barriers which are no longer in use. The large dam in the mid course supplies water to a fish farm.



Figure 31. Slide 33. Here we see an aerial photograph taken from UAV. It presents the location of the dam and the impoundment at a low flow conditions. We surveyed this area 3 times in summer 2018.

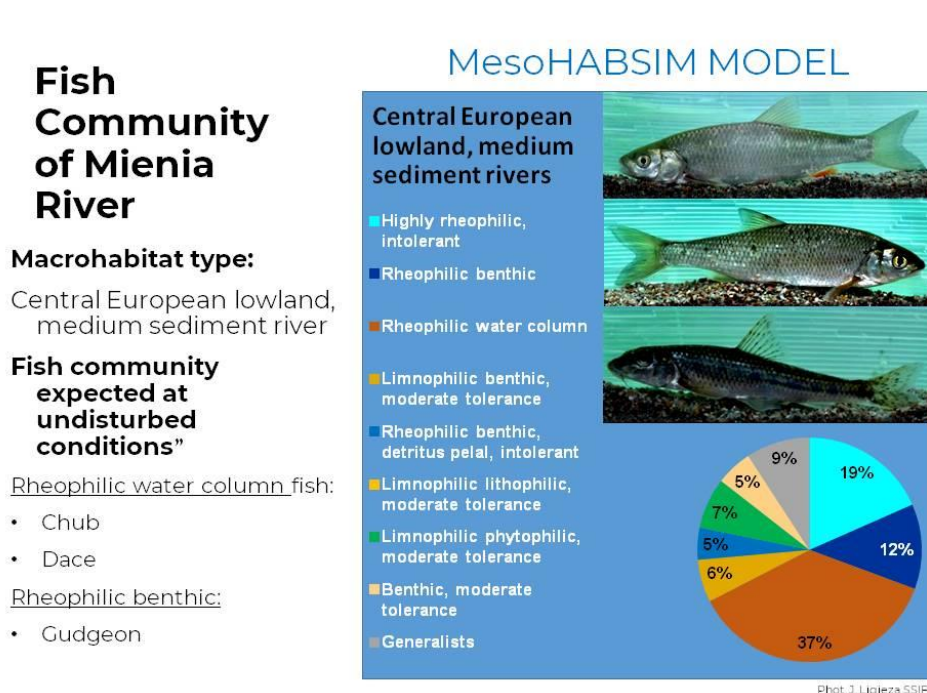


Figure 32. Slide 34. The River Mienia belongs to a Central European lowland, medium sediment Macrohabitat Type. The fish community is diverse, but consists mostly of cyprinid species and should be dominated by rheophilic water column fish guild with species such as chub and dace.

MesoHABSIM MODEL

Example of Mienia river (Central Poland)

- Habitat Use Criteria for abundant fish guilds

Exp. proportion	Fish Guild	Depth [m]	Velocity [m s ⁻¹]	Substrate type (Choriotope)	HMU Type	Cover
37%	Rheophilic water column	0.5-4.0	0.15-0.7	mesolithal, microlithal, psammal, akal, debris, xylal	run, fast run, pool, plunge-pool, backwater, riffle	boulders, undercut banks, woody debris, canopy shading
19%	Highly rheophilic, intolerant	0.25-1.5	0.3-1.2 max. 2.0	solid rock, gigalithal, megalithal, makrolithal, mesolithal, microlithal	riffle, riffle, cascade, rapid, fast run, plunge-pool, pool, backwater	boulders, undercut banks, woody debris
12%	Rheophilic benthic	0.3-2.0	0.15-0.9	megalithal, makrolithal, mesolithal, microlithal, psammal	riffle, riffle, cascade, rapid, fast run, run, glide, plunge-pool, pool,	boulders, undercut banks, woody debris



Figure 33. Slide 35. The habitat use criteria that were used for habitat model development are presented in the table.

Impact of dam on Mienia River

MesoHABSIM MODEL

Scenario 1 (No dam)

- a) Historical flows (1974-2000)
- b) Simulated near future flows with Climate Change (2024-2050)
 - Climate Change simulated as median of flow predicted with 9 climate models

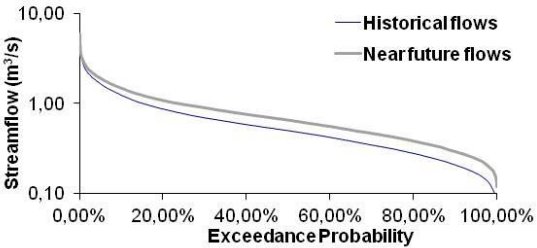


Figure 34. Slide 36. After model development, three scenarios were simulated and evaluated on an RAA diagram. Scenario one represents reference conditions: river without a dam and current habitat distribution as we found it in the downstream section. It includes a sub-scenario of near Future conditions under predicted climate change. Flows for this scenario have been simulated with help of SWAT model and nine climate change simulation models. To represent Near Future Conditions median values of daily flows predicted by these models were used in a habitat time series analysis. The flow duration curve demonstrates the change in flow rate due to climate change and indicates an overall increase of flows.

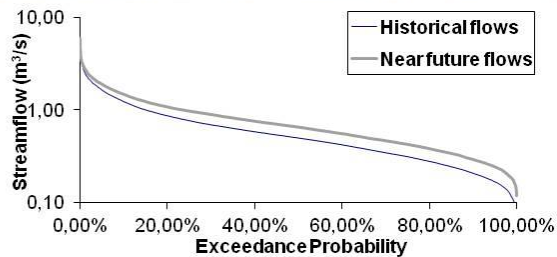
Impact of dam on Mienia River

Scenario 2 (with dam)

MesoHABSIM MODEL



- a) Historical flows (1974-2000)
- b) Simulated near future flows (2024-2050)



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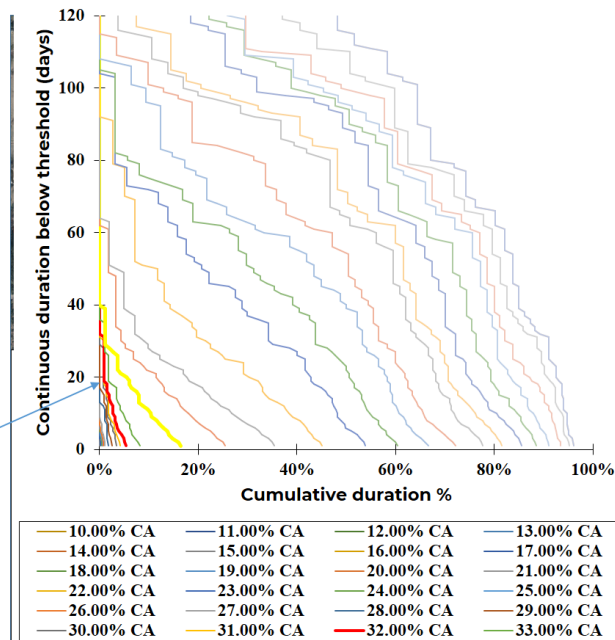


Figure 35. Slide 37. Scenario 2 represents the current situation of the river with the dam, but also considers historical and future flow conditions, the latter under climate change assumptions.

UCUT curves Scenario 1a (No dam, hist. flows)

MesoHABSIM MODEL

- a) Rare habitat threshold 0.32% channel area
- b) Persistent duration 19 days



Author: K.Suska SSIFI



Figure 36. Slide 38. The third scenario is an investigation using the impoundment for flow augmentation in the river during the summertime lows. In order to define that, we first need to identify the rare-persistent habitat threshold and the associated flows. For this purpose, we conducted a habitat time series analysis for conditions in Scenario 1a and plotted a UCUT curve diagram. As a rare threshold, 32% of a channel area of suitable habitat was selected with 19 days of persistent duration. In this scenario, the amount of flow to 32% of the habitat would be equivalent to

180 l/s. To provide the same amount of habitat with the dam in place, 250 l/s would need to flow downstream of the dam.

39

Impact of dam on Mienia River

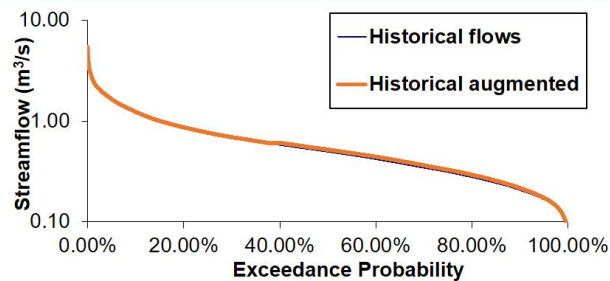
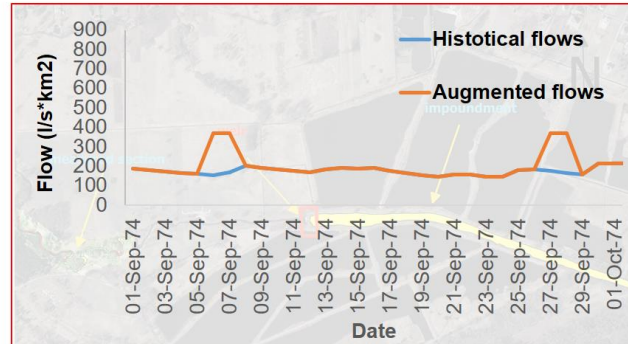
Scenario 3 (flow augmentation from fish ponds)

- two days of flow increase 400 l/s when inflow less than 250 l/s for 18 days (rare threshold)

- Historical flows (1974-2000)
- Simulated near future flows (2024-2050)



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Figure 37. Slide 39. Therefore, for scenario 3, we simulated flow augmentation when the flows were under 250 l/s for longer than 18 days. The augmentation from the ponds would be equivalent to 400 l/s and last 2 days. This would cause only a small change in the historical flow duration curve.

40

Impact of dam on Mienia River

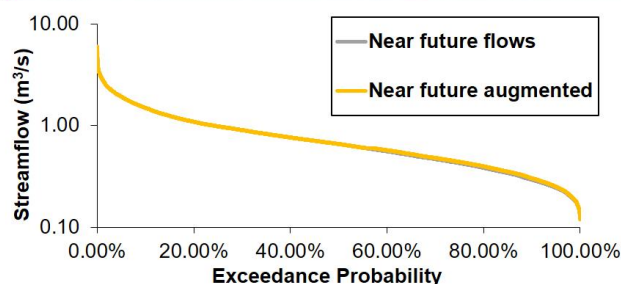
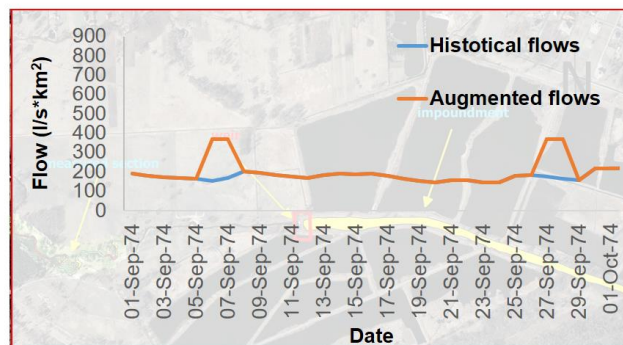
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- Historical flows (1974-2000)
- Simulated near future flows (2024-2050)



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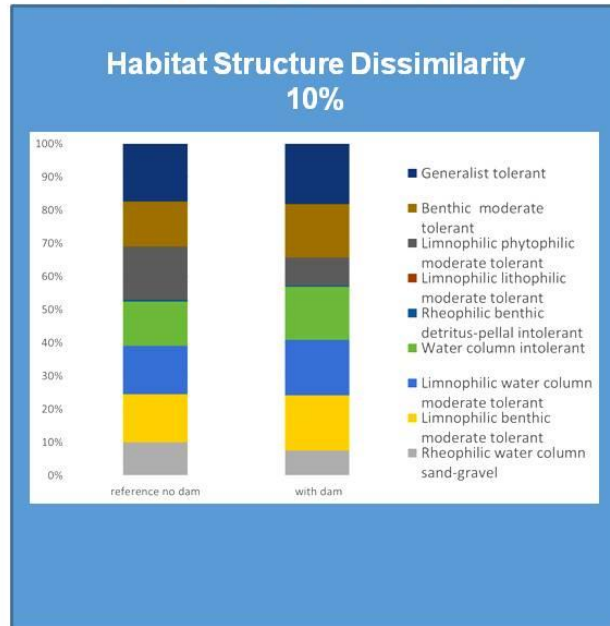
Figure 38. Slide 40. Scenario 3b simulates the same augmentation as Scenario 3a but under Near Future flow conditions.

Impact of dam on Mienia River Comparing scenarios

- The proportions of available habitat for fish guilds for no dam and dam scenario (1 and 2)
- Distribution structure differs by 10%
- Impoundment created by dam reduces habitat for
 - Rheophytic water column sand-gravel species
 - Limnophytic phytophilic moderate tolerant species



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41

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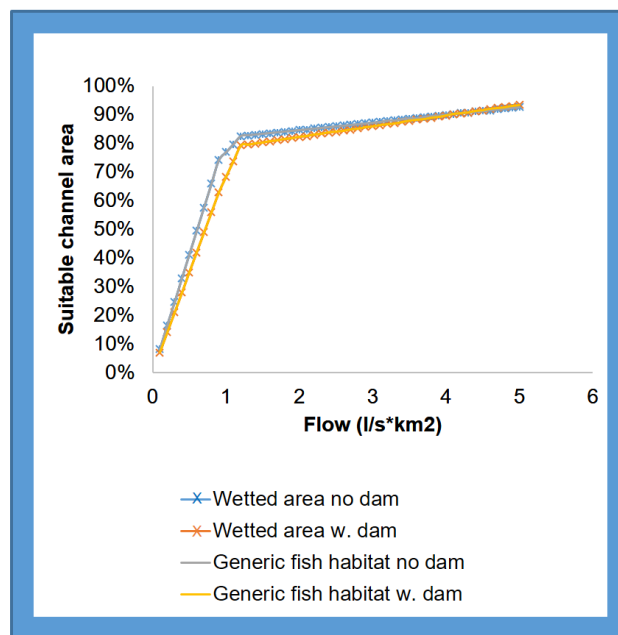
Figure 39. Slide 41. Dam construction altered the habitat structure by only 10%. This is due to the habitat structure of a no-dam scenario being dominated by low gradient river habitats most suitable for lentic species. Comparison with expected fish community structure indicated a lack of rheophytic guild habitats overall. This may be a consequence of historical modifications of the watershed.

Impact of dam on Mienia River Comparing habitat quantity

- The quantity of habitat unsuitable for any fish of the community
- Entire wetted area is suitable in both scenarios



MesoHABSIM MODEL



42

Figure 40. Slide 42. According to our model, the entire wetted area offered suitable habitat for generic fish with the dam in place.

43

Impact of dam on Mienia River

Scenario 1 (No dam)

- a) Historical flows (1974-2000)
- b) Simulated near future flows (2024-2050)

MesoHABSIM MODEL

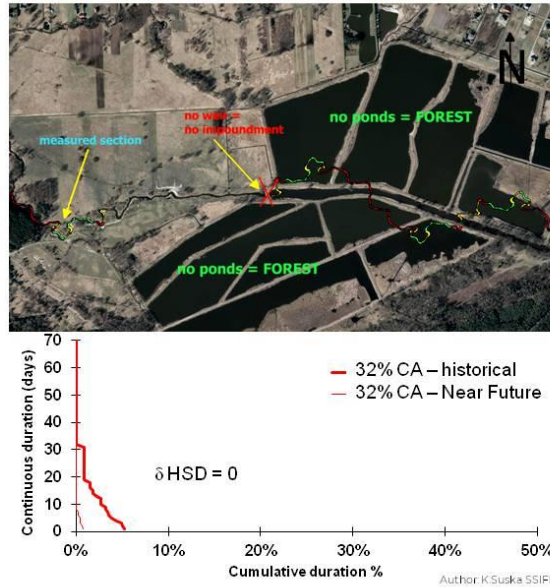


Figure 41. Slide 43. When comparing the number of HSD for no-dam scenarios (1a and 1 b), climate change will actually reduce the HSD. Since the River Mienia is still far from pristine, this can be considered a positive development.

44

Impact of dam on Mienia River

Scenario 2 (with dam)

- a) Historical flows (1974-2000)
- b) Simulated near future flows (2024-2050)

MesoHABSIM MODEL

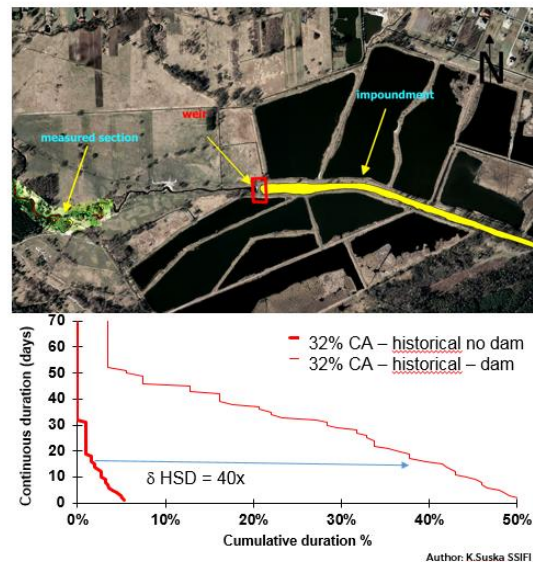


Figure 42. Slide 44. Comparing scenario 1a with 2a. With the dam in place, the HSD is increasing dramatically as the rare-persistent threshold changes by 4000%, i.e. there is a 40-times increase in stress days frequency (from 0.9% to 36.2%).

MesoHABSIM MODEL

Impact of dam on Mienia River

Scenario 2 (with dam)

- a) Historical flows (1974-2000)
- b) Simulated near future flows (2024-2050)

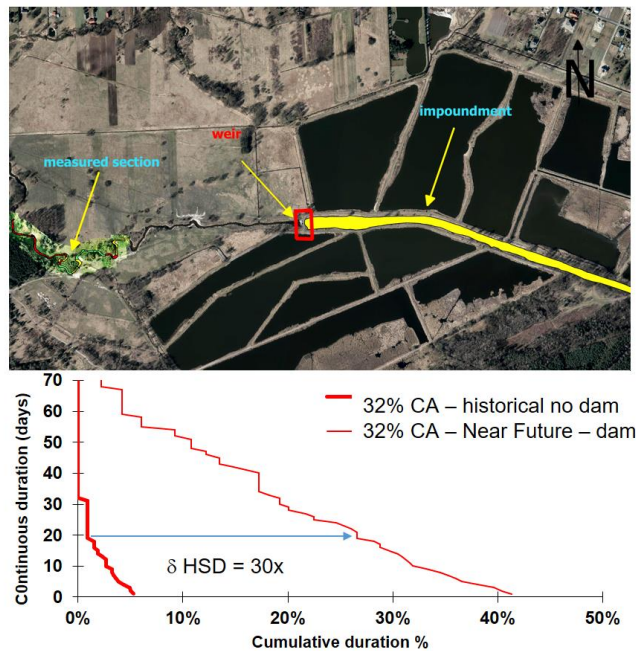


Figure 43. Slide 45. Comparing scenario 1a with 2b. Under the climate change scenario, HSD will still greatly exceed the reference value and drops less than 3000%, i.e. 30-times increase in stress days frequency (from 0.9% to 26.6%)

MesoHABSIM MODEL

Impact of dam on Mienia River

Scenario 3 (flow augmentation from fish ponds)

- two days of flow increase 400 l/s when inflow less than 250 l/s for 20 days (rare threshold)

- a) Historical flows (1974-2000)
- b) Simulated near future flows (2024-2050)

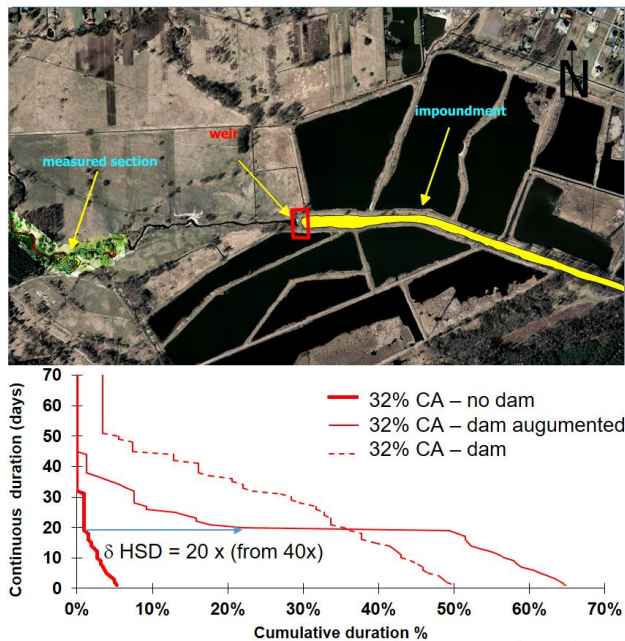


Figure 44. Slide 46. Comparing scenario 1a with 3a. Under historical conditions, flow augmentation would lower the HSD by half to a 20-times increase from reference value (from 0.9% to 22%).

Impact of dam on Mienia River

Scenario 3

(flow augmentation from fish ponds)

- two days of flow increase 400 l/s when inflow less than 250 l/s for 19 days (rare threshold)

- Historical flows (1974-2000)
- Simulated near future flows (2024-2050)

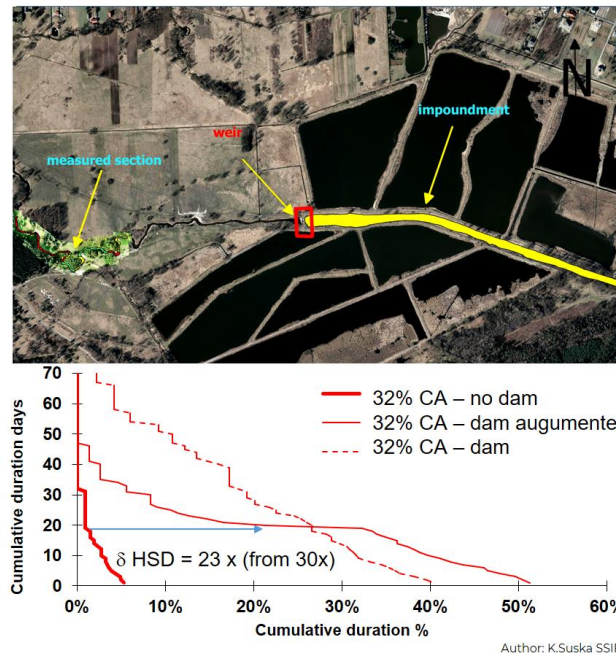


Figure 45. Slide 47. Comparing scenario 1a with 3b. Under the climate change scenario, the augmentation would have less of an effect, as it would be implemented less frequently. It drops to 23 times the reference value (from 0.9% to 21.4%).

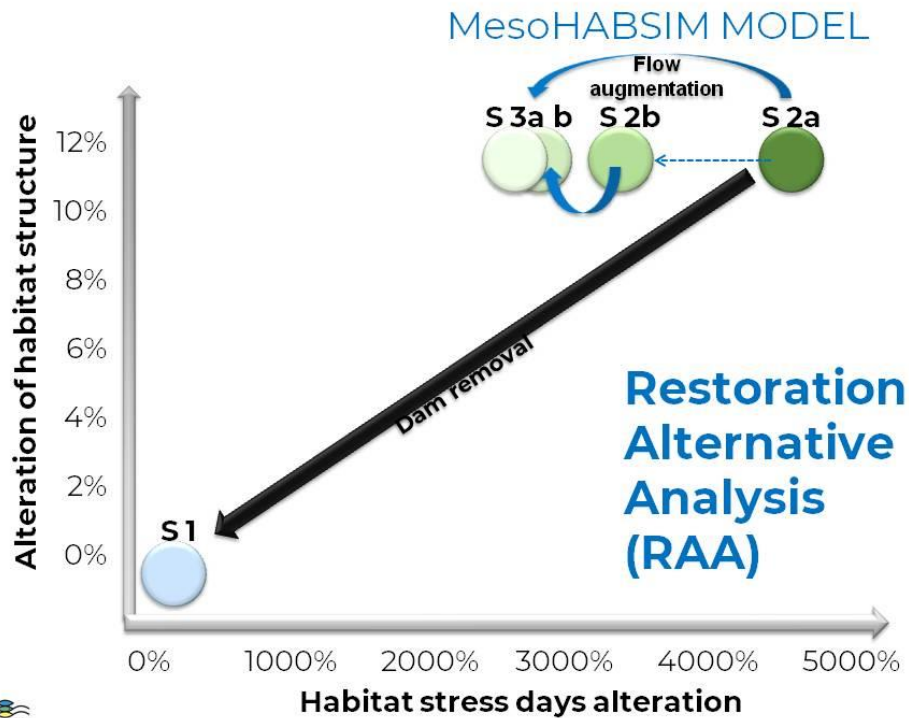


Figure 46. Slide 48. The Restoration Alternative Analysis (RAA) diagram demonstrates the simulated scenarios, clearly indicating that dam removal would be by far the best of these options. This scenario would also most successfully mitigate the impact of climate change. However, it is conceivable that

more sophisticated augmentation scenarios, combined with some habitat restoration, could offer better results while leaving the dam in place.

49

Conclusions

- The **Restoration Alternative Analysis (RAA)** allows to identify impact of dams on fish habitat.
- Mitigation alternatives such as flow augmentation strategies can be tested.
- Best available scenarios can be easily identified.
- Even on small lowland river the impact of a dam is substantial.

Figure 47. Slide 49. This deliverable of the AMBER project demonstrated a concept of applying the Restoration Alternative Analysis (RAA) in investigating the impact of dams on adjacent habitats. The method allows for tests for alternatives and identification of the best available options. Even a small fish hatchery dam on a lowland stream could be shown as creating an impact on fish habitat. Further tests on other facilities and dam types will be conducted during the AMBER project.

50

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- **AMBER - D2.2** Conceptual model of ecological impacts of barriers in EU considering fish habitat selection criteria for running waters (*Version 3.0, March 2019*).

Figure 48. Slide 50. Core references.



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www.amber.international

Partners



Figure 49. Slide 51. AMBER project Partners.

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