INTEGRATIVE HYDROPEAKING MANAGEMENT IN AUSTRIA

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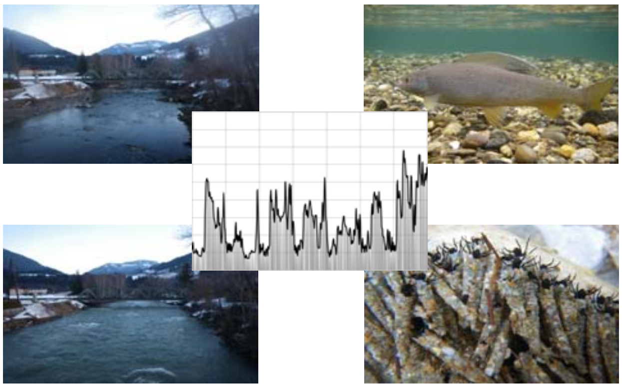
Overview

- Introduction
- Objectives
- Spatial scales
- Evaluation tool
  - – operational steps
  - – example of application
  - – summary
  - – open research questions and outlook

Introduction

Hydro peaking causes one of the most important environmental impacts on running water ecosystems in Austria.



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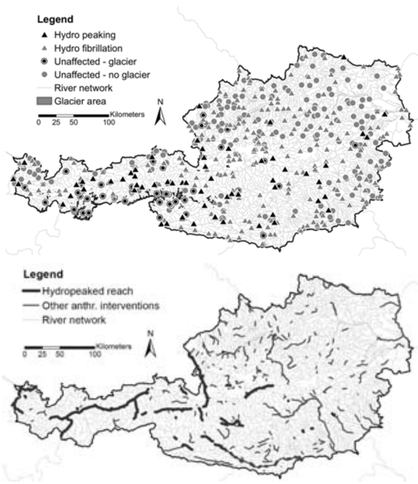
Introduction



- 59% of Austrian hydrographs are affected by anthropogenic interventions (13% hydropeaking, 46% other). (Greimel *et al*, 2015)
- More than 800 km river stretches are affected by hydropeaking (caused by high- head storage power schemes).
- At least 3000 km river stretches are affected by other anthropogenic interventions (caused by Schwellbetrieb, run-off-the-river power plants…)
- Short term flow fluctuations and its ecological impacts are probably a more widespread problem than assumed!

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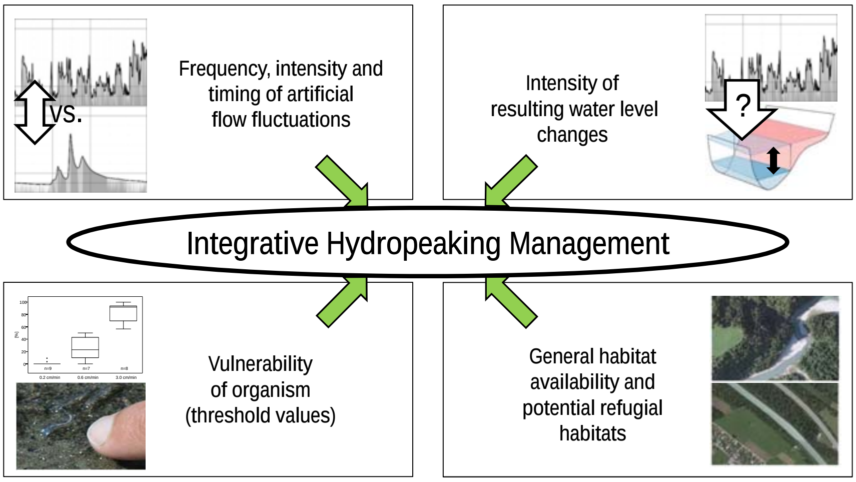
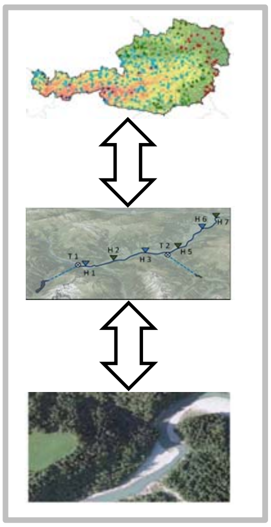
Objectives



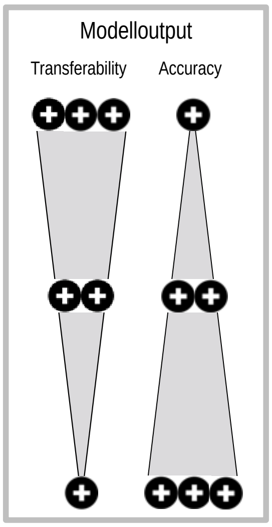
Objectives

- The development of a nationwide applicable evaluation tool…
  - to evaluate the ecological effects of mitigation measures.
  - to contrast ecological benefits and economic losses of specific mitigation measures.
- That requires…
  - a close collaboration of hydrologists, hydraulic engineers, ecologists and power plant operators.
  - to work on highly different spatial scales.

Spatial scales



- Nationwide scale
  e.g.: hydrograph characterization, empirical models, threshold definitions
- River-reach-scale
  e.g.: longitudinal hydropeaking assessment, Evaluation tool
- Point-scale
  e.g.: hydraulic models, HyTEC experimental channel, hydrographs

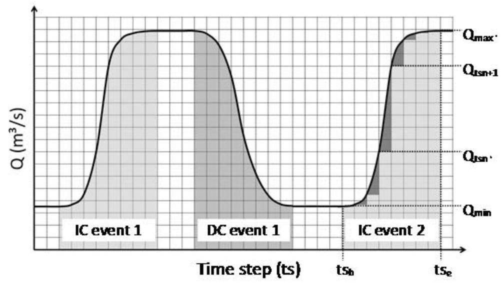


Evaluation tool – Operational steps

1) Detection of flow fluctuation intensity, frequency and timing
2) Identification of ecological relevant flow fluctuations
3) Longitudinal hydropeaking assessment
4) Assessment of resulting water level changes
5) Ecological impact assessment
6) Evaluation of mitigation measures

Evaluation tool – Operational steps

1) Detection of flow fluctuations (Greimel *et al*, 2015)



- An algorithm detects several continuous fluctuation events which are recorded in hydrographs.
- Intensity and frequency of increase and decrease events are described by a set of parameters.

Event-based intensity parameters: definitions and units.

Nr.	Parameter	Acronym	Definition	Unit
1	Maximum flow fluctuation rate	MAFR	$\max(\mathrm{abs}((Q_{tsn+1}) - (Q_{tsn})))$	m^3/s^2
2	Mean flow fluctuation rate	MEFR	Amplitude/Duration	m^3/s^2
3	Amplitude	AMP	$Q_{max} - Q_{min}$	m^3/s
4	Flow ratio	FR	Q_{max}/Q_{min}	
5	Duration	DUR	$ts_e - ts_b$	s

ts_b - time step event beginning, ts_e - time step event ending, Q_{max} - maximum event flow, Q_{min} - minimum event flow, Q_{tsn} - flow of a specific time step, Q_{tsn+1} - flow of subsequent time step, max – maximum, abs – absolute, s – second (1 ts ≙ 900 seconds or 15 minutes).

Evaluation tool – Operational steps

2) Identification of ecological relevant flow fluctuations (Greimel *et al*, 2015)

Intensity levels in relation to the mean maximum annual parameter value (%) (01.01.2004 - 31.12.2008) and corresponding natural exceedings per year (days ≙ 95 % Confidence Region) for parameter maximum and mean flow fluctuation rate at unaffected hydrographs in Austria (N=221).

Threshold level	Maximum flow fluctuation rate		Mean flow fluctuation rate	
	IC	DC	IC	DC
100	1 - 1	1 - 1	1 - 1	1 - 1
90	1 - 2	1 - 2	1 - 2	1 - 2
80	1 - 2	1 - 2	1 - 2	1 - 2
70	2 - 3	2 - 3	2 - 3	2 - 3
60	2 - 4	2 - 5	2 - 5	2 - 5
50	2 - 6	2 - 8	2 - 7	2 - 9
40	3 - 11	3 - 14	3 - 11	3 - 15
30	4 - 19	4 - 26	4 - 21	4 - 28
20	6 - 39	6 - 51	7 - 43	7 - 57
10	11 - 86	11 - 114	13 - 99	14 - 124

IC – increase events, DC – decrease events.

- Using the maximum flow fluctuation rate of natural events as reference enables a standardized selection of specific flow fluctuations.
- e.g.: A threshold level of 40% captures only natural events with very high flow rates (mean natural occurrence: 3-15 days/year).

Monthly frequencies of selected decrease events 2008 at one exemplary hydrograph per sub-daily fluctuation regime (similar catchment area) (threshold level: 40%; parameter: mean flow fluctuation rate).

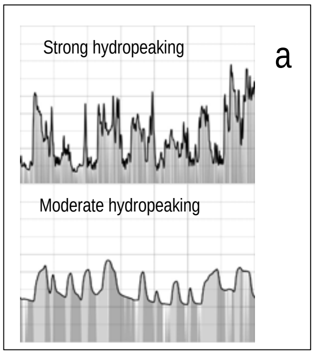
Sub-daily flow regime	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Hydro peaking	113	189	142	84	165	269	327	262	124	115	107	75
Hydro fibrillation		1		1			7					
Unaffected - glacier influence					1	1	4	2	1			
Unaffected - no glacier influence						3	6	1				

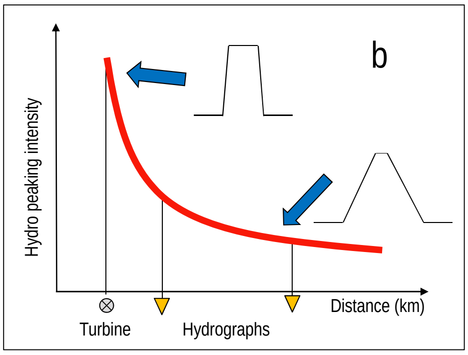
Evaluation tool – Operational steps

3) Longitudinal hydropeaking assessment (Greimel *et al*, in prep.)

Hydro peaking intensity is highly variable due to

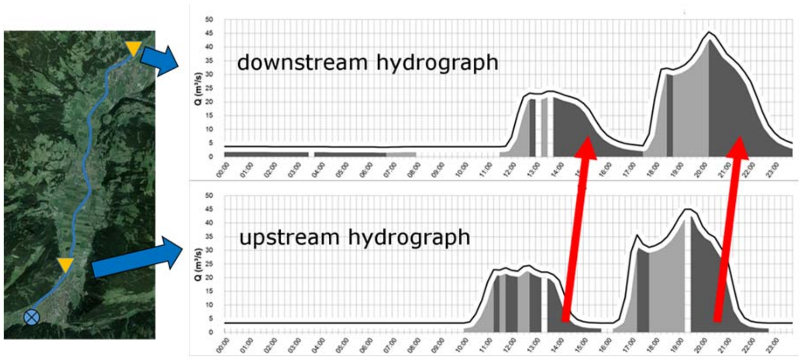
a) different operation modes of the power plants (multiple stretches) and
b) different distances to the power plant outlet (one specific stretch – retention effects)





Evaluation tool – Operational steps

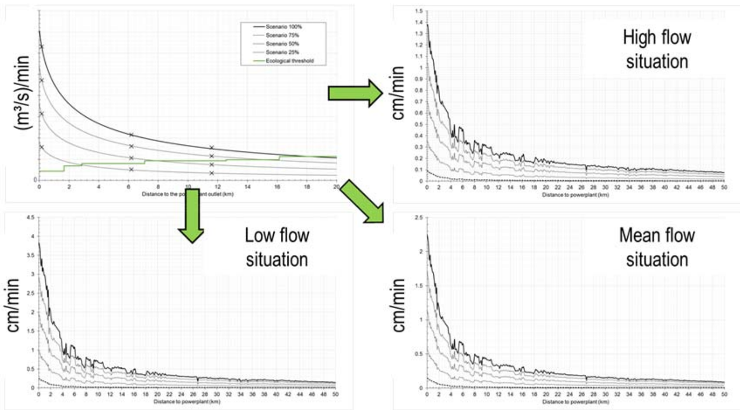
3) Longitudinal hydropeaking assessment (Greimel *et al*, in prep.)



A power plant specific longitudinal assessment of hydro peaking intensity is enabled by the tracking of specific flow fluctuations using multiple hydrographs.

Evaluation tool – Operational steps

4) Assessment of resulting water level changes



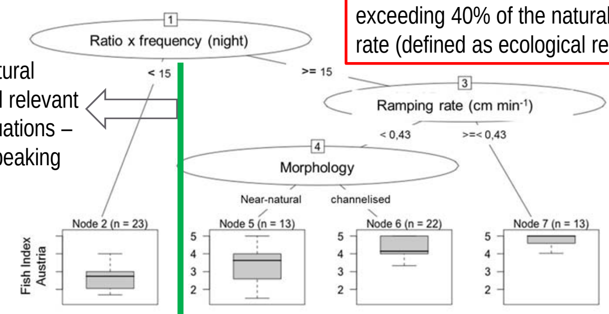
The assessment of resulting water level changes can be carried out by regression models (variables: altitude, mean runoff rate, catchment size, river width) (Greimel *et al*, in prep.) or hydraulic modelling.

Evaluation tool – Operational steps

5) Ecological impact assessment

Referring exclusively to flow fluctuations exceeding 40% of the natural maximum flow rate (defined as ecological relevant).

Solely natural ecological relevant flow fluctuations – no hydropeaking impact

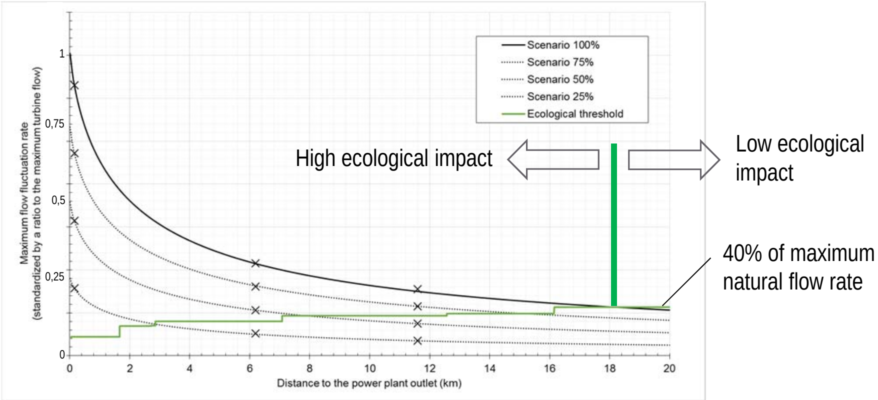


In addition anthropogenic flow fluctuations with ecological relevance - impact

According to node 1 „ratio x frequency" (HP-index), it can be assumed that ecological impacts are low, if there are no anthropogenic events with very high flow fluctuation rates (HP-index: <15).

Evaluation tool – Operational steps

5) Ecological impact assessment



Potential ecological impacts can be evaluated by contrasting detailed hydrological and/or hydraulical information and known ecological thresholds (e.g. stochastic model – see above; experimental channel and stranding thresholds).

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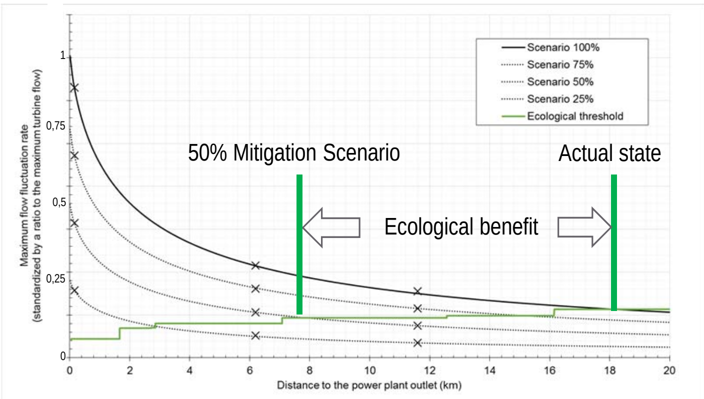
Evaluation tool – Operational steps

6) Evaluation of mitigation measures



Specific mitigation scenarios can be achieved by different mitigation types (e.g. constructional measures vs. operational measures). Specific economical losses and ecological benefits can be contrasted.

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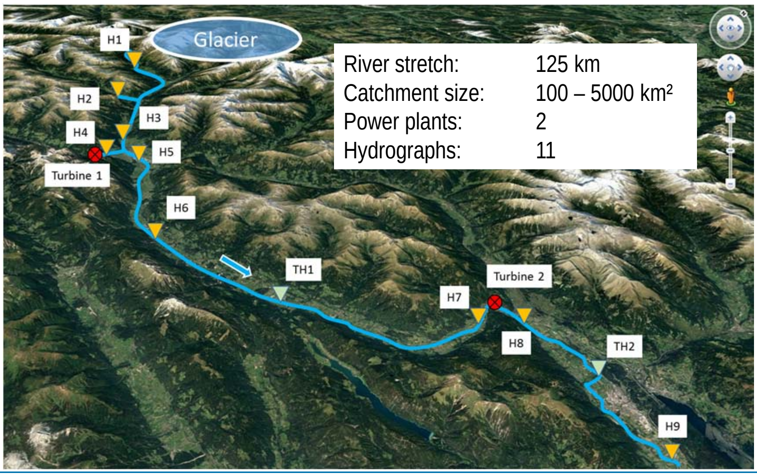
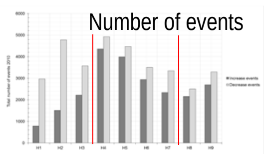
Evaluation tool – Example of application

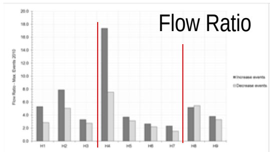
Overview

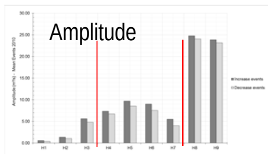


Evaluation tool – Example of application

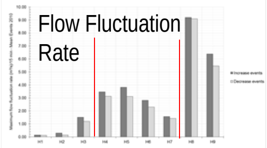
1) Detection of flow fluctuations…

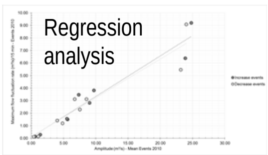


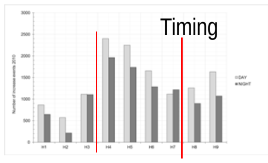




…enables a detailed event description at specific hydrographs. However, we need to look at ecological relevant events to see the differences between hydropeaked and unaffected reaches…

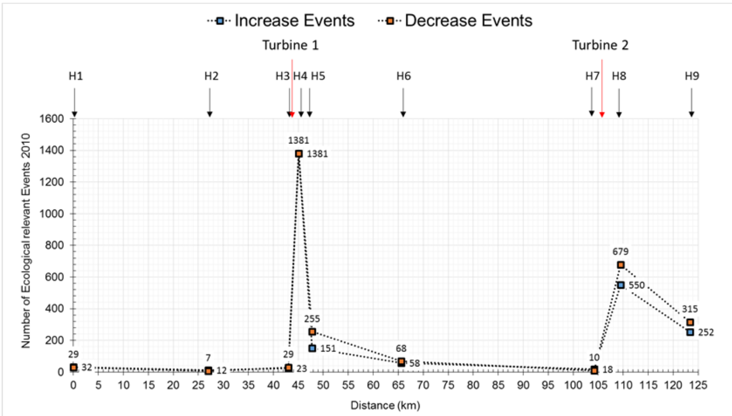






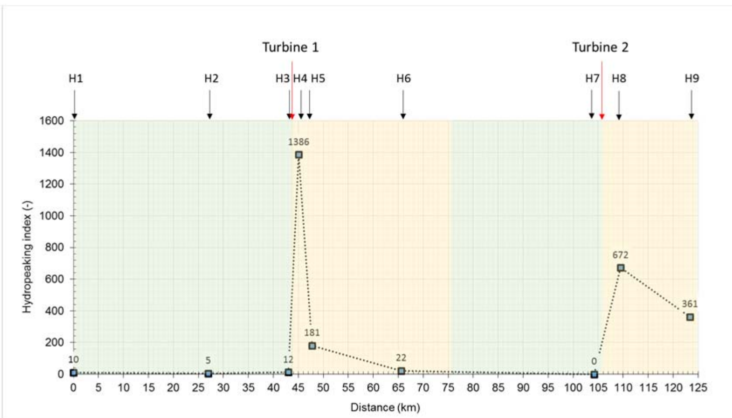
Evaluation tool – Example of application

2) Identification of ecological relevant flow fluctuations (exceeding 40% of the natural maximum flow fluctuation rate)



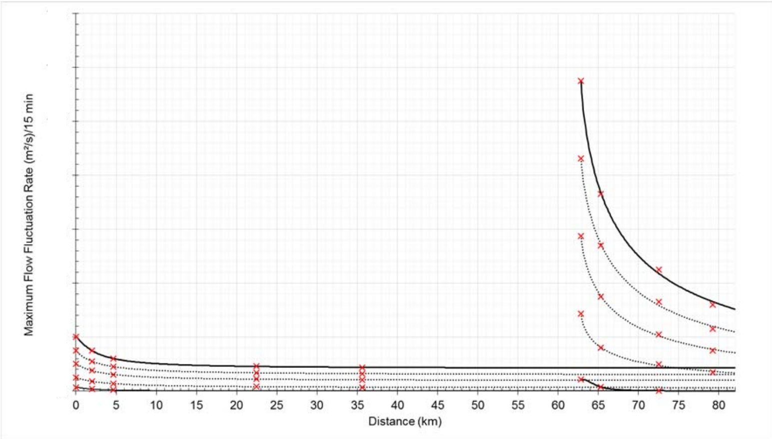
Evaluation tool – Example of application

2) Identification of ecological relevant flow fluctuations – a first step to evaluate ecological impacts (Threshold - hydropeaking index: 15)



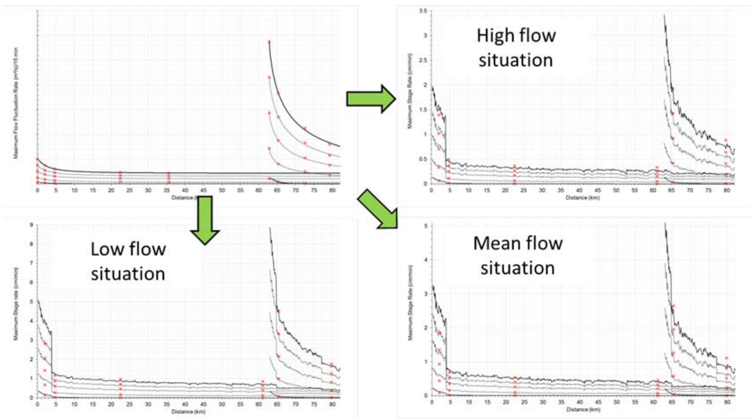
Evaluation tool – Example of application

3) Power plant specific longitudinal hydropeaking assessment



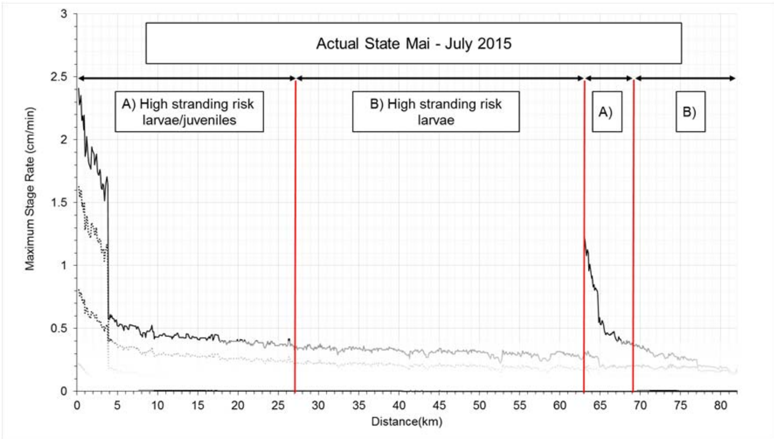
Evaluation tool – Example of application

4) Approximate determination of resulting water level changes



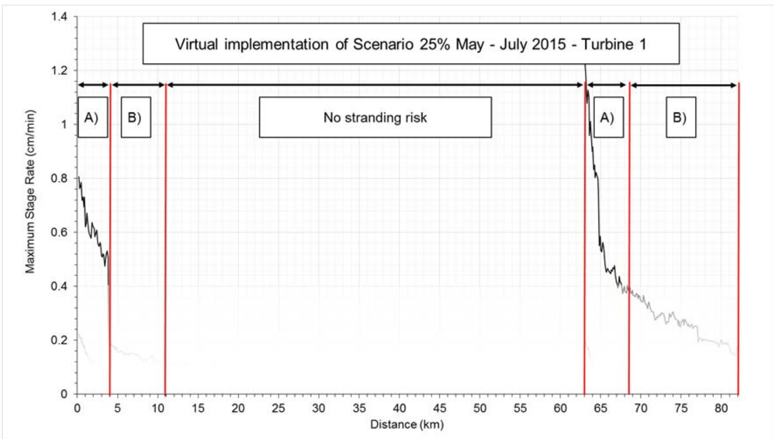
Evaluation tool – Example of application

5) Ecological impact assessment



Evaluation tool – Example of application

6) Evaluation of mitigation measures (Stranding)



Evaluation tool – Summary

- The presented tool enables to…
  - grasp intensity, frequency and timing of anthropogenic flow fluctuations.
  - contrast highly different situations (e.g. different operation modes, river sizes, natural hydrological conditions).
  - quantify the ecological impact in a longitudinal view.
  - Evaluate potential effects of mitigation measures for fish.

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Evaluation tool – Outlook

- During the next years the goal will be to apply and to improve the presented tool:
  - Hydromorphological modifications due to mitigation measures should be quantified.
  - The contrast of predicted ecological benefits and actual monitored effects should help to identify knowledge gaps concerning further bottlenecks.
  - The tool should be extended to evaluate potential hydropeaking impacts for other species potentially based on other parameters/variables (e.g. Benthos).

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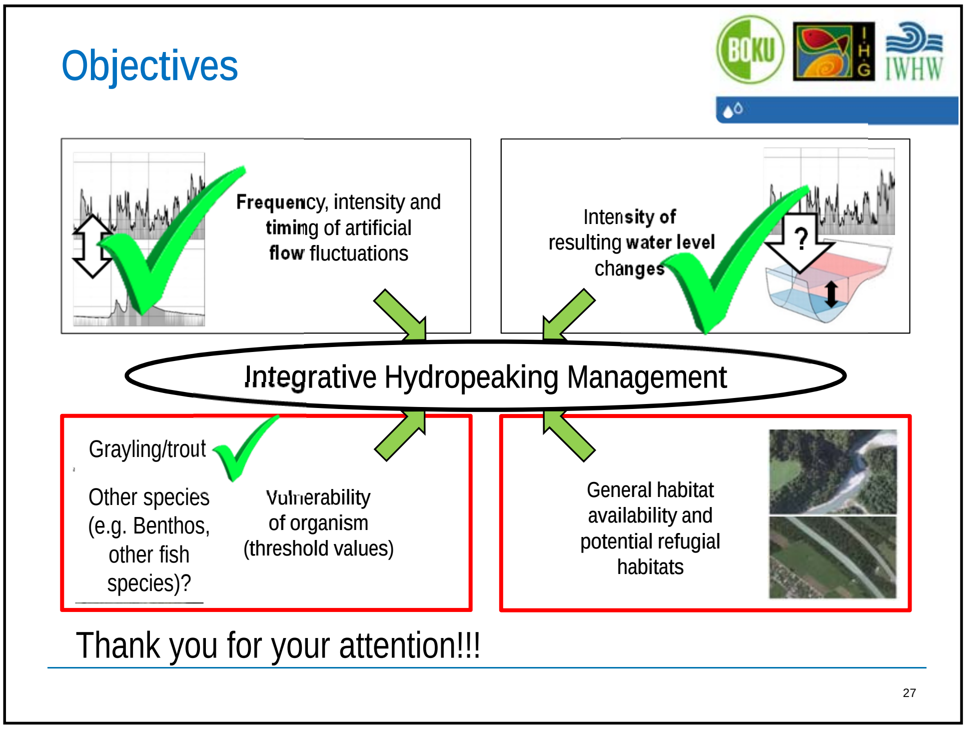
Objectives
IWHW
Frequency, intensity and timing of artificial flow fluctuations
Intensity of resulting water level changes
?
Integrative Hydropeaking Management
Grayling/trout
Other species (e.g. Benthos, other fish species)?
Vulnerability of organism (threshold values)
General habitat availability and potential refugial habitats
Thank you for your attention!!!
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