Hydropeaking – From Process understanding to mitigation measure design

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Special Issue „Hydropeaking“
(Science of the Total Environment)

Guest editors:

Hauer, C. (BOKU); **Siviglia A.** (ETH Zürich); **Zolezzi, G.** (University of Trento);

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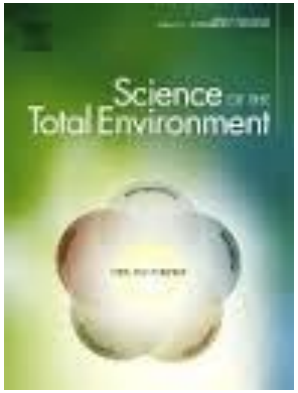


Timeline:

15th of July 2015: Invitation for Contribution

30th of Sept. 2015: Notification of interest

30th of June 2016: Deadline for submission

15th of Oct. 2016: Closing review process

- 24 notifications

- 18 submitted papers

- 16 accepted papers

Outline

- **Presentation of SI – publications**
- **Points of Discussion**
- **Conclusions**

Presentation of SI - publications

16 accepted papers ⇨ ***5 topics***

Topic 1 - Hydropeaking process understanding and biotic response (***6 papers***)

Topic 2 - Modelling tools and extended integrated methods for hydropeaking analysis (***6 papers***)

Topic 3 - New conceptual approaches for hydropeaking management (***1 paper***)

Topic 4 - Mitigation measure design and practical experiences (***2 papers***)

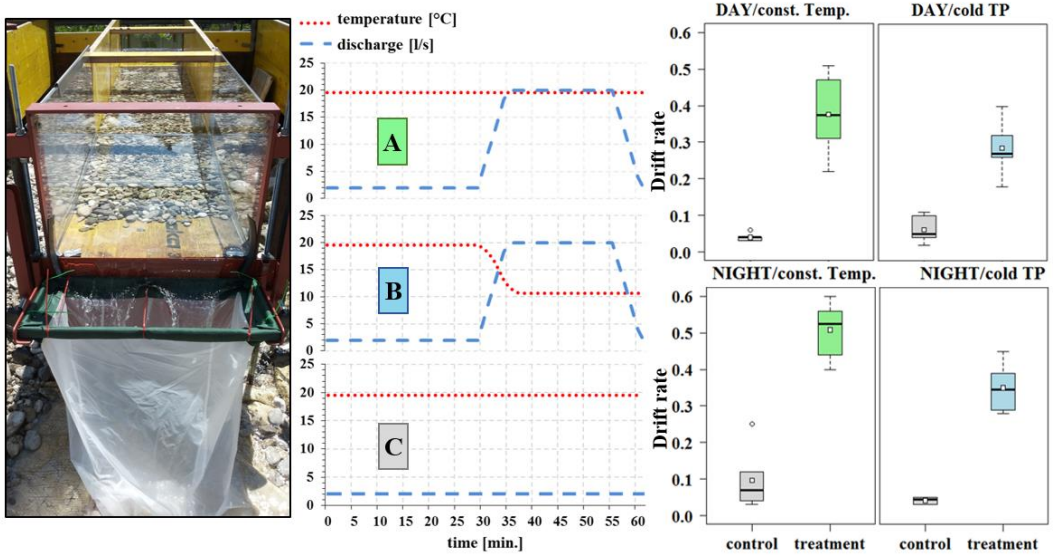
Topic 5 - Socio-environmental-social interaction related to hydropeaking (***1 paper***)

Topic 1

Hydropeaking process understanding and biotic response

Effects of hydro- and thermopeaking on benthic macroinvertebrate drift

Schülting, L., *Feld, C.K. & Graf, W.*

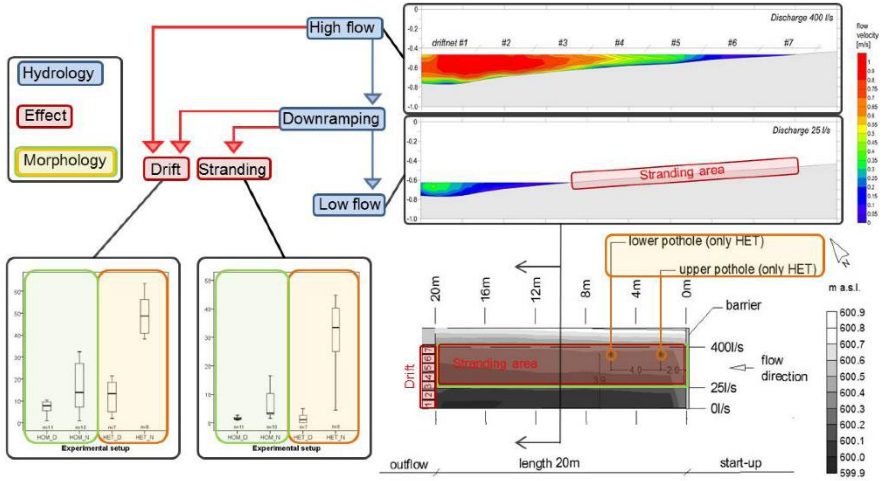


Highlights

- Hydropeaking (HP) significantly increased drift of most macroinvertebrate taxa
- HP combined with ***cold thermopeaking*** led to ***reduced total drift rates***
- HP during night led to higher drift rates
- Increase in drift during night was lower in thermopeaking treatments
- Rheophilic and interstices associated taxa were less affected by HP

Effects of river bank heterogeneity and time of day on drift and stranding of juvenile European grayling (Thymallus thymallus L.) caused by hydropeaking

Auer, S., *Zeiringer, B., Führer, S., Tonolla, T., & Schmutz, S.*

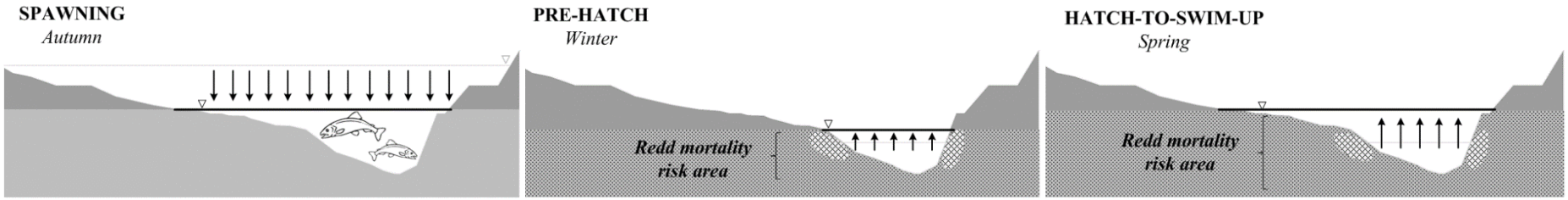


Highlights

- Nocturnal hydropeaking events significantly increased drift and stranding of juvenile European graylings
- ***Stranding risk*** for juvenile European grayling provoked by a hydropeaking event was significantly ***increased*** if ***potholes*** were present on the gravel bank
- A reduced downramping rate of a hydropeaking event significantly lowered drift and stranding rates

Effects of hydropeaking on salmonid gravel stages: a modelling approach for implementing mitigation strategies

Casas-Mulet, R., *Saltveit, S.J., & Alfredsen, K.T.*

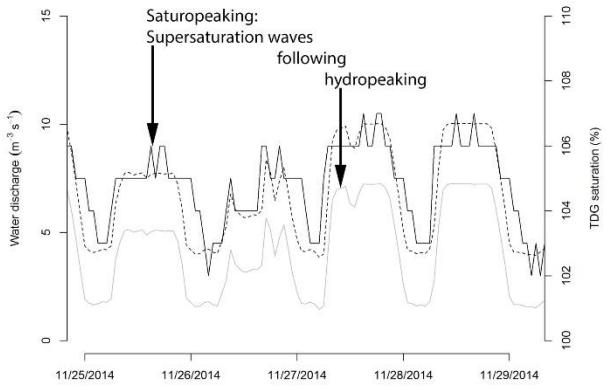


Highlights

- Salmon early life stages development and survival are affected by hydropeaking
- ***Flow-related mitigation*** options can ***minimise*** such ***early-stages mortality***
- A modelling tool-set to assess the implementation of three options is presented
- The proposed options are operationally and economically feasible most years

First observations of saturopeaking: characteristics and implications

Pulg, U., *Vollset, K.W., Velle, G., & Stranzl, S.*

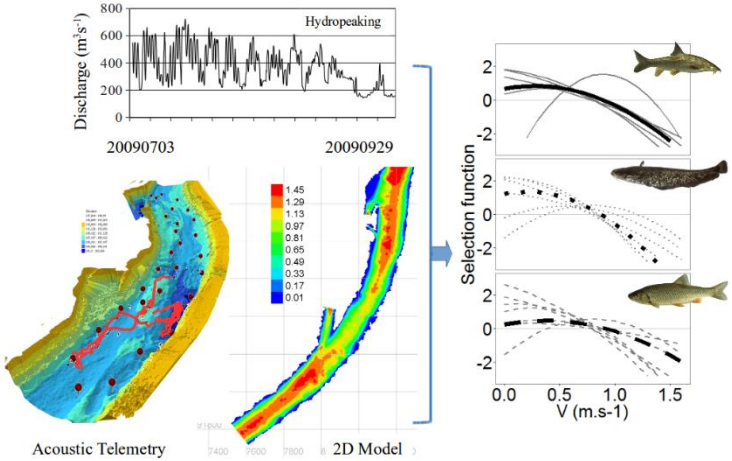


Highlights

- Characteristic waves of supersaturated water were discovered which were significantly correlated with hydropeaking
- The term ***"saturopeaking"*** is introduced for these waves, defined as the artificial, rapid, periodic and frequent fluctuation of ***gas saturation*** caused by ***hydropeaking***.
- Saturopeaking may have significant ecological impacts on biological communities, which have never been investigated up to now.

Fish habitat selection in a large hydropeaking river: strong individual and temporal variations revealed by telemetry

Capra, H., *Plichard, L., Bergéa, J., Pella, H., Ovidio, M., McNeil, E., & Lamouroux, N.*

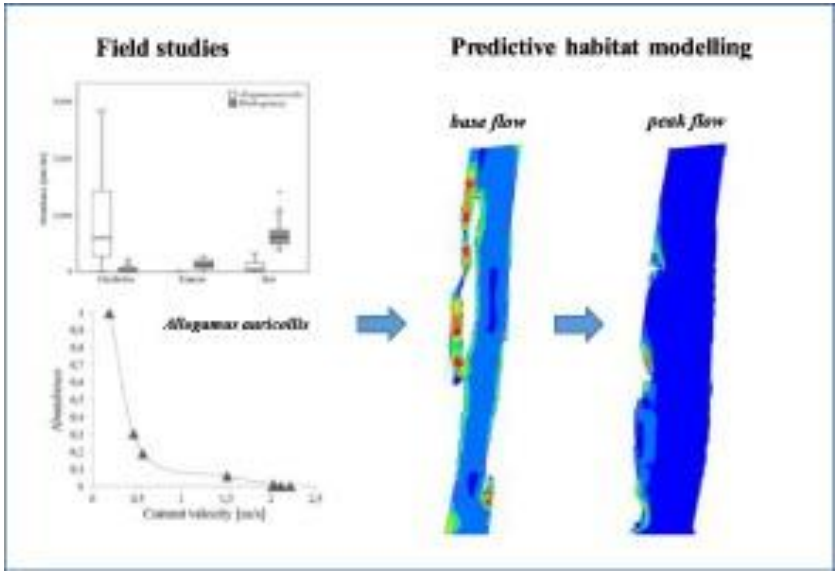


Highlights

- Managing hydropeaking in rivers requires understanding dynamic ecological responses
- We continuously tracked 18 individual fish in a large hydropeaking river
- The dynamics of hydraulic and thermal microhabitats was modeled
- Individual habitat selection varied with time and with current and past hydraulics
- ***Hydropeaking*** may force individuals to ***adopt*** a ***least-constraining strategy***

Habitat use and tolerance levels of macroinvertebrates concerning hydraulic stress in hydropeaking rivers – a case study at the Ziller river in Austria

Leitner, P., *Hauer,C., & Graf, W.*



Highlights

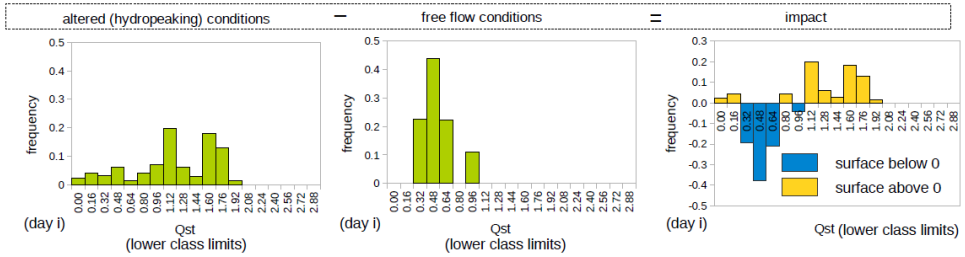
- Habitats of ***stagnophilic macroinvertebrate*** taxa are ***significantly minimized*** in ***channelized stretches***
- The WFD compliant national Austrian assessment method fails to detect impacts of hydropeaking
- The development of a stressor-specific sampling design is required
- The ***hydraulic stress analysis*** provides expertise on the ***resistance*** of ***certain taxa***

Topic 2

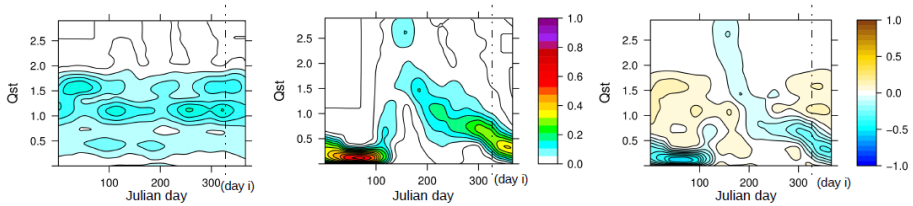
Modelling tools and extended integrated methods in for hydropeaking analysis

A graphical approach to characterize sub-daily flow regimes and evaluate its alterations due to hydropeaking

Alonso, C., *Román, A., Dolores Bejarano, M., de Jalon, D.G., & Carolli, M.*



Aggregate daily results into a year graph & plot a smooth approximation of frequency (z) against Julian day (x) and the value class of the variable (y) (e.g standardized hourly flow, Qst).

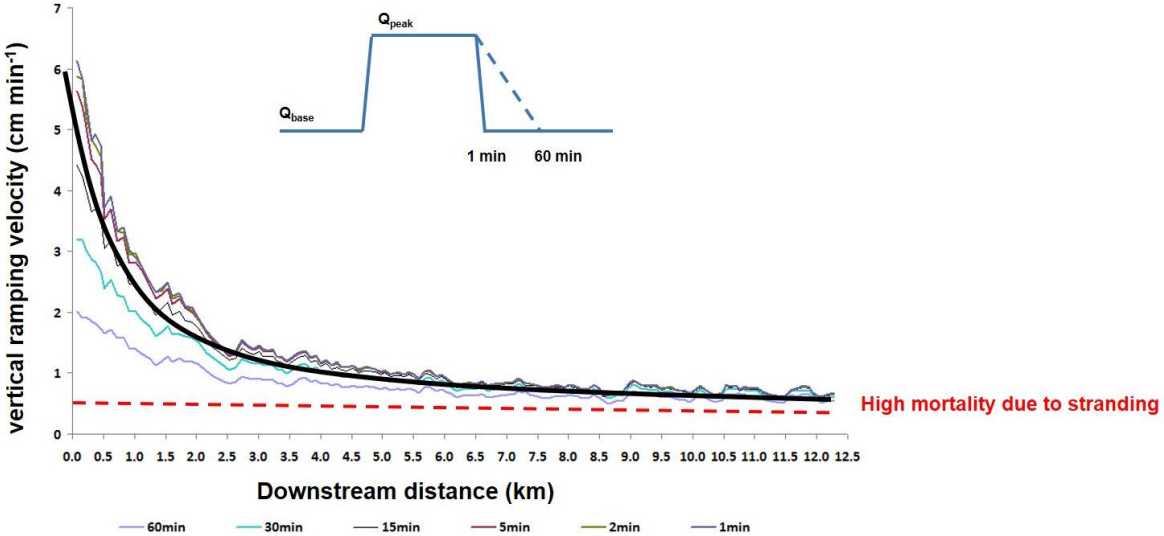


Highlights

- A graphic method for characterizing flow regime at short time intervals is proposed
- Presented ***graphical display*** allows ***sensitive metrics visual identification***
- Hydropeaking alteration can be assessed ***without*** a priori ***subjective assumptions***
- This method evaluates hydropeaking impact by comparison with reference flow conditions

Longitudinal assessment of hydropeaking impacts on various scales for an improved process understanding and the design of mitigation measures

Hauer, C., *Holzapfel, P., Leitner, P., & Graf, W.*



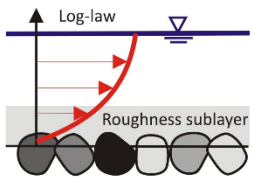
Highlights

- Peak flow retention leads to a significant decrease in vertical ramping velocities at the first five kilometers
- Analysis of ***peak flow retention*** allows a ***pre-liminary assessment*** for ***mitigation measure design***
- For morphological mitigation measures self-formed, near natural morphology should be targeted
- The connectivity to tributary systems with a natural flow and sediment regime is important

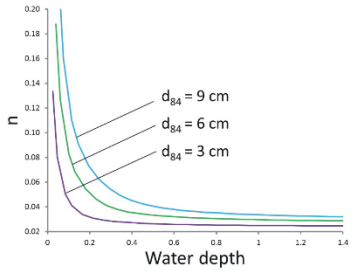
Depth-dependent hydraulic roughness and its impact on the assessment of hydropeaking

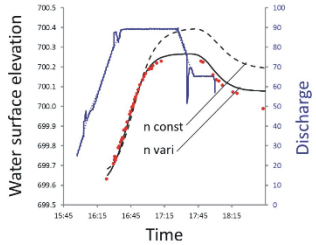
Kopecki, I., *Schneider, M., & Tuthan, J.A.*

Depth-dependent roughness is calculated using a modified log-law



Roughness rating curves are created for water depth and sediment grain size





Rating curves are used in a 2D hydrodynamic model

Hydropeaking case study with rapidly changing flows

Measured water surface time series are compared for constant and depth-dependent roughness models

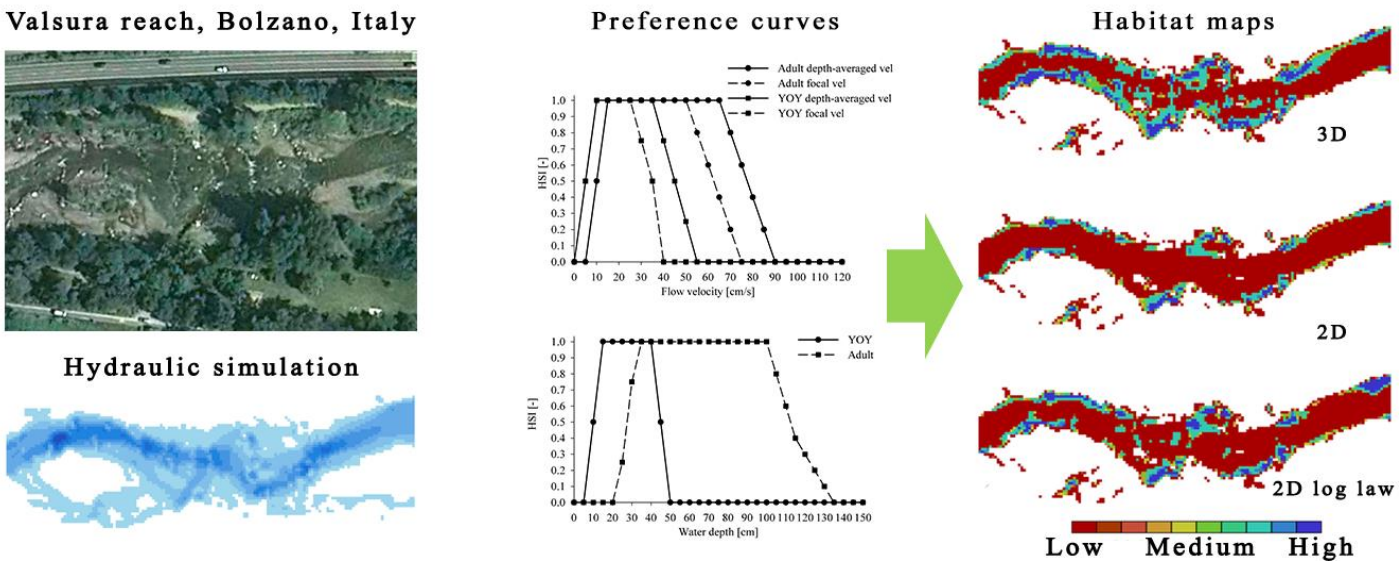
Results show the temporal and spatial distribution of modelled water depths are significantly more accurate when applying depth-dependent roughness

Highlights

- A ***new water depth-dependent roughness coefficient*** is proposed
- Spatiotemporal accuracy of transient flow models increases
- ***Hydropeaking assessment*** can be ***improved*** concerning hydraulics in ***dewatering areas***

The role of 3D-hydraulics in habitat modelling of hydropeaking events

Pisaturo, G.R., *Righetti, M., Noack, M., Schneider, M., Dumbser, M., & Cavedon, V.*

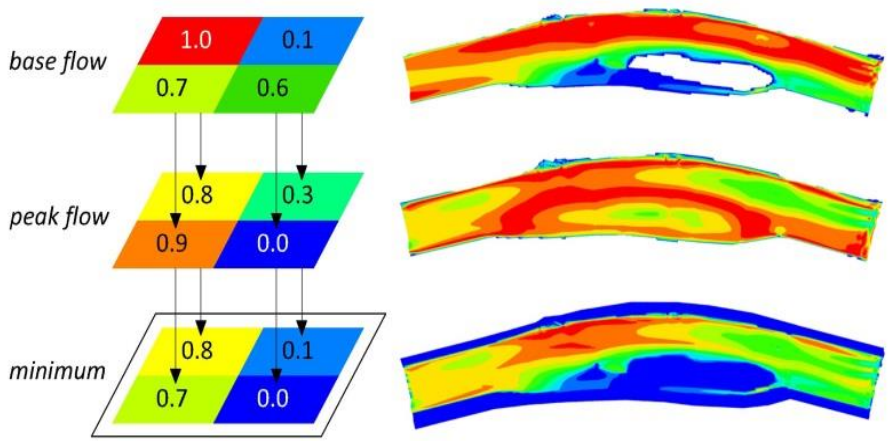


Highlights

- Development of a 3D CFD model with non-hydrostatic correction
- Comparison of habitat simulation between standard 2D and new 3D approach
- Effects of 3D hydraulics on habitat evaluation for different fish life stages
- ***Better evaluation*** of ***morphological mitigation measures*** in terms of hydropeaking

Evaluation of hydropeaking impacts on the food web in alpine streams based on modelling of fish- and macroinvertebrate habitats

Holzapfel, P., *Leitner, P., Habersack, H., Graf, W. & Hauer, C.*

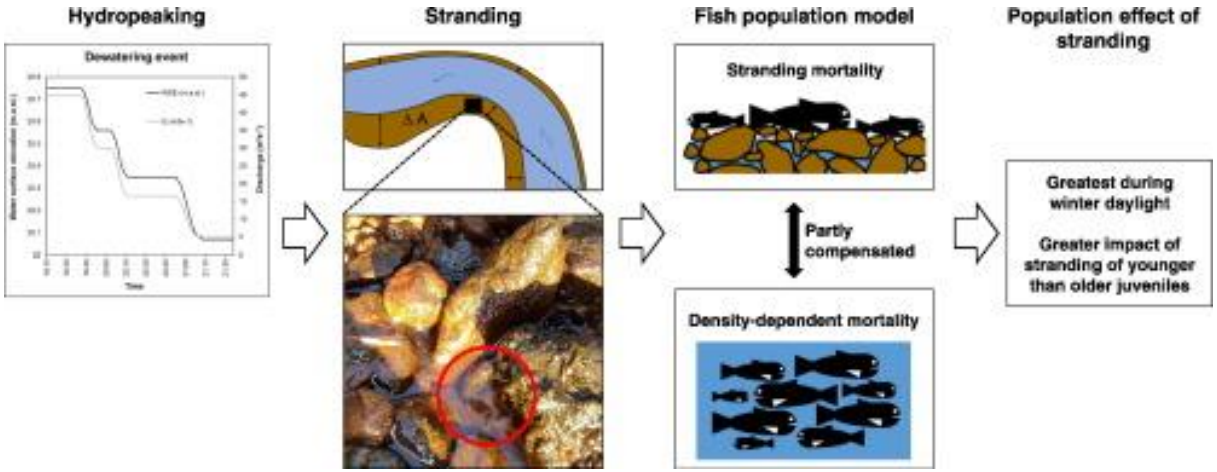


Highlights

- Development of a ***novel approach*** in ***predictive habitat modelling***
- ***Evaluation*** of flow fluctuations on potential ***epibenthic feeding grounds*** by revealing patterns of ***overlapping*** between ***fish*** and ***macroinvertebrate habitats***
- The potential for benthic feeding in hydropeaked rivers is most convenient during base flow conditions

Modelling the effects of stranding on the Atlantic salmon population in the Dale River, Norway

Sauterleute, J. F., *Hedger, R. D., Hauer, C., Pulg, U., Skoglund, H., Sundt-Hansen, L. E., Bakken, T.H. & Ugedal, O.*



Highlights

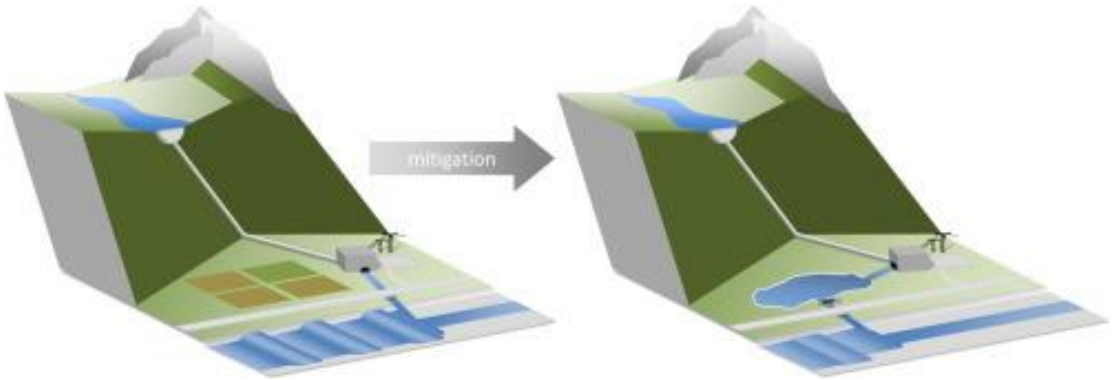
- Long-term impact of stranding of juvenile Atlantic salmon on the population
- Implementation of stranding into individual-based population model
- ***Largest negative effect*** on abundance for hydropeaking ***during winter daylight***
- Sensitivity analysis suggests ***greater impact*** of stranding of ***older juveniles***

Topic 3

New conceptual approaches for hydropeaking management

A conceptual framework for hydropeaking mitigation

Bruder, A., *Tonolla, D., Schweizer, S. P., Vollenweider, S., Langhans, S. D., & Wüest, A.*



Highlights

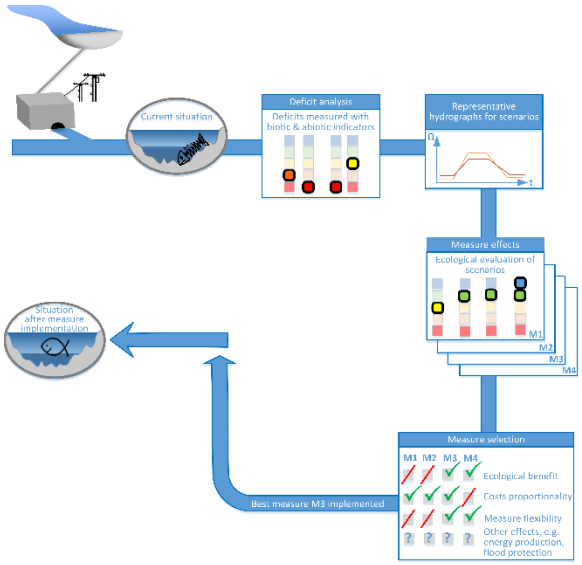
- Hydropeaking mitigation can be achieved with structural and operational measures
- We developed a ***framework*** to predict the ***consequences of mitigation*** on ***river ecosystems***
- Mitigation measures require interdisciplinary assessments in an integrative process

Topic 4

Mitigation measure design and practical experiences

Evaluation of mitigation measures to reduce hydropeaking impacts on river ecosystems - a case study from the Swiss Alps

Tonolla, D., *Bruder, A. & Schweizer, S.*

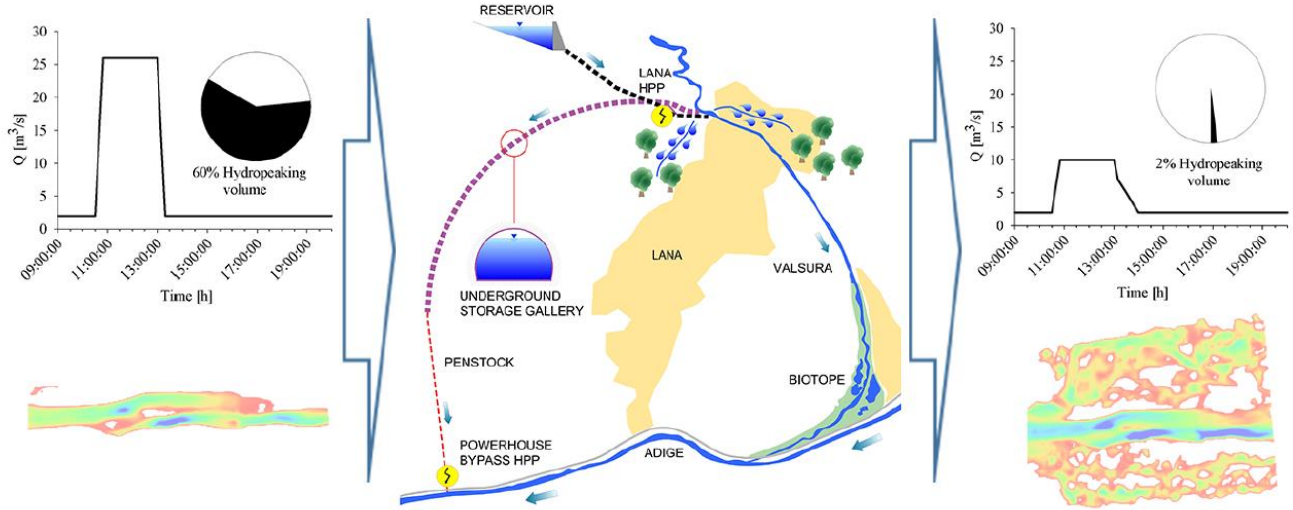


Highlights

- We propose a procedure for the evaluation of hydropeaking impacts and measures
- ***Evaluatio***n should be based on ***representative hydrographs*** and ***ecological indicators***
- Mitigation measures should be ***evaluated*** with ***key stakeholders***

Hydropeaking mitigation project on a multi-purpose hydro-scheme on Valsura River in South Tyrol/Italy

Premstaller, G., *Cavedon, V., Pisaturo, G. R., Schweizer, S., Adami, V., & Righetti, M.*



Highlights

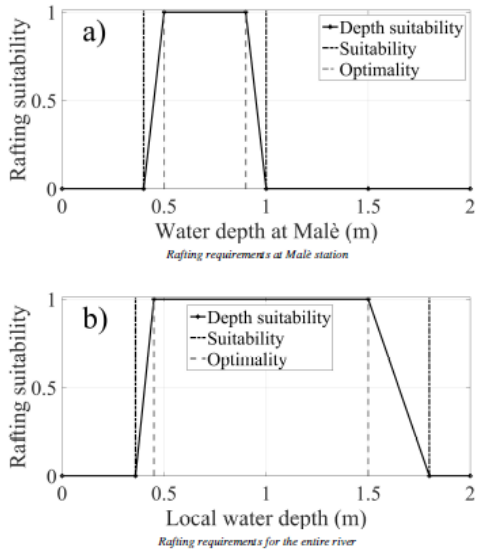
- An deficit analysis of a heavily hydropeaked river is performed
- Hydraulic limits for a functional ecological reproduction
- Reference river investigations and habitat suitability simulations
- ***Comparison*** of ***constructive*** and ***operational mitigation measures***

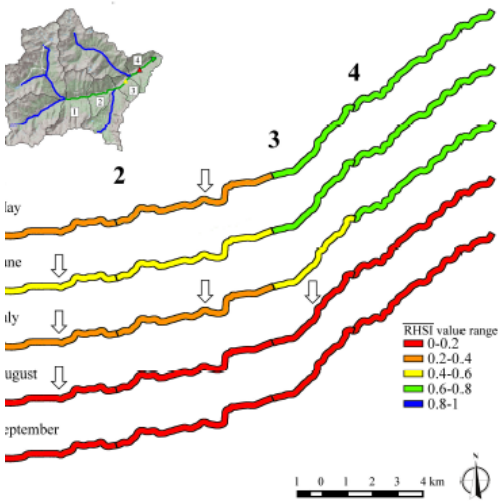
Topic 5

Socio-environmental-social interaction related to hydropeaking

Modelling white-water rafting suitability in a hydropower regulated Alpine River

Carolli, M., *Zolezzi, G., Geneletti, D., Siviglia, A., Carolli, F., & Cainelli, O.*





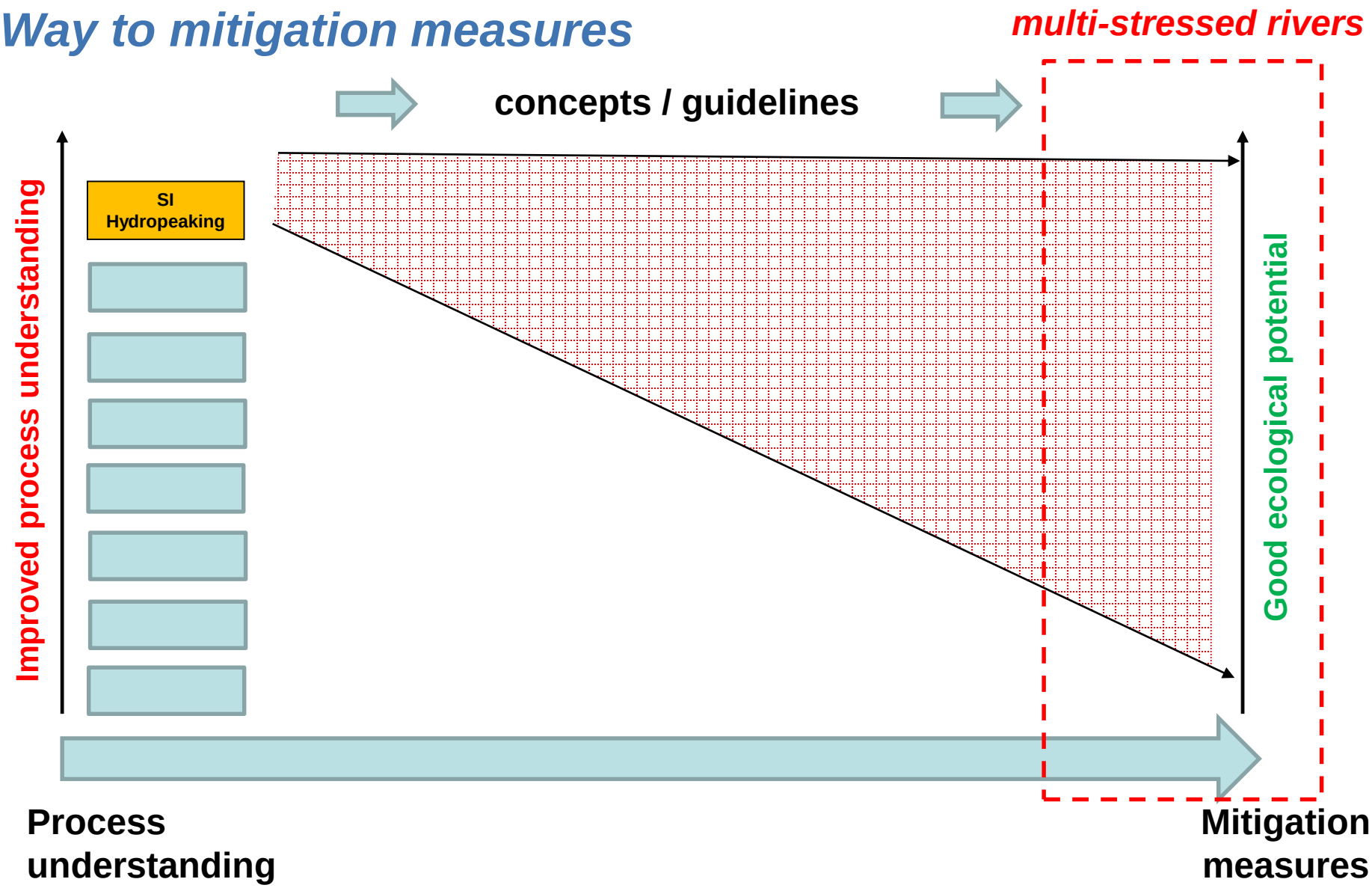
Highlights

- Modelling based approach to assess recreational flow requirements
- Derive of ***novel rafting-suitability indices*** based on water depth
- ***New modelling algorithm*** for investigate sub-daily flows

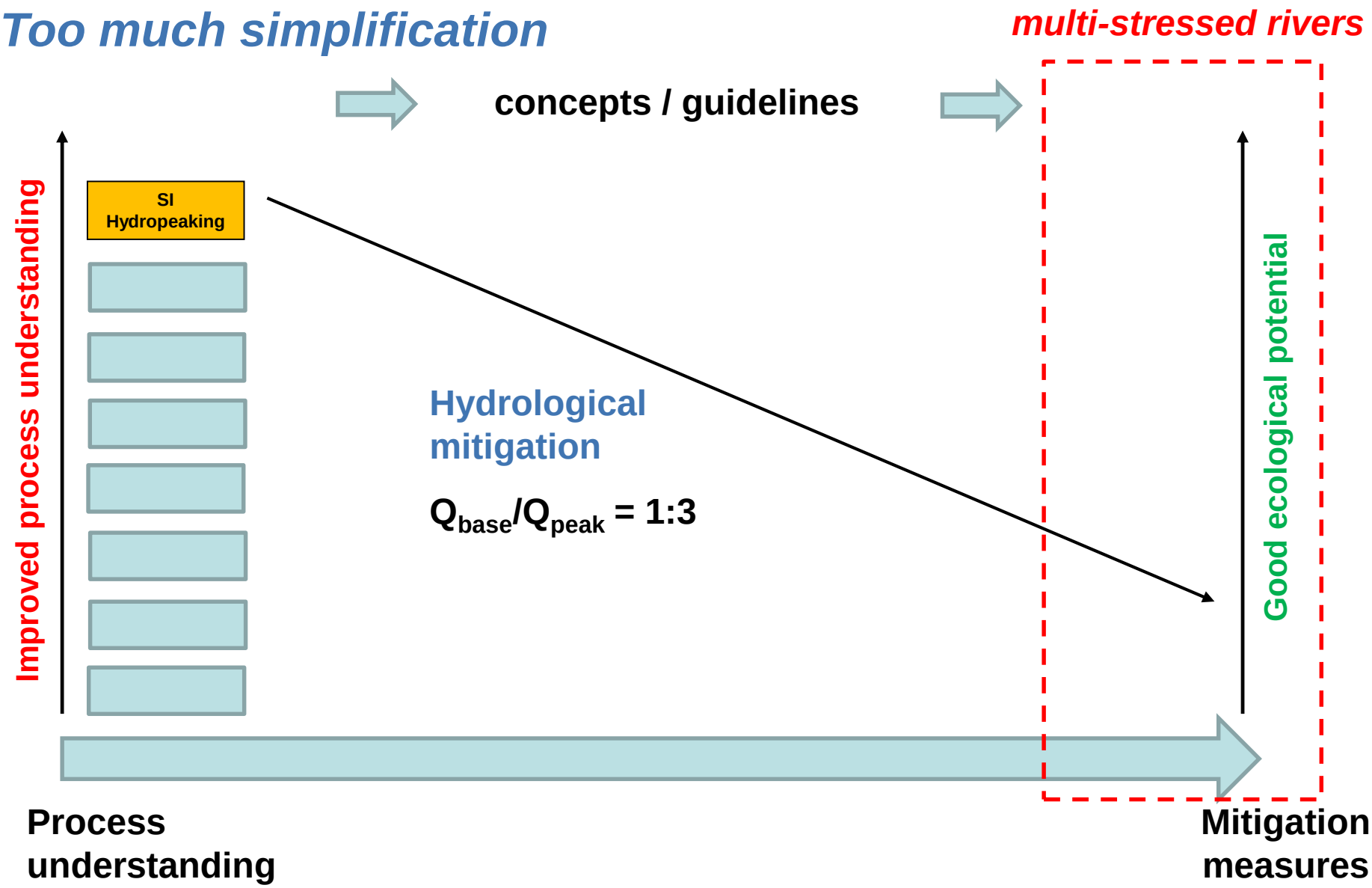
Points of Discussion (SI Hydropeaking)

Process understanding

Way to mitigation measures



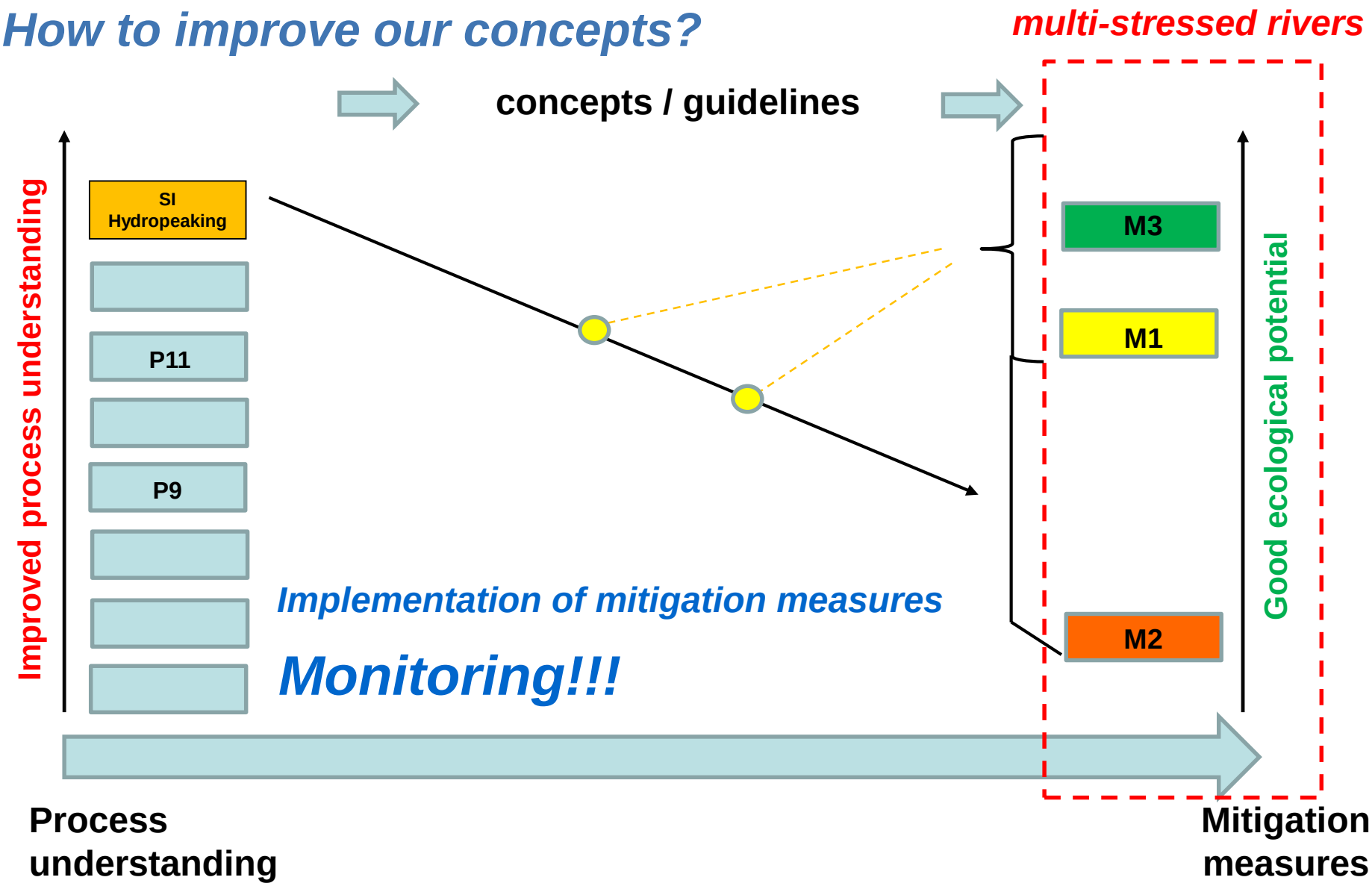
Too much simplification



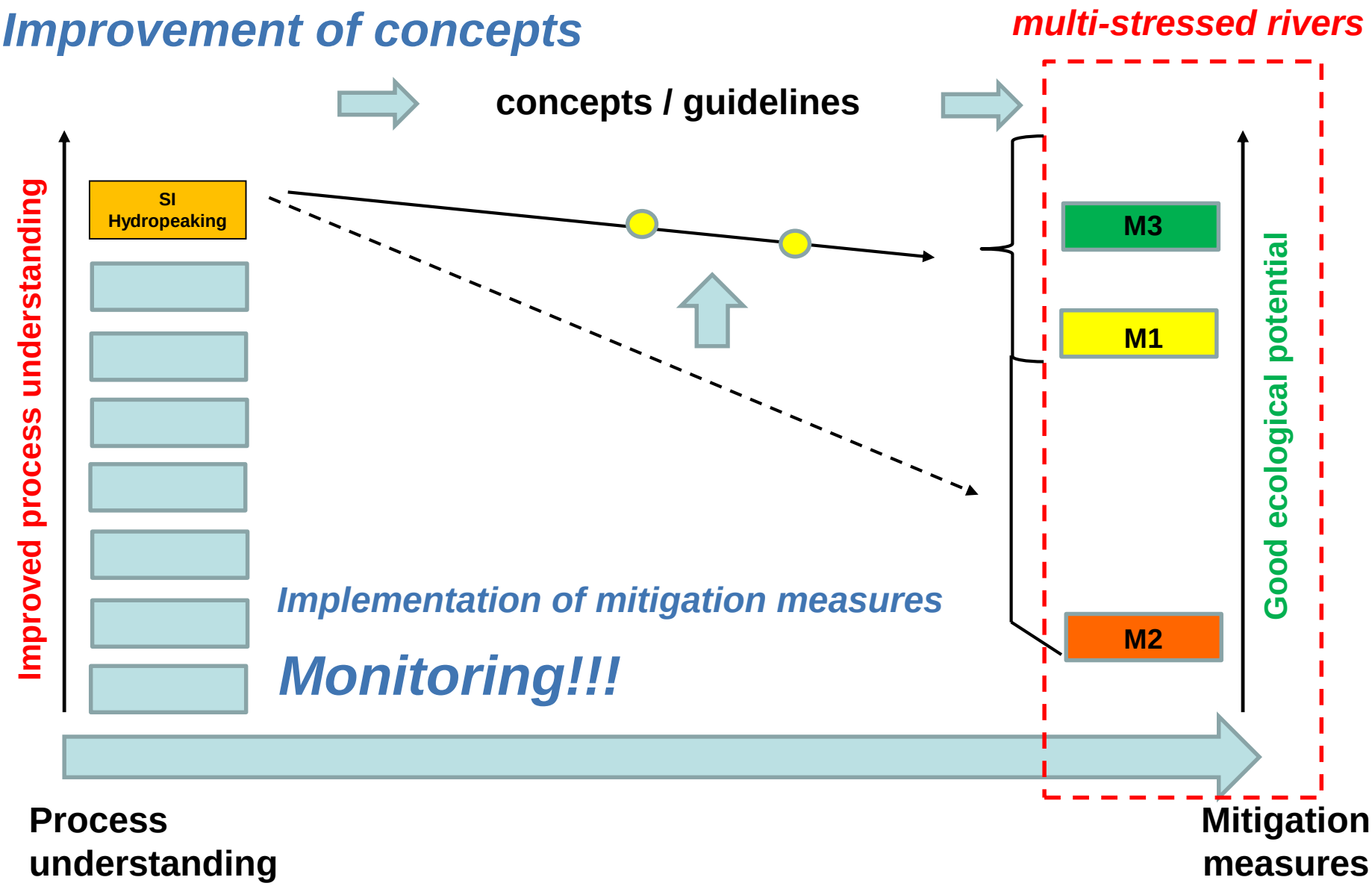
Hydromorphological High-Quality Rivers

Storana in Hovet (E-CO) / Norway

How to improve our concepts?



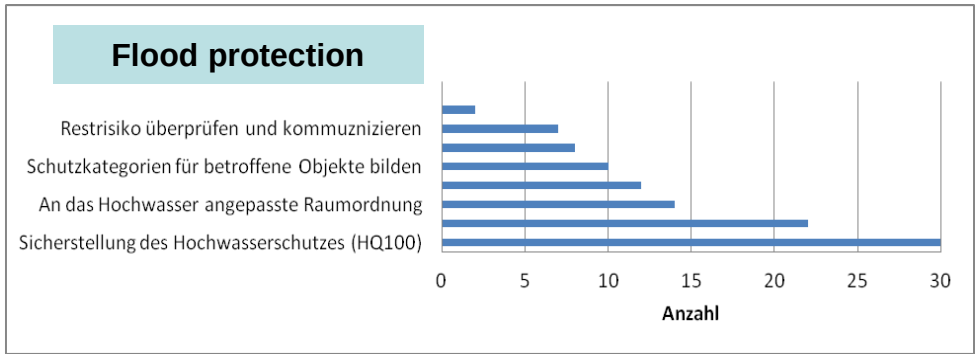
Improvement of concepts

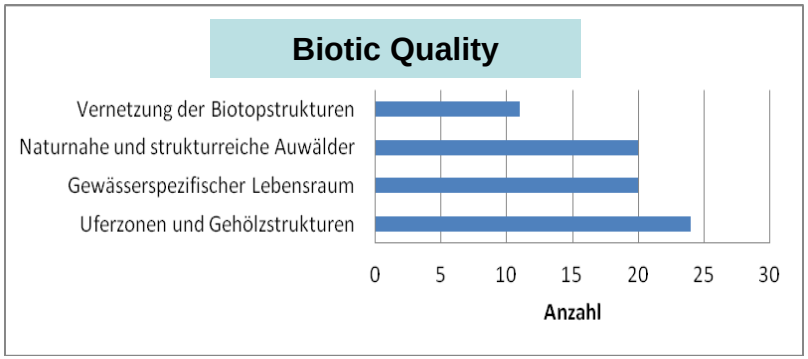


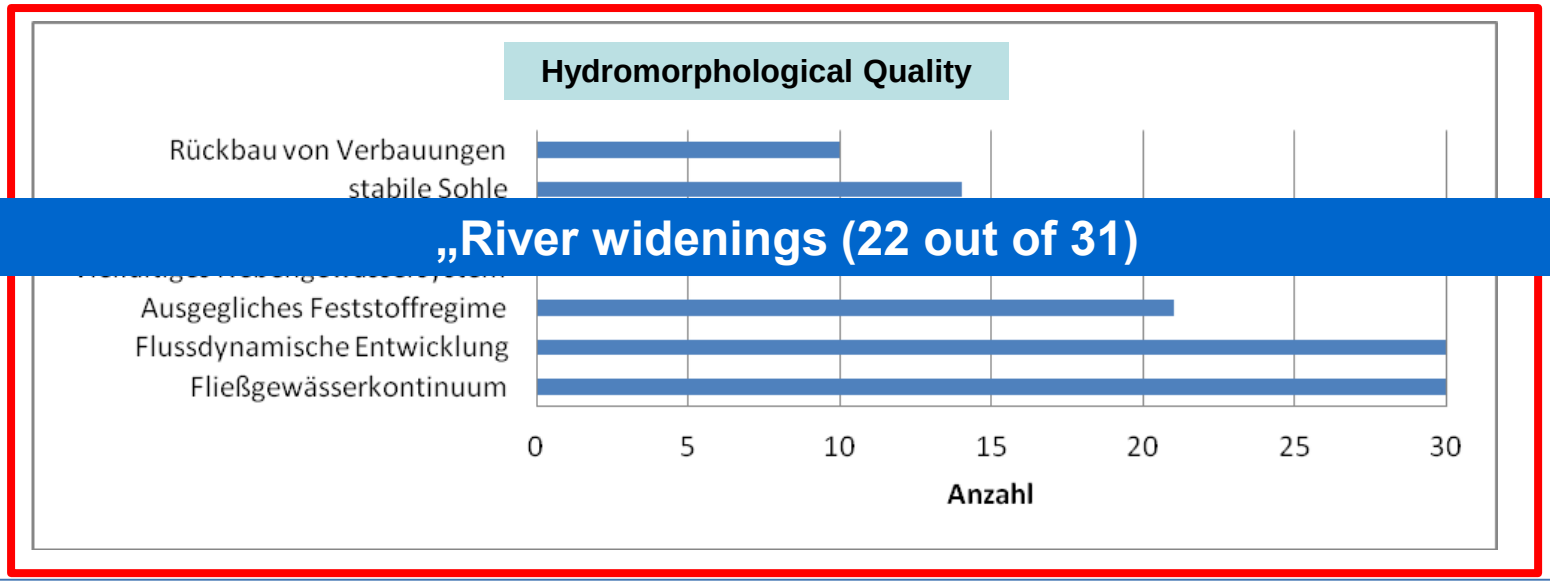
Evaluation of GEKs in Austria

König, K. *&* ***Hauer C. (2016)*** *Österreichische Wasser und Abfallwirtschaft 11-12. early view*

- 31 Integrative river basin managemet plans investigated (years 1989 – 2016)



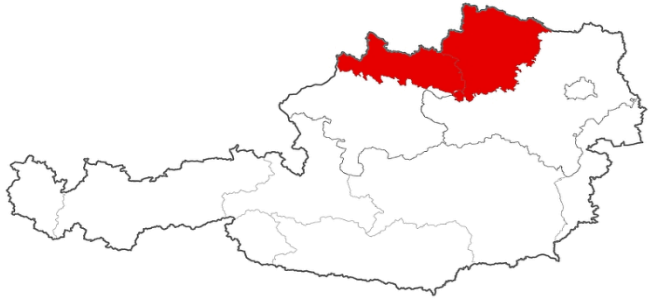


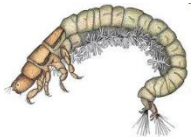


„River widenings (22 out of 31)

Evaluation of GEKs in Austria

Bohemian Massif





www,flussnetzwerke.de

Decrease in number of individuals > 80 %

Leitner *et al.* (2015)

Outcome (König & Hauer, 2016)

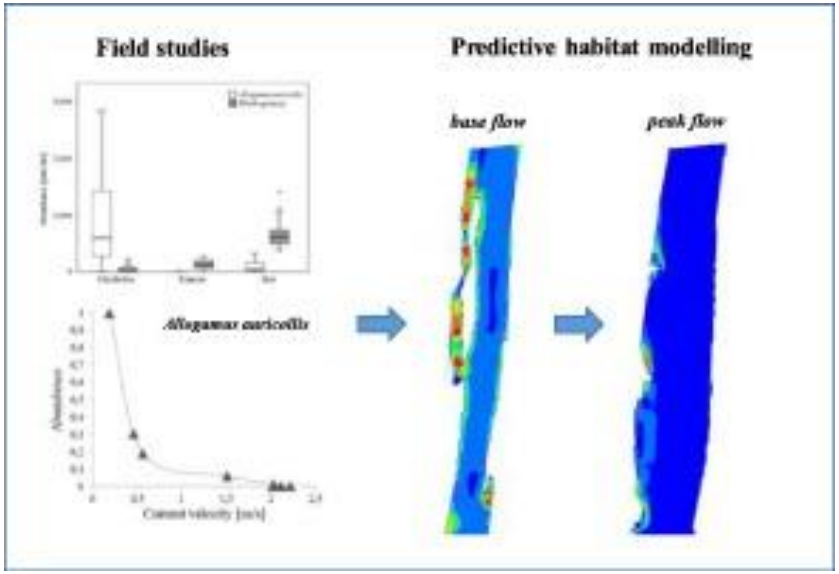
…..an overall deficit concerning the implementation of ***mid- and long term monitoring*** *into the GEK concept*

Conclusions

……Improvements required *(abiotic and biotic monitoring)!*

Habitat use and tolerance levels of macroinvertebrates concerning hydraulic stress in hydropeaking rivers – a case study at the Ziller river in Austria

Leitner, P., *Hauer,C., & Graf, W.*



Highlights

- Habitats of stagnophilic macroinvertebrate taxa are significantly minimized in channelized stretches
- The WFD compliant national Austrian assessment method fails to detect impacts of hydropeaking
- The development of a stressor-specific sampling design is required
- The hydraulic stress analysis provides expertise on the resistance of certain taxa in terms of hydropeaking

Conclusions

Most of the published papers focus on ***process understanding*** and ***tools*** for the ***detection of hydropeaking impacts*** or the ***design of mitigation measures.***

Only, ***three papers*** (groups three and four) explicitly focus on the ***design of mitigation measures***, but several others in groups one and two clearly mention the relevance of their results.

Process understanding has been improved but interactions of hydropeaking with ***several components*** of the whole river system have still received very limited and insufficient attention (e.g. ***riparian vegetation***, ***sediment transport***, ***sediment bed composition***).

The published research in the present special issue suggest that ***advanced*** and ***effective tools*** are presently available to support the ***design of mitigation measures***, including predictive, quantitative modelling.

Conclusions

In the ***next years / decades***, research has learn from the ***monitoring*** of the ***effects of mitigation measures***, once implementation and management will be more widespread and enough time has passed since their implementation to allow ***assessing*** their consequences at the ***proper spatial*** and ***time scales***.

It is ***highly recommended*** that ***accurate short, mid-term and long-term monitoring plans*** will be ***designed*** and ***operated*** to detect the ***responses of river biota*** (e.g. fish, macroinvertebrates, riparian and aquatic vegetation), on the ***physical environment*** (e.g. changes in flow patterns / sediment dynamics, channel morphology).

Thanks for your attention!

University of Natural Resources and Life Sciences, Vienna

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