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Institute of
Hydraulic Engineering
and River Research

Urslau case study:
A comparison of transport equations with long-term monitored bedload data

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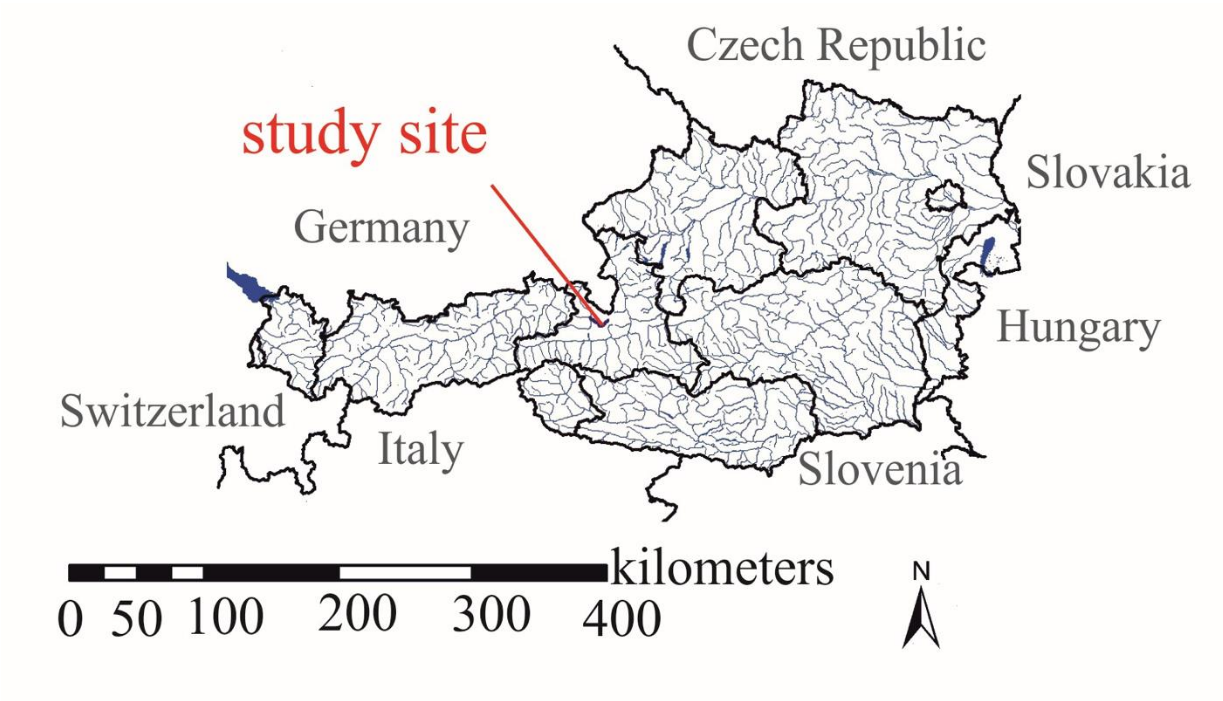
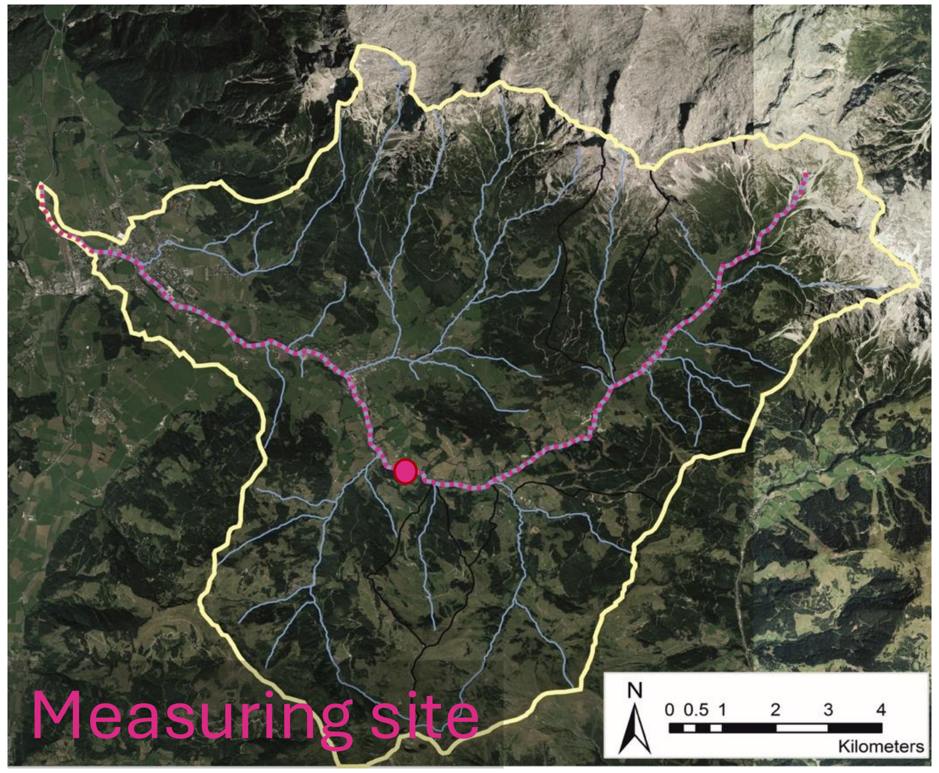
SedNet

Content

- Study site - Urslau
- Bedload monitoring methods
- Bedload transport data
- Measured vs. calculated bedload data
- Conclusions

Study Site Urslau





- Europe / Austria / Salzburg

- Urslau stream
- Total flow length of 21.3 km
- Total catchment size: 122 km^2
- Northern Limestone Alps, Greywacke

Steep upper reach

Middle reach

Bedload monitoring site

- Bedload monitoring site (since 2011)

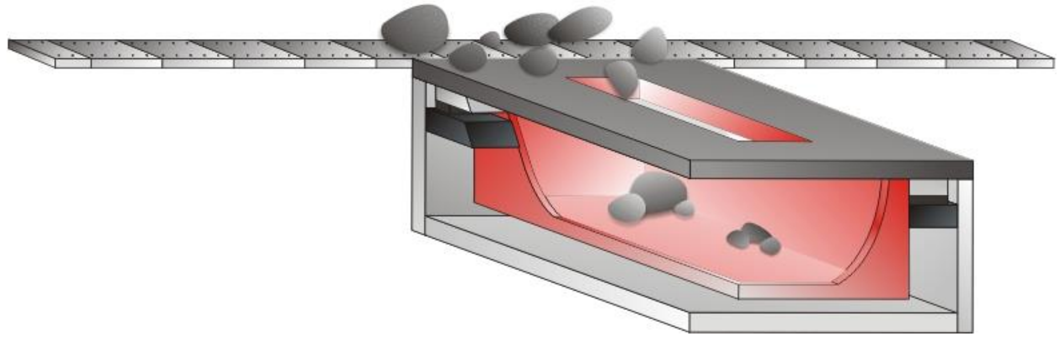
- Catchment size: 56 km^2
- Bed slope: 0.021
- Stream width: 8 m
- Bed material: d_m = 0.05 m, d_{90} = 0.09 m

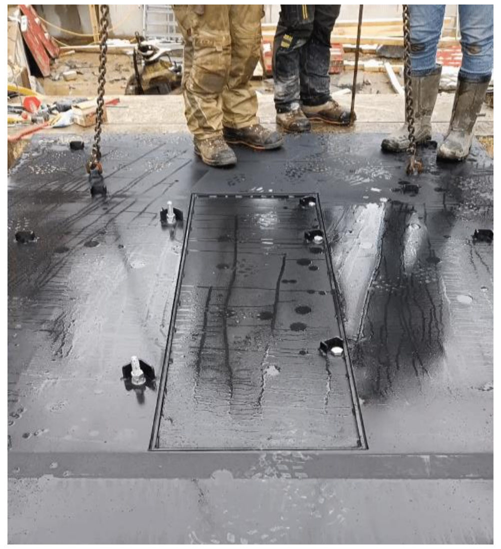
Integrative Bedload Monitoring

Mobile net sampler

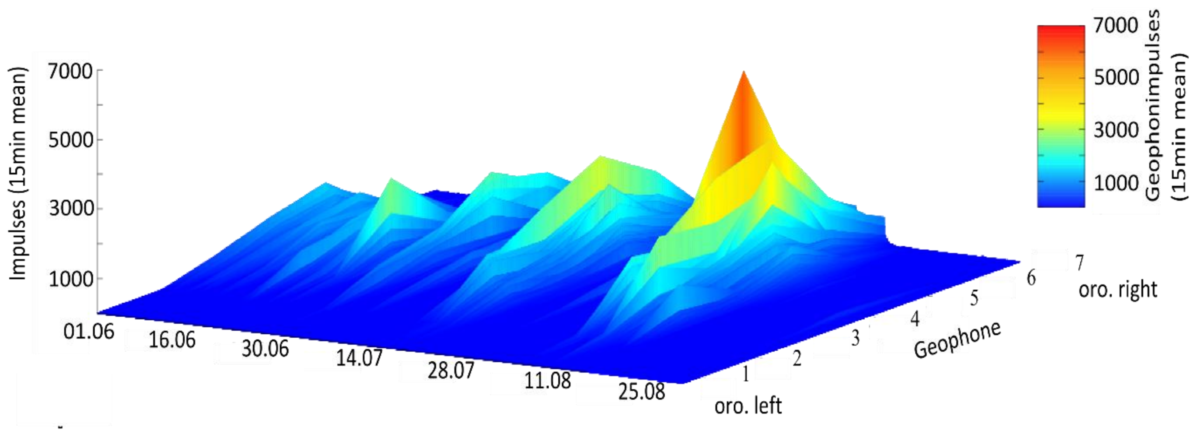
Plate Geophones

Slot sampler

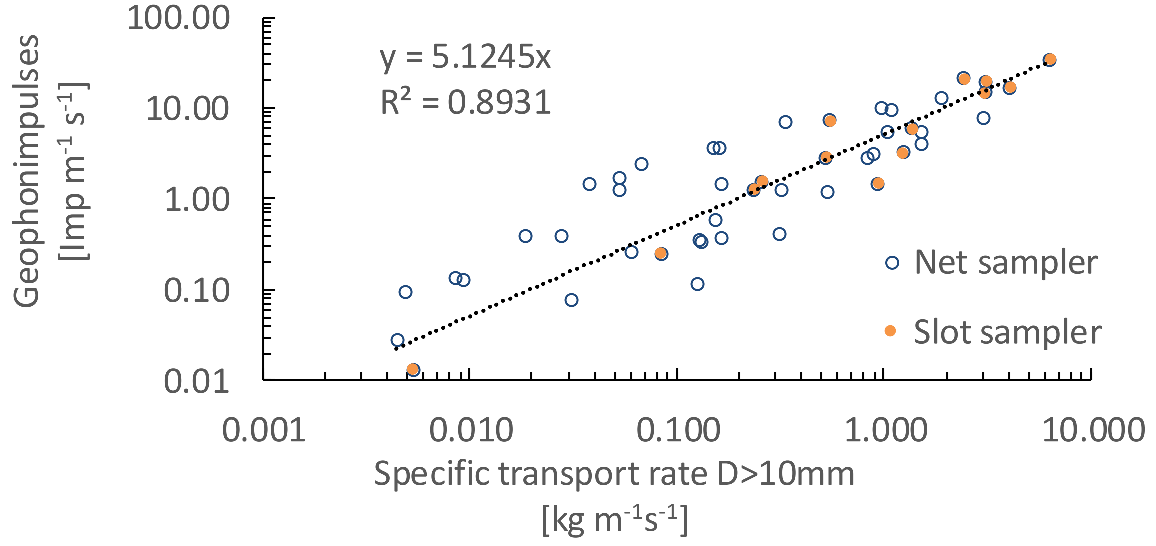




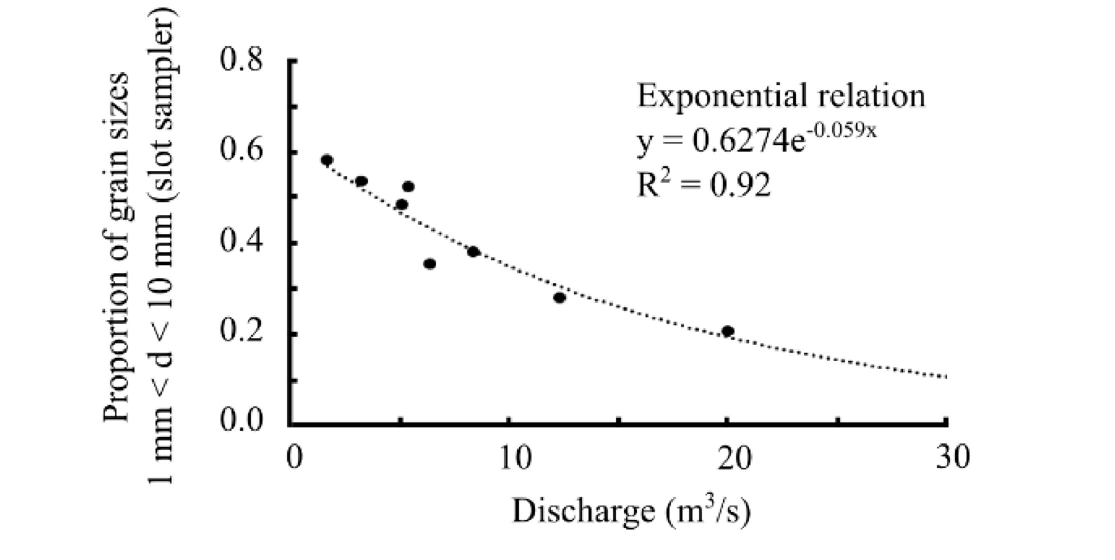
Continuous recording of Geophonimpulses (01.06.16-31.08.2016)



Calibration function

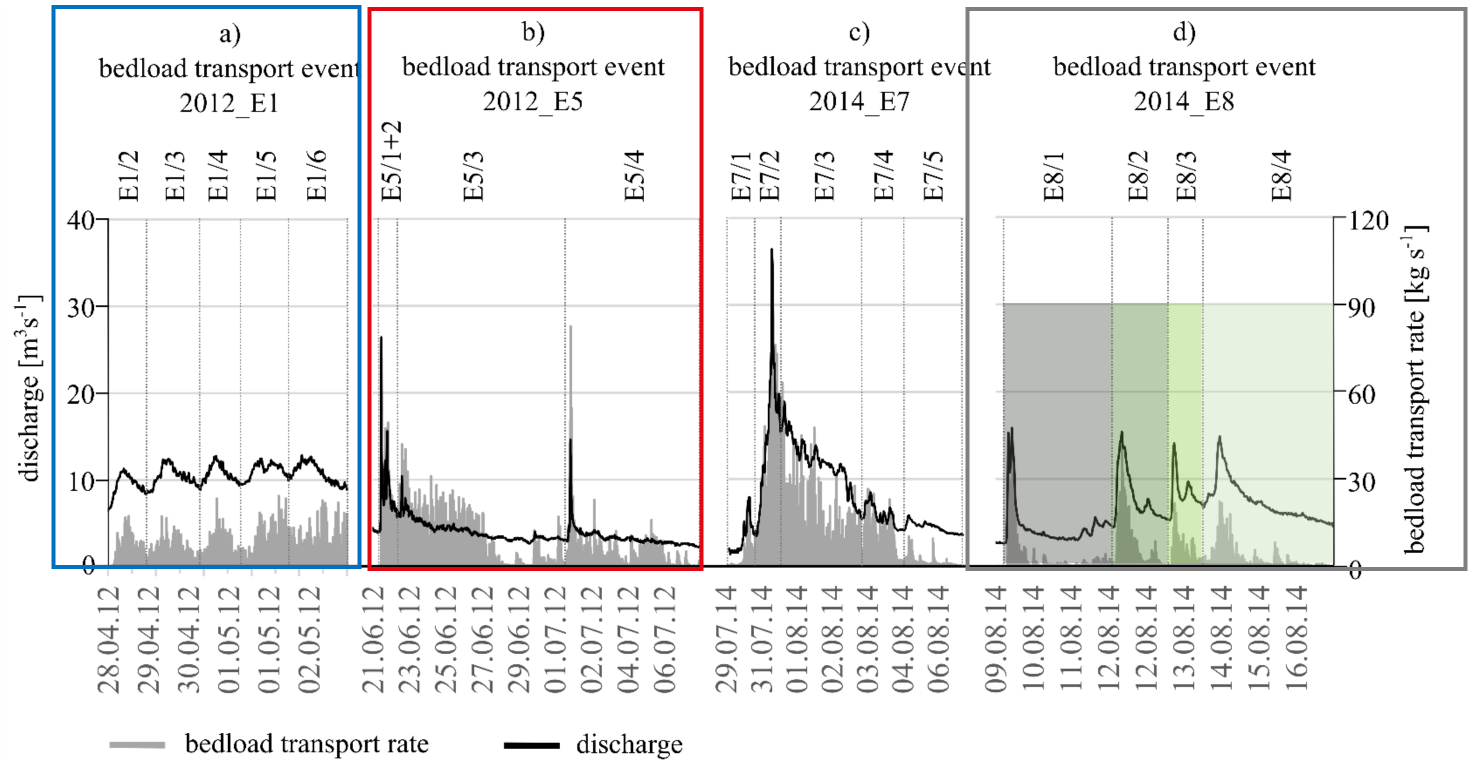


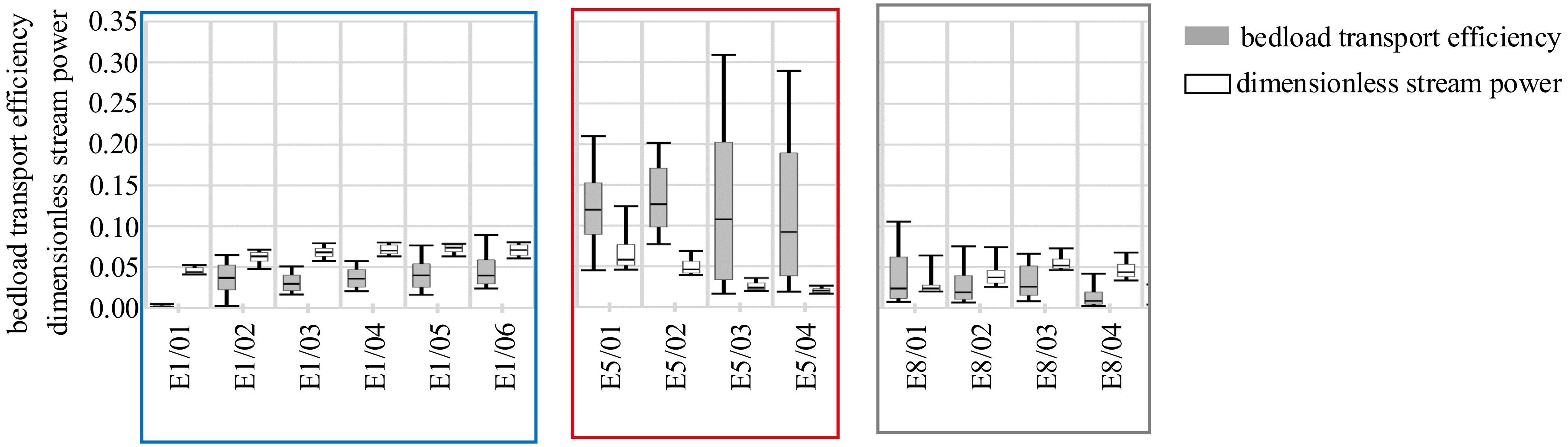
Proportion 1-10mm vs. discharge



Bedload transport data

(Kreisler et al., *Geomorphology*, 2017)





$$e_p = \frac{I_b \tan\alpha}{\Omega_{ex}}$$

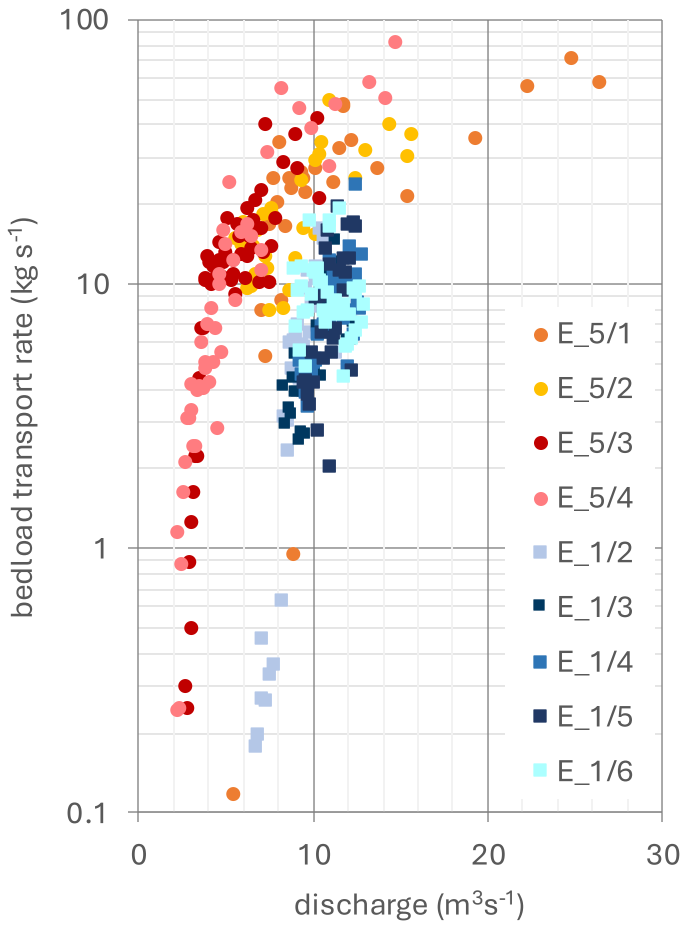
e_p bedload transport efficiency (Bagnold, 1966)

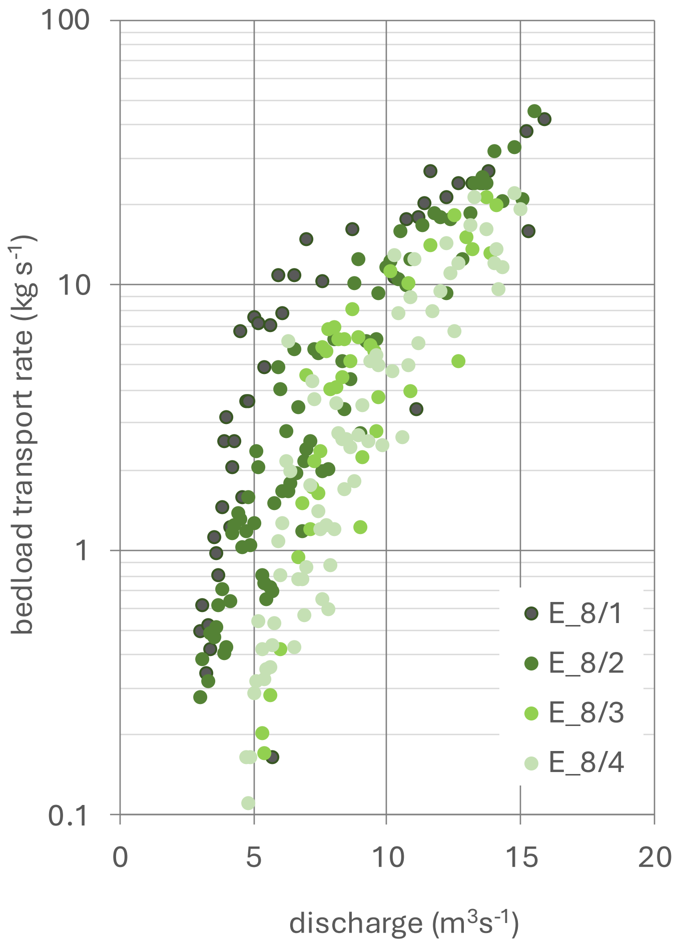
(I_b immersed bedload volume, Ω_{ex} excess stream power, α inner fric. angle = 52°)

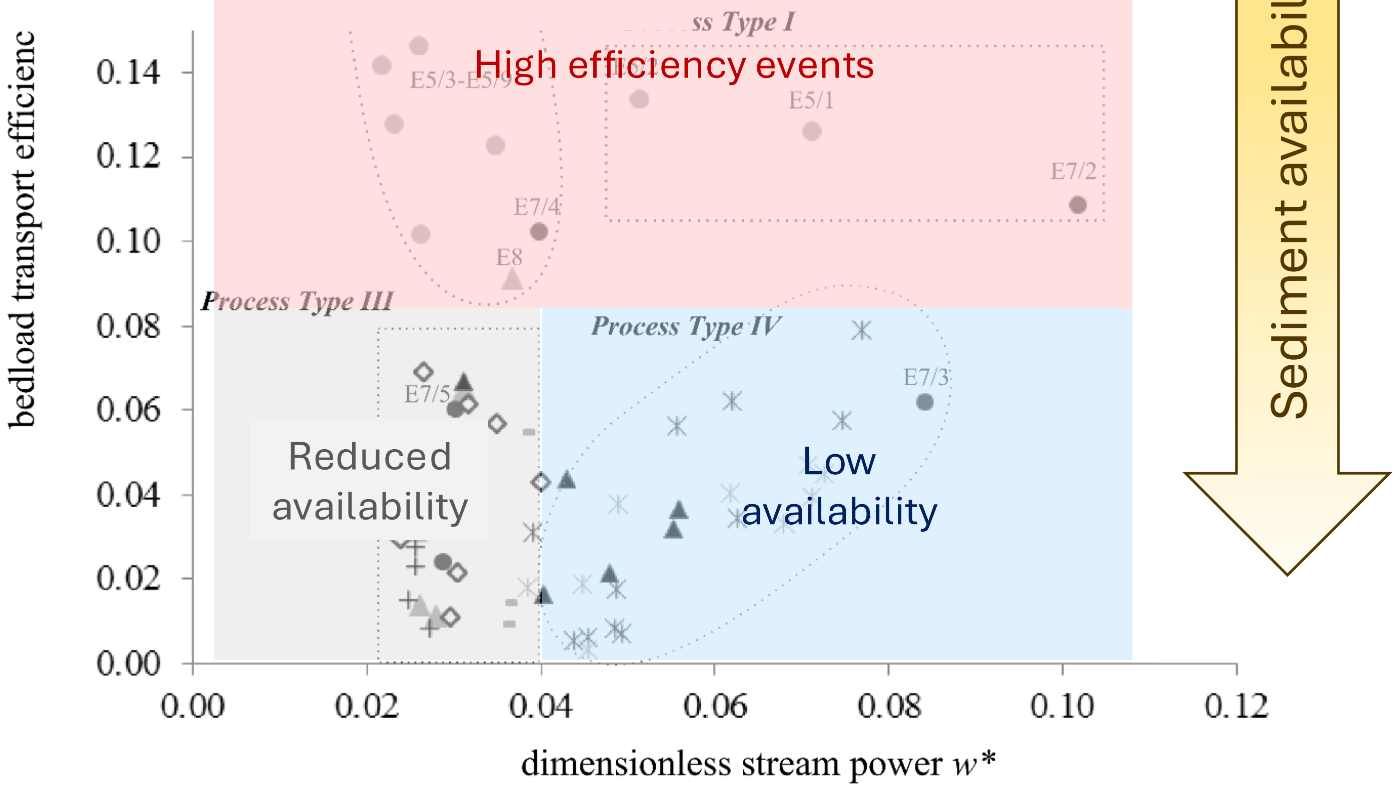
$$\omega^* = \omega / \left[g(\rho_s - \rho)\sqrt{\left(\frac{\rho_s}{\rho} - 1\right) g D_{84}^3} \right]$$

ω* dimensionless stream power

(ω=ρgqS stream power, D84 char. grain size)







Long-term, integrative measured bedload data, high spatial variability

Process understanding, bedload transport event types

Evaluation of bedload transport formulas

- Development of bedload transport formulas (mostly) in laboratory settings
- Natural processes and transport dynamics not adequately considered
- Comparisons in the literature are typically based on point measurements

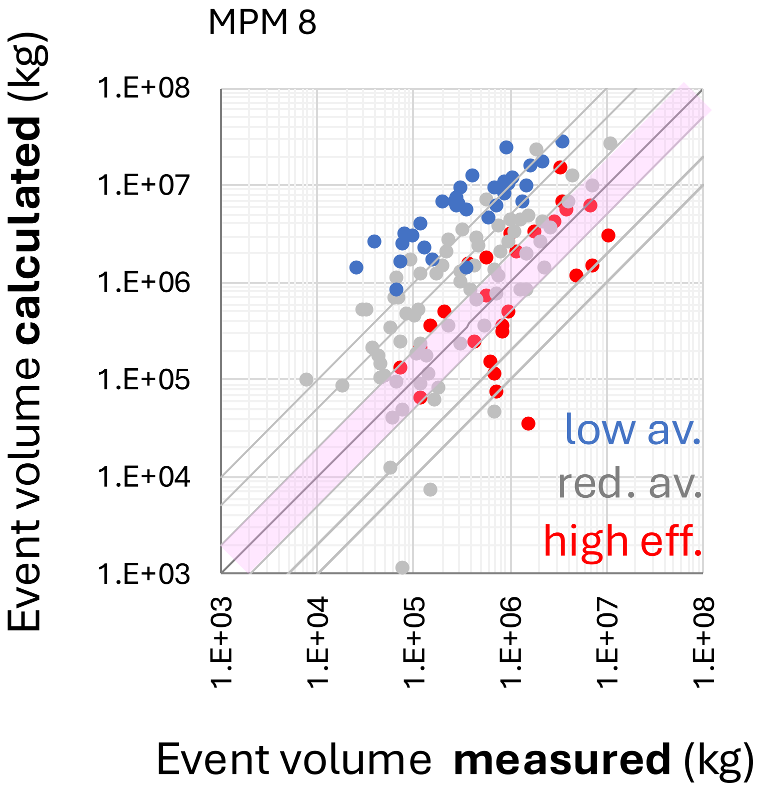
➤ **Continuous long-term data as a basis for evaluating calculation approaches**

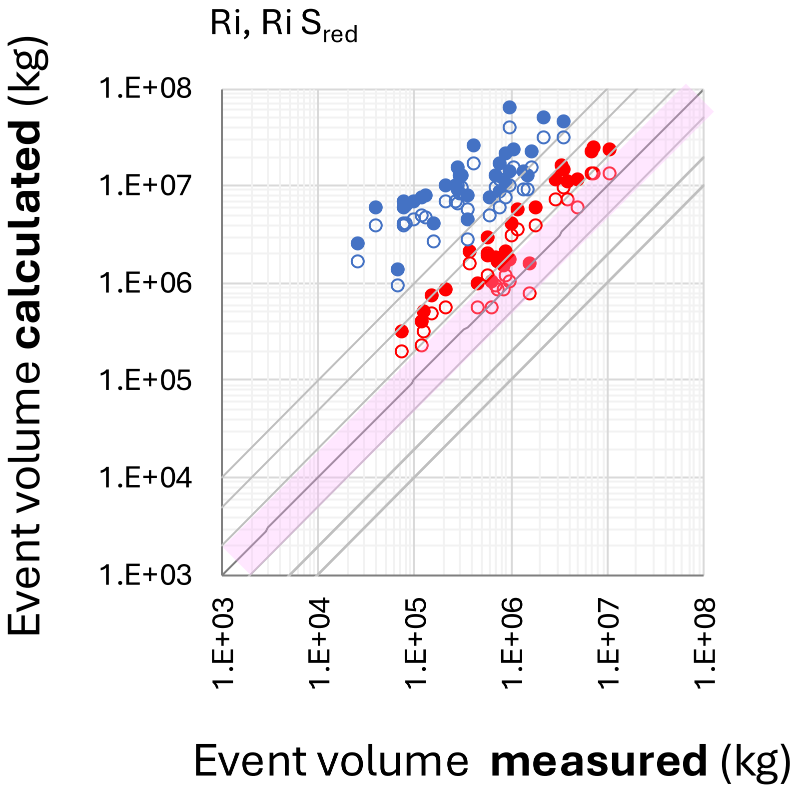
Measured vs. calculated bedload data – Event Volumes

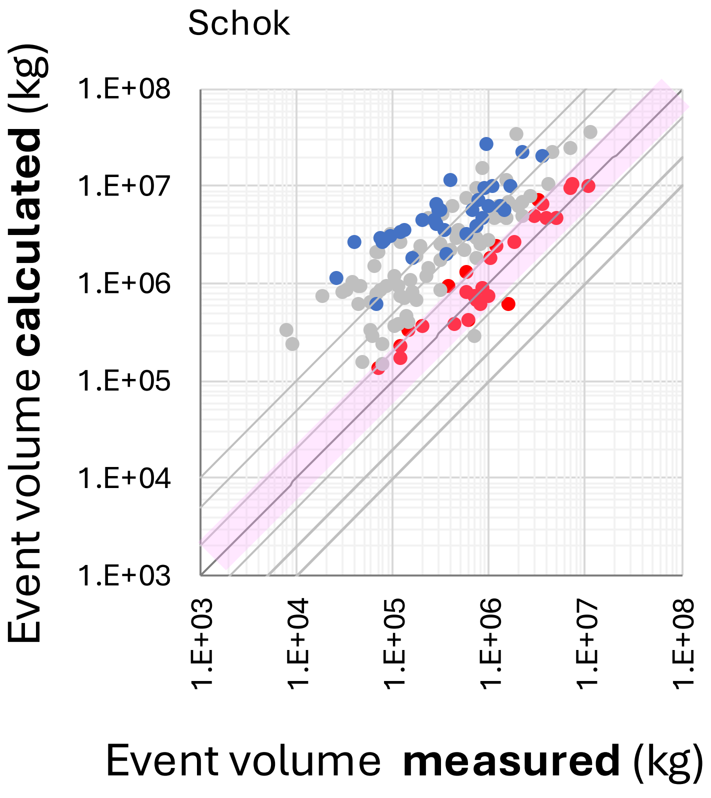
(Lammer et al., *Sediment Research*, 2024)

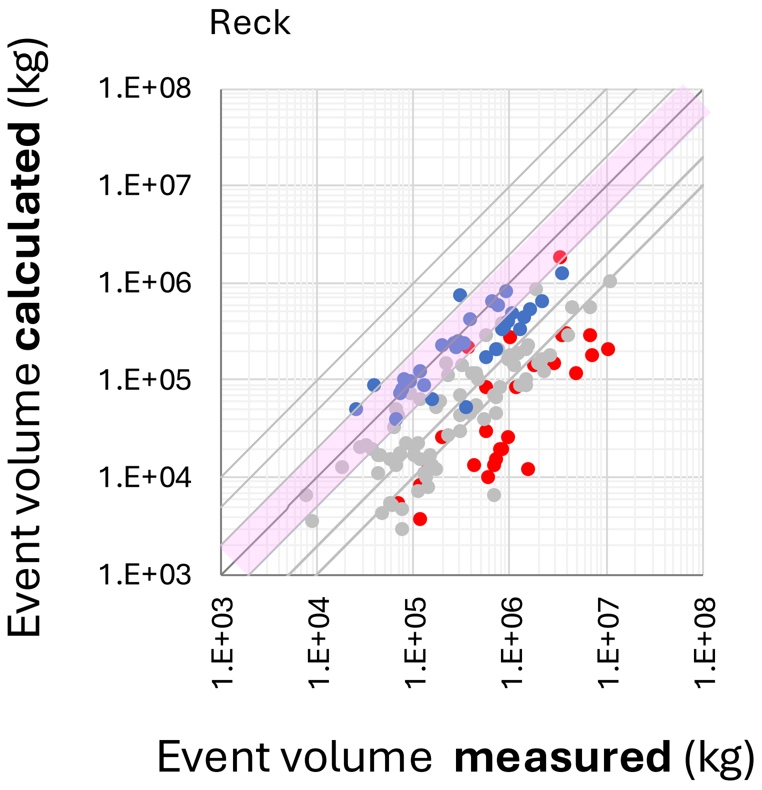
1) Bedload volumes (kg) (data from 2011-2020)

Discrepancy factor $r_d = \frac{calculated\ bedload}{measured\ bedload}$









MPM-8 (Meyer-Peter and Mueller 1948)

$$\Phi_b = 8 * (\theta' - \theta_c)^{3/2}$$

θ'...reduced dimensional boundary shear stress
θ_c...critical Shields number

Ri (Rickenmann 1990, 2001)

$$q_b = 1.5 * S^{1.5}(q - q_c)$$

q...unit discharge
q_c...critical discharge at initation of motion

Schok (Schoklitsch 1962)

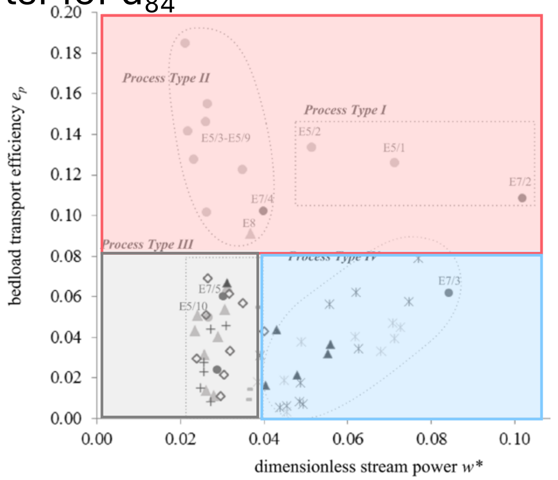
$$q_b = \frac{2.5}{s} S^{1.5}(q - q_c)$$

q...unit discharge
q_c...critical discharge at initation of motion

Reck (Recking 2013, 2016)

$$\Phi_{b,d84} = 14\ {\tau_{84}^{*}}^{2.5} \Big/ \left[1 + \left(\frac{\tau_m^*}{\tau_{84}^*}\right)^4\right]$$

$\tau_m^* = 1.5 * S^{0.75}$ is the mobility shear stress
τ_{84}^* = Shields parameter for d_{84}



Ri_Sred (Rickenmann and Recking, 2011)

$$S_{red} = S\left(\sqrt{\frac{f_0}{f_{tot}}}\right)^e q_b$$

f_o/f_{tot} ...base roughness/total roughness

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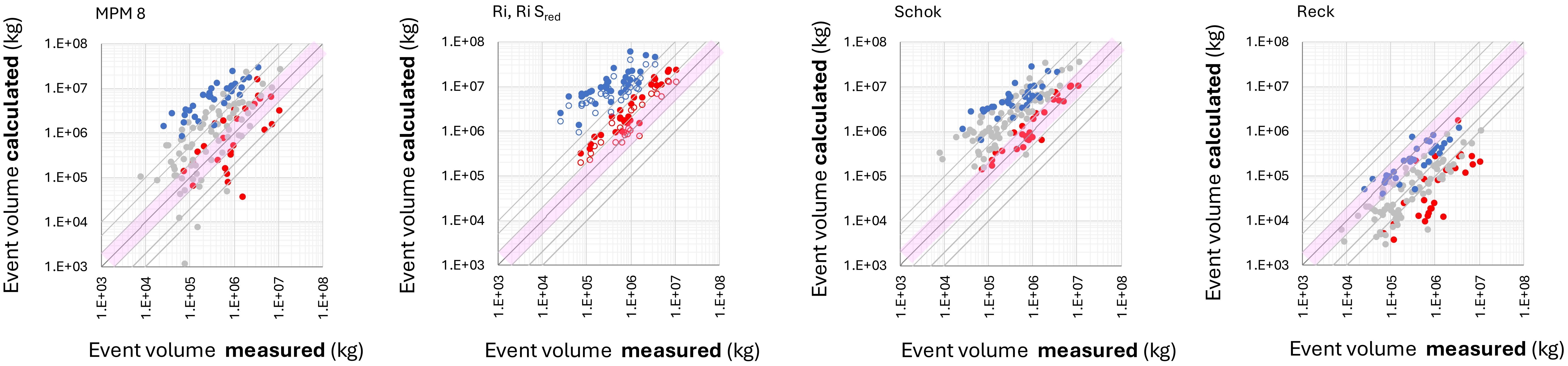
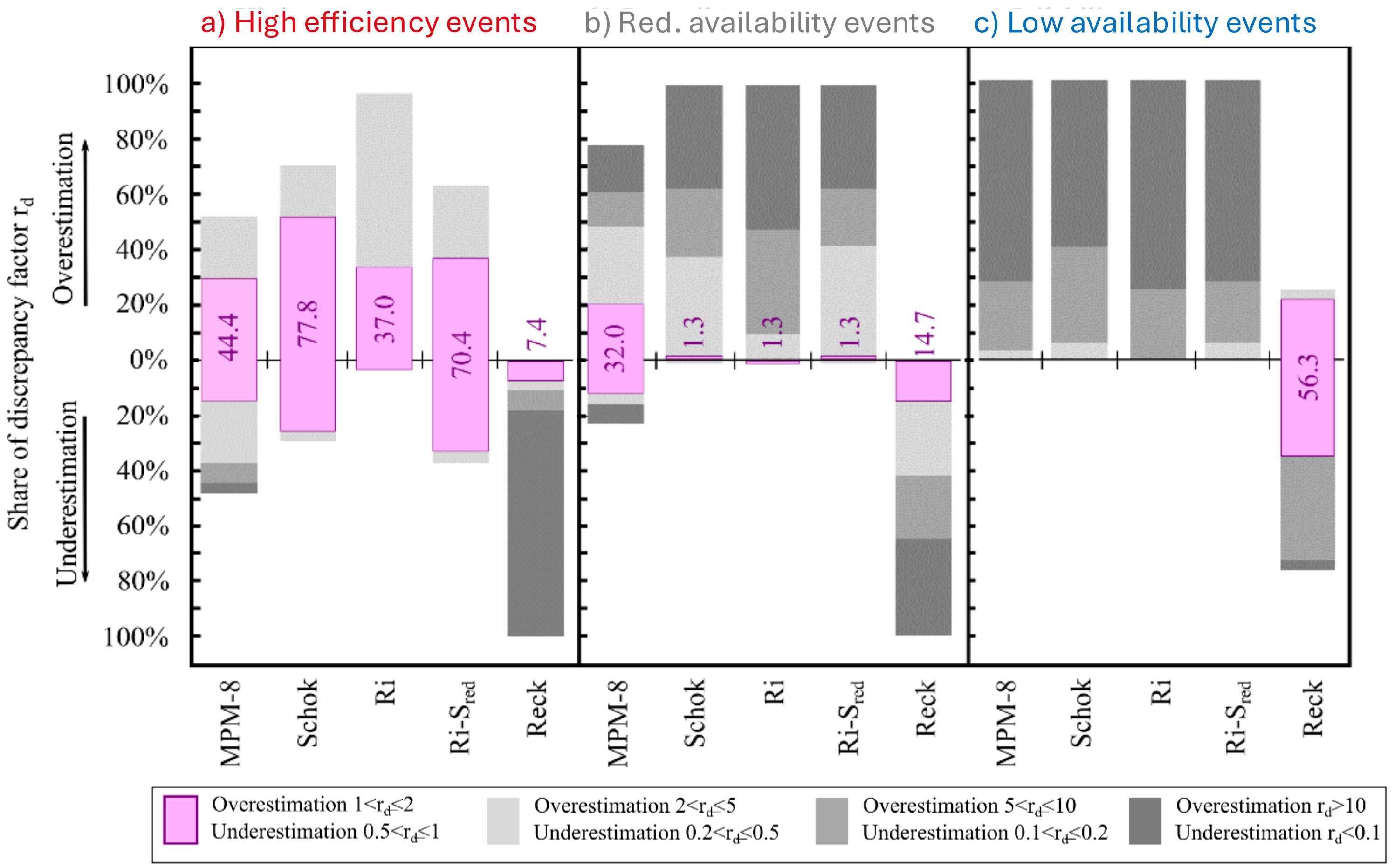
Measured vs. calculated bedload data – Event Volumes

(Lammer et al., *Sediment Research*, 2024)

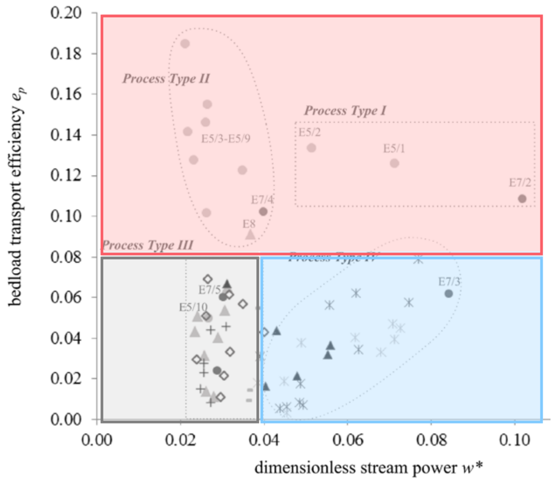


Discrepancy factor

$$r_d = \frac{calculated\ bedload}{measured\ bedload}$$



Applicability of the formulae could be improved by performing a **classification into event types** after Kreisler at al. (2017), which implies a consideration of **sediment availability**.



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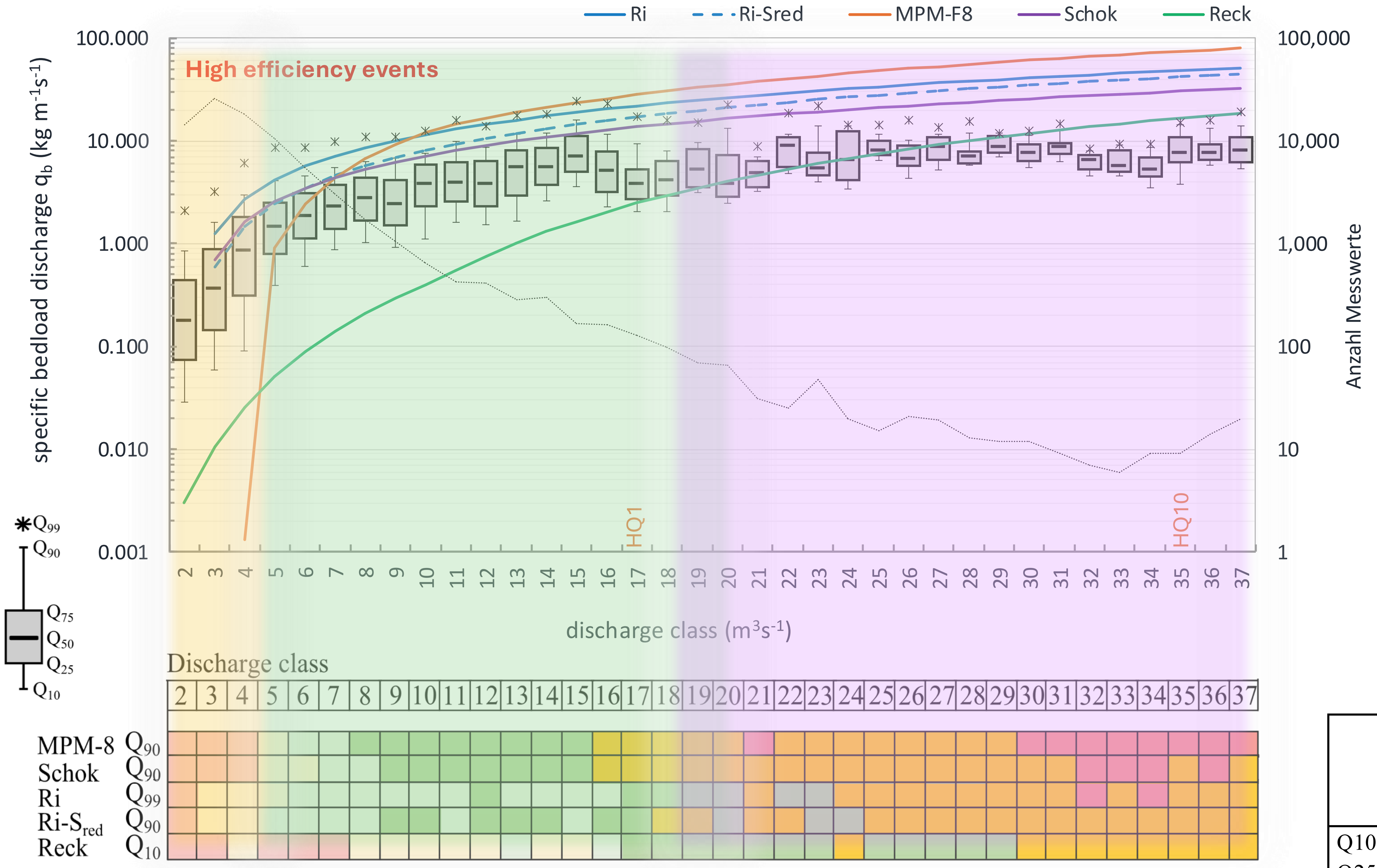
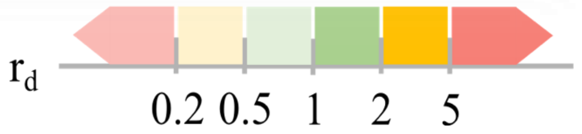
Measured vs. calculated bedload data – Transport Rates

(Lammer et al., *Sediment Research*, 2024)



$$r_d = \frac{calculated\ bedload}{measured\ bedload}$$



Data base: 1min data from 2011-2020 wide range of transport rates for given flow rates

Underestimation of transport capacity

Close agreement

$r_{d\ mean}$ *DKL 6-20* : Ri/Q_{99} =1.0

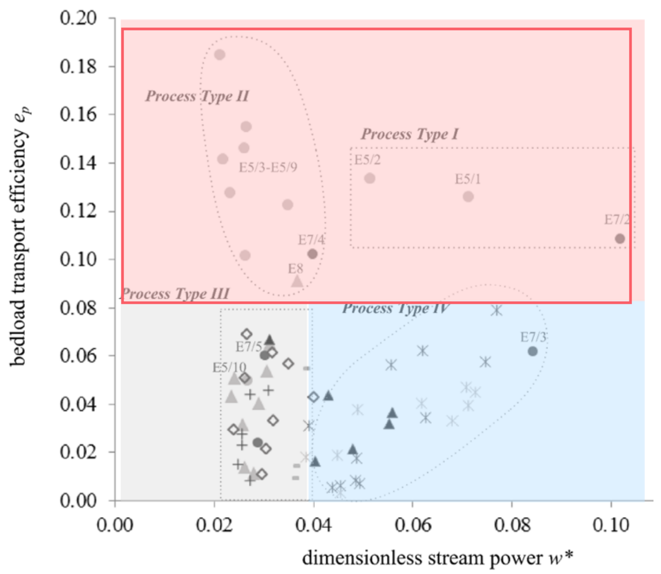
Ri S_{red}/Q_{90}= 1.0

MPM-8/Q_{90}= 1.5

Schok/Q_{90}= 0.9

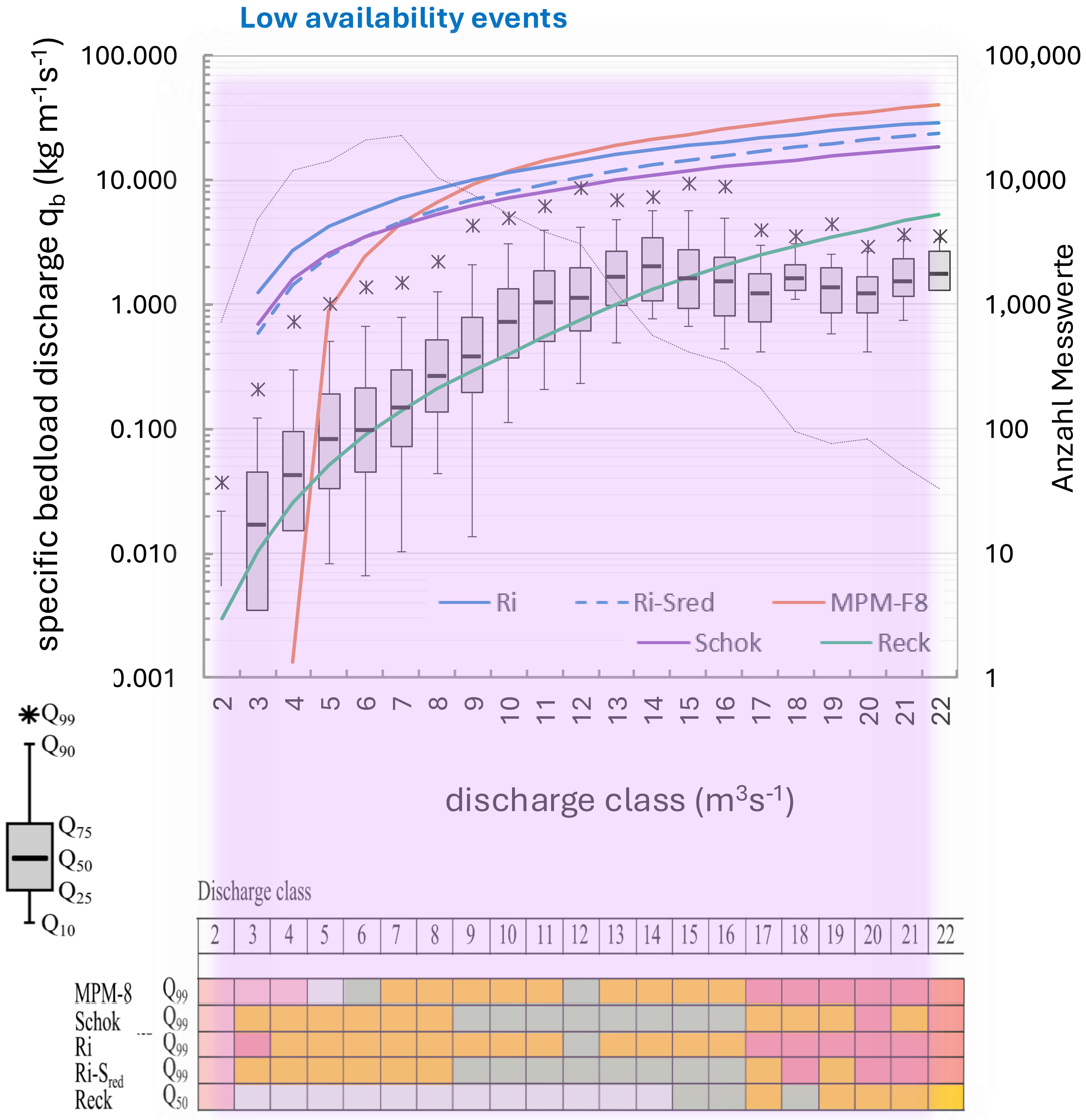
Overestimation of transport capacity

	RMSLE				
	MPM-8	Schok	Ri	Ri-S$_{red}$	Reck
Q10	1.6	1.2	1.6	1.3	0.4
Q25	1.3	0.9	1.3	1.0	0.6
Q50	1.0	0.6	1.0	0.7	1.0
Q75	0.8	0.3	0.7	0.4	1.3
Q90	0.7	0.2	0.4	0.3	1.6
Q99	0.8	0.7	0.3	0.6	2.1

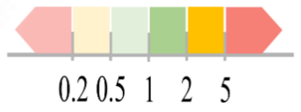


Measured vs. calculated bedload data – Transport Rates

(Lammer et al., *Sediment Research*, 2024)



$$r_d = \frac{calculated\ bedload}{measured\ bedload}$$



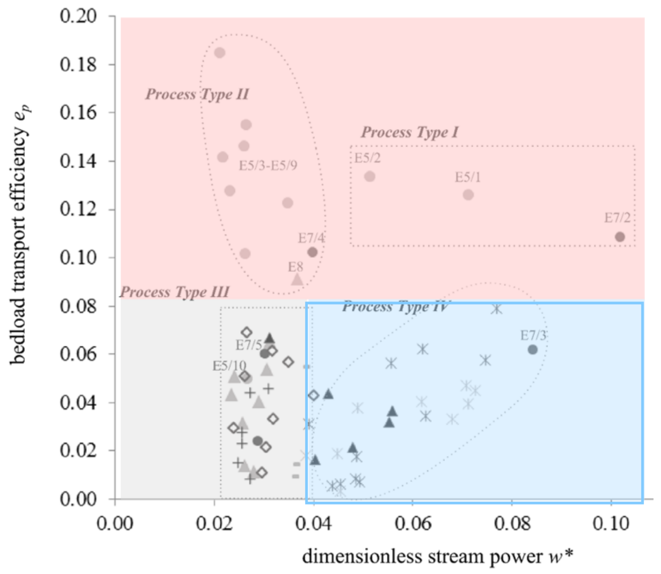
Data base 1min data 2011-2020

Overestimation of measured transport rates

Best Performance - Recking

($r_{d\ mean}$ dc 3-17: Reck/Q_{50}=0.8)

	RMSLE				
	MPM-8	Schok	Ri	Ri-S_{red}	Reck
Q10	2.2	1.8	2.2	1.9	0.4
Q25	2.0	1.7	2.1	1.8	0.2
Q50	1.8	1.5	1.9	1.6	0.2
Q75	1.6	1.2	1.6	1.3	0.4
Q90	1.3	1.0	1.4	1.1	0.6
Q99	0.8	0.5	0.9	0.6	1.1



Conculsions

- Combination of direct and indirect measuring devices in the **integrated measuring system** enables comprehensive monitoring of the transport process
- Recording important **continuous long-term data** on natural processes
- Monitored bedload data at the Urslau show a **high variability** – challenges for calculation
- Classification into **event types** considers varying sediment availability

- Applicability of the formulae could be improved by performing a **classification into event types,** good performance of transport capacity based formulas for high efficiency events
- Necessary to select the appropriate formula depending on the given research or management questions

- **Long-term records of integrative measured bedload data are basis for the evaluation and further development of transport formulas -** need for natural measurement data of the bedload transport process!

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Thank you for your attention!

Habersack, H., **Kreisler, A.**, Rindler, R., Aigner, J., Seitz, H., Liedermann, M., & Laronne, J. B. (2017).
Integrated automatic and continuous bedload monitoring in gravel bed rivers. *Geomorphology*, *291*, 80-93, DOI: 10.1016/j.geomorph.2016.10.020.

Kreisler, A., Moser, M., Aigner, J., Rindler, R., Tritthart, M., & Habersack, H. (2017).
Analysis and classification of bedload transport events with variable process characteristics. *Geomorphology*, 291, 57-68.

Lammer, A., Rindler, R., Tritthart, M., Liedermann, M., Moser, M. Shire-Peterlechner, D. Schwarz, S. & Habersack, H. (2024).
Evaluating the performance of transport equations through long-term records of integrative measured bedload data. *International Journal of Sediment Research*, 40, 158-171.