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Bedload monitoring in the Gesäuse National Park

**Dorian Shire-Peterlechner, Rolf Rindler,
Sabrina Schwarz, Andrea Kreisler,
Helmut Habersack**

Summary

Species diversity of aquatic life forms are significantly determined by the availability of different habitats and their composition. In this context, the bed substrate (bedload) plays an important role in regard to the ecological functionality. As aquatic habitat for macrozoobenthos or also as spawning habitat for gravel spawning salmonids such as the brown trout. In both cases, the availability of sediments deposited in various grain sizes is a prerequisite for the formation of adequate habitats. Since 2014 the bedload monitoring station located in the Gesäuse national park at the Johnsbach stream derives precious long-term nature-based data, fundamental to various riverine applications and basic research. This paper focuses on relevant issues for aquatic lifeforms, namely: sediment composition, dynamics and quantity.

Keywords

Integrated Bedload Monitoring, Sediment Variability, Long-Term Monitoring

Introduction

Bedload measurements in gravel bed streams is fundamental for an enhanced understanding of bedload transport characteristics and set the fundament for riverine applications ranging from engineering tasks to morphodynamic models (Tritthart et al. 2011). The Institute of Hydraulic Engineering and River Research (IWA) at the University of Natural Resources and Life Sciences continuously measures the bedload transport at a total of seven gravel bed rivers in Austria. These sites range from alpine streams, such as the Johnsbach stream, to lowland rivers, such as the Danube, with catchment sizes ranging from 55-104,177 km² (Liedermann et al. 2020). In this regard the Johnsbach stream in the Gesäuse national park with a catchment area of 65 km² is the second smallest catchment with a bedload monitoring station operated by the IWA. The bedload monitoring station was established in 2014 in cooperation with the Austrian Torrent and Avalanche Control (WLV) in the course of the FWF funded project Sedyn-X (Interdisciplinary Investigation of Sediment Flows). Since 2016 the monitoring is funded by the WLV. At the Johnsbach stream, the integrative bedload monitoring station consists of direct (basket sampler and bedload trap) and indirect (geophone system) measurement methods (Habersack et al. 2017). The geophone system continuously records bedload activity and is calibrated with the basket sampler and bedload trap. The bedload quantity and availability are massively influenced at the Johnsbach stream by the input of side catchments until just before the measuring station (Rascher et al. 2017). The range of bedload flux becomes visible in long time series. Annual bedload yields range from D>10mm 1,900 t (2018) to 13,500 t (2016). Grain size distributions thereby range from d_{50} 15-72 mm (D>8mm basket sampler, period 2016-2020).

Methods

Integrative bedload monitoring

At the Johnsbach stream the bedload monitoring facility is designed as an integrative bedload measuring station, measuring transport parameters listed in table 1, combining **direct** and **indirect** measurement methods.

Table 6: parameters of bedload transport with the measuring capabilities of the indirect (green column) und direct (red columns) measuring devices used at the Johnsbach stream (- not suitable, + partially suitable, ++ suitable, +++ highly suitable (modified Habersack et al. 2017)

Transport parameters	Geopone plates	Basket sampler	Bedload trap
Specific bedload discharge [$kg\ m^{-1}s^{-1}$]	-	+++	+++
Bedload discharge [$kg\ s^{-1}$]	-	++	-
Bedload yield [kg] or [t]	-	+	-
Grainsize distribution	-	+++	+++
Initiation of motion [m^3s^{-1},m]	+++	++	++
Temporal variability	+++	++	++
Spatial variability	+++	++	+

Specific bedload discharge q_b is defined as the bedload transport within a meter of river width per timestep. The bedload discharge is calculated by integrating the specific bedload discharge over the entire river width. Summarizing the bedload discharge over time the bedload yield is calculated. The direct bedload measurement samples are sieved in order to obtain the sediment grain size distribution. The initiation of motion quantifies the necessary discharge at which bedload particles start to move. Measuring temporal and spatial variability is essential, since bedload discharge varies strongly by time and throughout the cross section. None of the measuring devices can measure all parameters of bedload transport (see table1), therefore, the measuring devices are combined to complement each other (Habersack et al. 2017).

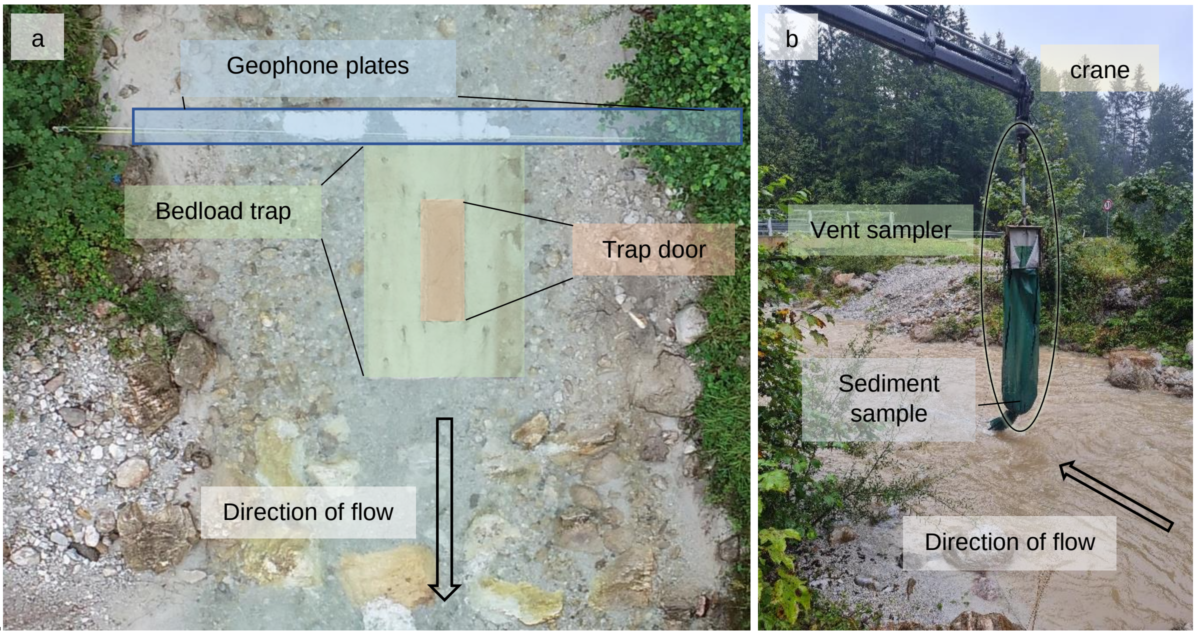

Figure 23: Integrative bedload monitoring at the Johnsbach stream: a) geophone pates and bedload trap (top few), b) vent sampler attached to crane with sediment sample.

Indirect bedload measuring: Geophone plates

Geophones are sensors originating from seismic technology capable of detecting vibrations (Habersack et al. 2017). In order to detect bedload transport, the geophone sensors, are mounted on the underside of steel plates. These steel plates are mounted on polymer mats protected by a steel frame covering the entire stream cross-section (see figure 1 a). As bedload particles are transported over the steel plates the impact generates vibrations, which are recorded after exceeding a certain amplitude. The sum of impulses per minute/second, maximum amplitude per minute/second and the integral of geophone signals are recorded continuously throughout the year. Particles D<10mm won't generate an impact exceeding the minimum amplitude for recording (Rickenmann and McArdell 2007). Therefore, particles D<10mm can't be measured with the geophone plates. Geophone plates make continuous recording of bedload transport activity both in time and space (laterally) (Rickenmann et al. 2014). Transferring the sum of impulses to bedload discharge is performed by calibrating the geophone impulses with direct bedload measurements.

Direct bedload measurement: Bedload trap

As one of the direct bedload measurement systems at the Johnsbach stream, the bedload trap or slot sampler is used during bedload transport events regardless of the magnitude. The bedload trap is located at the level of the stream bed, directly downstream of the geophone device. This bedload trap contains a sample box placed on load cells. The entire construction is covered with a lid, with a removable longitudinal trap door (see figure 1 a). The trap door is initially closed and opened for the measurement hydraulically. The load cells measure the increase of mass during the measurement (Kreisler et al. 2017). Bedload is first detected by the geophone plate and then collected in the sample box, and can therefore be used for geophone calibration. The bedload sample is later sieved to analyze the grain size distribution.

Direct bedload measurement: Basket sampler (Vent Sampler)

As a second direct measurement device at the Johnsbach stream during low to medium transport events, the Vent sampler comes to use. It was designed after the sampler introduced by Bunte et al. (2004). The inlet frame has the dimensions of 0.5 × 0.5 m. The net can be exchanged since it is mounted to a separate frame which attaches to the inlet frame (see figure 1 b) Depending on quantity and size distribution of bedload discharge, different nets with mesh sizes ranging from 1 mm to 8 mm come to use. With a crane (crane truck) the sampler is positioned downstream from a geophone plate in the riverbed for a defined period of time (Habersack et al. 2017). As with the slot sampler, the bedload particles are detected as impulses on the geophone plate before entering the basket sampler. The sample is weighed and sieved to analyze the grain size distribution of particles larger than the net size. After taking several samples during a transport event, the dynamics of grain size compositions can be analyzed.

Results

As an example of temporal and special variability of the bedload transport process the following 3D graph during the event of 08.07.2022 is displayed in figure 2. Bedload discharge occurs concentrated in the middle of the cross section, variating between geophone 5-9.

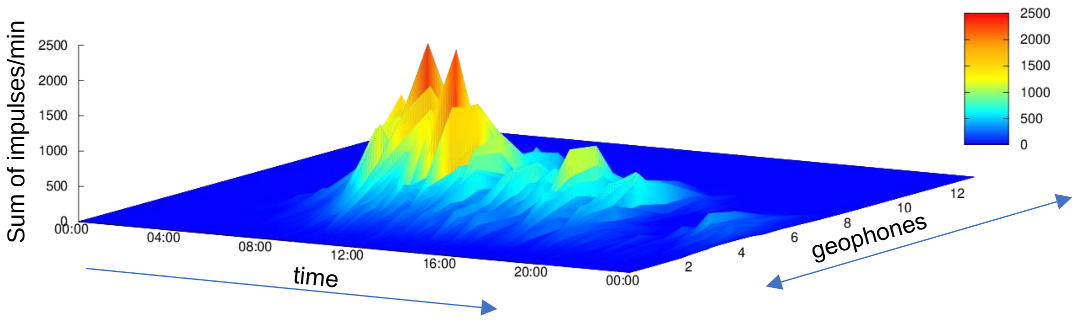

Figure 24: 24 hours geophone impulse graph of 08.07.2022 showing the temporal and special distribution, red indicates a high number of impulses per minute, blue indicates low impulses per minute.

During a single flood event the grain size distribution and specific bedload discharge can vary strongly over time as shown for example during the event of 26.04.2019 in figure 3. This measurement was performed at the same location in the river cross section with a specific bedload discharge ranging from 0-2.1 kg $m^{-1}s^{-1}$ and a highly dynamic sediment composition +/- 90% of size classes.

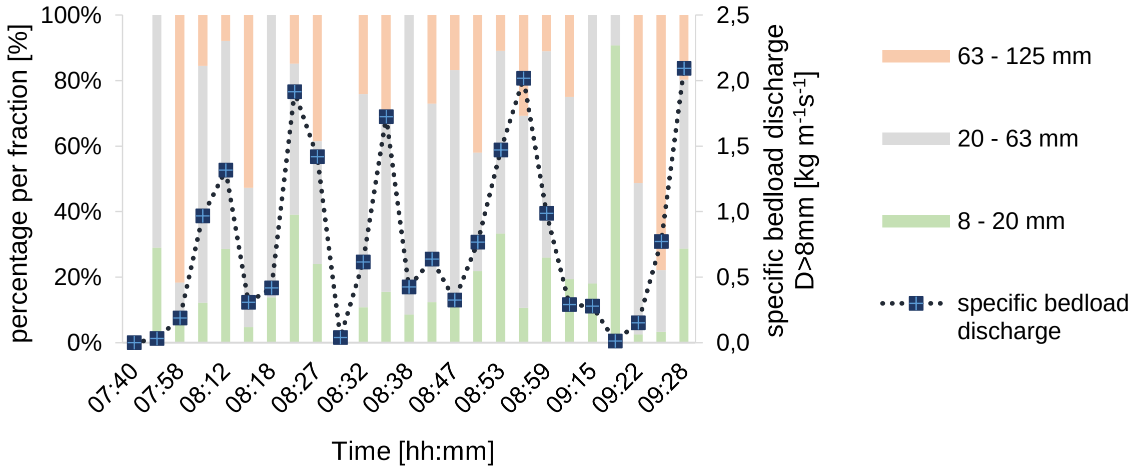

Figure 25: Grain size distribution during the event of 26.04.2019 derived from basket sampler D>8mm. the left vertical axis refers to the percentage per fraction displayed as a bar chart, the specific discharge is displayed as squares linked by a line and refers to the right vertical axis.

Comparing basket sampler measurements of the years 2016-2020 regarding the grain size distribution, the diversity of the transported sediments is illustrated in figure 4. With a d_{50} ranging from 15mm-72mm the sediment samples are highly diverse. Figure 4 displays grain size distributions of particles D>8mm since the largest mesh size used was 8mm. Each line in figure 4 consists of multiple measurements at a single event which were averaged for display.

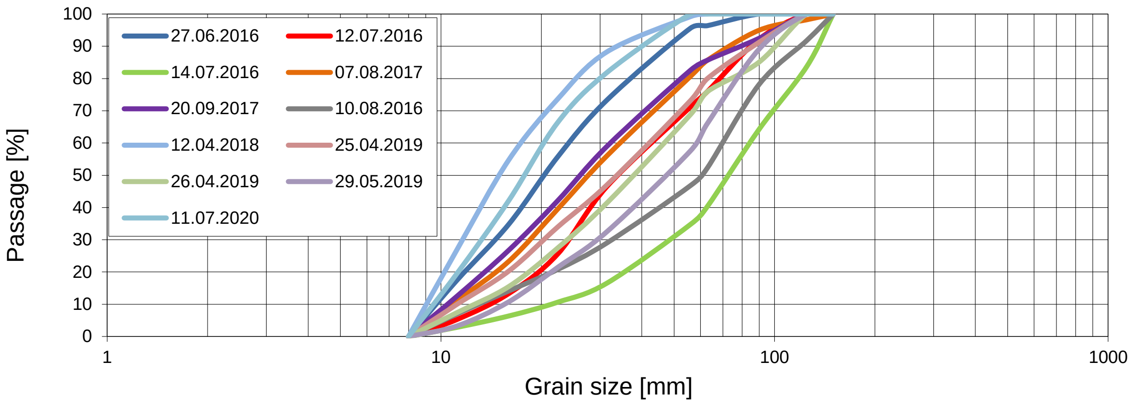

Figure 26 Grain size distribution >8mm derived by the basket sampler of the years 2016-2020, each measurement campaign consists of multiple single samples which were averaged for display.

Applying an integrative bedload monitoring setup, combining direct and indirect monitoring methods enable the continuous recording of bedload transport in a high temporal and spatial resolution. With an annual bedload mass ranging from 1,900-13,500 tons per year (particles D>10mm, 2014-2021) the Johnsbach river is a highly dynamic river regarding to the bedload flux. Grain size distributions ranging from d_{50} 15-72 mm display the heterogeneity of samples obtained with the Vent sampler. With the examples above, the sediment flux ranging from a single event scale to annual bedload masses, the capabilities and the available long-term data of the Johnsbach bedload monitoring station is highlighted.

In future, the Johnsbach will be particularly interesting since the main human impact (gravel mining) ended as the national park Gesäuse was founded, as addressed in Rascher et al. (2018). Therefore, the increase of bedload yield and a change in sediment composition is expected.

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Contact

Dorian Shire-Peterlechner, Institute of Hydraulic Engineering and River Research, Department of Water – Atmosphere – Environment, University of Natural Resources and Life Sciences, Vienna, Austria, Email: dorian.shire@boku.ac.at