General comments (GC)

GC1

"Specifically, in relation to the hydrophone method, I would like to see a clearer explanation of the method and some data that demonstrate the variability of the power-spectral density between hydrophone recordings."

We evaluated the variability of the PSD for all hydrophone records (n=448, Figure1a). This variability is illustrated by computing the central frequency and the peak frequency in the frequency band of bedload (15-350 kHz) (Figure 1b). The central frequency is affected by the grain size and vary between 50 and 270 kHz with a median value of 140 kHz. The first quartile and the third quartile are 127 and 154 kHz respectively that reflect a small variability of the central frequency. This is in agreement with the median grain size of sediment (D_{50}) distribution that vary between 0.3 and 3 mm with a median value of 0.9 mm (Q1=0.8 mm and Q3=1.1 mm).

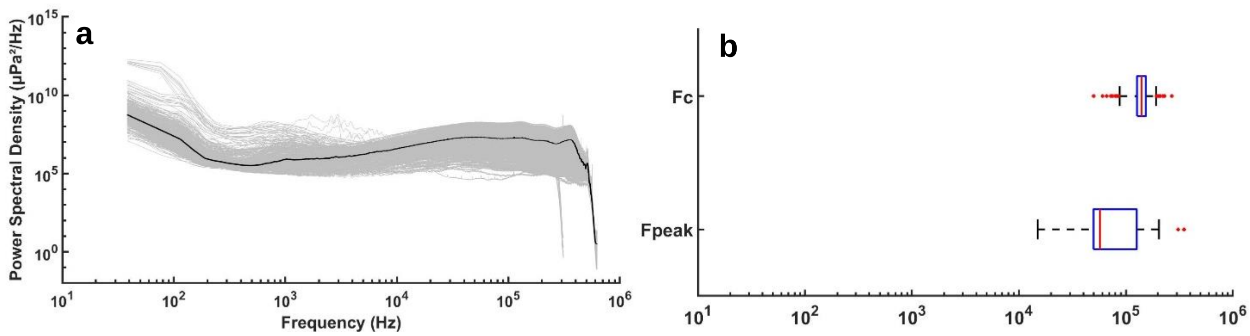


Figure 1: a) Power Spectral Density (PSD) for each hydrophone drift of the study (n=448), the median PSD in black; b) Distribution of the frequency peak and central frequency of each PSD.

GC2

"I would like the paper to describe if there are significant differences observed between the frequency spectrum of the studied sandy gravel-bed river and the frequency spectra in the comprehensive literature on gravel-bed rivers. How does the different grain size distribution affect the observed frequency spectrum?"

Different frequency spectrum from three different rivers are plotted in the Figure 2a. As expected by Thorne (1986), the central frequency decreases with the D_{50} (Figure 2a). We acquired 98 concomitant hydrophone records and sediment samplings and we compared these measured values to the theoretical relation of Thorne (2014) (Figure 2b). For the investigated range of D_{50}, the central frequency measured are in line with the theory (82% of the dataset are in the factor 2). For this range of grain size, Geay et al. (2020) found that rivers investigated did not follow Thorne's law because of the attenuation of high frequency sound waves in these steep rivers. The shift of the bedload frequency band towards high frequencies (figure 2a) means more bedload signal in this area of the PSD. However, the slope of the study reach is mild and the turbulence is relatively low. Therefore, the high frequency sound wave are not attenuated and the acoustic power in high frequency region is not neglected. The use of hydrophone method in large lowland sandy-gravel bed rivers could be an asset considering the bedload frequency band of sands.

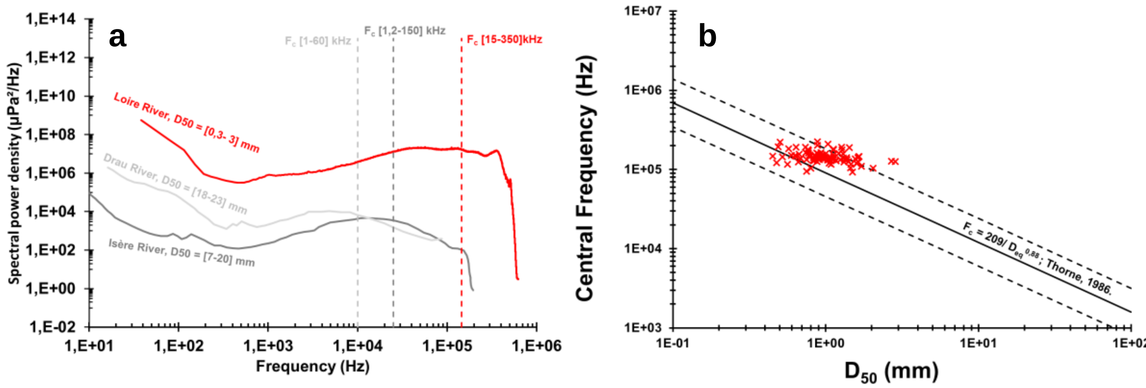


Figure 2: a) Comparison of PSD from 3 rivers with varying D_{50}; b) Comparison between measured central frequency of PSD of the Loire River and related D_{50} with relation of Thorne (1986).

We propose to add the figure 2a to the section 4.1. in order to provide PSD information related to other rivers, and also a paragraph: "*Moreover, the median PSD differ from the Isère River (Petrut et al., 2018) and from Drau River (Geay et al., 2017). These rivers are characterised by coarser sediments (see Fig. 5a) and the central frequency of the PSD are decreasing for an increasing* D_{50}*. These observations are in line with Thorne's (1986) theory. The central frequency of the median spectrum of the Loire is about 140 kHz. The frequency band of the bedload is shifted towards high frequencies due to finer grain size.*"

Specific comments (SC)

SC1

Lines 57-58 "to estimate the capacity of acoustic signals to detect the bedload axes on relatively wide cross-sections for various discharge conditions".

"Are you referring to estimating the accuracy of acoustic methods for measuring bedload transport rates for wide transects across a range of flow conditions?"

Yes, we are referring to the accuracy of acoustic methods to measure cross sectional variations of bedload fluxes over various discharge conditions. This sentence was modified in the revised version of the paper.

"to estimate the accuracy of acoustic methods to measure cross sectional variations of bedload fluxes for various discharge conditions;"

SC2

Line 116 "giving better results"

"How do you know that they are better results? Please provide a clearer description of the method used to determine data quality."

We just wanted to refer to Jamieson et al. (2011, p. 1066) observations here: *"A positive bias in bed velocity magnitude could be generated by interpolating bed velocity magnitude alone (i.e., without direction), where inconsistent bed velocity directions (which are typically higher in regions of zero to low bed velocity, where a moving bed is more difficult to detect with the ADCP) generates higher than expected bed velocity.*"

We changed "*giving better results*" by "*limiting the over estimation*".

SC3

Lines 147-148 "and could allow a better understanding of the apparent bedload velocity gradient along bedforms."

"It's not clear to me what this means. Why would this give a better understanding of the bedload velocity gradient along bedforms? Is it because the ADCP footprint is relatively small compared with the bedform dimensions? If so, please state typical bedform dimensions relative to the footprint."

This is exactly what we mean. We propose to change this sentence by: "*This configuration permitted to fix the footprint for each beam to about 0.0046 m² and a distance 146 of 0.56 m between opposed beams. This allowed to describe apparent bedload velocity with a finer accuracy especially in the presence of bedforms of 0.2 m height and 3.9 m long (in average)."*

SC4

Lines 161-162 "The determination of a proxy to evaluate sediment transport directly from DTM measurements is difficult."

"Explain why it was difficult."

Because there are several dune parameters such as dune celerity, height or length that influence bedload rate and all these parameters are evolving according to discharge variations. We propose to modify this sentence by: "*The determination of a proxy to evaluate sediment transport directly from DTM measurements is difficult because dune migration is function of several parameters. A semi-empirical equation that integer these parameters was used to compare bedload transport rates with the reference measurement.*"

SC5

Lines 240-241 "and the integration of median PSD over a wider range of frequency in the present study."

"What is meant by median? I'm not sure what this is referring to and I think it needs to be explained more clearly. Is the PSD integrated across the median value of each frequency bin?"

To make things more clearly, we decided to add this comment to the final version: "*For each drift, a spectral probability density is computed (Merchant et al., 2013). Then a median Power Spectral Density is determined as done in Geay et al. (2017). Median PSD are preferred to mean PSD as it enables to filter rare and powerful acoustic events such as the hydrophone impinging the riverbed.*"

SC6

Lines 251-257 "The comparison can be made between indirect methods to discuss the acceptability of the BTMA reference. The apparent bedload velocity and the acoustic power are not well-correlated with mean dune morphological parameters (dune celerity and height). The aDcp method is measuring the apparent velocity of the grain being transported from the stoss to the lee side of a dune. It must be noted that apparent bedload velocity is higher than dune celerity with about a factor 100, whereas the grain size (D50) is smaller than dune height with the same order. Therefore, sediments that are 100 times smaller than dune height allows the dune migration with a celerity 100 times smaller than their own celerity."

"I'm not sure this section is necessary and I struggle to understand some of the arguments being made. What is meant by the acoustic power and apparent bedload velocity not being well correlated with the morphological parameters? Where is this shown in the data? The comparison between apparent bedload velocity and dune celerity is interesting but I think most readers would already understand that the bedload velocity is much smaller."

We wanted just to mention that relations between dune parameters (height and celerity) and acoustic methods are not consistent. We chose not to show these relations with figures to avoid overload of the paper. This can be illustrated by a short table of the coefficient of determination (COD) for each relation. We added this table.

Table 1: Coefficient of determination between dune parameters and acoustic methods (log values).

	P	V_a	$q_{s\ BTMA}$	H_{dune}	C_{dune}
P	-	-	-	-	-
V_a	0.76	-	-	-	-
$q_{s\ BTMA}$	0.70	0.48	-	-	-
H_{dune}	0.20	0.27	0.16	-	-
C_{dune}	0.22	0.24	0.36	0.22	-

We agree that the following sentence is confusing and not necessary. We wanted to show differences between the magnitude order of dune celerity and apparent bedload velocity, keeping in mind that the apparent bedload velocity participate to dune migration. Just to be clear, you mentioned that bedload velocity is smaller but this is the opposite, the bedload velocity is higher than dune celerity. We modified the text, keeping just this part of the sentence: "*It must be noted that apparent bedload velocity is higher than dune celerity with about a factor 100."*

SC7

Lines 257-258: "On the other hand, the apparent bedload velocity is positively correlated with the acoustic power. The RMA regression model explains 76% of the dataset dispersion (Fig. 6a)."

Line 261 "and water discharge explain 71% of the dataset dispersion"

"What it meant by 'explains 76% of the dataset'? This needs to be accurately described. This paragraph needs to be re-written."

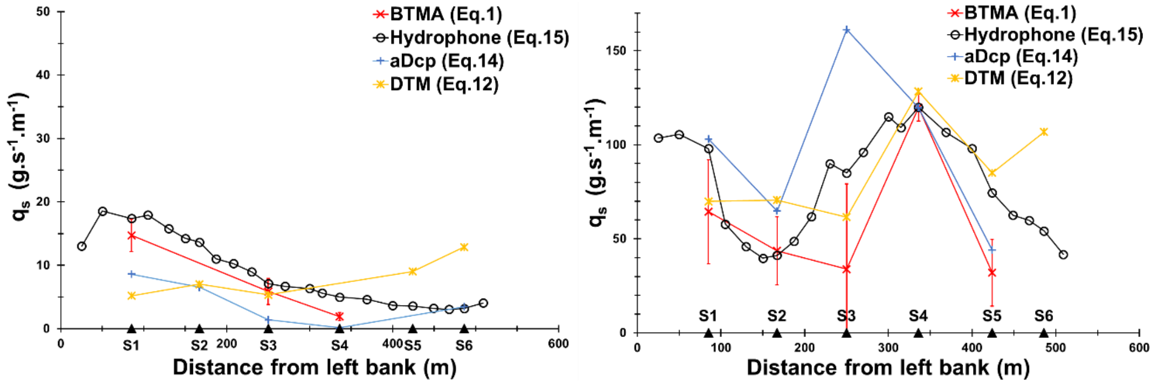
The COD (R^2) of the RMA regression is equal to 0.76 this mean that the equation of the RMA regression (model) determines 76% of point distribution (scattering). We modified these two sentences by: *"The COD of the RMA regression is equal to 0.76.*"; and "*The COD of the RMA regression established between BTMA bedload rates and water discharge is 0.71.*"

SC8

Line 286 "there was no reference measurements"

"Why not? Please explain. Can you please add labels, e.g. S1, to the BTMA data points in both panels of Fig. 8 to clearly identify the reference measurements? Why is there no S2 in Fig. 8a? Why are reference measurements missing from Fig. 8b?"

As mentioned in the material and method section, BTMA method is very time-consumming and it is not possible to measure all sampling points for each field survey. This is the case for S2, S5 and S6 on the figure 8a and also for S6 on the figure 8b. We added sampling points on figures 8a et 8b as requested:



<u>SC9</u>

Line 294 I would like to see some discussion as to why the hydrophone method is producing larger values of unit bedload rate compared with the BTMA measurements. Just a thought, but could it be related to the omnidirectional hydrophone picking up higher noise magnitudes that are not directly below the boat?

A hydrophone senses every noises that are propagating in the water column. Therefore, the hydrophone can sense noises that are far away from its location. Noises are more and more attenuated with increasing distance (Geay et al., 2019). Particularly, when there is few bedload noises close to the hydrophone, the hydrophone can sense bedload noises that are generated far away. This behaviour could explain why the hydrophone tends to overestimate bedload fluxes when bedload fluxes are weak.

<u>SC10</u>

Lines 303-305 “For this survey, acoustic signals (i.e. acoustic power, apparent bedload velocity) followed the same evolution pattern as isokinetic samplers along the cross section except for S3.”

“Again, why is this the case? Is it due to a lack of directionality?”

As the aDcp method, isokinetic sampler method is a “point/local” measurement which is function of the local grain size. The sediment grain size variability is important to explain the spatio-temporal variability in bedload sediment dynamics in large sandy gravel bed rivers. For instance, we made some measurements where one BTMA caught some sediment transported and the other one (located about 4 m away on the same cross section) was empty due to coarser grain size at this specific location. So, it is clear that an uncertainty is due to the limited spatial resolution of these two methods compared with hydrophone method that integer longitudinal variability of bedload (drifts are about 30 m long depending of flow velocity). Moreover, the presence of bedforms, specifically bars, increases the bedload (and grain size) variability (Venditti et al., 2012; Cordier et al., 2020).

SC11

"Line 325 Immediately downstream of the bar there are bedload transport values that are higher than those observed further downstream. Is this due to the omnidirectional hydrophone picking up bedload noise from the bar upstream?"

It is possible that the hydrophone senses the noise that are generated at the bar top and that acoustic power decreases smoothly when increasing the distance from the bar edge. The small increase of noise could be the noise of a dune that fall on the avalanche face (lee face) of the bar when the hydrophone was over the bar front, but we can only make assumptions here.

All other technical corrections mentioned by the referee were adopted in the final version of the paper.

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