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Interactive comment on "Long-term river trajectories to enhance restoration efficiency and sustainability on the Upper Rhine: an interdisciplinary study (Rohrschollen Island, France)" *by* David Eschbach et al.

David Eschbach et al.

david.eschbach@live-cnrs.unistra.fr

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R1: I am disappointed by some of the author's replies, also considering that my comments were not too difficult to address and aiming to improve quality and clarity of the paper.

AR: We thank you sincerely for your helpful remarks aiming to improve the paper, in quality and clarity. We are profoundly sorry that you considered our first corrections not satisfactory. We have carefully considered all your comments (RC1 & RC2) and

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have done our best to satisfy your and the editors requests. We sincerely hope our corrections and the revised version will be considered positively.

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R1: Specifically, I think that the author could pay more attention to the following aspects:

(1) Dating by IRSL. The authors replied that there are not reverse ages: is PIT 2 showing a “normal” relation between depth and ages of sediments (figure 7)? I understand that this could be the only option for dating: on the other hand, I think it could be useful to say that there were no other options.

AR: The IRSL ages shown in Figure 7 for PIT 2 are 179 $\pm$ 35 (at 40 cm), 170 $\pm$ 26 (58 cm) and 165 $\pm$ 22 (97 cm). First, it is important to note that these ages all overlap well within the given uncertainties. For a set of three ages there are n * (n-1) possibilities (6 in our cause) of how these ages can be arranged. The end members would be 1-2-3 and 3-2-1 (where 3 is the youngest and 1 is the oldest age). We have computed the likelihood for the different possible combinations based on their uncertainties using the following MATLAB code (by courtesy of Prof. S. Hergarten, Freiburg):

n = 1000000; a = randn(3,n); a(1,:) = 179 + a(1,:) * 35; a(2,:) = 170 + a(2,:) * 25; a(3,:) = 165 + a(3,:) * 22; [~,index] = sort(a); index = 100*index(1,:)+10*index(2,:)+index(3,:); h = hist(index,1:1000); % probabilites of the 6 possible orders in percent; h = 100*h(h~=0)/n;

For this we received the following results:

% 1 2 3 / 1 3 2 / 2 1 3 / 2 3 1 / 3 1 2 / 3 2 1

% 11.47 / 15.22 / 10.08 / 22.51 / 15.00 / 25.72

This indicates that the observed order of values has a likelihood of more than 10% and, indeed, we are considering this a statistically likely enough case to be regarded

as “normal” (from a statistical point of view). In other words, the only information we can deduct from the dates of PIT 2 is that they reveal a rapid phase of sediment deposition - with an absence of a significant correlation between depth and ages -, which corresponds to the phase of correction works of the Rhine on the Rohrschollen site.

AC: Furthermore, in order to follow your suggestion, we propose to add a sentence to specify that the IRSL method is the only option for dating in this context. Section 3.3.3: “, . . . as any other alternative approach is achievable in this context (Preusser et al., 2016)”, after “Dating of sediments sampled from both pits was carried out using Infrared Stimulated Luminescence (IRSL). . .”.

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R1: (2) Section 4.4. The authors replied that “. . . effects of the restoration project cannot be developed here. . .”. If so, why in the “Introduction “ they say “. . .and to assess potential benefits and limits of the restoration” (page 3, line 5) and “. . .evaluate efficiency and sustainability of the restoration effects. . .” (page 3, line 13)? I understand that they want to avoid overlapping between this paper and another one submitted to “Geomorphology”: in this case, my suggest would be to make some change in the “Introduction” to make the whole work more consistent.

AR: We fully understand the remark of Reviewer#1 and we thank him for this helpful comment. From a general point of view, the aim of the paper is to show that long-term trajectory of the hydrosystem is useful to improve the efficiency and the sustainability of the Rohrschollen restoration project (and potentially of other river restoration projects). This is presented in the introduction, as well as in the discussion (section 4.4). We discuss the general knowledge produced thanks to the historical study, and which is useful in the restoration context (limits, benefits, efficiency, sustainability), but we don’t aim to show the post-restoration changes observed in the Rohrschollen Island with large detail, because we believe that (i) this would be beyond the scope and topic of the paper, and (ii) would make the paper unnecessarily long. Furthermore, these detailed results

have been published by Eschbach et al. (2017) and may be published in the near future (Eschbach et al., in review). Nevertheless, we fully agree with Reviewer#1 (RC1 and RC2) that the restoration project and the morphological evolution of the restored channel should be better presented in the Study area section, notably to strengthen the discussion. Consequently, we propose to add / modify several sentences in the introduction and the discussion, both modifications being linked together.

AC: End of the Introduction, we propose to modify the objectives in order to make them coherent with the discussion ("evolutionary trends" is more general than "evolution"; the objective (v) opens avenues towards other river restorations): "..., (iv) deduce post-restoration evolutionary trends and (v) propose operational outlook to improve efficiency and sustainability of Rohrschollen's restoration, and by extension of other river restoration projects (Sear et al., 1994; Grabowski and Gurnell, 2016)", after "...(iii) characterize assess physio-chemical sediment properties (e.g. heavy metals and organic contaminant concentrations) to trace anthropogenic activities and evaluate the potential impact of the restoration on pollutant remobilization (Middelkoop, 2000; Fedorenkova et al., 2013; IKSR-CIPR-ICBR, 2014; Middelkoop, 2000).". At the end of the Study area section, we propose to add some details on the restoration and post-restoration adjustments: "As the bankfull discharge of the new channel is 20 m3.s-1, flooding in the Island occurs when the discharge exceed this threshold. A three years monitoring showed that bedload transport, active lateral and vertical morphodynamics occur along the new channel (active bank erosion, formation of bars and logjams, enhancement of pool-riffle sequences, increase of groundwater – surface water exchanges...; Eschbach et al., 2017; Eschbach et al., in review), but not along the Bauerngrundwasser which is affected by the hydraulic backwater of the agricultural dam (Eschbach et al., 2017; Eschbach et al., in review; see also the pictures of Fig. 1).", after "Water input from the flood gate ranges between 2 m3.s-1 (when Q Rhine < 1550 m3.s-1) and 80 m3.s-1 (when Q Rhine > 1550 m3.s-1).".

In the Discussion, Section 4.4. §1, we propose to add: "More specifically, the restora-

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tion induced, in the new channel, the recovery of bedload transport, lateral and vertical dynamics, as well as groundwater - surface water exchanges.", after "In part, this functioning has been targeted by recent restoration efforts.".

Section 4.4. §1, we propose to complete (two more sentences) and modify the end of the section: "... because the removal of very large amounts of fine sediments seems unthinkable. Furthermore, the strong hydrological alteration by the canalization works makes the functional alteration of the hydrosystem irreversible as well. In this constrained context, the main challenge of the restoration was to recover processes as dynamic floods (on the whole island) and a morphodynamic gravel bed channel in a relatively restricted environment (new channel; see also below). On the basis of an environmental monitoring conducted during three years after the end of the restoration works, it appears that these restoration objectives are attained (Eschbach et al., 2017; Eschbach et al., in review) and that the restoration choices were relevant (see also below).", after "This highlight the fact that impacts of correction work and further engineering works are irreversible...".

Section 4.4. §2, we propose to add: "This demonstrates once again the relevancy of the principles of this restoration.", after "Thus, in the specific case of the Rohrschollen Island, both risks are drastically lowered by this local hydraulic constraint.".

Section 4.4. §3, we propose to add: "... as it is the case on the Rohrschollen Island (new channel).", after "It also allows to identify floodplain areas with high hydromorphological functional potentials, i.e. sectors with thin layers of fine sediments located outside palaeochannels, notably on former gravel bars, ...".

Section 4.4. §3, we propose to add: "... (as it has been performed on the Rohrschollen Island),...", after "In such geomorphological areas, where the efficiency of restored lateral channels may be the highest, managers are encouraged to excavate new channels and enhance morphodynamics by floods, which even may erode self-formed lateral channels in some cases...".

Section 4.4. §3, we propose to add: "... (which may be impossible if sediments are polluted) and/or natural fine sediments removal by the restoration of active bank erosion in lateral channels.", after "It probably will require in the future innovative flood management strategies (Hudson, 2008) that may notably be based on floodplain artificial excavations of fine sediments...".

Section 4.4. §3, we propose to add: "... to balance a relative sediment deficit in the upstream section of the new channel by artificial gravel augmentations, in the next years/decades (Eschbach et al., in review).", after "For example, it will probably be necessary...".

Section 4.4. §3, we propose to add: "...and modelling, both in the frame of fluvial hydrosystem temporal trajectories.", after "This opens up avenues for developing integrative methodological approaches to improve pre-restoration knowledge and to implement post-restoration monitoring...".

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R1: (3) Sinuosity (Figure 9). Yes, I agree that sinuosity can be measured in a braided rivers: the point is that if you are analyzing a multithread river (braided, wandering; see figure 4) other indices would be more useful to be taken into account (e.g. braiding index).

AR: In order to take into account the remarks RC1 and RC2 of the Reviewer#1, we have calculated the thalweg's sinuosity on the basis of the straight length of the reach (Fig. 8). So, the sinuosity in 1872 is 1.09 rather than 1.00, which was effectively wrong. Furthermore, we have added a Braiding and Anastomosing Index (BAI; table of Fig. 8) which corresponds to the mean number of these two types of channels, (channels showing stagnant water have been excluded). Indeed, this index shows in a relevant way the modifications of the channel pattern (BAI decreased from 7.90 to 1.00).

AC: As a consequence, the following changes in the text are also proposed:

Section Study area, we propose to add: “Before engineering works, it was a braiding and anastomosing fluvial hydrosystem.”, after “The Rohrschollen artificial Island is located 8 km South-East of the city of Strasbourg and owes its existence to the construction of a power plant in 1970.”.

Section 4.1., we propose to add: “The braiding and anastomosing index ranged between 7.9 and 5.4 (Fig. 8)”, after “. . .5 km from the thalweg.”.

Beginning of the section 4.2.2., we propose to add: “. . . , the braiding and anastomosing index decreased from 5.36 to 2.45”, after “At the scale of the natural reserve, from 1828 to 1838. . .”.

Section 4.2.2., we propose to add: “(. . .; the braiding and anastomosing index decreased to 1 in 1872)”, after “(Fig. 4-b. . .)”.

At the end of the title of Figure 9, we propose to add : “. . . BAI is a Braiding and Anastomosing Index which corresponds to the mean number of these two types of channels (channels showing stagnant water have been excluded)”.

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AR-AC: As asked by Reviewer#1 in RC1, we propose to add the following conclusions summarizing the main findings of our study:

“In this study we show the relevance of considering temporal trajectories in process-based river restoration. An interdisciplinary approach deployed at different spatio-temporal scales has been developed by combining planimetric data with sedimentological, chemical and geochronological analysis, as well as a hydrological model. Prior to anthropogenic disturbances, the hydrosystem was mostly characterized by a high-energy depositional environment of braiding channels with high lateral mobility and important surfaces of gravel bars and pioneer vegetation. Correction works provoked a drastic temporal trajectory change, by intensifying filling of fine and polluted (Zn) sediments in palaeochannels and decreasing flood frequency. In contrast, the floodplain

recorded lower deposition rates by quasi-unpolluted sediments. More recently, canalization resulted in very low sedimentation rates, but strong hydrological and hydrogeological disturbances. Our results highlight potential risks that restoration projects may face and need to mitigate along large rivers, e.g. removal fine and potentially polluted sediments by reactivating erosion/deposition processes in former channels. On the Rohrschollen Island, this risk is reduced by the backwater effect of the agricultural dam which limit lateral erosion in the palaeochannel. On the contrary, floodplain areas outside palaeochannels show thin layers of fine sediments and appear more relevant to restore dynamic lateral channels. Managers may benefit from excavating new channels on such areas, as it has been performed on the Rohrschollen Island. They are even encouraged to develop self-erosion of lateral channels by dynamic floods. Finally, this research underscores the necessity to base functional river restorations on the knowledge of hydrosystem past-trajectories that includes the physico-chemical characterization of sediments in order to maximize restoration efficiency and sustainability."

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AR-AC: In addition, we propose also some other short text modifications (modifications of only one to three words are not listed below):

Study area section, we propose to add: "...from braiding to anastomosing and meandering...", after "Slope decrease and inherited geomorphological factors explain the longitudinal evolution of the channel pattern...".

Study area section, we propose to add: "Before engineering works, it was a braiding and anastomosing fluvial hydrosystem.", after "The Rohrschollen artificial Island is located 8 km South-East of the city of Strasbourg and owes its existence to the construction of a power plant in 1970."

In order to answer to a comment of Reviewer#1 in RC1 concerning the CM diagram method, we propose to add: "... we determined the competence of palaeochannel deposits by plotting the median (D50) and the coarsest percentile (D99) of the grain-

size distributions in the CM diagram according to Passega (1964, 1977) and Bravard and Peiry (1999).", after "To further characterize transport and depositional processes, we. . .".

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