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Discussions

Interactive comment on "Beaver dam influences on streamflow hydraulic properties and thermal regimes" *by* Milada Majerova et al.

Anonymous Referee #1

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This manuscript is based on water temperature measurements made at various locations along a stream reach that contains three beaver dam complexes. The temperature measurements cover a three-week period in September, 2013, and are supplemented by modelled depth and velocity distributions generated by application of the Delft3D hydraulic model. The objective is to relate thermal conditions to hydraulic conditions. The analysis consists primarily of a graphical evaluation of the univariate distributions of temperature, velocity and depth, grouped by geomorphic unit class, and time series plots illustrating temperature variability and differences among locations within the reach.

This research is timely and relevant to the readership of HESS given the expansion of beaver populations in many regions and the profound impacts of their activities on

fluvial habitats. However, the data set and the analysis are limited, and the internationally significant contribution of this work is unclear from the current version of the manuscript. Specific comments are provided below. I recommend that the manuscript could be acceptable for publication in HESS following major revisions to address the points raised below.

1. The introduction fails to set up the significance of this work in a convincing manner. For example, after reviewing a number of papers, the authors claim that "[r]egardless of such findings, the connections . . . are not well understood. Many questions remain . . .." Unfortunately, the authors fail to identify any of these questions. In contrast to the authors' statement, I would argue that most if not all of the phenomena noted by the authors at their study site have been documented in previous studies. Furthermore, the physical processes governing thermal variability are well understood in general terms, and most of the observed patterns could be qualitatively deduced from first principles.

Reading between the lines in the introduction, an implicit hypothesis appears to be that the existing literature is not fully relevant to systems with beaver influences. If so, then it would be useful to spell out what is distinctive about beaver-influenced systems. For example, perhaps beaver-affected streams are unique due to the spatial arrangement of the various geomorphic units and the advective connectivity among them.

In any event, I would encourage the authors to identify specific gaps in our current understanding, and then to generate some specific hypotheses or research questions to guide the data analysis, interpretation and presentation (cf McKnight, 2017). Doing so would help to clarify for the reader what this study adds to our understanding, relative to what we have learned from decades of previous stream temperature research.

2. The lack of specificity and clarity noted in the preceding point is exacerbated by issues associated with the use of the literature as supporting information. For example, the authors make a broad statement that "[b]eaver dams and beaver activity can significantly alter . . . various heat exchange mechanisms (e.g.., groundwater exchanges,

Westhoff et al., . . .).” However, none of the cited papers focused on systems influenced by beaver dams, and only Westhoff et al. (2007) specifically quantified the effect of groundwater discharge on stream temperature patterns. Hannah et al. (2004) speculated on the effect of groundwater discharge but made no measurements to quantify it; Keery et al. (2007) described the use of stream and bed temperature time series to compute vertical water exchange between a stream and its bed, but not its influence on stream temperature; and Beschta (1997) did not even mention groundwater.

Another issue related to references is the use of grey-literature and/or perspective articles, such as Sullivan and Adams (1991) and Beschta (1997), and even an AGU abstract (Butler and Hunt, 2013). It would be more effective to draw upon the peer-reviewed and data-based stream temperature literature, and especially papers focused on understanding stream thermal processes and thermal heterogeneity.

3. The analysis is limited to narrative descriptions of univariate distributions of depth, velocity and temperature, grouped by geomorphic units, followed by qualitative interpretations in relation to governing processes. There is no formal statistical analysis and no hypothesis testing (statistical or otherwise), nor is there any formal application of hydraulic or heat-transfer principles to guide the analysis and interpretation. As a consequence, there is no basis for putting the results into a broader context that could be applied to understand or predict thermal heterogeneity for other systems or time periods.

One possible starting point for further analysis is the observation that thermal heterogeneity should depend, in part, on the covariation of depth and velocity among different locations, not just the univariate distributions. It may be useful to examine how the different geomorphic units and their thermal regimes map within a depth-velocity plot, or possibly a space with axes representing non-dimensional numbers relevant to hydraulics and heat transfer (e.g., Reynolds number and possibly the thermal Peclet number).

The authors allude to some heat-budget modelling (line 374ff). I strongly encourage the authors to incorporate that analysis into a revised version of the manuscript.

4. The authors discuss the role of aquatic macrophytes in producing vertical stratification in the backwater areas (line 348ff). Could more information be provided about the macrophytes, such as species, density and height of protrusion above the water surface? Perhaps include a photograph in the supplemental information. Were the macrophytes accounted for in the hydraulic modelling? The authors may find the work of Willis et al. (2017) relevant.

5. The authors refer to local groundwater discharge in the backwater area (line 351). What data were used to determine locations of groundwater discharge? Does groundwater discharge occur at other locations than the backwater area? I suggest the authors add more detail to the site description to address this and the preceding comment.

6. Further to the discussion of stratification in the backwater area, the authors found a time lag of up to 8 hr for the diurnal peak temperature in the bottom layer relative to the surface layer and main channel flow. They also note that Clark et al. found different patterns of time lag. Can the authors suggest a physically based explanation?

7. The authors used a hydraulic model to estimate depth and velocity distributions. They compared simulated depths to measurements and provided values for mean bias error and root-mean-square error. However, no comparisons are reported between modelled and observed velocities. Do the authors have any sense of how large these errors may be, and whether the results are robust to combined errors in depth and velocity?

8. The study focused on a three-week period in September, which was characterized by low-flow conditions. Based on the literature and process considerations, I would expect thermal heteorogeneity to increase with decreasing streamflow and with increasing solar radiation. It is unclear whether the observed patterns in this study would

be relevant for other periods, particularly earlier in the summer when both streamflow and solar radiation would be higher. This concern could be addressed to some degree by focusing on the variability of heterogeneity within the study period. (e.g., contrasting day and night, and days with differing insolation).

9. Following on the preceding point, do the authors have meteorological and streamflow data for the study period? This information would be useful for interpreting the time series plots and the within-period variation of thermal heterogeneity (Figures 5 and 6).

10. The authors relate the observed temperature variability to fish habitat suitability, but only in a passing way (line 359ff). Perhaps this discussion topic could be developed in more detail with reference to the relative roles of temperature and depth/velocity as controls on habitat suitability. For example, environmental flow needs are often determined with respect to depth and velocity, with no reference to thermal regime (Olden and Naiman, 2010). In the current case, do the locations with optimal temperatures coincide with optimal hydraulic conditions for the resident fish species?

11. In Figures 5 and 6, temperature differences are shown between upstream and downstream locations. Examination of the figures suggests that much of the difference is caused by an advective shift in the timing of the diel temperature wave rather than changes in temperature caused by energy exchange (especially Figure 6B). It may be interesting to account for this effect by shifting the time series to account for travel time, and then looking at temperature differences, as was done by Rutherford et al. (2004).

12. In the plots that show upstream-downstream differences as well as temperature time series, it would be useful to adjust the y-axis intervals so that the right-hand axis has a horizontal line corresponding to $\Delta T = 0$ for a visual reference. Indeed, the use of an exaggerated scale for the right-hand y-axis overstates the magnitude of the differences. Consider using the same scale for both temperature series and their difference.

13. The reference list needs editing for completeness and correctness. I have not gone

through the references in detail, but noted the following points:

line 439. “Chapman u. Hall”

line 443. Article title in all caps.

line 445. Issue number missing (each issue is numbered separately).

line 558-559. No journal name or volume number.

References

McKnight, D. M. (2017), Debates - Hypothesis testing in hydrology: A view from the field: The value of hydrologic hypotheses in designing field studies and interpreting the results to advance hydrology, Water Resour. Res., 53, 1779–1783, doi:10.1002/2016WR020050.

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Willis et al. (2017), Seasonal aquatic macrophytes reduce water temperatures via a riverine canopy in a spring-fed stream. Freshwater Science, DOI: 10.1086/693000.

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