Review of the manuscript

Title: *The effect of beaver ponds on water physico-chemical composition in the Carpathians (Poland and Slovakia)*

This manuscript examines the influence of Eurasian beaver (Castor fiber) ponds on the physico-chemical composition of stream water in two Carpathian regions spanning Poland and Slovakia. The authors compare in-channel and overflow-type ponds across different seasonal and hydrological conditions. The topic is both timely and relevant given the widespread recolonization of Eurasian beavers and the increasing emphasis on nature-based water quality management in Europe. The Carpathian setting adds important biogeographical context.

The manuscript is generally well written and logically organized, and the authors have assembled a valuable dataset. The introduction provides appropriate background, and the discussion connects findings to the broader literature on beaver-mediated ecosystem processes.

However, the study has several methodological, analytical, and interpretive weaknesses that currently limit its robustness. Firstly, there is a notable lack of information regarding the quantification of detection limits and analytical uncertainties. This raises concern that the observed differences may be within the analytical uncertainty range of the employed methods, potentially rendering some of the reported changes statistically or analytically insignificant. Clarifying the magnitude of measurement precision and error propagation is therefore essential for assessing the robustness of the findings.

The absence of a control stream, incomplete treatment of hydrological and geomorphological variables (e.g., residence time, hyporheic exchange), and the reliance on PCA as the primary analytical tool weaken the causal inferences that can be made. In addition, the discussion sometimes over-interprets the observed data, especially regarding microbial processes, without corresponding measurements or mechanistic evidence.

Overall, I find the study promising and potentially suitable for publication after major revisions that fully address the issues outlined below

Major comments

The landscape and geomorphic context of the studied sites needs to be clarified. It is not entirely clear whether the overflow-type ponds are located within semi-confined valley settings and whether they inundate the entire valley bottom or only a portion of it. Similarly, please specify whether the studied ponds form cascading systems (i.e., multiple ponds connected in sequence) or if they are isolated structures separated by stream reaches. Providing a more detailed geomorphic and hydrological description of each pond type would greatly improve the reader’s understanding of the environmental setting and the spatial variability in the measured parameters.

Study design.

Firstly, there is a notable lack of information regarding the quantification of detection limits and analytical uncertainties. Most results are expressed as percentage changes, yet the underlying absolute concentrations and associated measurement errors are not reported. Table 2, for example, presents only upstream values—downstream concentrations should also be shown to allow direct evaluation of differences and variability. Moreover, Figure 4 (despite the very small and hard-to-read legend) appears to show input and output values that are strikingly similar. This raises concern that the observed differences may be within the analytical uncertainty range of the employed methods, potentially rendering some of the reported changes statistically or analytically insignificant. Clarifying the magnitude of measurement precision and error propagation is therefore essential for assessing the robustness of the findings.1.

Statistical design and analytical approach

The use of Principal Component Analysis (PCA) as the primary method of data interpretation might not optimal for addressing the research questions. PCA is a dimension-reduction tool used for exploring structure in multivariate datasets, not for hypothesis testing or identifying drivers of variability. The study's stated objectives—to assess the effects of beaver pond type, season, and age on water chemistry would hint towards inferential statistical approaches that explicitly test these relationships. For example:

- Multiple regression analysis (e.g., linear or generalized linear models) linking dependent variables (e.g., NO_3^-, NH_4^+, DO, pH) to independent predictors (pond type, age, season).
- Multivariate analysis of variance (MANOVA) or PERMANOVA, if multivariate relationships are of interest.

Including these analyses would allow the authors to quantify the strength and significance of each factor, rather than relying solely on visual clustering. The PCA can still be retained as a descriptive complement but should not serve as the basis for major conclusions.

Hydrological context: residence time and hyporheic exchange

The paper does not account for hydrological processes that are fundamental to understanding biogeochemical changes in beaver ponds.

Residence time: Water residence time controls oxygen availability, redox gradients, and microbial processing rates. Beaver ponds with longer residence times are expected to show greater reductions in dissolved oxygen and nitrate due to denitrification and organic matter decomposition. Conversely, short residence times may result in weaker effects. The manuscript should discuss residence time conceptually, even if it cannot be quantified directly. If possible, proxy indicators (e.g., pond size, depth, flow velocity) could be used to infer relative differences in residence time among sites.

Hyporheic exchange: The study also omits consideration of hyporheic exchange, the mixing between surface water and groundwater within streambed sediments. This process significantly affects nutrient transformations, nitrification, and dissolved oxygen concentrations. Importantly, hyporheic processes occur irrespective of beaver activity and can confound interpretations if not acknowledged. Including this discussion would demonstrate awareness of key hydrological-biogeochemical linkages and strengthen the conceptual framework of the paper.

Interpretation of microbial and biogeochemical processes.

The authors attribute seasonal changes in nitrogen species (NO_3^-, NH_4^+) and DO to microbial processes such as denitrification, nitrification, and ammonification. While these mechanisms are plausible, the current dataset does not include direct measurements of these processes (e.g., redox profiles, dissolved organic carbon, or isotopic composition). As such, these explanations remain hypothetical. This means wording should be cautious: "likely related to" or "consistent with".

- Highlighting the need for further studies measuring microbial activity or redox potential directly.
- Discussing potential alternative explanations, such as dilution effects, sediment adsorption, or vegetation uptake.

Additionally, please consider that reduced DO levels in beaver ponds may not always signify enhanced denitrification; they may also reflect increased biological oxygen demand (BOD) from organic matter accumulation.

Methodological transparency.

Several key methodological details are missing or unclear, which hinders reproducibility and assessment of data quality. Please expand the Materials and Methods section to include the following:

- Calibration and maintenance of probes: Specify the calibration, field recalibrations.
- Sampling design: Clarify whether samples were collected under baseflow or post-rain conditions. Define how "normal water levels" were determined (e.g., relative to long-term discharge averages).
- Temporal resolution: Indicate how long each sampling campaign lasted and whether samples were taken at consistent times of day (important for DO and temperature).
- Analytical precision: Report detection limits and analytical errors for key parameters (NO_3^-, NH_4^+, SO_4^{2-}).
- Pond characteristics: Include basic information on pond area, depth, dam height, and vegetation cover. These features are crucial for interpreting variability among sites.
- Data processing: Explain any data transformations or normalization applied before PCA.

Figures and tables

The figures contain useful information but are difficult to interpret in their current form. They all could benefit from more detailed figure captions. The following revisions are recommended:

- Figure 1: Add a scale bar and north arrow. Increase contrast for better readability.
- Figures 2–3: Clearly define all abbreviations and units. For seasonal plots, consider color-coding by season rather than by site to emphasize temporal patterns.
- Figures 4–7: Reduce the number of variables plotted. Focus on the most ecologically relevant ones (e.g., pH, NO_3^-, NH_4^+, DO, SO_4^{2-}). Move less critical parameters (e.g., Mg^{2+}, K^+) to supplementary materials.
- Figures 8–11 (PCA): Improve label readability and explain the meaning of PC1 and PC2 in the caption. Include the percentage of variance explained by each component.
- Tables: Ensure consistent unit formatting and significant figures.

Minor comments

- Terminology: Use "physico-chemical properties" or "water chemistry" consistently throughout.
- Units: Ensure all concentrations use consistent units (mg L^{-1}).
- pH interpretation: A pH decrease is not inherently negative; interpret it relative to baseline conditions.

- Seasonal terminology: Define “warm” and “intermediate” seasons clearly (e.g., May–September, October–April).

This comment was prepared as part of MSc course work at Wageningen University under supervision of Dr. Annegret Larsen. Comments which were good quality and likely helpful for the authors and editorial team were combined and uploaded as one review document.