Cover letter

April 3rd, 2025

Number: hess-2024-399
Manuscript Title: Impacts of Inter-basin Water Diversion Projects on the Feedback Loops of Water Supply-Hydropower Generation-Environment Conservation Nexus

Dear Prof. Pieter van der Zaag,

We would like to express our sincere gratitude for the opportunity to submit our manuscript entitled " Impacts of Inter-basin Water Diversion Projects on the Feedback Loops of Water Supply-Hydropower Generation-Environment Conservation Nexus" to Hydrology and Earth System Sciences. We much appreciate your professional and insightful comments. All the concerns raised have been carefully treated and an itemized reply to your comments is presented in the revision files. Our changes are marked in Red in the revised manuscript.

Thank you very much again for your time and kind help. Looking forward to hearing from you.

Sincerely yours,

Dedi Liu
Email: dediliu@whu.edu.cn

Reference Number: hess-2024-399-RC1

RESPONSES TO REVIEWER #1'S COMMENTS

We would like to express our sincere appreciation for your professional and insightful remarks on our paper. The comments are valuable and helpful for us to improve the quality of the manuscript. All the concerns raised have been carefully treated and an itemized reply to the reviewer's comments is presented in the revision files.

Major comments/questions

Point #1

COMMENT: *Line 129 to 131: How do the dam release rules factor into the estimation of dam discharge, and are they integrated alongside the catchment area ratio?*

RESPONSE: The authors much appreciate the reviewer's insightful comments and apologetic for not clearing discussing the estimation of dam discharge. Lines 129-131 describe the method for calculating the runoff to the primary reservoir and the interval runoff of each pair reservoirs, but the formula for the inflow to the *i*th reservoir was not included. Specifically, the discharge from the reservoir is determined by the inflow and the specific operational rules of the reservoir. The inflow to the primary reservoir in a reservoirs group is calculated using the runoff from the hydrological stations simulated by the VIC model and the ratio of the catchment area. The inflow to the *i*th reservoir is the sum of the discharge from the (*i*-1)th reservoir and the interval runoff. The interval runoff for each reservoir is calculated using the runoff simulated by the VIC model and the catchment area ratio. The discharge for each reservoir is allocated according to its regular operational rules and the rules set for each scenario (flood control is the primary requirement, and the scheduling rules are adjusted according to different combinations of priorities for water supply, hydropower generation, and environment conservation). To address the issue of the missing explanation in the manuscript, modifications have been made in lines 129-131, and relevant references have been added. The revised and relevant parts are:

"After getting the acceptable runoff simulation results at the selected hydrological stations, the runoff to reservoirs and the interval runoff of each pair reservoirs are estimated according to the catchment area ratio of each reservoir with its upstream and downstream hydrological stations. The calculation formulas are as follows:

$$Q_{i,t}^{s}=\begin{cases}\dfrac{Q_{\mathrm{d},1,t}^{s}\times A_{1}}{A_{\mathrm{d},1}}, i=1\\ Q_{\mathrm{u},i,t}^{s}+\dfrac{\left(Q_{\mathrm{d},i,t}^{s}-Q_{\mathrm{u},i,t}^{s}\right)\times\left(A_{i}-A_{\mathrm{u},i}\right)}{\left(A_{\mathrm{d},i}-A_{i}\right)}, i>1\end{cases} \tag{4}$$

$$\Delta Q_{i,t}=Q^{s}{}_{i,t}-Q^{s}{}_{i-1,t}, i>1 \tag{5}$$

where $Q_{i,t}^{s}$ is the runoff to the ith reservoir at tth period, m^3/s; $Q_{\mathrm{u},i,t}^{s}$ and $Q_{\mathrm{d},i,t}^{s}$ are the simulation runoff results of the upstream and downstream hydrological stations of the ith reservoir at tth period, m^3/s; A_i is the catchment area of ith reservoir, m^2; $A_{\mathrm{u},i}$ and $A_{\mathrm{d},i}$ are the catchment areas of the upstream and downstream hydrological stations, m^2. $\Delta Q_{i,t}$ is the interval runoff of the ith reservoir at tth period, m^3/s.

The inflow to the ith reservoir is the sum of the discharge from the (i-1)th reservoir and the interval runoff. The calculation formulas are as follows:

$$Q_{i,t}=\begin{cases}Q^{s}{}_{1,t}, i=1\\ Q_{\mathrm{out},i-1,t}+\Delta Q_{i,t}, i>1\end{cases} \tag{6}$$

where $Q_{i,t}$ is the inflow to the ith reservoir at tth period, m^3/s; $Q_{\mathrm{out},i-1,t}$ is the water release from the (i-1) th reservoir in period t, m^3/s." (**On page 5-6 of the revised manuscript**)

Point #2

COMMENT: *Section 2.3 Was the FDC constructed using naturalised flows or the current/modified flows in this study? What are the implications?*

RESPONSE: We are very thankful for the reviewer's insightful comment and valuable reminder. In this manuscript, the FDC was constructed using the simulated runoffs from 1976-2020 by VIC model. The FDC was constructed in order to find the discharges at the different percent duration points for various river sections, water years (e.g., wet, normal, and dry years), and months, and these discharges are taken as multi-level ecological flow standards. The MTMMHC method, combined with the modified FDC, can solve four key problems existed in the current ecological flow standards: spatial transferability, monthly variability, inter-annual variability and scalability (Li, et al., 2015). This method has been widely applied in various river basins (Li and Kang, 2014), with multiple simulations conducted for ecological flow standards and classification in the HRB. The results of this manuscript align well with these studies in terms of EF trends, flow ranges, and grading number across different water years and months, thus providing support and validation for our results (Li and Kang, 2014; Zhang and Liu, 2023). To clarify this point, relevant statements and references have been added in the revised manuscript:

> "The year groups are divided into wet years (precipitation below the 25th percentile, P<25 %), normal years (25 %≤P≤75 %), and dry years(P>75 %) firstly. Then, a flow duration curve (FDC, Franchini et al., 2011) is constructed using the total-period method based on daily average flows simulated from 1976-2020 by VIC model. Finally, the average of flows corresponding to the 90th and 95th percentiles of the FDC ($Q_{(90)xy}$ and $Q_{(95)xy}$, m^3/s) for the *y*th month of the *x*th year is taken as the Minimum Ecological Flow (MEF_{xy}, m^3/s)." (**On page 6 of the revised manuscript**)

Relevant references:

Li, C., Kang, L., Zhang S., Zhou, L.W.: A Modified FDC Method with Multi-level Ecological Flow Criteria, J. Yangtze River Sci. Res. Inst., 32 (11): 1-6, 13, https://doi.org/10.11988 /ckyyb.20140814, 2015. (in Chinese)

Li, C., and Kang, L.: A New Modified Tennant Method with Spatial-Temporal Variability, Water Resour. Manag., 28(14), 4911-4926, https://doi.org/10.1007/s11269-014-0746-4, 2014.

Zhang, X., and Liu, D.: A Method to determine the threshold of water exploitation index based on ecological flow estimation., China Rural Water and Hydropower, 2023 (2): 88-100+107. https://doi.org/10.12396/znsd.221653, 2023. (in Chinese)

Point #3

COMMENT: *Section 2.3 / Table 4: The MTMMHC method effectively sets ecological flows retrospectively, but how can it be adapted for real-time dam operations? How can operational decisions account for the significant variation in MEF between wet and dry years, especially when such conditions are uncertain at the start of the year?*

RESPONSE: We greatly appreciate the reviewer's insightful comments and apologize for not clearly discussing the applicability of the MTMMHC method in real-time dam operations in the original manuscript. Ecological flow (EF) refers to the minimum flow required to sustain the health and function of aquatic ecosystems. There are over 200 methods for EF assessment (EFA) worldwide, typically categorized into four types: hydrological, hydraulic, habitat simulation, and holistic methods (Tharme, 2003). Traditionally, ecological flow is estimated using a percentage of the long-term average annual flow, without accounting for the effects of reservoir operations. The Tennant method, which determines EF based on predetermined percentages of average annual flow, is the most widely used hydrological method (Tharme, 2003). The MTMMHC method builds upon the Tennant method, modifying it based on three parameters: average periodic flow, water period, and percentage (Li and Kang, 2014). This modification helps mitigate the impacts of extreme inter-annual flow variations and uneven intra-annual distribution. In this study, a multi-level ecological flow standard is established through the MTMMHC method, which is determined by runoffs in various river sections, water years (e.g., wet, normal, and dry years), and months, and is independent of specific reservoir operations. All scenarios are modeled using the same ecological flow standard to clarify the differences in their environment conservation.

Accordingly, in the revised manuscript, we have added some content to express the applicability the MTMMHC method at the Methodology of the manuscript. The corresponding part is:

> "In order to establish a multi-level ecological flow standard to aid in evaluating river ecological health, the multi-level ecological flows are estimate by the MTMMHC method. There are over 200 methods for ecological flows (EFs) estimation worldwide, typically categorized into four types: hydrological, hydraulic, habitat simulation, and holistic methods (Tharme, 2003). The Tennant method, which determines EFs based on predetermined percentages of average annual flow, is the most widely used hydrological method (Tharme, 2003). The MTMMHC method (Li and Kang, 2014) modifies the Tennant method based on three parameters: average periodic flow, water period, and percentage. It can solve four key problems existed in the current ecological flow standards: spatial transferability, monthly variability, inter-annual variability and scalability (Li, et al., 2015). Indeed, the MTMMHC method can avoid the impacts of extreme inter-annual flow events and uneven intra-annual distribution. This enables the calculation of different guarantee rates for various river sections, water years (e.g., wet, normal, and dry years), and months. It reflects the temporal and spatial variability of EFs, and provides a comprehensive and reasonable multi-level ecological flows standards. The steps of the MTMMHC method are as follows." (**On page 6 of the revised manuscript**)

Relevant references:

Tharme, E.: A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Res. Appl. 19(5-6): 397–441, https://doi.org/10.1002/rra.736, 2003.

Li, C., and Kang, L.: A New Modified Tennant Method with Spatial-Temporal Variability, Water Resour. Manag., 28(14), 4911-4926, https://doi.org/10.1007/s11269-014-0746-4, 2014.

<u>Point #4</u>

COMMENT: *Figures (from figure 7): The caption for the figures should be more informative. For Figures 7 and 8, for instance, it should state the scenarios, with or without IWDP respectively, the priorities and what each LRR represents (S, H or E). Also, it would be good for Figure 8 to be immediate below 7 so readers can easily compare the effect if IWDPs.*

RESPONSE: The authors are very thankful for the reviewer's insightful comments and helpful suggestions. We have added this information to the caption of Figures: state the scenarios, with or without IWDP respectively, the priorities, and what each *LRR* represents (S, H, or E), and we have listed Figures 7 and 8 together. The revised parts are:

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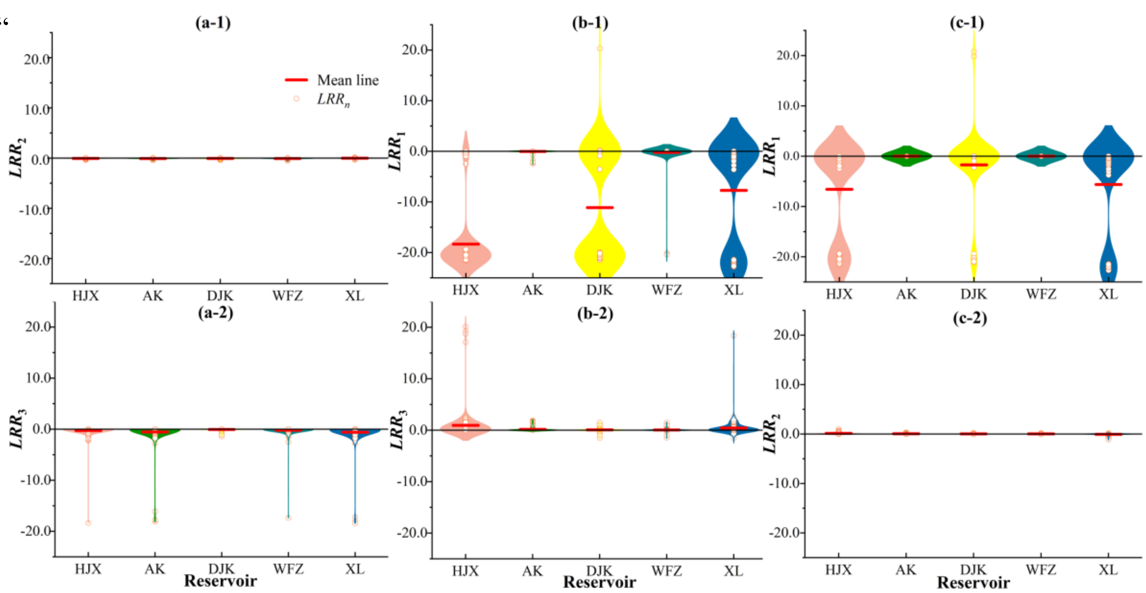

Figure 7. the differences of indexes (i.e., *LRR*$_1$, *LRR*$_2$, *LRR*$_3$ for log response ratio of the S, H, and E component) without IWDPs (i.e., between S_{0-p-n} and S_{0-4-n}) at the monthly scale: (a-1) is *LRR*$_2$ with the highest priority in S (i.e., between S_{0-1-2} and S_{0-4-2}), (a-2) is *LRR*$_3$ with the highest priority in S (i.e., between S_{0-1-3} and S_{0-4-3}), (b-1) is *LRR*$_1$ with the highest priority in H (i.e., between S_{0-2-1} and S_{0-4-1}), (b-2) is *LRR*$_3$ with the highest priority in H (i.e., between S_{0-2-3} and S_{0-4-3}), (c-1) is *LRR*$_1$ with

the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

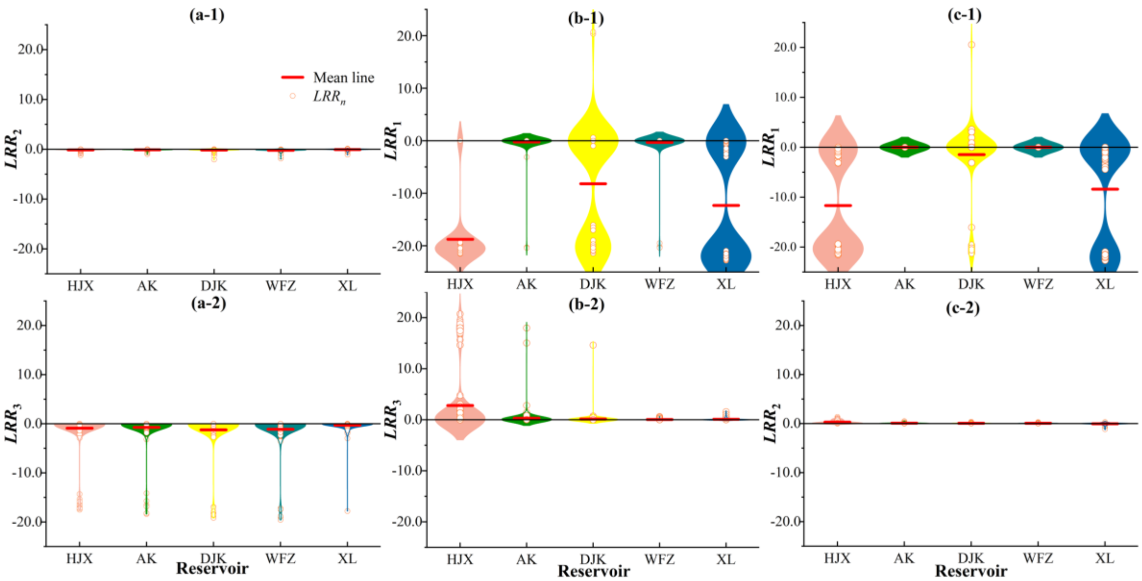

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}2}$ and $S_{3\text{-}4\text{-}2}$).

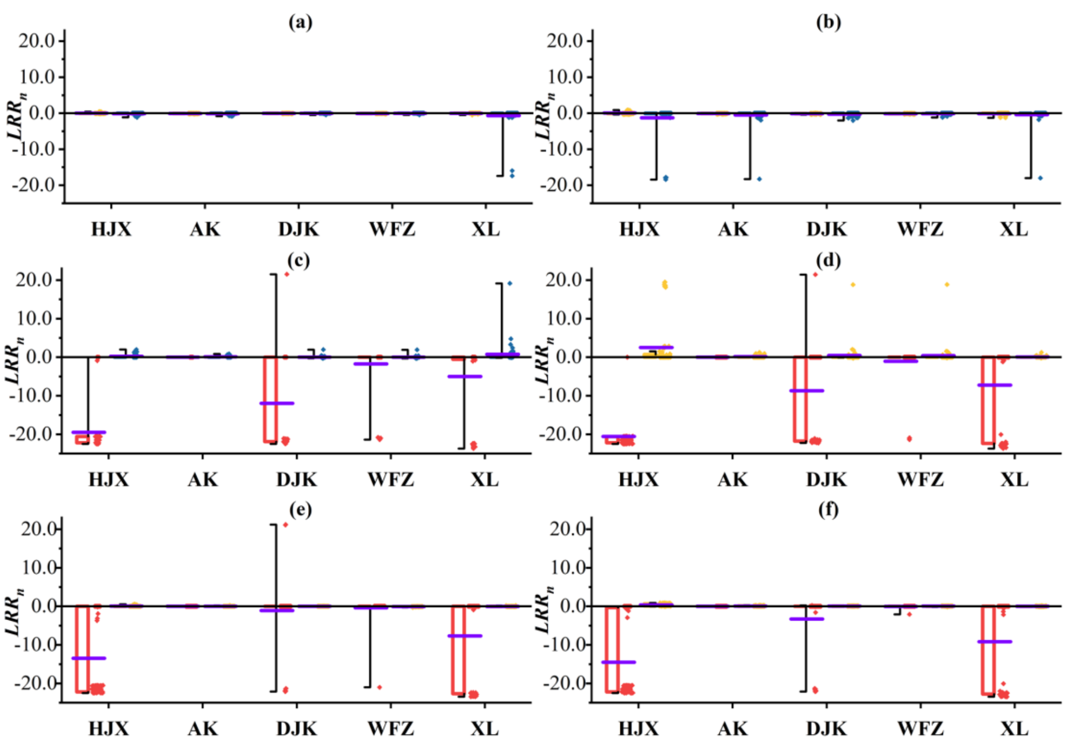

Figure 9. LRR_n with different highest priorities (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{m\text{-}4\text{-}n}$) at the seasonal scale: (a) and (b) are LRR_n with the highest priority in S without IWDPs (i.e., between $S_{0\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{3\text{-}4\text{-}n}$),

(c) and (d) are ***LRR**$_n$* with the highest priority in H without IWDPs (i.e., between S_{0-2-n} and S_{0-4-n}) and with IWDPs (i.e., between S_{3-2-c} and S_{3-4-n}). (e) and (f) are ***LRR**$_n$* with the highest priority in E without IWDPs (i.e., between S_{0-3-n} and S_{0-4-n}) and with IWDPs (i.e., between S_{3-3-n} and S_{3-4-n}).

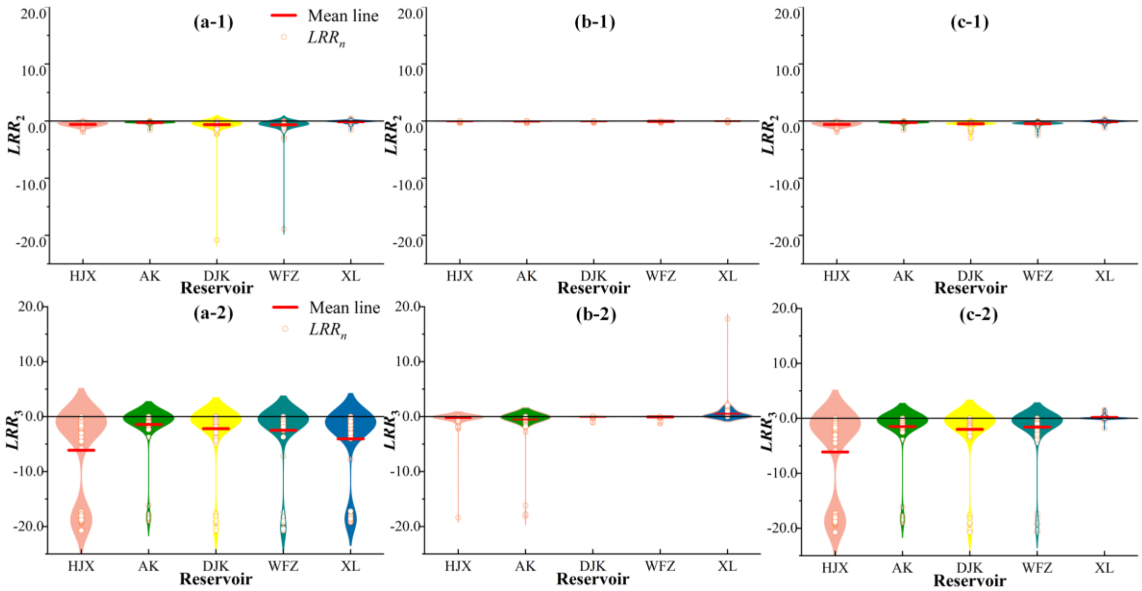

Figure 10. ***LRR**$_n$* **values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water donation (i.e., between S_{1-1-n} and S_{0-4-n}), (b-1) and (b-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water receiving (i.e., between S_{2-1-n} and S_{0-4-n}), (c-1) and (c-2) are *LRR*$_2$ and *LRR*$_3$ when there are both donation and receiving (i.e., between S_{3-1-n} and S_{0-4-n}).**

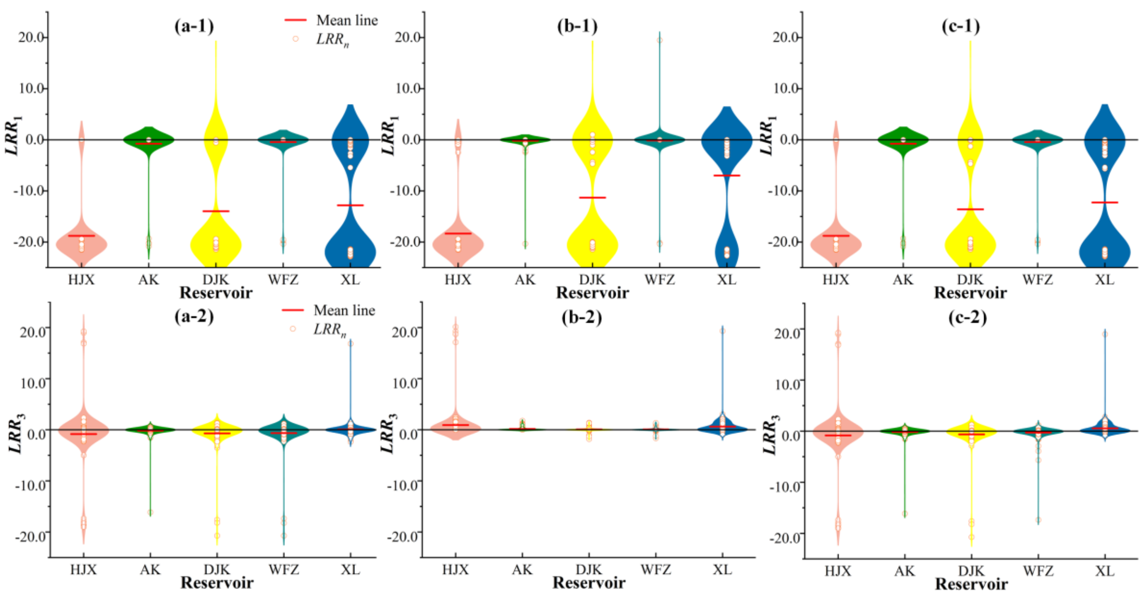

Figure 11. ***LRR**$_n$* **values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water donation (i.e., between S_{1-2-n} and S_{0-4-n}), (b-1) and (b-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water receiving (i.e., between S_{2-2-n} and S_{0-4-n}), (c-1) and (c-2) are *LRR*$_2$ and *LRR*$_3$ when there are both donation and receiving(i.e., between S_{3-2-n} and S_{0-4-n}).**

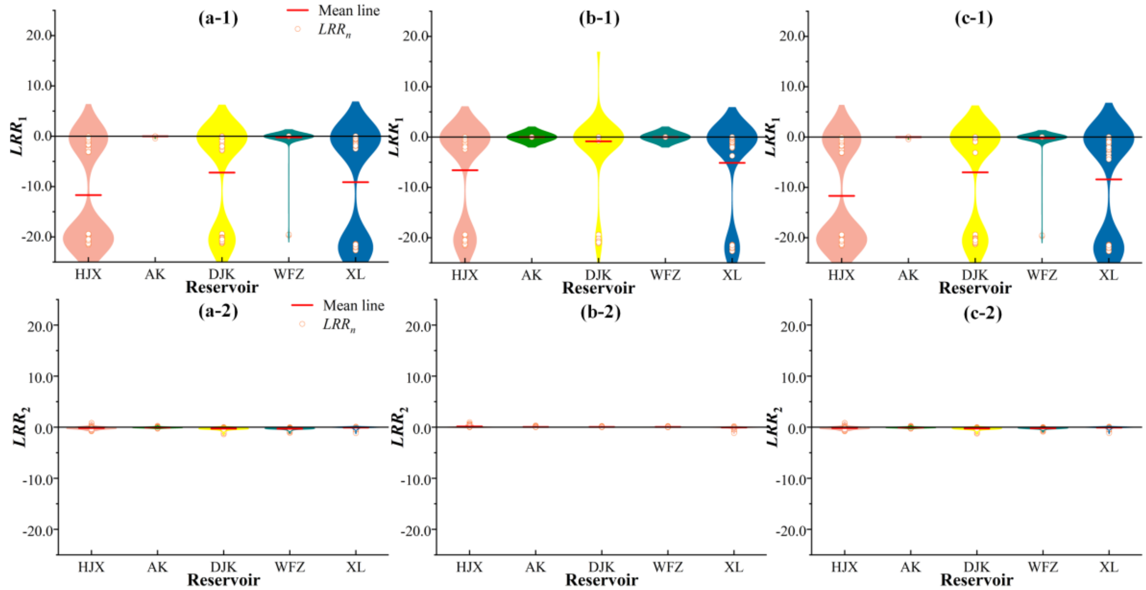

Figure 12. ***LRR*$_n$ values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_1$ and *LRR*$_2$ when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR*$_1$ and *LRR*$_2$ when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR*$_1$ and *LRR*$_2$ when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

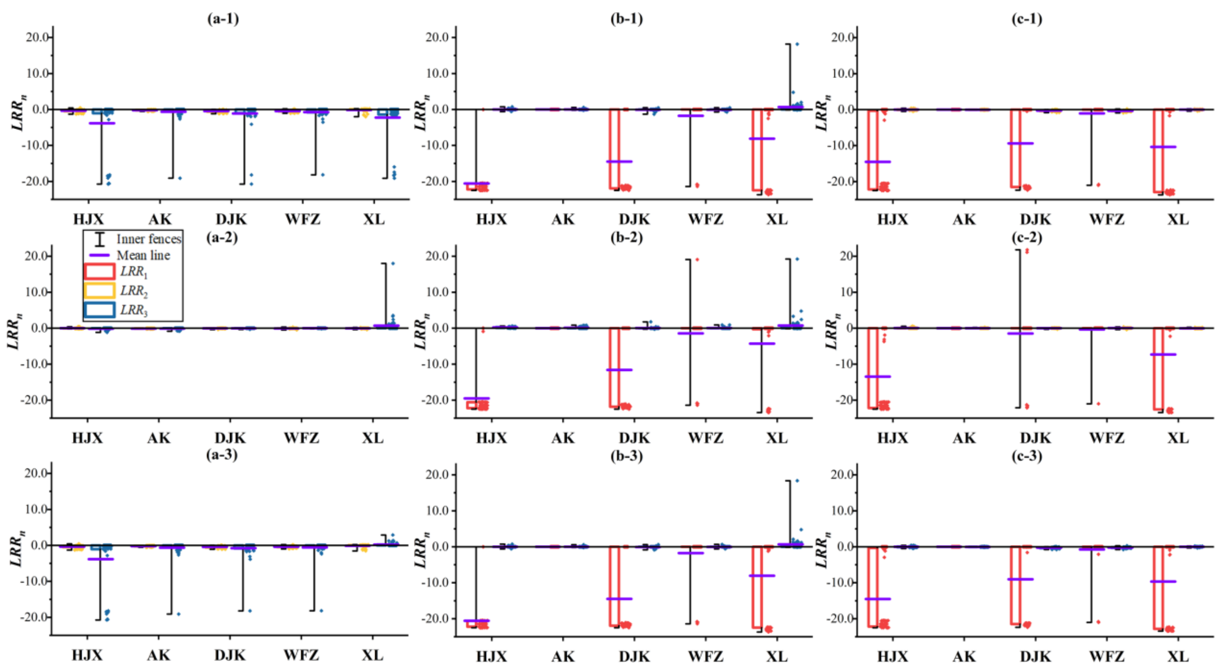

Figure 13. ***LRR*$_n$ values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are *LRR*$_n$ when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

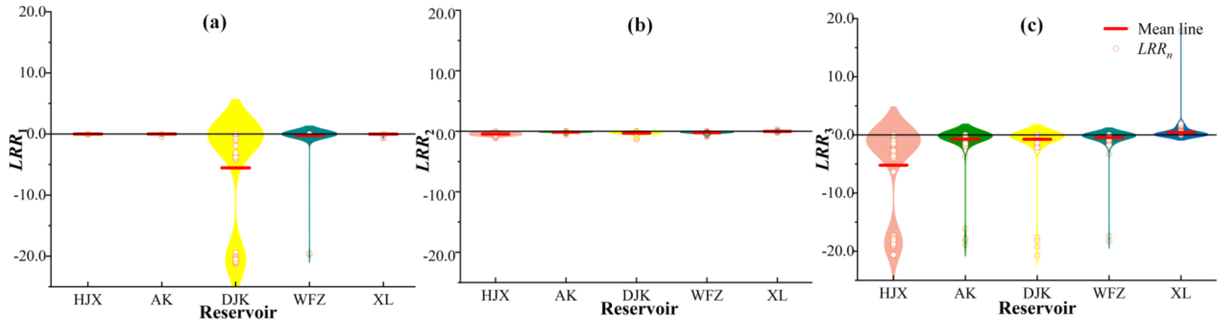

Figure 14. the differences of indexes (i.e., (a) *LRR*$_1$, (b) *LRR*$_2$, (c) *LRR*$_3$ for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale."

<u>Point #5</u>

COMMENT: *Line 454- 464: What metrics were used to quantify runoff variations across time scales? Was the link between runoff and feedback loops validated?*

RESPONSE: We greatly appreciate the reviewer's insightful comments and their thorough thinking and guidance on this study. We apologize for not providing a more in-depth discussion and explanation of this issue in the manuscript, which led to your confusion. To verify the results, wavelet transform analysis of runoff for HJX, AK, DJK, WFZ, and XL dam sites, as shown in Fig. 1. It can be found that the runoff in all reservoirs exhibits strong periodicity at a time scale of 4-8 months during 2006-2017, while downstream reservoirs (i.e., DJK, WFZ, and XL) show strong periodicity at 1-3 months during 2018-2020. Overall, the runoff exhibits stronger periodicity at the 3-month scale, which provides strong evidence that the seasonal results can help analyze the variations in periodic feedback loops. The link between runoff and feedback loops is determined by comparing the values of LRR_n with the runoff at different spatiotemporal scales. We found that the trends in LRR_n and runoff show similar patterns in their spatiotemporal evolution, and the mathematical implications of LRR_1, LRR_2, and LRR_3 (e.g., differences in water supply, hydropower generation, and ecological flow satisfaction rates under different scenarios) suggest that runoffs are the key factors determining the LRR_n values. To make it easier to understand, we give an example here: Fig. 2 illustrates LRR_1 (i.e., the log response ratio of the S component) between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$, LRR_2 (i.e., the log response ratio of the H component) between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$, LRR_3 (i.e., the log response ratio of the E component) between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$ and runoff for HJX dam sites. We also conducted a Granger causality test between LRR_n

and runoffs and found significant causal links. However, since this part is not the focus of this study, in the revised version, we have enriched the presentation, but no longer present the results of wavelet transform analysis of runoff and the Granger causality test between LRR_n and runoffs.

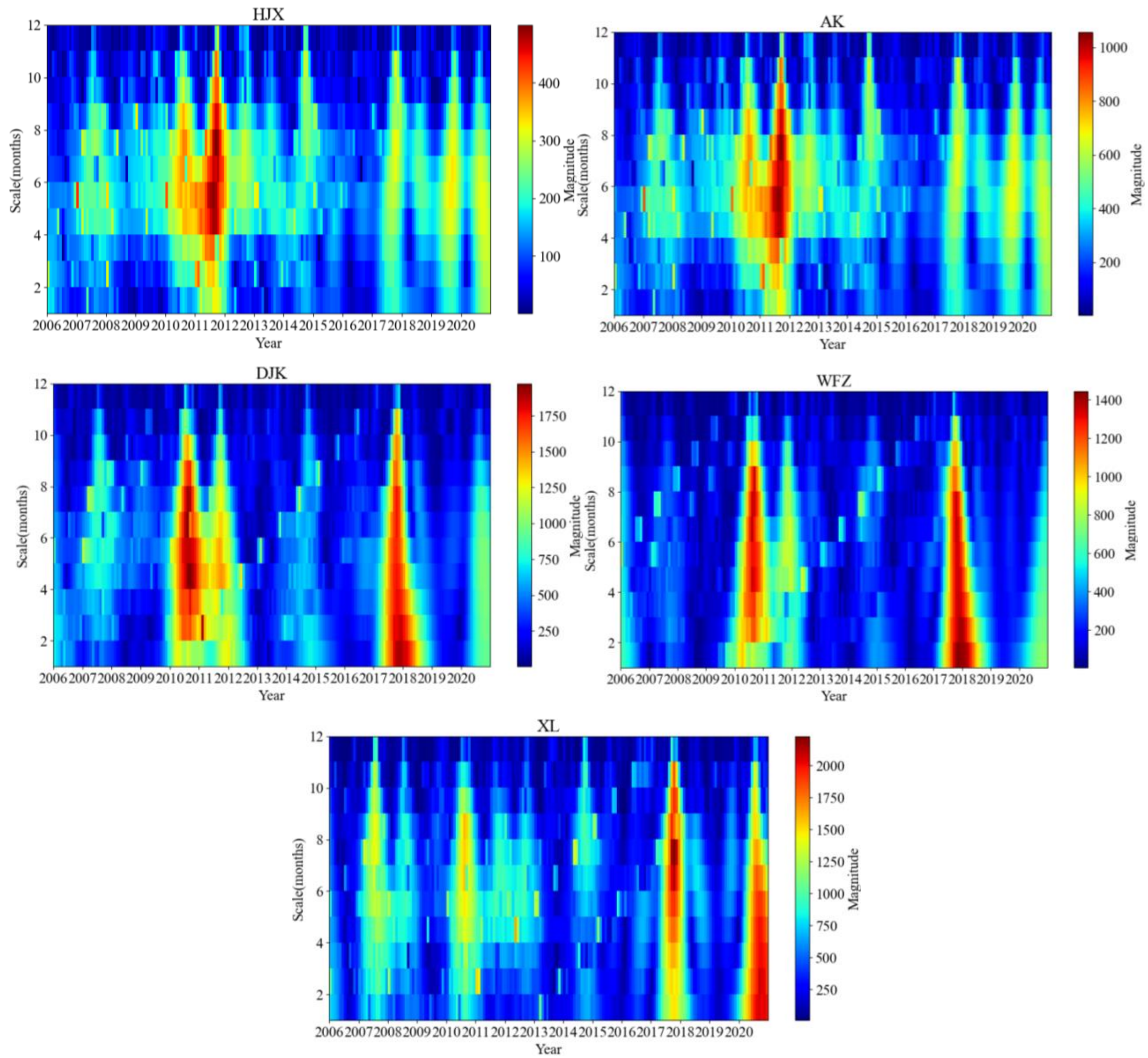

Fig.1. Wavelet transform analysis of runoff for HJX, AK, DJK, WFZ, and XL dam sites.

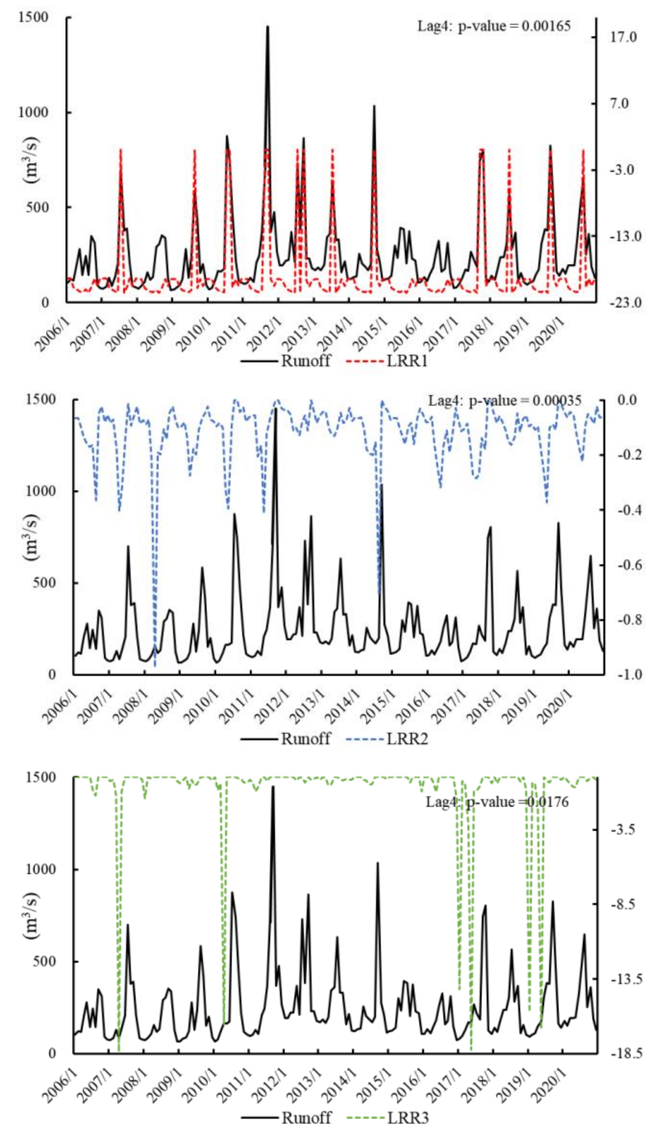

Fig. 2. LRR_1 (i.e., the log response ratio of the S component) between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$, LRR_2 (i.e., the log response ratio of the H component) between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$, LRR_3 (i.e., the log response ratio of the E component) between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$ and runoffs for HJX dam site.

The corresponding part is:

"The consistency in the signs of mean LRR_n values across seasonal as shown in Figure 9 and 13 and annual scales as shown in Supplementary material Table S1-S5 with those at the monthly scale indicates an inherent similarity and stability in SHE nexus feedback loops over different temporal resolutions. Compared with the values of LRR_n at monthly scale, the values at the seasonal scale show its stronger periodic variations. Based on the variations in LRR_n and the mathematical implications of LRR_1, LRR_2, and LRR_3, this study found that these periodic variations align closely with the runoff variations, and the temporal and spatial variations in feedback loops are primarily attributed to variations in runoff. The wavelet transform analysis has also been applied in the runoffs for HJX, AK, DJK, WFZ, and XL dam sites. And the results are in consisted with that in Hutuo

River Basin (Xu et al., 2018), the periodic variations have been found at the seasonal scale. The *LRR*$_n$ values at the seasonal scale can help analyze the variations in periodic feedback loops. Different from the monthly or seasonal scales, results at the annual scale reveal the long-term trends and periodic variations in the inter-annual and spatial trends of the SHE nexus from a macro perspective. The impacts of reservoir operation and the regulation on SHE nexus can be clearly simulated and observed at the monthly scale, so the immediate changes in the nexus at monthly scale can provide information for short-term decision-making in reservoirs." (**On page 23-24 of the revised manuscript**)

Point #6

COMMENT: *Results and Discussion: Very little discussion or reference to other studies. For instance, no comparison to real world observations from the HRB; have any of the scenarios occurred in reality? And if so, were the feedback loops in line with the findings? Also, the impacts of IWDPs on feedback loops are reported, but how do these findings translate into actionable management strategies? Are there optimal thresholds for water donation and receiving that maximize system-wide stability of the SHE nexus? How can this framework guide policy or reservoir operation strategies in basins like HRB? Are there specific recommendations for balancing S, H and E, especially in low flow months, where competition between water supply, hydropower, and environmental needs intensifies?*

RESPONSE: We much appreciate the reviewer's insightful comments and apologetic for the lack of discussion or reference with other studies in the original manuscript. In the revised manuscript, we have added more discussions based on real world observations from the HRB and relevant studies. In addition, for the Han-to-Wei Water Diversion Project (Wei et al., 2020), the Middle Route of the South-to-North Water Diversion Project (Li et al., 2016), the Northern Hubei Water Resources Allocation Project (He and X, 2020), and the Changjiang-to-Han River Water Diversion Project (Zhang et al., 2022) discussed in Sections 4.3 and 4.4, the actual (trial) water diversion times are as follows: 2023, 2014, 2021, and 2014, respectively. The Three Gorges Reservoir to Hanjiang River (Yang et al., 2012) is still under construction and has not yet been diverted, so long-term research based on real-world conditions cannot be conducted. Therefore, this manuscript constructs a Multisource Input-Output Reservoir Generalization (MIORG) model based on the operational conditions of IWDPs, reservoir parameters, and scheduling rules, with long-term scale runoff inputs, to address the different impacts of IWDPs on the dynamic SHE nexus with multiple scenarios. Thus, in the Results and Discussion section, we have added discussions between the relevant studies in HRB and our results.

Based on the results from this manuscript, we have found that water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E. While water receiving has positive impacts on these feedbacks. Additionally, upstream IWDPs have a significant influence on the downstream SHE nexus. In our future research, a model will be developed to simulate SHE nexus system, and the optimal thresholds for water donation, water receiving and water resource utilization will be determined through optimal algorithms and deep learning models.

Regarding the results in this study, we can provide some recommendations: water donation or regional water supply can be increasing in abundant water periods in order to reduce spilled water and increase hydropower generation efficiency. In dry periods, it is necessary to consider the priority order of the water supply, hydropower generation, environment conservation, determine water utilization threshold for each component to maximize the benefits. We have added several water management recommendations to the conclusion.

We have made extensive revisions in the manuscript:

“4 Results

4.1 Calibration and verification of VIC model

The HRB was discretized into 2103 grids of 5-arc minutes. Inputting meteorological forcing, soil parameter, and vegetation parameter data for each grid, runoffs were simulated. Model warm-up was spanned 1972-1975, while its calibration was conducted from 1976 to 2005, and the validation was from 2006 to 2013. And runoff from 2014 to 2020 was extension simulated for its post-validation. All the results are shown in Figure 6. It can be found that the accuracies of the simulations at all hydrological stations are acceptable, and the superior performances were found in upstream. For instance, *NSE* for calibration and validation were 0.896 and 0.774, with corresponding R^2 of 0.908 and 0.866 at BH. Due to the intense human activity impacts in mid–lower reaches of the HRB, the poorer performance were found at HJG while their *NSE* values still exceed 0.600. *PBIAS* for all these six stations during calibration and validation periods ranged within [-5 %，11 %], which also indicates satisfactory agreement.

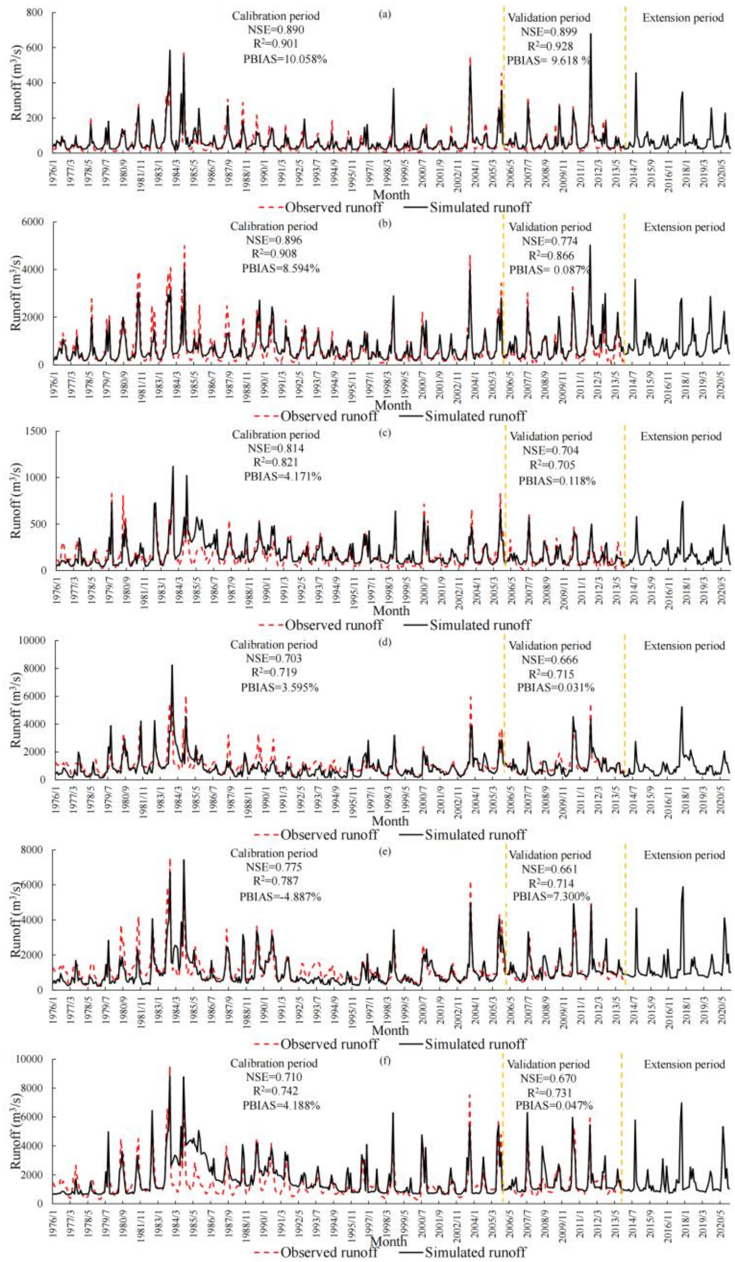

Figure 6. Calibration and validation results of simulation at hydrological stations: (a)Xiangjiangping, (b) Baihe, (c) Huanglongtan, (d) Huangjiagang, (e) Xiangyang, (f) Huangzhuang.

4.2 Multi-level ecological flows classification and calculation results

The multi-level ecological flows at HJX, AK, DJK, WFZ, and XL reservoir dam sites for each month were determined through the MTMMHC method. Their EFs are categorized into four levels: *MEF*, EF_2, OEF_{min} and OEF_{max}. The results at XL reservoir dam site from the MTMMHC method are presented in Table 4. Their Efs for wet, normal, and dry years show the decreasing trends, with higher values during the flood season. Its peak ecological flow occurs in August during wet years while in July during both normal and dry years. All the peak EFs for the other four sites occur between July and September. The peak EF for HJX and AK reservoir dam sites during wet, normal, and dry years occur between July and August. The peak values for DJK and WFZ are dispersed, and theyare found in September, August, and July. The EFs at the five reservoir dam sites from June to September are significantly higher than their in other months. These EFs for wet, normal, and dry years are similar to the related ecological flow quantification results in HRB (Zhang, et al., 2022, Li and Kang, 2014).

Table 4. Multi-level ecological flows resulted from MTMMHC method.

Site	Month	Hydrological years											
		Wet year				Normal year				Dry year			
		MEF (m^3/s)	EF_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)	*MEF* (m^3/s)	EF_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)	*MEF* (m^3/s)	EF_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)
XL dam site	Jan	1197	1476	1550	1668	825	849	872	910	664	666	668	670
	Feb	1265	1467	1539	1656	836	863	890	933	675	678	681	686
	Mar	1268	1486	1569	1702	842	869	896	938	685	690	696	705
	Apr	1249	1329	1426	1581	868	892	916	955	691	698	704	714
	May	1273	1675	1822	2058	861	887	912	953	705	714	723	738
	Jun	1653	1681	1877	2192	877	916	955	1017	763	786	809	846
	Jul	1818	2629	2987	3560	1288	1430	1572	1799	875	921	968	1043
	Aug	1885	2522	2849	3372	1266	1401	1537	1753	811	845	879	933
	Sep	1465	2822	3225	3869	1174	1279	1384	1553	834	879	924	997
	Oct	1368	2276	2611	3148	978	1036	1094	1186	733	752	772	802
	Nov	1315	1586	1748	2007	897	932	966	1022	691	697	704	714
	Dec	1194	1471	1549	1675	845	873	900	944	680	686	691	700

4.3 Responses of indexes in feedback loops with different clusters of IWDPs in a reservoirs group

4.3.1 Responses of indexes in feedback loops without and with IWDPs

To analyse the feedback loops of SHE nexus without (i.e., $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) across the multiple temporal (i.e., monthly, seasonal and annual) and spatial (i.e., five reservoirs) scales, the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ or between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ are determined at the time scales in a reservoirs group. Monthly differences are presented in Figures 7 and 8, while the seasonal results are shown in Figure 9. Corresponding annual-scale results can be found in Supplementary material Tables S1 and S2.

If there was no IWDPs and S-Priority was set, both the mean values of LRR_2 (i.e., -0.06, -0.09, -0.07, -0.10, and -0.02) and the mean values of LRR_3 (i.e., -0.27, -0.54, -0.07, -0.20, and -0.61) in five reservoirs remain below 0 as shown in Figure 7 (a). As there are a large number of negative values of LRR_2 in all reservoirs with S-Priority as shown in Figure 7 (a-1), the hydropower generation is found to be reduced in most months. However, there are still some positive values of LRR_2 in reservoirs. XL reservoir shows a higher occurrence of positive values of LRR_2 when there is abundant water such as July in 2007 and September in 2017 (i.e., 0.15 and 0.12, respectively). As shown in Figure 7 (a-2), all the five reservoirs exhibit a negative LRR_3 in all months. The value of

LRR_3 for the DJK reservoir is closest to 0. The smallest mean values of LRR_3 for the XL and AK reservoirs are -0.61 and -0.54, respectively. The reduction of ecological flow satisfaction rates for DJK is smaller than those for other reservoirs due to its effective regulating. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. There are also differences between the results of LRR_2 and LRR_3, the range of LRR_3 value is wider, while its of LRR_2 are relatively concentrated and closer to 0.

If there was no IWDPs and H-Priority was set, the values of LRR_1 for all five reservoirs are less than zero in most months, and the mean values of LRR_3 exceed zero as shown in Figure 7 (b). The water supply for HJX, DJK, and XL is significantly decreased, with their mean values of LRR_1 are -18.35, -11.55, and -7.72, while the water supply for AK and WFZ has slight reductions (i.e., the mean values of LRR_1 are -0.17 and -0.23, respectively) as shown in Figure 7 (b-1). There are two positive values of LRR_1 for DJK reservoir occurring in January 2010 and in July 2011 (i.e., 20.32 and 0.19, respectively). In January 2010, higher water storage resulting from H-Priority increases water availability. With H-Priority, reservoirs with regulating capacity will store more water, leading to increased generation flow during dry periods (Zhang et al., 2014). While in July 2011, an increase in the discharge flow from the upstream reservoir increase the water supply. As shown in Figure 7 (b-2), the values of ecological flow satisfaction rates for HJX reservoir experiences a significant increase, with a mean value of LRR_3 of 0.92, followed by XL and AK (i.e., their mean values of LRR_3 are 0.40 and 0.14). DJK and its downstream reservoirs have negative values of LRR_3 in abundant water months because of the increased storage capacity and the reduced inflow into DJK. The water resource allocation of DJK affects the SHE system of downstream reservoirs. There are also differences between the results of LRR_1 and LRR_3, the values of LRR_3 are relatively closer to 0 than those of LRR_1. The feedbacks on S are more pronounced than on E. The extreme values of LRR_1 and LRR_3 are always found in months with small water flow in river but with high-water supply demand.

If there was no IWDP and E-Priority was set, the mean values of LRR_1 for HJX, DJK, and XL reservoirs are -6.59, -1.74, and -5.64 as shown in Figure 7 (c-1). However, the values of LRR_1 for AK and WFZ are almost zero because their increased discharge water from upstream are prioritized to be released for hydropower generation, and no excess is for water supply. Thus, the prioritizing E has less impact on S for reservoirs due to the main function of hydropower generation. DJK and XL exhibit some positive values of LRR_1 because the increased inflows from upstream. Therefore, the increased inflow to upstream reservoirs alleviates the negative feedbacks of E on S in downstream reservoirs. As shown in Figure 7 (c-2), the mean values of LRR_2 for HJX, AK, DJK, and WFZ reservoirs are 0.13, 0.05, 0.02, and 0.04. While XL has a negative mean value of LRR_2 at -0.06, it experiences more decreases in hydropower generation primarily due to its smaller installed capacity (Zhang, 2008). Negative values of LRR_2 can be found in abundant water months. The ranges of LRR_1 and LRR_2 are also different. The former one is wide while the other one is narrow and their values are closer to zero.

The differences between the $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios were determined to analyse the feedback loops with IWDPs as shown in Figure 8 (a), (b), and (c). It can be found that the positive or negative signs of the LRR_n values with IWDPs are consistent with those without IWDPs. If there are IWDPs and S-Priority was set, the mean value of LRR_3 for XL shows an increase while all the values of LRR_2 and LRR_3 for other four reservoirs are lower than those without IWDPs as shown in Figure 8 (a) and Figure 7 (a). The mean values of LRR_2 with IWDPs for the five reservoirs are -0.13, -0.11, -0.17, -0.21, and -0.07, and the mean values of LRR_3 are -0.91, -0.75, -1.25, -1.13, and -0.29. And DJK reservoir get more extreme values due to the impacts of IWDPs. The values of LRR_2 with IWDPs are lower than -0.45 (i.e., the minimum value of LRR_2 without IWDPs) in 6 % of the months while the values of LRR_3 are lower than -1.40 (i.e., the minimum value of LRR_3 without IWDPs) in 8 % of the months. It is evident that IWDPs strengthens the negative feedbacks of the S component on the other two components in HJX, AK, DJK and WFZ, while IWDPs weaken negative feedbacks of S on E for XL. As shown in Figure 8 (b-1), If there were IWDPs and H-Priority was set, the mean values of LRR_1 for HJX, AK, and XL reservoirs significantly decrease to -18.78, -0.78, and -12.24, but the mean value of LRR_1 for DJK reservoir are increased by 3.49 due to IWDPs. The differences of water supply between the $S_{3\text{-}2\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios remain negligible despite further reductions in water supply with H-Priority. As shown in Figure 8 (b-2), The values of LRR_3 for HJX, AK, DJK, and WFZ increase further than them in Figure 7 (b-2) without IWDPs. The values of LRR_3 for XL decrease slightly due to the positive feedbacks of the H component on E and the IWDPs impacts. As shown in Figure 8 (c-1), If there were IWDPs and E-Priority was set, the mean values of LRR_1 for HJX and XL decrease by 5.11 and 2.77, respectively. And the mean values of LRR_1 for AK and WFZ remain at almost zero, while the mean value of LRR_1 for DJK increases by 0.26 with IWDPs compared to without IWDPs. As shown in Figure 8 (c-2), the mean values of LRR_2 for five reservoirs increase by 0.18, 0.04, 0.03, 0.02 and 0.01 with IWDPs compared to without IWDPs. The positive feedbacks of E component on H are strengthened, while the negative feedbacks are weakened.

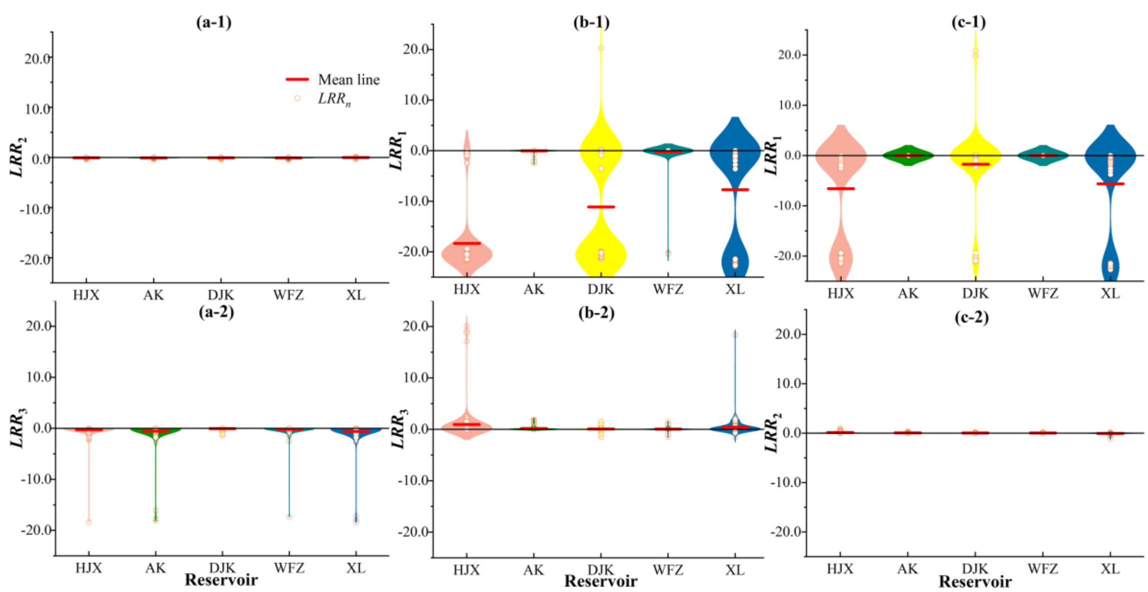

Figure 7. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) without IWDPs (i.e., between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}2}$ and $S_{0\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in

H (i.e., between $S_{0\text{-}2\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

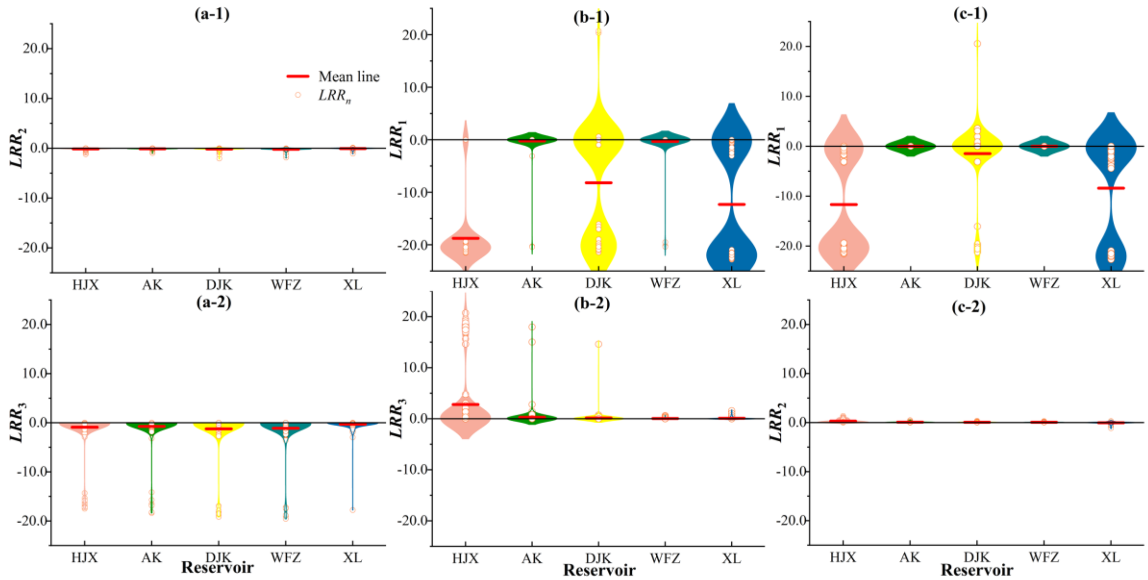

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}2}$ and $S_{3\text{-}4\text{-}2}$).

In this study, March, April, May are taken as spring, June, July and August are taken as summer, September, October and November are taken as autumn, and December, January and February of the following year are taken as winter. The values of LRR_n for five reservoirs at seasonal scale are shown in Figure 9. If there was no IWDP but S-Priority was still set, positive values of LRR_2 for HJX and XL are found in summer, while all negative values of LRR_2 for other three reservoirs are found in all seasons as shown in Figure 9 (a). The mean values of LRR_3 for the five reservoirs are -0.12, -0.11, -0.02, -0.02, and -0.67, and all values of LRR_3 are negative in all seasons. If there were IWDPs and S-Priority was set, the mean value of LRR_3 for XL increases while the values of LRR_2 and LRR_3 for other four reservoirs are less than those without IWDPs as shown in Figure 9 (b). These negative values indicate that IWDPs significantly strengthen the negative feedbacks of the S component on H and E in reservoirs and weaken negative feedback of S on E in XL. If there was no IWDPs but H-Priority was set, negative values of LRR_1 and positive values of LRR_3 are found for the five reservoirs as shown in Figure 9 (c). For HJX, DJK and XL reservoirs, the negative values of LRR_1 are found in winter while zero values of LRR_1 are found in summer. The mean values of LRR_1 are close to zero in AK and WFZ reservoirs in all seasons. Positive values of LRR_3 are smaller in HJX, AK, DJK and WFZ reservoirs, while those in XL are greater in winter with a low flow. If there were IWDPs and H-Priority was set, the values of LRR_1 for all reservoirs are lower than those without IWDPs as shown in Figure 9 (d). Values of LRR_3 for HJX, AK, DJK and WFZ reservoirs are greater than those without IWDPs, while those for XL are close to zero. If there was no IWDPs and E-Priority was set, negative values of LRR_1 for HJX, DJK, WFZ and XL reservoirs can be found in almost every season, while zero values of LRR_1 for AK reservoir can be found in all seasons. As shown in Figure 9 (e), two positive values of LRR_1 for DJK are found in spring and in winter of 2007 due to the increased discharge water from AK reservoir. The positive values of LRR_2 for the five reservoirs are found in most seasons, but few negative values are found in summer. If there were IWDPs and E-Priority was set, more positive values of LRR_2 for five reservoirs and less negative values of LRR_1 are found in HJX, DJK, WFZ and XL reservoirs.

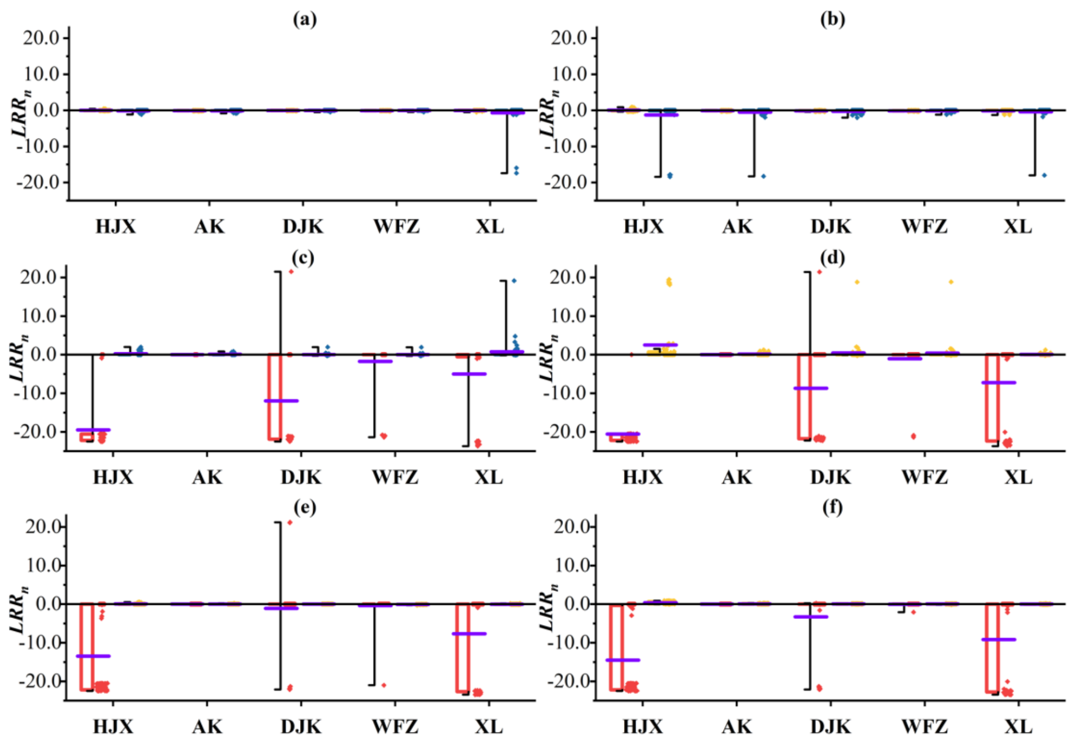

Figure 9. LRR_n with different highest priorities (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{m\text{-}4\text{-}n}$) at the seasonal scale: (a) and (b) are LRR_n with the highest priority in S without IWDPs (i.e., between $S_{0\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{3\text{-}4\text{-}n}$), (c) and (d) are LRR_n with the highest priority in H without IWDPs (i.e., between $S_{0\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}2\text{-}c}$ and $S_{3\text{-}4\text{-}n}$). (e) and (f) are LRR_n with the highest priority in E without IWDPs (i.e., between $S_{0\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{3\text{-}4\text{-}n}$).

4.3.2 Responses of indexes in feedback loops with only water donation, water receiving, and both donation and receiving

To analyse the impacts of only water donation (i.e., $S_{1\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), only water receiving (i.e., $S_{2\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), and both donation and receiving (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) on feedback loops of SHE nexus across the multiple temporal and spatial scales, the differences of indexes between $S_{m\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ are determined in a reservoirs group. The results of the monthly differences are shown in Figure 10-12. The seasonal results are shown in Figure 13. Corresponding annual-scale results can be found in Supplementary material Tables S3 -S5.

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 for five reservoirs are negative and lower than those without IWDPs as shown in Figure 10 (a-1) and (a-2). More small negative values are found in DJK, water donation has negative impacts on the negative feedback of S on H and E for five reservoirs. If there was only water receiving and S-Priority was set, values of LRR_2 and LRR_3 for HJX and AK are the same as those without IWDPs. Meanwhile, for DJK, WFZ, and XL, the values are close to zero. XL exhibits a lot of positive values of LRR_3 as shown in Figure 10 (b-1) and (b-2). If there were both water donation and receiving, the mean values of LRR_2 for five reservoirs are -0.59, -0.26, -0.48, -0.47 and -0.09, and mean values of LRR_3 for five reservoirs are -6.12, -1.50, -2.01, -1.60 and 0.14 as shown in Figure 10 (c-1) and (c-2). There are negative impacts on negative feedbacks of S on H and E for HJX, AK, DJK and WFZ and positive impacts of the negative feedbacks of S on E for XL.

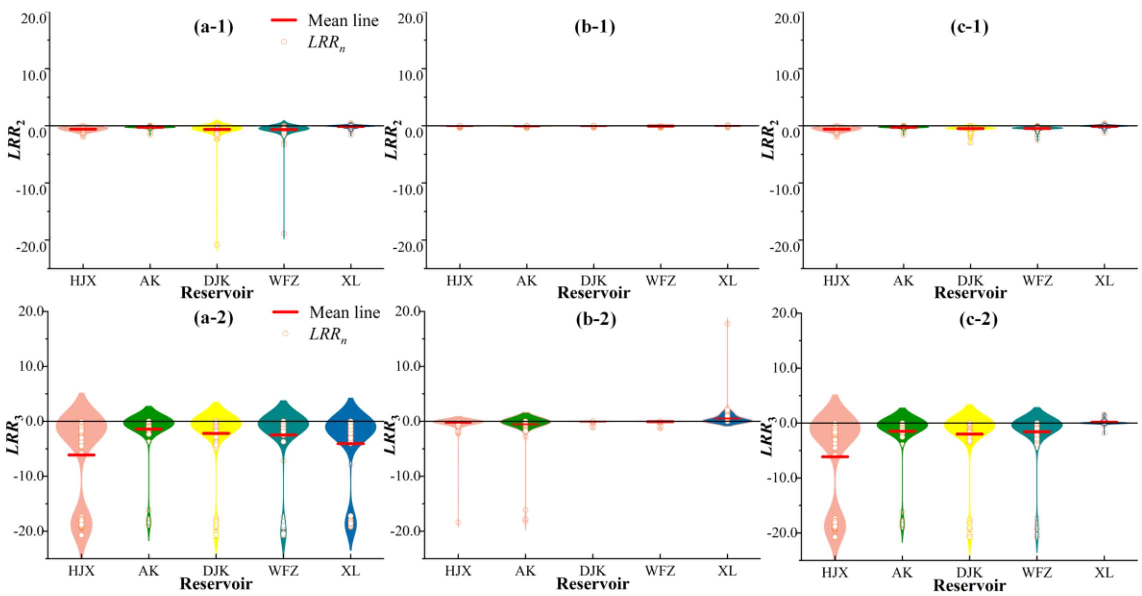

Figure 10. LRR_n values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are LRR_2 and LRR_3 when there is only water donation (i.e., between $S_{1\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are LRR_2 and LRR_3 when there is only water receiving (i.e., between $S_{2\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are LRR_2 and LRR_3 when there are both donation and receiving (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 for five reservoirs are lower than those without IWDPs as shown in Figure 11 (a-1) and (a-2). Negative values of LRR_3 for five reservoirs are found in low flow months such as November, December and January. Thus, water donation is found to have negative impacts on feedbacks of H on S and E, especially in low flow months. If there was only water receiving and H-Priority was set, values of LRR_1 and LRR_3 for DJK, WFZ and XL are greater than those without IWDPs as shown in Figure 11 (b-1) and (b-2). Water receiving has positive impacts on feedbacks of H on S and E. If there were both water donation and receiving and H-Priority was set, the mean values of LRR_1 and LRR_3 for DJK, WFZ and XL are still lower than those without IWDPs. And the mean value of LRR_3 for XL is greater than those without IWDPs as shown in Figure 11 (c-1) and (c-2).

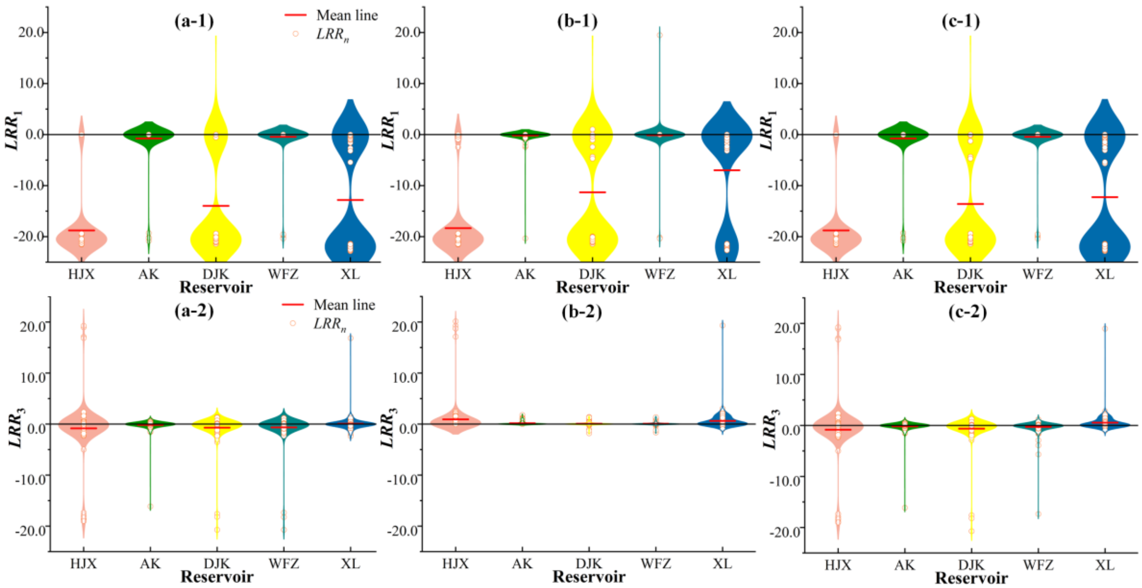

Figure 11. ***LRR**$_n$* **values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are** ***LRR**$_2$* **and** ***LRR**$_3$* **when there is only water donation (i.e., between S$_{1\text{-}2\text{-}n}$ and S$_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are** ***LRR**$_2$* **and** ***LRR**$_3$* **when there is only water receiving (i.e., between S$_{2\text{-}2\text{-}n}$ and S$_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are** ***LRR**$_2$* **and** ***LRR**$_3$* **when there are both donation and receiving(i.e., between S$_{3\text{-}2\text{-}n}$ and S$_{0\text{-}4\text{-}n}$).**

If there was only water donation and E-Priority was set, then values of LRR_1 and LRR_2 for five reservoirs are shown in Figure 12 (a-1) and (a-2). The mean values of LRR_1 for these five reservoirs are -11.70, 0, -7.23, -0.22, and -9.14, respectively. And the mean values of LRR_2 are -0.16, -0.07, -0.29, -0.30, and -0.08. All these values are lower than the those without IWDPs. Different from the values of LRR_n without IWDPs, there are no positive values of LRR_1 for DJK and few positive values of LRR_2 for five reservoirs due to the decreased inflows from upstream with water donation. If there was only water receiving and E-Priority was set, values of LRR_1 and LRR_2 for DJK, WFZ and XL are greater than those without IWDPs. If there were both water donation and receiving and E-Priority was set, the mean values of LRR_1 and LRR_2 for DJK, WFZ and XL are still lower than those without IWDPs as shown in Figure 12 (c-1) and (c-2).

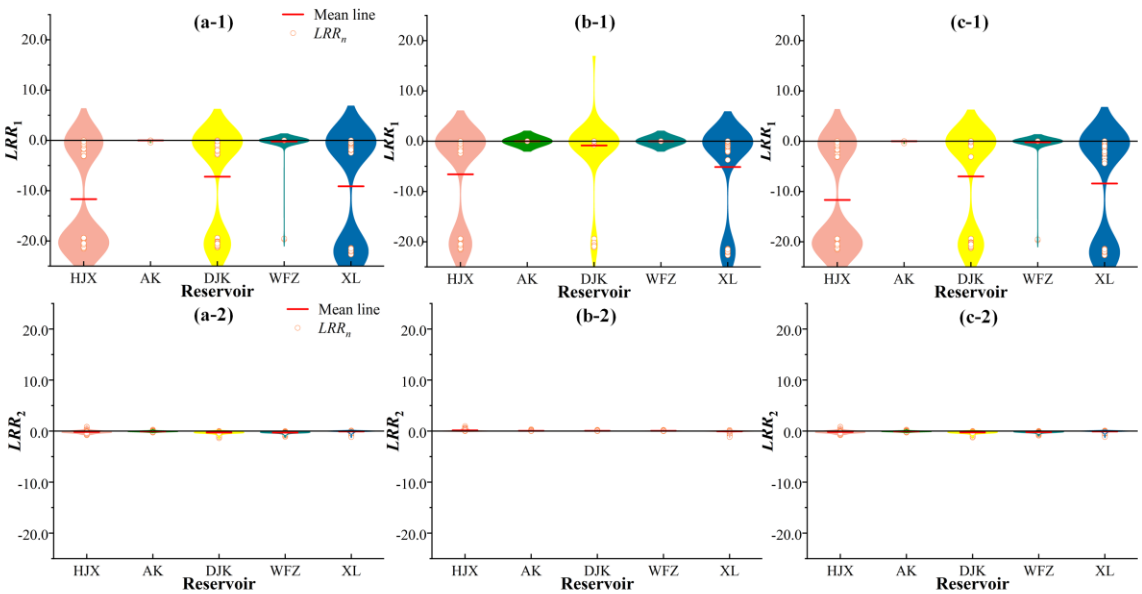

Figure 12. LRR_n values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are LRR_1 and LRR_2 when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are LRR_1 and LRR_2 when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are LRR_1 and LRR_2 when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 as shown in Figure 13(a-1) are lower than those without IWDPs in all seasons as shown in Figure 9 (a). If there was only water receiving and S-Priority was set, mean values of LRR_2 and LRR_3 for DJK, WFZ and XL (i.e., -0.04, -0.05, -0.03 and -0.01, 0, 0.70) as shown in Figure 13 (a-2) are all greater than those without IWDPs. If there were both water donation and receiving and S-Priority was set, mean values of LRR_2 for five reservoirs decrease by 0.33, 0.12, 0.34, 0.36 and 0.07 compared to those without IWDPs. Mean values of LRR_3 for HJX, AK, DJK and WFZ decrease by 3.69, 0.52, 0.72, 0.55, and its for XL increases by 0.89 compared to those without IWDPs as shown in Figure 13 (a-3). If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 as shown in Figure 13(b-1) are lower than those without IWDPs. Water donation has negative impacts on feedbacks of H on S for HJX, DJK and XL. If there was only water receiving and H-Priority was set, mean values of LRR_2 for DJK, WFZ and XL increase by 0.73, 0.32 and 0.73, and mean values of LRR_3 for DJK, WFZ and XL increase by 0, 0.01 and 0.01 compared to those without IWDPs. If there were both water donation and receiving and H-Priority was set, mean values of LRR_2 for five reservoirs are -20.58, 0, -14.49, -1.75, -8.07, and mean values of LRR_3 for five reservoirs are 0.01, 0.01, -0.05, -0.02 and 0.68 as shown in Figure 13 (b-3). If there was only water donation and E-Priority was set, it can be found that values of LRR_1 and LRR_2 in all seasons are lower than those without IWDPs as shown in Figure 13(c-1). Mean values of LRR_1 for five reservoirs decrease by 14.58, 0.01, 9.39, 1.04 and 10.38, and mean values of LRR_2 for five reservoirs decrease by 0.05, 0.04, 0.28, 0.33 and 0.22. If there was only water receiving and E-Priority was set, mean values of LRR_1 and LRR_2 for DJK, WFZ and mean values of LRR_1 for XL are greater than those without IWDPs, while mean values of LRR_2 for XL get an increase as shown in Figure 13 (c-2). If there were both water donation and receiving and E-Priority was set, Values of LRR_1 and LRR_2 for DJK and WFZ and values of LRR_1 for XL as shown in Figure 13 (c-3) are greater than those with only water donation, while lower than those without IWDPs. While values of LRR_2 for XL are greater than those without IWDPs because of the reduced spilled water. Therefore, values of LRR_n at seasonal scale demonstrate a consistent conclusion with those at the monthly scale. Moreover, the values of LRR_n are relatively stable in summer, while they change greatly in winter at seasonal scale. The impacts of IWDPs on SHE nexus are more significant in low flow seasons.

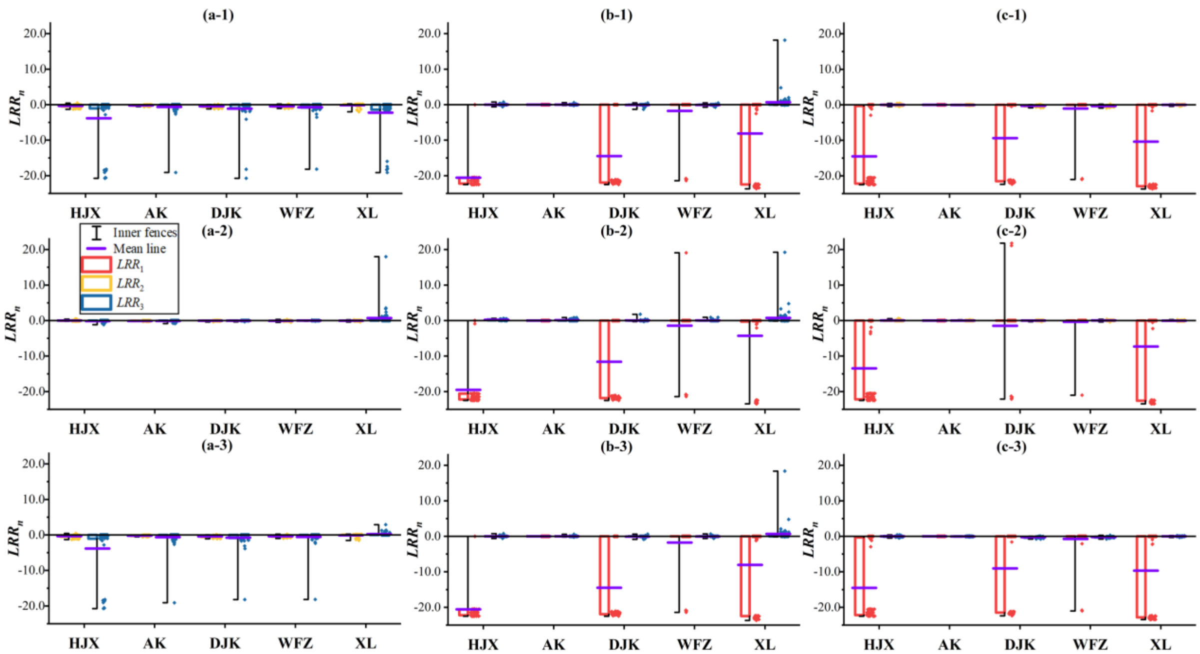

Figure 13. LRR_n values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are LRR_n when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

4.4 Responses of the three components with IWDPs

To identify the impacts of IWDPs on S, H and E components in a reservoirs group, differences between indexes without IWDPs and with IWDPs (i.e., $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) are determined. Negative values of LRR_1 for five reservoirs are found in all months, mean values of LRR_1 for five reservoirs are 0, 0, -5.54, -0.22 and -0.01 as shown in Figure 14 (a). It is found that values of LRR_1 for DJK are significantly smaller than those for other reservoirs. Mean values of LRR_2 for five reservoirs are -0.46, -0.15, -0.32, -0.26 and -0.03 as shown in Figure 14 (b). Positive values of LRR_3 are found in XL and negative values of LRR_3 are found in HJX, AK, DJK and WFZ in all months, mean values of LRR_3 for five reservoirs are -5.21, -0.75, -0.76, -0.47 and 0.43 as shown in Figure 14 (c).

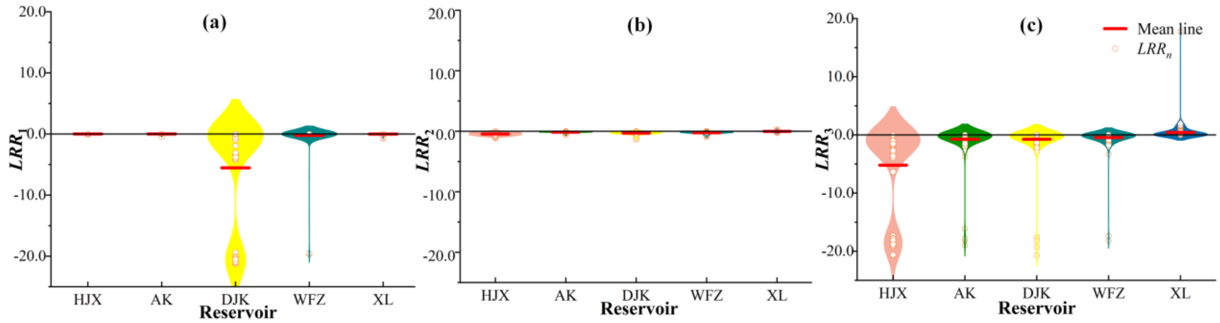

Figure 14. the differences of indexes (i.e., (a) LRR_1, (b) LRR_2, (c) LRR_3 for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale.

5 Discussion

The proposed framework reveals significant negative feedbacks of the water supply (S) on both hydropower generation (H) and environment conservation (E), as evidenced by reductions in hydropower generation (negative LRR_2 in Figure 7 (a-1)) and ecological flow satisfaction rate (negative LRR_2 in Figure 7 (a-2)) with S-Priority. The negative feedbacks of the S component on E are more pronounced than those on H, as evidenced by the wider range of variation in LRR_3 values compared to LRR_2 values. These findings are consistent with previous studies on the SHE nexus (Chen et al.,2018; Khalkhali et al., 2018). It has been found that there are a few positive feedbacks between S and H in abundant water months even the spilled water leads to a reduction in hydropower generation (Jiang et al., 2018). Thus, the increasing water storage or increasing water supply still can ensure hydropower generation. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. And Gao et al. (2023) find that the higher water supply demand, the lower ecological flow left in river. The environment conservation of downstream river systems is critically influenced by upstream water supply decisions (Gupta, 2008). Contrary to the unidirectional positive nexus between hydropower generation and environment conservation proposed by Wei et al. (2022), our study reveals bidirectional feedbacks of H and E, aligning with Wu et al. (2021). The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir, Zhang et al., 2008) even in abundant water months, particularly. The increased flows for hydropower generation alleviates the pressure of ecological damage in river. However, the more flows for hydropower generation from the reservoir, the less supplied amount of available water resources (Doummar et al., 2009), and leads to negative impacts on the S component. The feedbacks of the H on S are more pronounced than on E, according to the wider range of variation in LRR_1 values compared to LRR_3 values. Negative feedbacks of the E component on S for reservoirs has been found in the scenario that main function is water supply while no significant effect on reservoirs has been found in the scenario that main function is hydropower generation (negative LRR_1 in Figure 7 (c-1)). There are both negative and positive feedbacks of the E component on H while the negative feedbacks are grown in abundant water months. Feedbacks of the E component on S are stronger than those on H, according to the values of LRR_n. The negative feedbacks between

S and H, and between S and E are strong in low flow months due to the high-water supply demand. More competitions for water can be found among S, H and E in low flow months, and their negative feedbacks of the SHE nexus have found to be strengthened (Wu et al., 2021). Feedback loops of SHE nexus in reservoirs with regulation function (e.g., AK and DJK) remain stable under the varying inflow conditions. These reservoirs reasonably allocate water among S, H and E components to prevent strengthening of negative feedbacks in low flow months. Furthermore, increasing hydropower generation flow might have impacts on downstream water quality and biodiversity (Botelho et al., 2017; Martinez et al., 2019), the feedbacks of H on E are enhanced.

Inter-basin water diversion projects (IWDPs) have negative impacts on the regional water supply from DJK and upstream reservoirs with negative LRR_1, consistent with Hong et al. (2016) and Ouyang et al. (2018). And all reservoirs have reduced their hydropower generation, but there are positive impacts on H in abundant water months with positive LRR_2 in Figure 14 (b). Many studies have highlighted the negative impacts of IWDPs on hydropower generation (Yang, et al., 2023), but the positive impacts are less frequently discussed. With the water donation for the Han-to-Wei Water Diversion Project, the Middle Route of the South-to-North Water Diversion Project and the Northern Hubei Water Resources Allocation Project, multiple algal bloom events occurred in the downstream of HRB (Tian et al., 2022), and the water donation had a significant negative impact on the environment conservation of the basin. Water receiving from the Three Gorges Reservoir to Hanjiang River are not compensate for all their negative impacts, and water receiving from the Changjiang-to-Hanjiang River Water Diversion Project benefits environment conservation for XL. It is evident that IWDPs significantly alter the feedback loops of the SHE nexus by modifying water availability. As IWDPs export or import water to or from an area, the amount of available water has to be altered. It can prompt a redistribution and re-planning of the available water (Li, et al., 2014). And the redistribution and re-planning can significantly impact on feedback loops of SHE nexus (Feng, et al., 2019). Although strong responses occur in feedback loops of SHE nexus, its positive or negative nature of feedback among these components remains stable with impacts of IWDPs. Thus, the redistribution and re-planning of available water can not alter their competitions and collaborations among the components of the SHE nexus. It is evident that water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E while receiving water has positive impacts on all these feedbacks. Water donation results in a reduction of available water (Mok et al., 2015; Wu et al., 2022) and leads to lower flow. More competition for water can be found among S, H and E, and negatively impacts on the feedbacks. Less competition is found among S, H and E in water receiving areas, and it has positive impacts on their feedbacks. The persistent feedback polarity with IWDPs suggests that simply increasing water supply (e.g., via compensation donations like Three Gorges-to-Hanjiang) cannot resolve inherent SHE conflicts—instead, adaptive allocation rules that account for these stable feedback patterns are needed.

The consistency in the signs of mean LRR_n values across seasonal as shown in Figure 9 and 13 and annual scales as shown in Supplementary material Table S1-S5 with those at the monthly scale indicates an inherent similarity and stability in SHE nexus feedback loops over different temporal resolutions. Compared with the values of LRR_n at monthly scale, the values at the seasonal scale show its stronger periodic variations. Based on the variations in LRR_n and the mathematical implications of LRR_1, LRR_2, and LRR_3, this study found that these periodic variations align closely with the runoff variations, and the temporal and spatial variations in feedback loops are primarily attributed to variations in runoff. The wavelet transform analysis has also been applied in the runoffs for HJX, AK, DJK, WFZ, and XL dam sites. And the results are in consisted with that in Hutuo River Basin (Xu et al., 2018), the periodic variations have been found at the seasonal scale. The LRR_n values at the seasonal scale can help analyze the variations in periodic feedback loops. Different from the monthly or seasonal scales, results at the annual scale reveal the long-term trends and periodic variations in the inter-annual and spatial trends of the SHE nexus from a macro perspective. The impacts of reservoir operation and the regulation on SHE nexus can be clearly simulated and observed at the monthly scale, so the immediate changes in the nexus at monthly scale can provide information for short-term decision-making in reservoirs."

"A framework was proposed to address the different impacts of IWDPs on the dynamic SHE nexus across the multiple temporal and spatial scales in reservoirs group with different priority functions, and to explore collaborative states in feedback loops. The HRB was taken as case study to verify the feasibility and reliability of this framework. Negative feedbacks can be found between S and H, and between S and E while positive feedbacks can be found between H and E in a reservoirs group without IWDPs. The negative feedbacks of S on H and the positive feedbacks of E on H are weakened or even broken in abundant water periods. All feedback loops are strengthened in low flow periods due to heightened competition for water resources. Water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E. While water receiving has positive impacts on these feedbacks. Less positive feedbacks are found with IWDPs than without them. Feedback loops of SHE nexus exhibit intrinsic similarity and stability across different time scales. The impact of reservoir operation and regulation on SHE nexus are clearer at the monthly scale. The seasonal scale offers the variations in periodic feedback loops. And the annual scale offers inter-annual and spatial trends of the SHE nexus from a macro perspective. Feedback loops in reservoirs with regulation function (e.g., AK and DJK) can remain stable under the varying inflow conditions at monthly scale. The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir) even in abundant water periods. Feedback loops for downstream reservoirs are influenced by their upstream reservoirs, especially in low flow periods. Thus, water donation or regional water supply can be increasing in abundant water periods to reduce spilled water and increase hydropower generation efficiency. In dry periods, it is necessary to consider the priority order of S, H, and E, and determine water utilization threshold for each component to maximize the benefits.

This framework offers a systematic and quantitative approach to examining the spatiotemporal variations of SHE nexus with external perturbations. It elucidates the existence and nature of collaborative states among S, H, and E. However, more work should be done to enrich the representation of every component such as the E component. This component should be reflected by a comprehensive set of water quality indicators. Then more details of the mechanism of the SHE nexus will be figured out."

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Minor comments

Point #7

COMMENT: *Line 107: "It has been widely application". Correct to "It has been widely applied".*

RESPONSE: We much appreciate and totally agree with the reviewer's insightful comment. The revised part is:

> "The VIC model has been widely applied in runoff simulations across various basins worldwide, consistently yielding outstanding results (Wang et al., 2012; Yeste et al., 2024; Su et al., 2024). (**On page 4 of the revised manuscript**)"

Relevant references:

Wang, G., Zhang, J., Jin, J., Pagano, T.C., Calow, R., Bao, Z., Liu, C., Liu, Y., Yan, X.: Assessing water reso urces in China using PRECIS projections and a VIC model. Hydrol. Earth Syst. Sci., 16(150):231-240, http s://doi.org/10.5194/hess-16-231-2012, 2012.

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Point #8

COMMENT: *Line 125: "approaching 1 meant". Correct to "approaching 1 means".*

RESPONSE: The authors much appreciate your thoughtful comment. We agree with the reviewer's point and will revise the sentence accordingly for clarity. The revised part is:

> "R^2 approaching 1 means the simulations are equal to the observations. (**On page 5 of the revised manuscript**)"

Point #9

COMMENT: *Line 145: You need to state that P is precipitation (I assume P<25% means precipitation below the 25th percentile).*

RESPONSE: We are very thankful for the reviewer's helpful suggestions and apologetic for providing an improper description in the original manuscript. In the revised manuscript, we have accordingly modified the description to clarify it more accurately and enhance the rigor of the article. The revised part is:

> "① The year groups are divided into wet years (precipitation below the 25th percentile, P<25 %), normal years (25 %⩽P⩽75 %), and dry years(P>75 %) firstly. (**On page 6 of the revised manuscript**)"

Point #10

COMMENT: *Figure 3: The arrows of outflows (reg. water supply flow, ET and seepage, water donation) start at different locations for the ith reservoir and the (i+1) th reservoir.*

RESPONSE: The authors much appreciate the reviewer's insightful comment and apologetic for not proving typical references to support this statement. The revised part is:

"

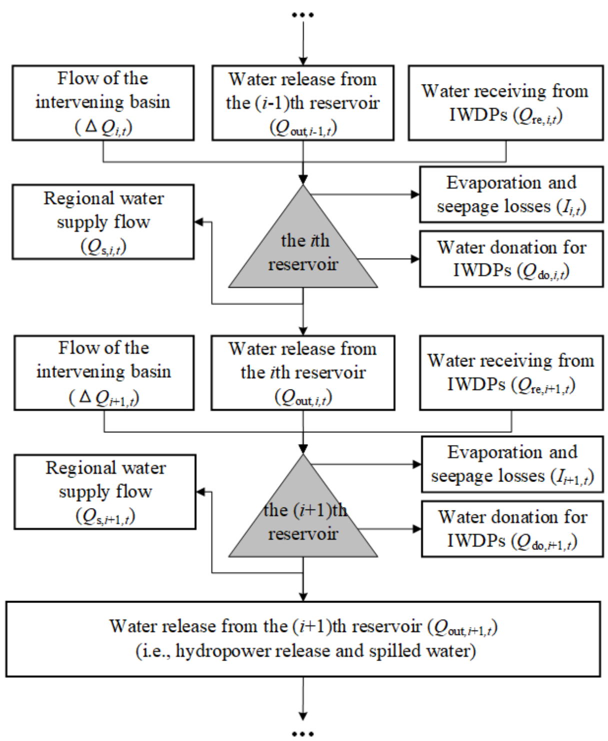

Figure 3. The multisource input-output to reservoirs in a reservoirs group."

Point #11

COMMENT: *Line 229: Should this read: "Thus, the differences between Nexus I and Nexus III can figure out impact of different IWDP clusters on the SHE nexus"?*

RESPONSE: We sincerely appreciate the reviewer's thoughtful comment and constructive suggestion. We agree with the reviewer's point and will revise the sentence accordingly for clarity. The revised part is:

"To analyse the feedback loops of SHE nexus without IWDPs, the differences between the $S_{0\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined (i.e., the feedback loops of Nexus I as shown in Figure 1.). To analyse the feedback loops with IWDPs (i.e., the feedback loops of Nexus II as shown in Figure 1.), the differences between the $S_{3\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{3\text{-}4\text{-}n}$ scenarios are determined. Thus, the differences between Nexus I and Nexus II can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus III as shown in Figure 1.), the differences between $S_{m\text{-}p\text{-}n}$ (m=1, 2, 3; p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined. The differences between Nexus I and Nexus III can figure out the impacts of different IWDP clusters on the SHE nexus. $S_{0\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules without IWDPs) and $S_{3\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules with IWDPs), are the baseline scenarios for distinguishing Nexus I, Nexus III, and Nexus II. In the same way, to clarify the impacts of IWDPs on the three components, the differences between the $S_{0\text{-}4\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios are determined. (**On page 10 of the revised manuscript**)"

Point #12

COMMENT: *Table 4: What are the units of the e-flows?*

RESPONSE: We are very thankful for the reviewer's insightful comments and helpful suggestions. The units of the e-flows are m^3/s, the additions are made in Table 4 as follows:

Table 4. Multi-level ecological flows resulted from MTMMHC method.

Site	Month	Hydrological years											
		Wet year				Normal year				Dry year			
		MEF (m^3/s)	E_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)	MEF (m^3/s)	E_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)	MEF (m^3/s)	E_2 (m^3/s)	OEF_{min} (m^3/s)	OEF_{max} (m^3/s)
XL dam site	Jan	1197	1476	1550	1668	825	849	872	910	664	666	668	670
	Feb	1265	1467	1539	1656	836	863	890	933	675	678	681	686
	Mar	1268	1486	1569	1702	842	869	896	938	685	690	696	705
	Apr	1249	1329	1426	1581	868	892	916	955	691	698	704	714
	May	1273	1675	1822	2058	861	887	912	953	705	714	723	738
	Jun	1653	1681	1877	2192	877	916	955	1017	763	786	809	846
	Jul	1818	2629	2987	3560	1288	1430	1572	1799	875	921	968	1043
	Aug	1885	2522	2849	3372	1266	1401	1537	1753	811	845	879	933
	Sep	1465	2822	3225	3869	1174	1279	1384	1553	834	879	924	997
	Oct	1368	2276	2611	3148	978	1036	1094	1186	733	752	772	802
	Nov	1315	1586	1748	2007	897	932	966	1022	691	697	704	714
	Dec	1194	1471	1549	1675	845	873	900	944	680	686	691	700

Generally, we are deeply grateful to the reviewer #1 for his/her insightful and careful review. The provided comments and suggestions have greatly helped improve the manuscript. We also expressed our gratitude in the "**Acknowledgments**" section of the revised manuscript.

RESPONSES TO REVIEWER #2'S COMMENTS

We would like to express our sincere gratitude for your detailed and constructive comments on our manuscript. The comments are valuable and helpful for us to improve the quality of the manuscript. All the concerns raised have been carefully treated and an itemized reply to the reviewer's comments is presented in the revision files.

Point #1

COMMENT: *While the methodology employed in the manuscript effectively addresses the issue of identifying the SHE nexus across multiple temporal and spatial scales, it is important to elaborate on the advantages of the chosen approach in the methodology or introduction section, rather than merely stating its ability to solve the problem.*

RESPONSE: We sincerely appreciate the reviewer's valuable comment regarding the need to elaborate on methodological advantages. We fully concur that explicitly articulating the strengths of our chosen analytical framework in the methodology/introduction sections will better contextualize our approach for readers. In the revised manuscript, we will expand upon some key advantages of our methodology in addressing the impacts of IWDPs across the multiple temporal and spatial scales on the dynamic SHE nexus. The Variable Infiltration Capacity (VIC) hydrological model offers significant advantages in multiple temporal and spatial scale runoff simulation. It has flexible spatial resolution, making it suitable for hydrological modeling at scales ranging from small catchments to large basins, with minimal loss of accuracy. VIC model can simulate hydrological processes at various time scales, from hourly to annual, catering to different research needs. The VIC model also efficiently uses gridded data, making it highly adaptable for large-scale regional or global studies, and supports a wide range of input data types. The Modified Tennant Method Based on Multilevel Habitat Conditions method builds upon the Tennant method, modifying it based on three parameters: average periodic flow, water period, and percentage (Li and Kang, 2014). It can solve four key problems existed in the current ecological flow standards: spatial transferability, monthly variability, inter-annual variability and scalability (Li, et al., 2015). This modification helps mitigate the impacts of extreme inter-annual flow variations and uneven intra-annual distribution. The Log Response Ratio method captures non-linear feedback loops within complex SHE nexus systems. And our scenarios architecture enables systematic exploration of SHE nexus systems by combining different clusters of IWDPs and the priority orders of S, H, and E, offering flexibility in modeling system behavior under different conditions.

The revised and relevant parts are:

> "To simulate runoff results at multiple temporal and spatial scales, the Variable Infiltration Capacity (VIC) hydrological model is selected. The VIC model offers significant advantages in multiple temporal and spatial scale runoff simulation. It is a large-scale distributed hydrological model based on the spatial distribution grid of Soil Vegetation Atmospheric Transfer Schemes (SVATS) (Liang, et al., 1994), making it highly adaptable to studies at different spatial scales and supporting a wide range of input data types. The VIC model can simulate hydrological processes at various time scales, from hourly to annual, catering to different research needs. It excelled at simulating both the energy balance and water balance between the land and atmosphere, thereby addressing the oversight of energy processes in traditional hydrological models. The VIC model has been widely applied in runoff simulations across various basins worldwide, consistently yielding outstanding results (Wang et al., 2012; Yeste et al., 2024; Su et al., 2024). There are five steps to construct a VIC model (Koohi et al., 2022): ① collect and organize data; ② preprocesses of the VIC model; ③ construct VIC model of the selected basin; ④ run the catchment module; ⑤ parameter calibration and validation. During the calibration process, important parameters highlighted in Table 1 are automatically calibrated using MATLAB to achieve the optimal parameter combination."(**On page 4 of the revised manuscript**)
>
> "In order to establish a multi-level ecological flow standard to aid in evaluating river ecological health, the multi-level ecological flows are estimate by the MTMMHC method. There are over 200 methods for ecological flows (EFs) estimation worldwide, typically categorized into four types: hydrological, hydraulic, habitat simulation, and holistic methods (Tharme, 2003). The Tennant method, which determines EFs based on predetermined percentages of average annual flow, is the most widely used hydrological method (Tharme, 2003). The MTMMHC method (Li and Kang, 2014) modifies the Tennant method based on three parameters: average periodic flow, water period, and percentage. It can solve four key problems existed in the current ecological flow standards: spatial transferability, monthly variability, inter-annual variability and scalability (Li, et al., 2015). Indeed, the MTMMHC method can avoid the impacts of extreme inter-annual flow events and uneven intra-annual distribution. This enables the calculation of different guarantee rates for various river sections, water years (e.g., wet, normal, and dry years), and months. It reflects the temporal and spatial variability of EFs, and provides a comprehensive and reasonable multi-level ecological flows standards. The steps of the MTMMHC method are as follows." (**On page 6 of the revised manuscript**)

"To analyse the feedback loops in Nexus I, Nexus II and Nexus III in Figure 1, the log response ratio (*LRR*) method (Patrick et al., 2022) is used to quantify the responses of S, H, and E with different clusters of IWDPs. This method captures non-linear feedback loops within complex SHE nexus systems." (**On page 9 of the revised manuscript**)

"To identify the impacts of different clusters of IWDPs on the SHE nexus, scenarios are set according to the following three aspects: with or without IWDPs (i.e., two types for IWDPs), different clusters of IWDPs (i.e., four clusters for the above two types), and the priority orders of S, H, and E. As there are three components for the highest priority, six scenarios can be obtained through the combination of the three components. As all S, H, and E are determined from standard scheduling rules, there are also three types for the standard scheduling rules. Combined with the types of different clusters of IWDPs, there will be a total of 30 scenarios (i.e., 4 clusters of IWDPs ×6 types for the highest priority combinations +2 types for IWDPs ×3 types for standard scheduling rules) as listed in Table 2. Specifically, to iteratively set the priority orders of S, H, and E, all three components are all in standard scheduling rules firstly. Secondly, the highest priority is set to water supply (as denoated by S-Priority), that means all reservoirs will first meet regional water demands (i.e., domestic, industrial, and ecological), with surplus water then allocated to hydropower generation and environment conservation needs. Additionally, increasing the regional water supply to 120% enhances the observability and analytical prominence of the quantitative outcomes derived from these nexus. And thirdly, hydropower generation (H-Priority) is prioritized to achieve the maximum output during the planned period. Finally, environmental conservation (E-Priority) is addressed through ensuring that the reservoir outflow meets $OEF_{xy(\max)}$. These scenarios offer flexibility in modeling SHE nexus system behavior under different conditions." (**On page 10 of the revised manuscript**)

Point #2

COMMENT: *The elements presented in Figure 4 are insufficient to clearly illustrate the geographical characteristics of the study area. Additionally, it is necessary to label the names of various hydrological stations and reservoirs on the map, so that readers can more easily interpret the information. The clarity of Figure 6 should be improved, and the color scheme used to differentiate observed and simulated data needs to be adjusted for better distinction. Furthermore, the title of Figure 6 could be simplified for conciseness.*

RESPONSE: We are very thankful for the reviewer's insightful comment and valuable reminder. We have revised Figure 4 to enhance the geographical characteristics of Hanjiang River Basin (HRB) by adding elements such as topography and rivers to make the map clearer. We have also labeled the hydrological stations and reservoirs on the map, ensuring that readers can easily identify these key locations. To eliminate readers' disputes over the territories in the map, we have made modifications to Figure 4 using the map with the examination approval number GS (2024) No.0650. Regarding Figure 6, we have improved its clarity by ensuring that text, line thickness, and other elements are sharp and legible. Additionally, we have adjusted the color scheme used to differentiate observed and simulated data, opting for more contrasting colors that are easily distinguishable, and have ensured the legend clearly indicates which color corresponds to each dataset. Lastly, we have simplified the title of Figure 6 to a more concise. The revised and relevant parts are:

“

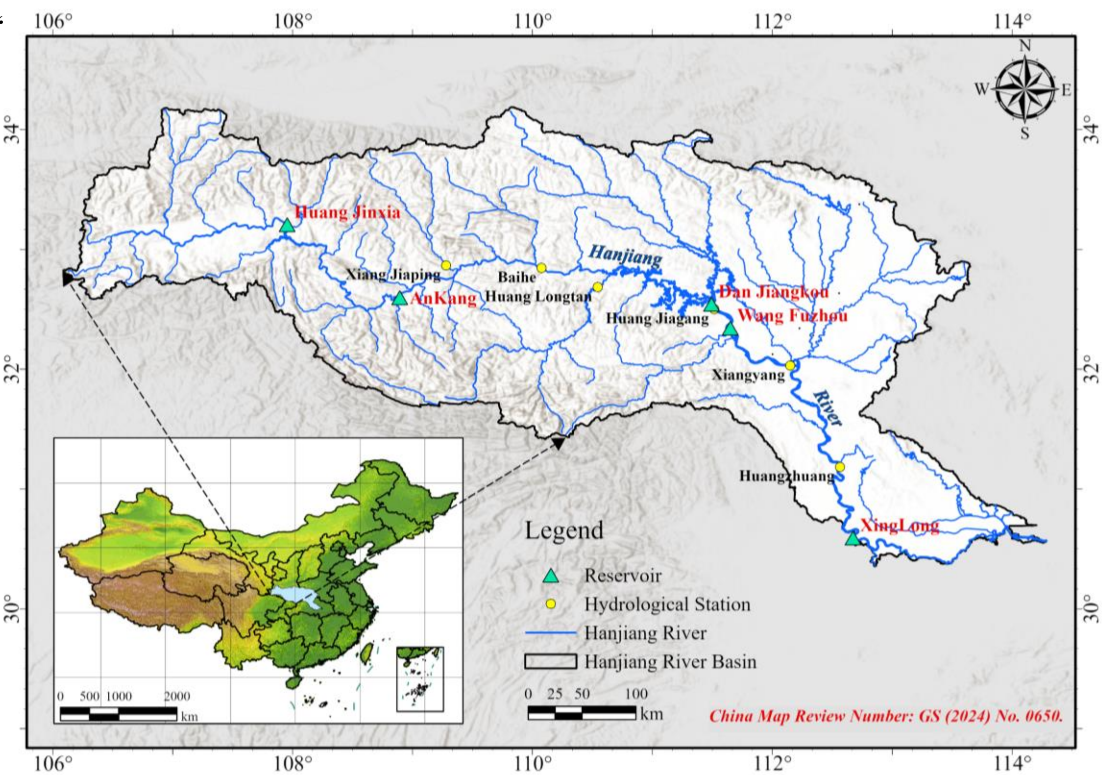

Figure 4. Overview map of the study area.

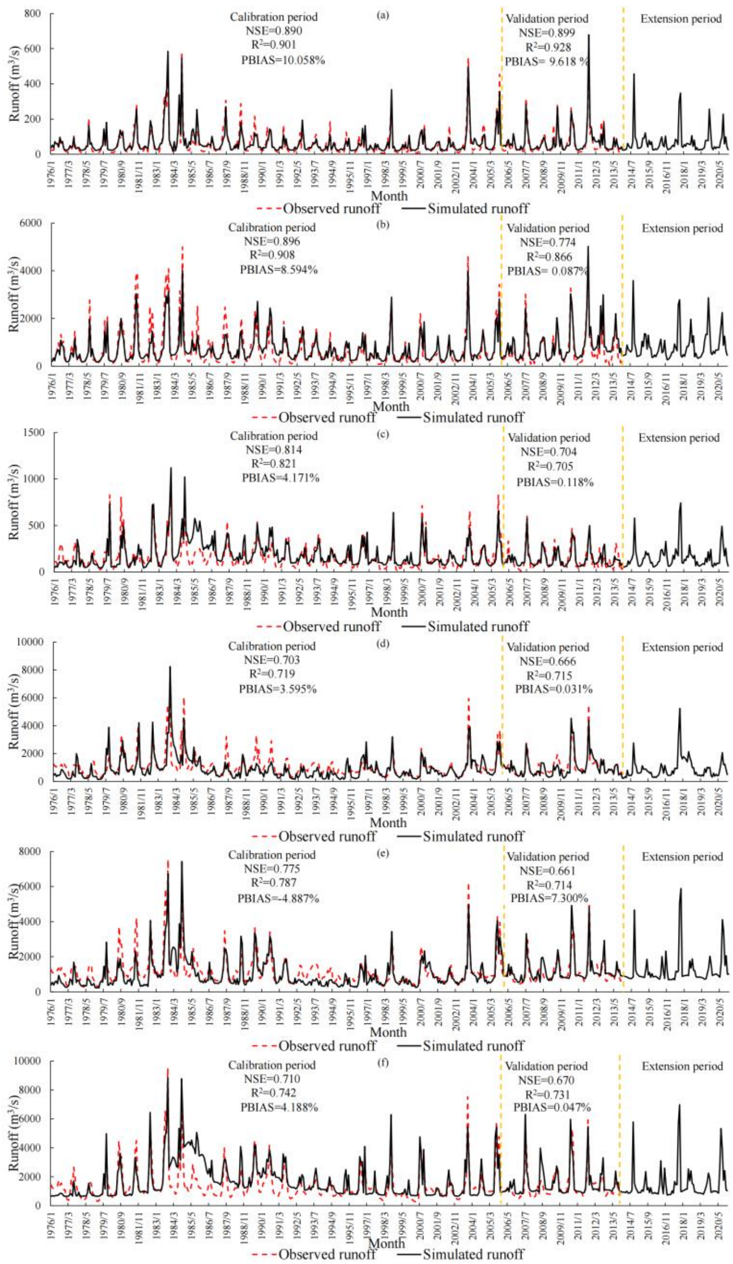

Figure 6. Calibration and validation results of simulation at hydrological stations: (a)Xiangjiangping, (b) Baihe, (c) Huanglongtan, (d) Huangjiagang, (e) Xiangyang, (f) Huangzhuang."

Point #3

COMMENT: *Is the framework proposed in the manuscript broadly applicable? It might be helpful for the manuscript to provide a clearer explanation of the framework and further clarify the scope of applicability of the proposed method.*

RESPONSE: We greatly appreciate the reviewer's insightful comments. This framework offers a systematic and quantitative approach to examining the spatiotemporal variations of SHE nexus with external perturbations. It elucidates the existence and nature of collaborative states among S, H, and E. All the methods in the framework, such as the VIC model, the Modified Tennant Method Based on Multilevel Habitat Conditions, and the Log Response Ratio method, are not region-specific and can be applied to the study of SHE nexus in different basins worldwide. Therefore, the proposed framework can be applied globally to identify the feedbacks of the SHE nexus in basins with inter-basin water diversion projects. The applicability of the framework is clearly explained in the paper. The corresponding part is:

> "To address the impacts of IWDPs across the multiple temporal and spatial scales on the dynamic SHE nexus, multiple temporal and spatial scales runoffs from the water donating basins are provided through a distributed hydrological model. And multi-level ecological flows and their corresponding multi-level ecological flow standards are also determined according to an available method with spatial-temporal variability. To facilitate the identification of the impacts of IWDPs on SHE nexus, scenario experiments are set by "with/without IWDPs". In order to take the different clusters of IWDPs into account, scenario experiments are classified by the impacts of IWDPs on water donation area, on water receiving area or on an area with both water donation and water receiving if there are IWDPs. To evaluate the feedback loops of the SHE nexus, the priority order of S, H, and E are iteratively set in all reservoir nodes. We set different types of the highest priority in S, H, and E and take the standard scheduling rules as reference scenarios. All scenarios are modeled in a multisource input-output reservoir generalization model, and differences between scenarios are quantified with a response ratio indicator. And the feedback loops with the different impacts of IWDPs are identified through a response ratio indicator. To explore the collaborative states, positive mutation in a response ratio across time-space is found between pairwise components of SHE. This framework can be applied globally to identify the feedbacks of the SHE nexus in basins with IWDPs. Thus, our research framework is illustrated as Figure 1." (**On page 3 of the revised manuscript**)

<u>Point #4</u>

COMMENT: *The manuscript offers limited description of the baseline scenarios. This section could be expanded to clarify the rationale behind the selection of the baseline scenarios, enabling readers to better understand the results.*

RESPONSE: We are very thankful for the reviewer's insightful comments and helpful suggestions. We have provided a more detailed description of the baseline scenarios and added explanations of the scenarios in the figure captions.

The revised parts are:

"To analyse the feedback loops of SHE nexus without IWDPs, the differences between the $S_{0\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined (i.e., the feedback loops of Nexus I as shown in Figure 1.). To analyse the feedback loops with IWDPs (i.e., the feedback loops of Nexus II as shown in Figure 1.), the differences between the $S_{3\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{3\text{-}4\text{-}n}$ scenarios are determined. Thus, the differences between Nexus I and Nexus II can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus III as shown in Figure 1.), the differences between $S_{m\text{-}p\text{-}n}$ (m=1, 2, 3; p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined. The differences between Nexus I and Nexus III can figure out the impacts of different IWDP clusters on the SHE nexus. $S_{0\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules without IWDPs) and $S_{3\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules with IWDPs), are the baseline scenarios for distinguishing Nexus I, Nexus III, and Nexus II. In the same way, to clarify the impacts of IWDPs on the three components, the differences between the $S_{0\text{-}4\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios are determined." (**On page 10 of the revised manuscript**)

"

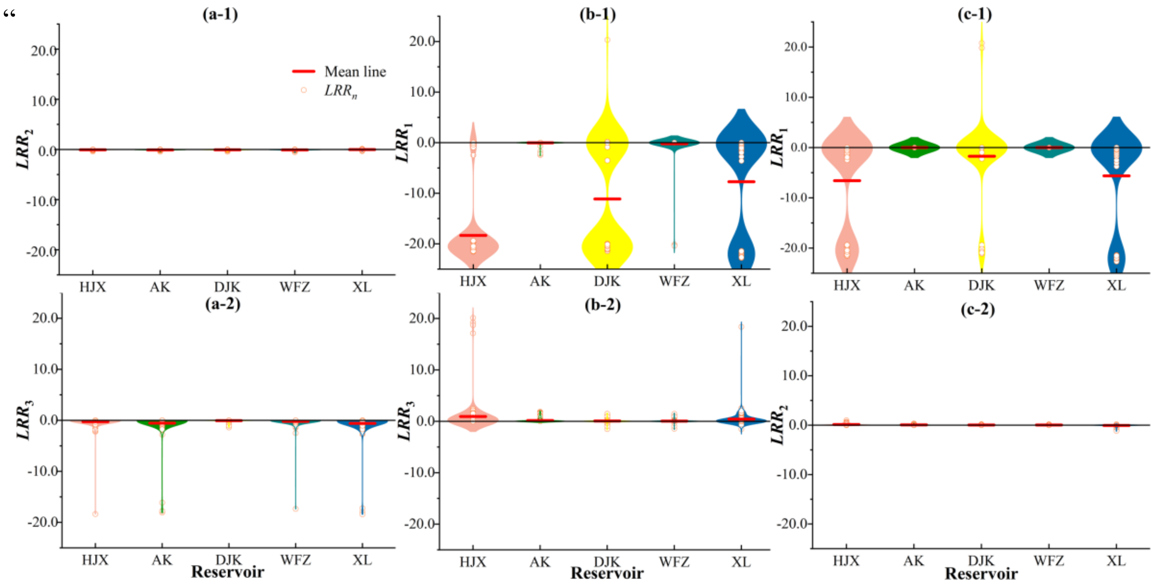

Figure 7. the differences of indexes (i.e., *LRR_1*, *LRR_2*, *LRR_3* for log response ratio of the S, H, and E component) without IWDPs (i.e., between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) at the monthly scale: (a-1) is *LRR_2* with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}2}$ and $S_{0\text{-}4\text{-}2}$), (a-2) is *LRR_3* with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (b-1) is *LRR_1* with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (b-2) is *LRR_3* with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (c-1) is *LRR_1* with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) is *LRR_2* with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

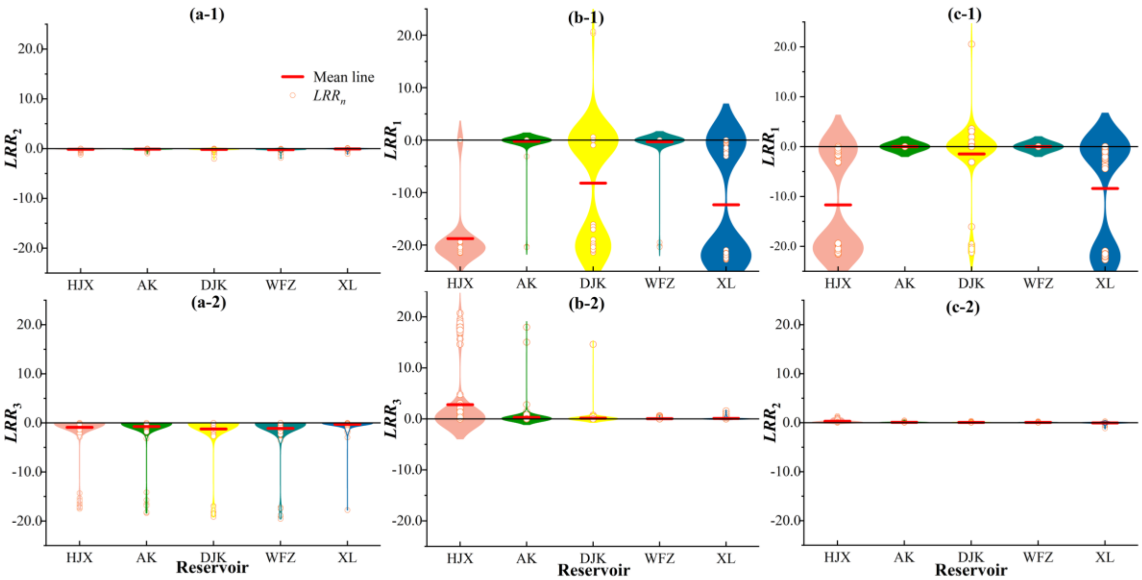

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between S_{3-p-n} and S_{3-4-n}) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between S_{3-1-2} and S_{3-4-2}), (a-2) is LRR_3 with the highest priority in S (i.e., between S_{3-1-3} and S_{3-4-3}), (b-1) is LRR_1 with the highest priority in H (i.e., between S_{3-2-1} and S_{3-4-1}), (b-2) is LRR_3 with the highest priority in H (i.e., between S_{3-2-3} and S_{3-4-3}), (c-1) is LRR_1 with the highest priority in E (i.e., between S_{3-3-1} and S_{3-4-1}), (c-2) is LRR_2 with the highest priority in E (i.e., between S_{3-3-2} and S_{3-4-2}).

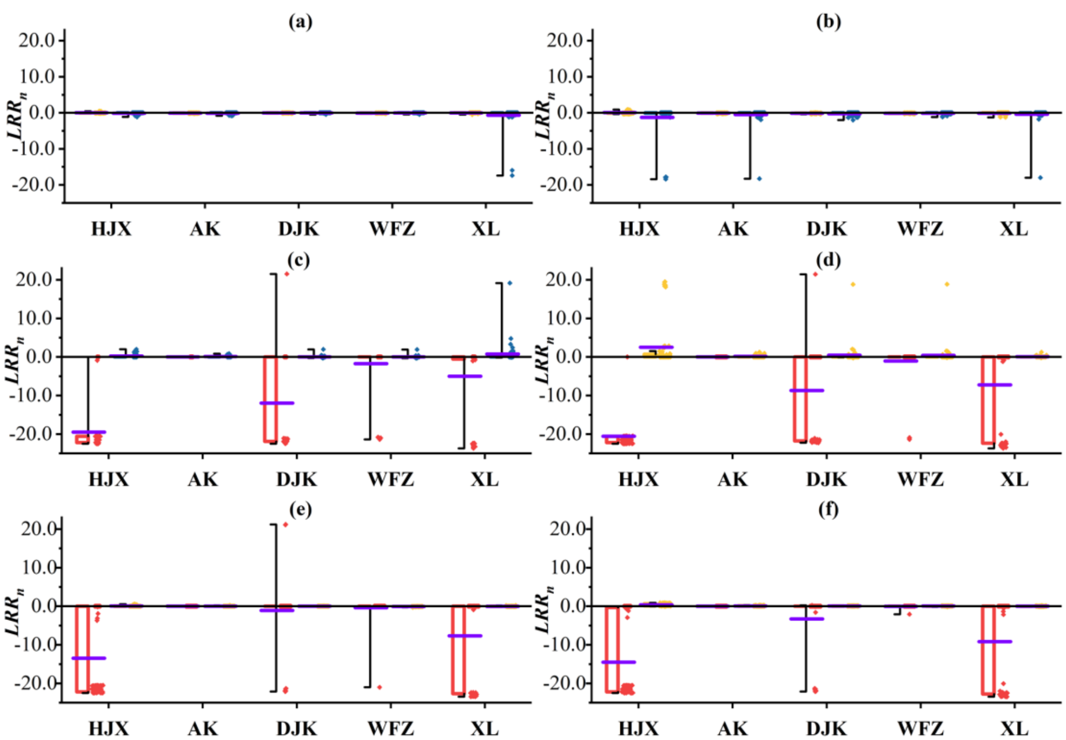

Figure 9. LRR_n with different highest priorities (i.e., between S_{m-1-n} and S_{m-4-n}) at the seasonal scale: (a) and (b) are LRR_n with the highest priority in S without IWDPs (i.e., between S_{0-1-n} and S_{0-4-n}) and with IWDPs (i.e., between S_{3-1-n} and S_{3-4-n}), (c) and (d) are LRR_n with the highest priority in H without IWDPs (i.e., between S_{0-2-n} and S_{0-4-n}) and with IWDPs (i.e., between S_{3-2-c} and S_{3-4-n}). (e) and (f) are LRR_n with the highest priority in E without IWDPs (i.e., between S_{0-3-n} and S_{0-4-n}) and with IWDPs (i.e., between S_{3-3-n} and S_{3-4-n}).

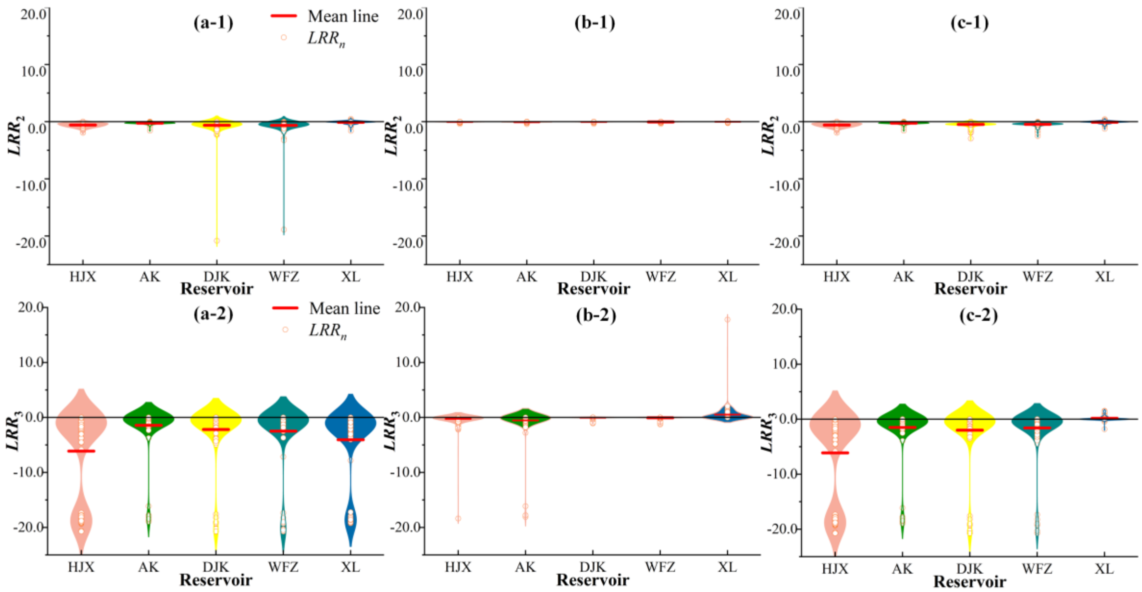

Figure 10. ***LRR**$_n$* **values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water donation (i.e., between $S_{1\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water receiving (i.e., between $S_{2\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR*$_2$ and *LRR*$_3$ when there are both donation and receiving (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

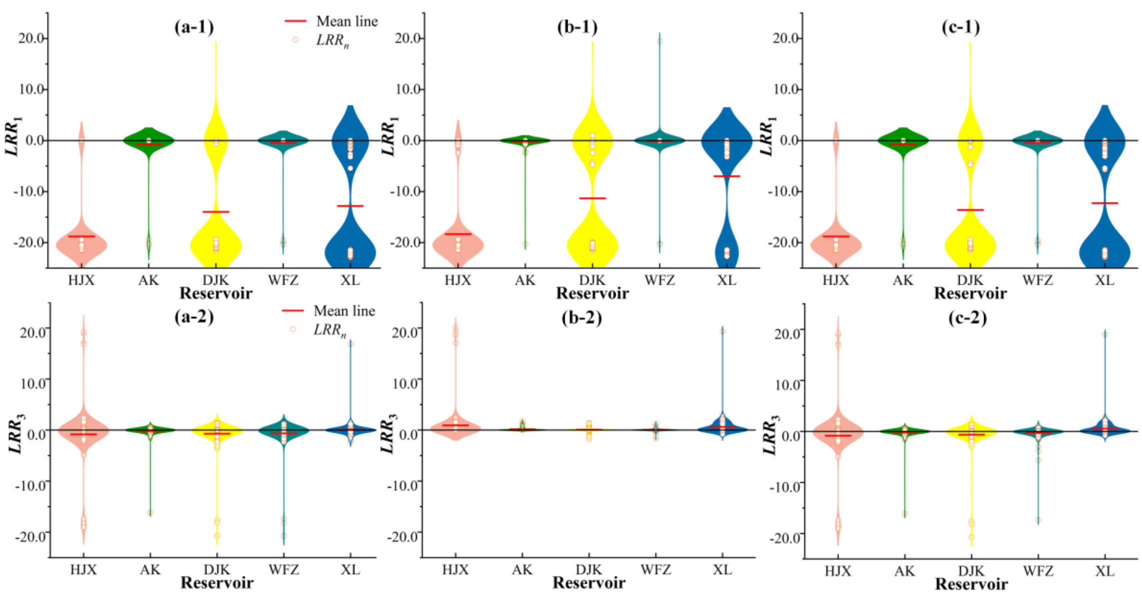

Figure 11. ***LRR**$_n$* **values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water donation (i.e., between $S_{1\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR*$_2$ and *LRR*$_3$ when there is only water receiving (i.e., between $S_{2\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR*$_2$ and *LRR*$_3$ when there are both donation and receiving(i.e., between $S_{3\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

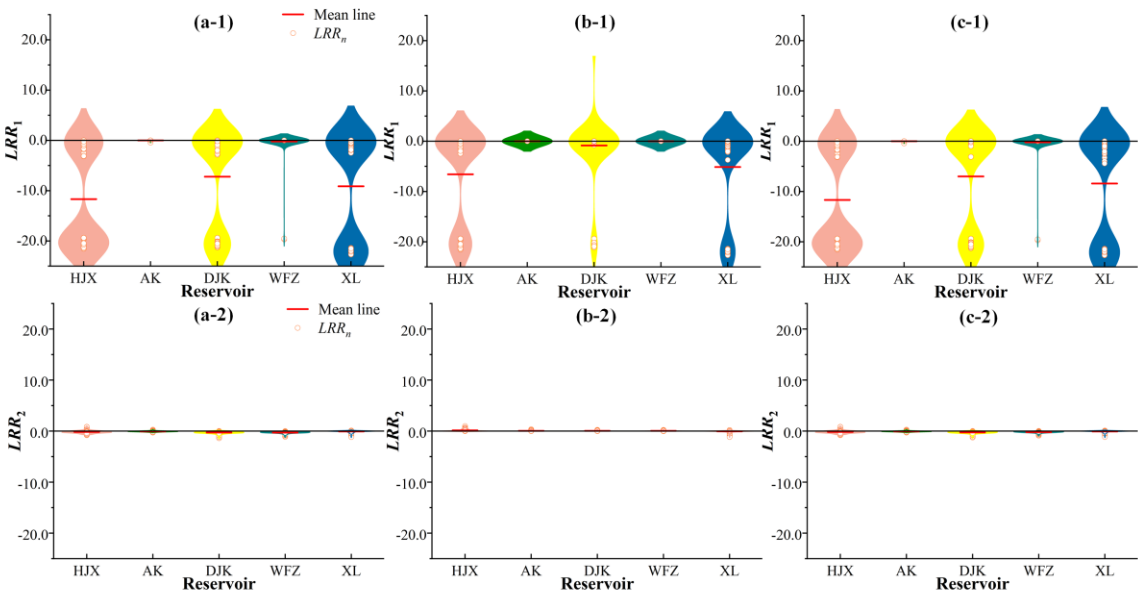

Figure 12. ***LRR_n*** **values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are** ***LRR_1*** **and** ***LRR_2*** **when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are** ***LRR_1*** **and** ***LRR_2*** **when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are** ***LRR_1*** **and** ***LRR_2*** **when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

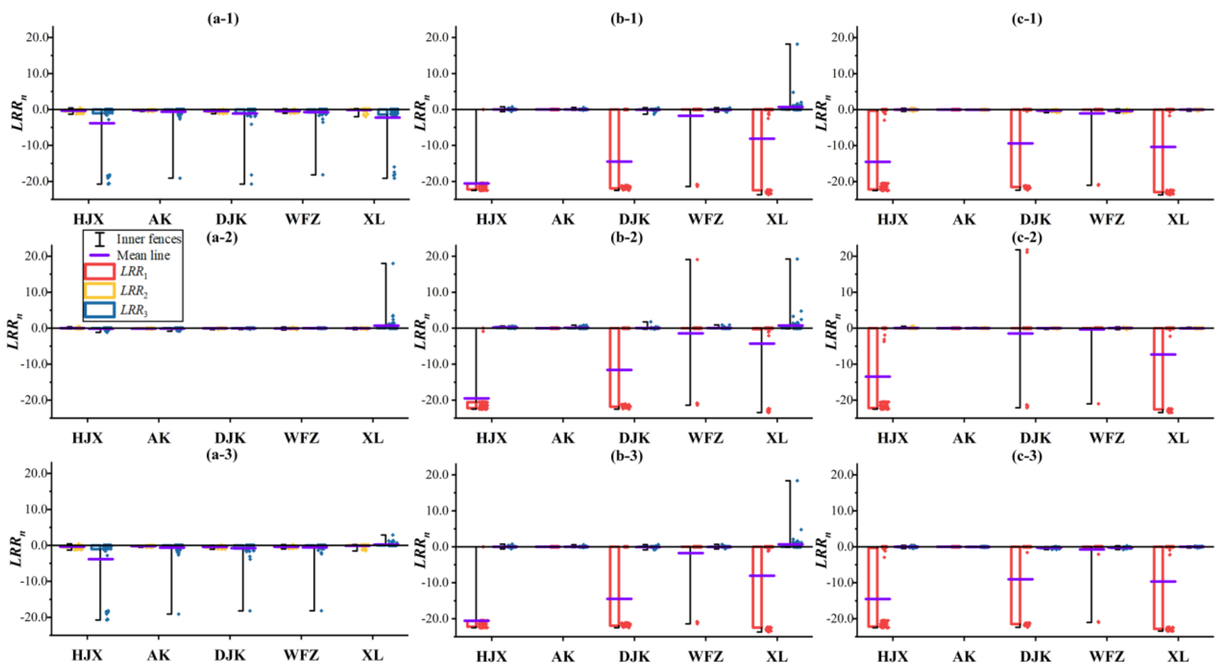

Figure 13. ***LRR_n*** **values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are** ***LRR_n*** **when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

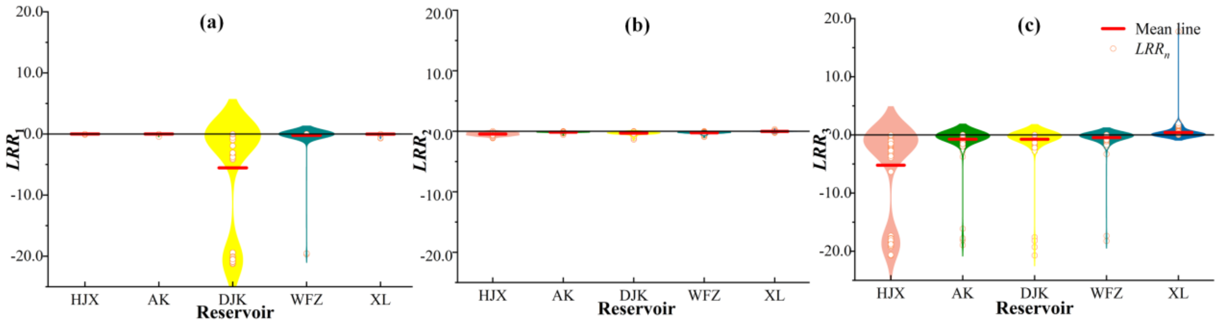

Figure 14. the differences of indexes (i.e., (a) *LRR_1*, (b) *LRR_2*, (c) *LRR_3* for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale."

Point #5

COMMENT: *The results and discussion section is too long, please make it more concise and highlight the key results.*

RESPONSE: We agree that the section could be more concise and focused on the key findings. In response to this comment, we have rigorously streamlined the Results and Discussion sections by retaining monthly and seasonal-scale analyses in the main text (as they directly address the core research objectives) while relocating annual-scale results to Supplementary material for transparency. Redundant descriptions of similar trends across timescales (e.g., overlapping statistical interpretations in Sections 4.3 and 4.4 of the original manuscript) were removed. Additionally, the Discussion section has been restructured as an independent chapter to strengthen logical coherence. Collectively, these revisions reduced the combined Results length by 34%, prioritized novel insights, and maintained data integrity through supplementary archiving. We believe the revised manuscript now offers a clearer narrative while preserving scientific rigor. The revised parts are:

"**4.3 Responses of indexes in feedback loops with different clusters of IWDPs in a reservoirs group**

4.3.1 Responses of indexes in feedback loops without and with IWDPs

To analyse the feedback loops of SHE nexus without (i.e., $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) across the multiple temporal (i.e., monthly, seasonal and annual) and spatial (i.e., five reservoirs) scales, the differences of indexes (i.e., *LRR_1*, *LRR_2*, *LRR_3* for log response ratio of the S, H, and E component) between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ or between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ are determined at the time scales in a reservoirs group. Monthly differences are presented in Figures 7 and 8, while the seasonal results are shown in Figure 9. Corresponding annual-scale results can be found in Supplementary material Tables S1 and S2.

If there was no IWDPs and S-Priority was set, both the mean values of LRR_2 (i.e., -0.06, -0.09, -0.07, -0.10, and -0.02) and the mean values of LRR_3 (i.e., -0.27, -0.54, -0.07, -0.20, and -0.61) in five reservoirs remain below 0 as shown in Figure 7 (a). As there are a large number of negative values of LRR_2 in all reservoirs with S-Priority as shown in Figure 7 (a-1), the hydropower generation is found to be reduced in most months. However, there are still some positive values of LRR_2 in reservoirs. XL reservoir shows a higher occurrence of positive values of LRR_2 when there is abundant water such as July in 2007 and September in 2017 (i.e., 0.15 and 0.12, respectively). As shown in Figure 7 (a-2), all the five reservoirs exhibit a negative LRR_3 in all months. The value of LRR_3 for the DJK reservoir is closest to 0. The smallest mean values of LRR_3 for the XL and AK reservoirs are -0.61 and -0.54, respectively. The reduction of ecological flow satisfaction rates for DJK is smaller than those for other reservoirs due to its effective regulating. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. There are also differences between the results of LRR_2 and LRR_3, the range of LRR_3 value is wider, while its of LRR_2 are relatively concentrated and closer to 0.

If there was no IWDPs and H-Priority was set, the values of LRR_1 for all five reservoirs are less than zero in most months, and the mean values of LRR_3 exceed zero as shown in Figure 7 (b). The water supply for HJX, DJK, and XL is significantly decreased, with their mean values of LRR_1 are -18.35, -11.55, and -7.72, while the water supply for AK and WFZ has slight reductions (i.e., the mean values of LRR_1 are -0.17 and -0.23, respectively) as shown in Figure 7 (b-1). There are two positive values of LRR_1 for DJK reservoir occurring in January 2010 and in July 2011 (i.e., 20.32 and 0.19, respectively). In January 2010, higher water storage resulting from H-Priority increases water availability. With H-Priority, reservoirs with regulating capacity will store more water, leading to increased generation flow during dry periods (Zhang et al., 2014). While in July 2011, an increase in the discharge flow from the upstream reservoir increase the water supply. As shown in Figure 7 (b-2), the values of ecological flow satisfaction rates for HJX reservoir experiences a significant increase, with a mean value of LRR_3 of 0.92, followed by XL and AK (i.e., their mean values of LRR_3 are 0.40 and 0.14). DJK and its downstream reservoirs have negative values of LRR_3 in abundant water months because of the increased storage capacity and the reduced inflow into DJK. The water resource allocation of DJK affects the SHE system of downstream reservoirs. There are also differences between the results of LRR_1 and LRR_3, the values of LRR_3 are relatively closer to 0 than those of LRR_1. The feedbacks on S are more pronounced than on E. The extreme values of LRR_1 and LRR_3 are always found in months with small water flow in river but with high-water supply demand.

If there was no IWDP and E-Priority was set, the mean values of LRR_1 for HJX, DJK, and XL reservoirs are -6.59, -1.74, and -5.64 as shown in Figure 7 (c-1). However, the values of LRR_1 for AK and WFZ are almost zero because their increased discharge water from upstream are prioritized to be released for hydropower generation, and no excess is for water supply. Thus, the prioritizing E has less impact on S for reservoirs due to the main function of hydropower generation. DJK and XL exhibit some positive values of LRR_1 because the increased inflows from upstream. Therefore, the increased inflow to upstream reservoirs alleviates the negative feedbacks of E on S in downstream reservoirs. As shown in Figure 7 (c-2), the mean values of LRR_2 for HJX, AK, DJK, and WFZ reservoirs are 0.13, 0.05, 0.02, and 0.04. While XL has a negative mean value of LRR_2 at -0.06, it experiences more decreases in hydropower generation primarily due to its smaller installed capacity (Zhang, 2008). Negative values of LRR_2 can be found in abundant water months. The ranges of LRR_1 and LRR_2 are also different. The former one is wide while the other one is narrow and their values are closer to zero.

The differences between the $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios were determined to analyse the feedback loops with IWDPs as shown in Figure 8 (a), (b), and (c). It can be found that the positive or negative signs of the LRR_n values with IWDPs are consistent with those without IWDPs. If there are IWDPs and S-Priority was set, the mean value of LRR_3 for XL shows an increase while all the values of LRR_2

and LRR_3 for other four reservoirs are lower than those without IWDPs as shown in Figure 8 (a) and Figure 7 (a). The mean values of LRR_2 with IWDPs for the five reservoirs are -0.13, -0.11, -0.17, -0.21, and -0.07, and the mean values of LRR_3 are -0.91, -0.75, -1.25, -1.13, and -0.29. And DJK reservoir get more extreme values due to the impacts of IWDPs. The values of LRR_2 with IWDPs are lower than -0.45 (i.e., the minimum value of LRR_2 without IWDPs) in 6 % of the months while the values of LRR_3 are lower than -1.40 (i.e., the minimum value of LRR_3 without IWDPs) in 8 % of the months. It is evident that IWDPs strengthens the negative feedbacks of the S component on the other two components in HJX, AK, DJK and WFZ, while IWDPs weaken negative feedbacks of S on E for XL. As shown in Figure 8 (b-1), If there were IWDPs and H-Priority was set, the mean values of LRR_1 for HJX, AK, and XL reservoirs significantly decrease to -18.78, -0.78, and -12.24, but the mean value of LRR_1 for DJK reservoir are increased by 3.49 due to IWDPs. The differences of water supply between the $S_{3\text{-}2\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios remain negligible despite further reductions in water supply with H-Priority. As shown in Figure 8 (b-2), The values of LRR_3 for HJX, AK, DJK, and WFZ increase further than them in Figure 7 (b-2) without IWDPs. The values of LRR_3 for XL decrease slightly due to the positive feedbacks of the H component on E and the IWDPs impacts. As shown in Figure 8 (c-1), If there were IWDPs and E-Priority was set, the mean values of LRR_1 for HJX and XL decrease by 5.11 and 2.77, respectively. And the mean values of LRR_1 for AK and WFZ remain at almost zero, while the mean value of LRR_1 for DJK increases by 0.26 with IWDPs compared to without IWDPs. As shown in Figure 8 (c-2), the mean values of LRR_2 for five reservoirs increase by 0.18, 0.04, 0.03, 0.02 and 0.01 with IWDPs compared to without IWDPs. The positive feedbacks of E component on H are strengthened, while the negative feedbacks are weakened.

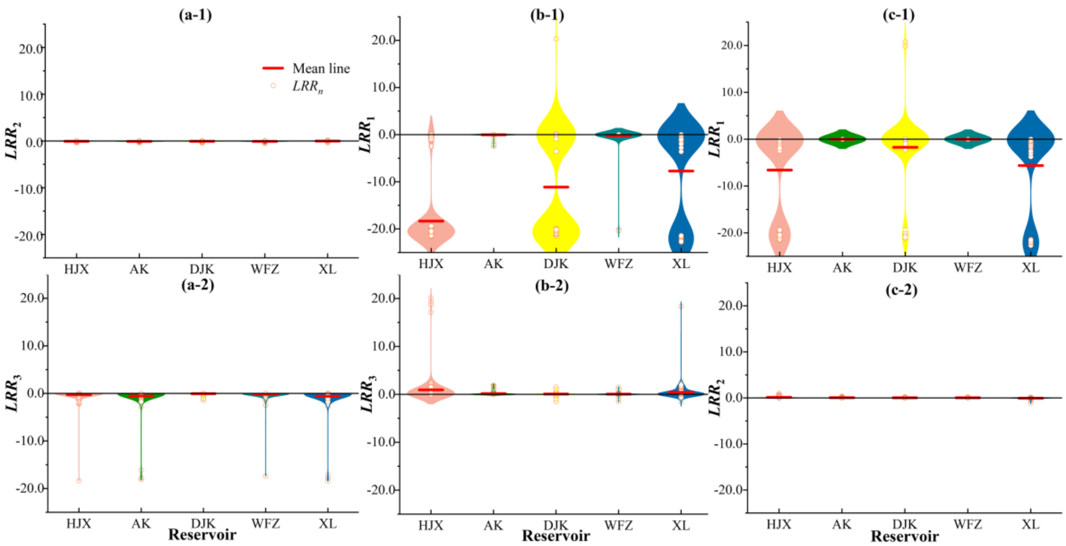

Figure 7. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) without IWDPs (i.e., between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}2}$ and $S_{0\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

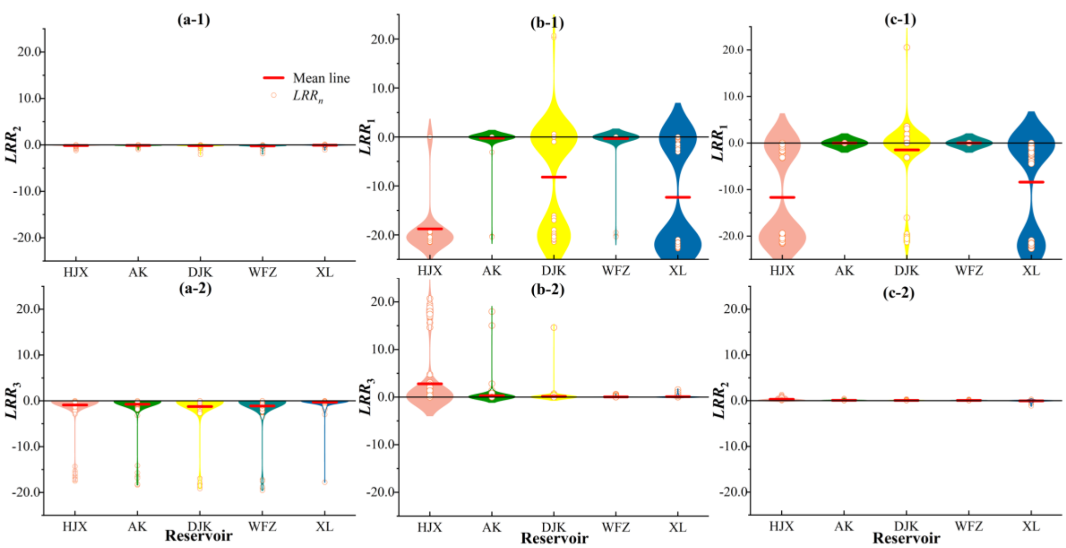

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}2}$ and $S_{3\text{-}4\text{-}2}$).

In this study, March, April, May are taken as spring, June, July and August are taken as summer, September, October and November are taken as autumn, and December, January and February of the following year are taken as winter. The values of LRR_n for five reservoirs at seasonal scale are shown in Figure 9. If there was no IWDP but S-Priority was still set, positive values of LRR_2 for HJX and XL are found in summer, while all negative values of LRR_2 for other three reservoirs are found in all seasons as shown in Figure 9 (a). The mean values of LRR_3 for the five reservoirs are -0.12, -0.11, -0.02, -0.02, and -0.67, and all values of LRR_3 are negative in all seasons. If there were IWDPs and S-Priority was set, the mean value of LRR_3 for XL increases while the values of LRR_2 and LRR_3 for other four reservoirs are less than those without IWDPs as shown in Figure 9 (b). These negative values indicate that IWDPs significantly strengthen the negative feedbacks of the S component on H and E in reservoirs and weaken negative feedback of S on E in XL. If there was no IWDPs but H-Priority was set, negative values of LRR_1 and positive values of LRR_3 are found for the five reservoirs as shown in Figure 9 (c). For HJX, DJK and XL reservoirs, the negative values of LRR_1 are found in winter while zero values of LRR_1 are found in summer. The mean values of LRR_1 are close to zero in AK and WFZ reservoirs in all seasons. Positive values of LRR_3 are smaller in HJX, AK, DJK and WFZ reservoirs, while those in XL are greater in winter with a low flow. If there were IWDPs and H-Priority was set, the values of LRR_1 for all reservoirs are lower than those without IWDPs as shown in Figure 9 (d). Values of LRR_3 for HJX, AK, DJK and WFZ reservoirs are greater than those without IWDPs, while those for XL are close to zero. If there was no IWDPs and E-Priority was set, negative values of LRR_1 for HJX, DJK, WFZ and XL reservoirs can be found in almost every season, while zero values of LRR_1 for AK reservoir can be found in all seasons. As shown in Figure 9 (e), two positive values of LRR_1 for DJK are found in spring and in winter of 2007 due to the increased discharge water from AK reservoir. The positive values of LRR_2 for the five reservoirs are found in most seasons, but few negative values are found in summer. If there were IWDPs and E-Priority was set, more positive values of LRR_2 for five reservoirs and less negative values of LRR_1 are found in HJX, DJK, WFZ and XL reservoirs.

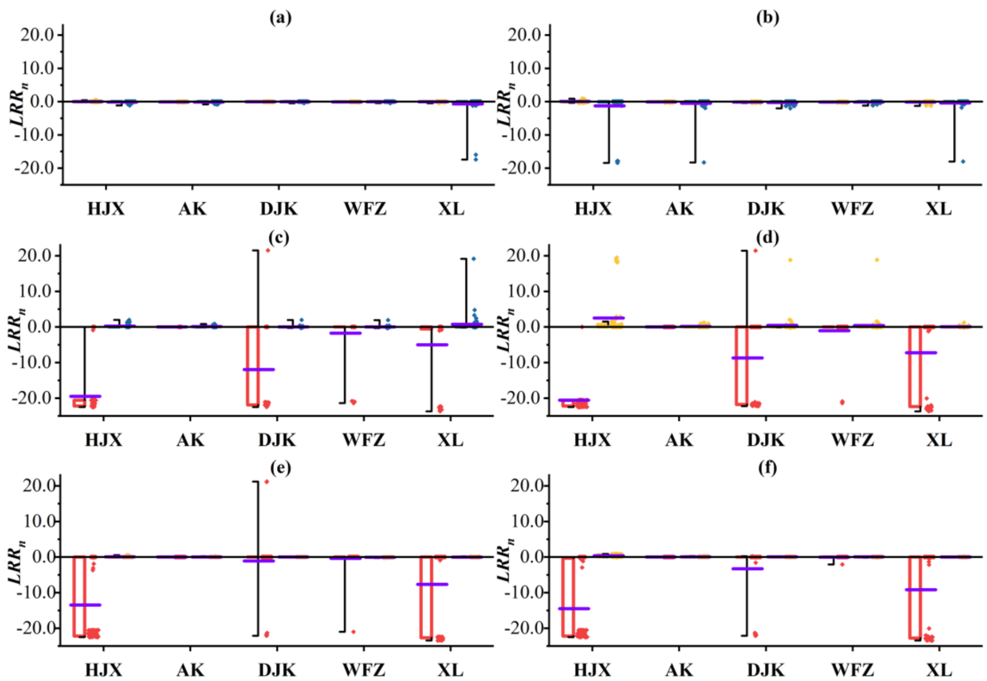

Figure 9. ***LRR_n*** **with different highest priorities (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{m\text{-}4\text{-}n}$) at the seasonal scale: (a) and (b) are *LRR_n* with the highest priority in S without IWDPs (i.e., between $S_{0\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{3\text{-}4\text{-}n}$), (c) and (d) are *LRR_n* with the highest priority in H without IWDPs (i.e., between $S_{0\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}2\text{-}c}$ and $S_{3\text{-}4\text{-}n}$). (e) and (f) are *LRR_n* with the highest priority in E without IWDPs (i.e., between $S_{0\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{3\text{-}4\text{-}n}$).**

4.3.2 Responses of indexes in feedback loops with only water donation, water receiving, and both donation and receiving

To analyse the impacts of only water donation (i.e., $S_{1\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), only water receiving (i.e., $S_{2\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), and both donation and receiving (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) on feedback loops of SHE nexus across the multiple temporal and spatial scales, the differences of indexes between $S_{m\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ are determined in a reservoirs group. The results of the monthly differences are shown in Figure 10-12. The seasonal results are shown in Figure 13. Corresponding annual-scale results can be found in Supplementary material Tables S3 -S5.

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 for five reservoirs are negative and lower than those without IWDPs as shown in Figure 10 (a-1) and (a-2). More small negative values are found in DJK, water donation has negative impacts on the negative feedback of S on H and E for five reservoirs. If there was only water receiving and S-Priority was set, values of LRR_2 and LRR_3 for HJX and AK are the same as those without IWDPs. Meanwhile, for DJK, WFZ, and XL, the values are close to zero. XL exhibits a lot of positive values of LRR_3 as shown in Figure 10 (b-1) and (b-2). If there were both water donation and receiving, the mean values of LRR_2 for five reservoirs are -0.59, -0.26, -0.48, -0.47 and -0.09, and mean values of LRR_3 for five reservoirs are -6.12, -1.50, -2.01, -1.60 and 0.14 as shown in Figure 10 (c-1) and (c-2). There are negative impacts on negative feedbacks of S on H and E for HJX, AK, DJK and WFZ and positive impacts of the negative feedbacks of S on E for XL.

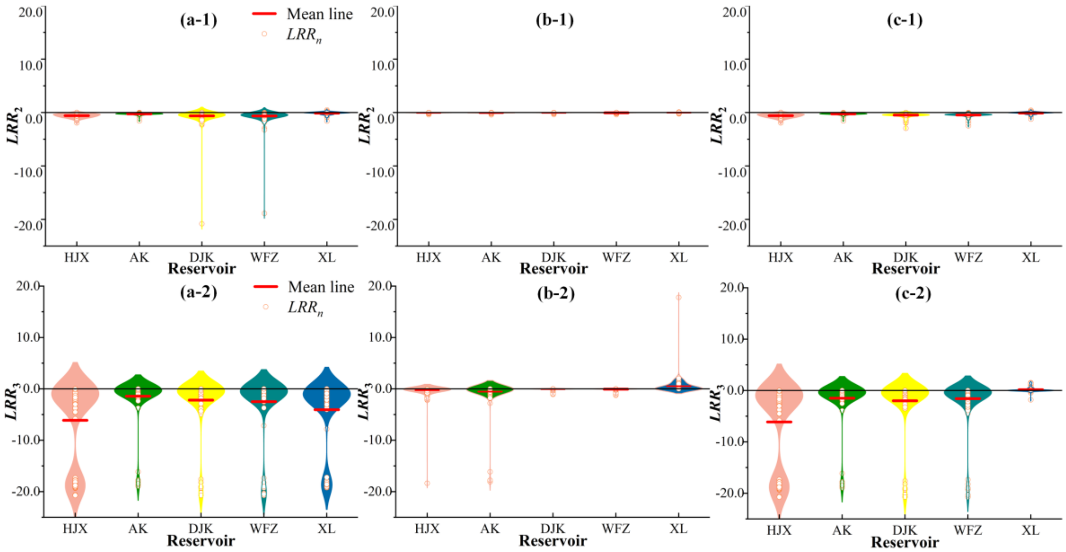

Figure 10. LRR_n values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are LRR_2 and LRR_3 when there is only water donation (i.e., between $S_{1\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are LRR_2 and LRR_3 when there is only water receiving (i.e., between $S_{2\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are LRR_2 and LRR_3 when there are both donation and receiving (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 for five reservoirs are lower than those without IWDPs as shown in Figure 11 (a-1) and (a-2). Negative values of LRR_3 for five reservoirs are found in low flow months such as November, December and January. Thus, water donation is found to have negative impacts on feedbacks of H on S and E, especially in low flow months. If there was only water receiving and H-Priority was set, values of LRR_1 and LRR_3 for DJK, WFZ and XL are greater than those without IWDPs as shown in Figure 11 (b-1) and (b-2). Water receiving has positive impacts on feedbacks of H on S and E. If there were both water donation and receiving and H-Priority was set, the mean values of LRR_1 and LRR_3 for DJK, WFZ and XL are still lower than those without IWDPs. And the mean value of LRR_3 for XL is greater than those without IWDPs as shown in Figure 11 (c-1) and (c-2).

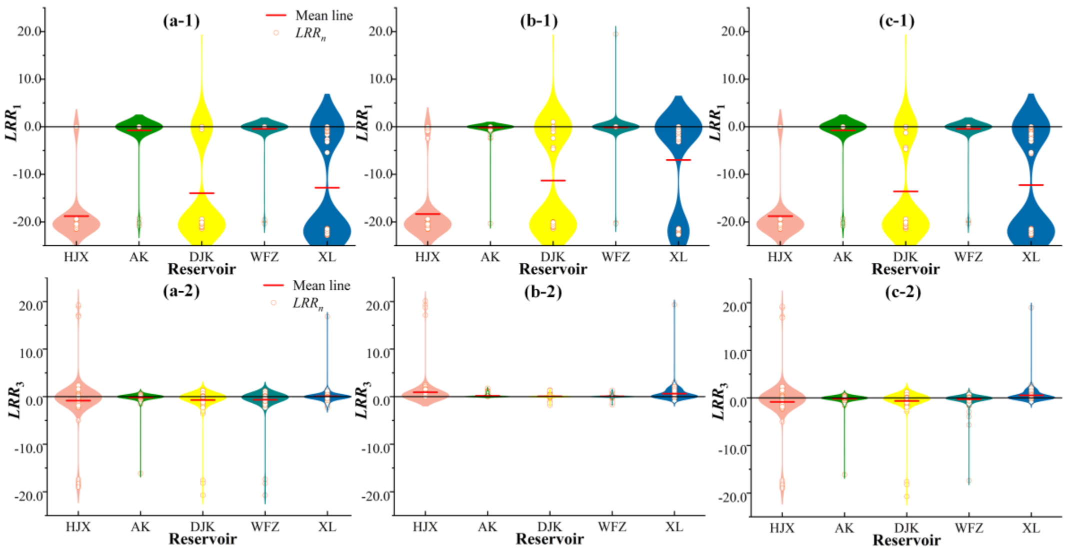

Figure 11. ***LRR_n* values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR_2* and *LRR_3* when there is only water donation (i.e., between $S_{1\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR_2* and *LRR_3* when there is only water receiving (i.e., between $S_{2\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR_2* and *LRR_3* when there are both donation and receiving(i.e., between $S_{3\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

If there was only water donation and E-Priority was set, then values of LRR_1 and LRR_2 for five reservoirs are shown in Figure 12 (a-1) and (a-2). The mean values of LRR_1 for these five reservoirs are -11.70, 0, -7.23, -0.22, and -9.14, respectively. And the mean values of LRR_2 are -0.16, -0.07, -0.29, -0.30, and -0.08. All these values are lower than the those without IWDPs. Different from the values of LRR_n without IWDPs, there are no positive values of LRR_1 for DJK and few positive values of LRR_2 for five reservoirs due to the decreased inflows from upstream with water donation. If there was only water receiving and E-Priority was set, values of LRR_1 and LRR_2 for DJK, WFZ and XL are greater than those without IWDPs. If there were both water donation and receiving and E-Priority was set, the mean values of LRR_1 and LRR_2 for DJK, WFZ and XL are still lower than those without IWDPs as shown in Figure 12 (c-1) and (c-2).

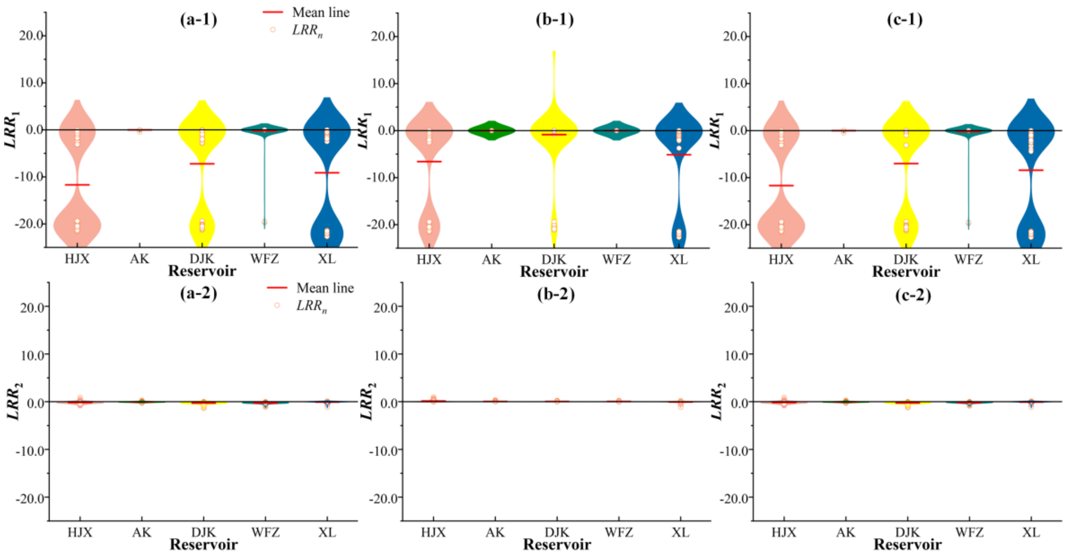

Figure 12. *LRR$_n$* values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR*$_1$ and *LRR*$_2$ when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR*$_1$ and *LRR*$_2$ when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR*$_1$ and *LRR*$_2$ when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 as shown in Figure 13(a-1) are lower than those without IWDPs in all seasons as shown in Figure 9 (a). If there was only water receiving and S-Priority was set, mean values of LRR_2 and LRR_3 for DJK, WFZ and XL (i.e., -0.04, -0.05, -0.03 and -0.01, 0, 0.70) as shown in Figure 13 (a-2) are all greater than those without IWDPs. If there were both water donation and receiving and S-Priority was set, mean values of LRR_2 for five reservoirs decrease by 0.33, 0.12, 0.34, 0.36 and 0.07 compared to those without IWDPs. Mean values of LRR_3 for HJX, AK, DJK and WFZ decrease by 3.69, 0.52, 0.72, 0.55, and its for XL increases by 0.89 compared to those without IWDPs as shown in Figure 13 (a-3). If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 as shown in Figure 13(b-1) are lower than those without IWDPs. Water donation has negative impacts on feedbacks of H on S for HJX, DJK and XL. If there was only water receiving and H-Priority was set, mean values of LRR_2 for DJK, WFZ and XL increase by 0.73, 0.32 and 0.73, and mean values of LRR_3 for DJK, WFZ and XL increase by 0, 0.01 and 0.01 compared to those without IWDPs. If there were both water donation and receiving and H-Priority was set, mean values of LRR_2 for five reservoirs are -20.58, 0, -14.49, -1.75, -8.07, and mean values of LRR_3 for five reservoirs are 0.01, 0.01, -0.05, -0.02 and 0.68 as shown in Figure 13 (b-3). If there was only water donation and E-Priority was set, it can be found that values of LRR_1 and LRR_2 in all seasons are lower than those without IWDPs as shown in Figure 13(c-1). Mean values of LRR_1 for five reservoirs decrease by 14.58, 0.01, 9.39, 1.04 and 10.38, and mean values of LRR_2 for five reservoirs decrease by 0.05, 0.04, 0.28, 0.33 and 0.22. If there was only water receiving and E-Priority was set, mean values of LRR_1 and LRR_2 for DJK, WFZ and mean values of LRR_1 for XL are greater than those without IWDPs, while mean values of LRR_2 for XL get an increase as shown in Figure 13 (c-2). If there were both water donation and receiving and E-Priority was set, Values of LRR_1 and LRR_2 for DJK and WFZ and values of LRR_1 for XL as shown in Figure 13 (c-3) are greater than those with only water donation, while lower than those without IWDPs. While values of LRR_2 for XL are greater than those without IWDPs because of the reduced spilled water. Therefore, values of LRR_n at seasonal scale demonstrate a consistent conclusion with those at the monthly scale. Moreover, the values of LRR_n are relatively stable in summer, while they change greatly in winter at seasonal scale. The impacts of IWDPs on SHE nexus are more significant in low flow seasons.

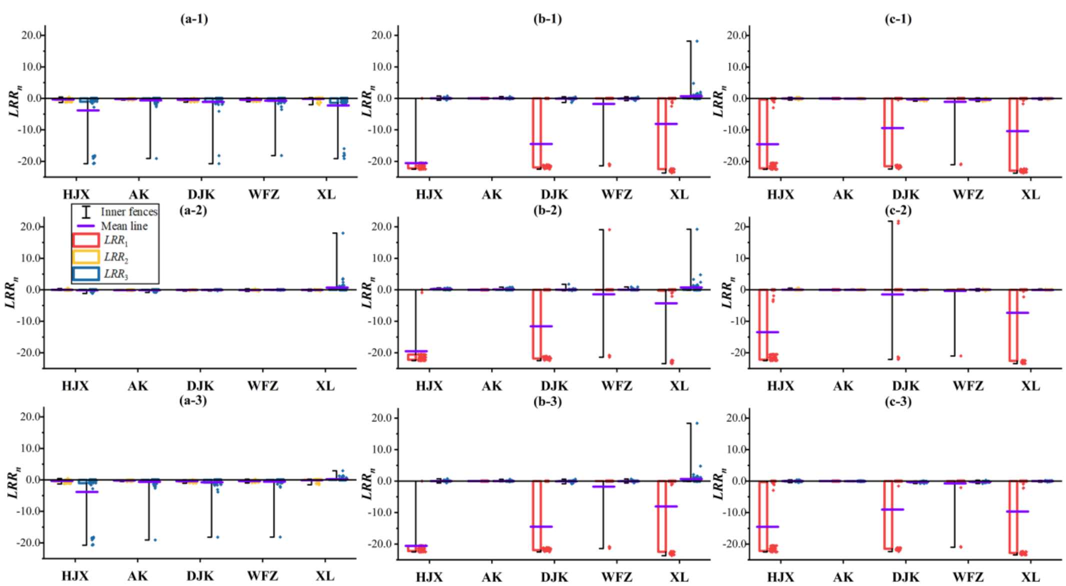

Figure 13. *LRR*$_n$ values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are *LRR*$_n$ when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

4.4 Responses of the three components with IWDPs

To identify the impacts of IWDPs on S, H and E components in a reservoirs group, differences between indexes without IWDPs and with IWDPs (i.e., $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) are determined. Negative values of LRR_1 for five reservoirs are found in all months, mean values of LRR_1 for five reservoirs are 0, 0, -5.54, -0.22 and -0.01 as shown in Figure 14 (a). It is found that values of LRR_1 for DJK are significantly smaller than those for other reservoirs. Mean values of LRR_2 for five reservoirs are -0.46, -0.15, -0.32, -0.26 and -0.03 as shown in Figure 14 (b). Positive values of LRR_3 are found in XL and negative values of LRR_3 are found in HJX, AK, DJK and WFZ in all months, mean values of LRR_3 for five reservoirs are -5.21, -0.75, -0.76, -0.47 and 0.43 as shown in Figure 14 (c).

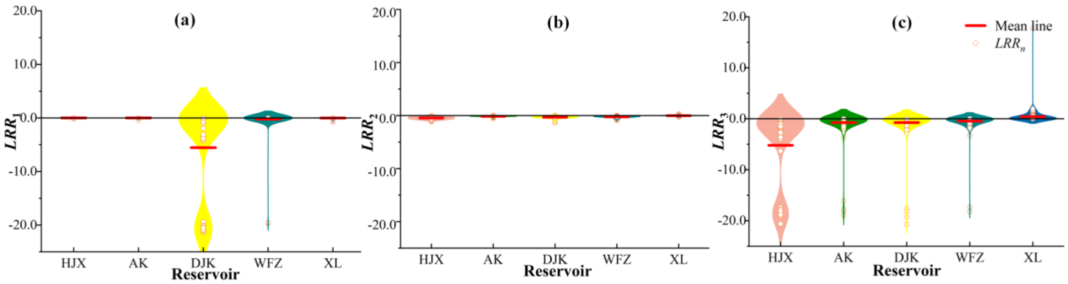

Figure 14. the differences of indexes (i.e., (a) LRR_1, (b) LRR_2, (c) LRR_3 for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale.

5 Discussion

The proposed framework reveals significant negative feedbacks of the water supply (S) on both hydropower generation (H) and environment conservation (E), as evidenced by reductions in hydropower generation (negative LRR_2 in Figure 7 (a-1)) and ecological flow satisfaction rate (negative LRR_2 in Figure 7 (a-2)) with S-Priority. The negative feedbacks of the S component on E are more pronounced than those on H, as evidenced by the wider range of variation in LRR_3 values compared to LRR_2 values. These findings are consistent with previous studies on the SHE nexus (Chen et al.,2018; Khalkhali et al., 2018). It has been found that there are a few positive feedbacks between S and H in abundant water months even the spilled water leads to a reduction in hydropower generation (Jiang et al., 2018). Thus, the increasing water storage or increasing water supply still can ensure hydropower generation. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. And Gao et al. (2023) find that the higher water supply demand, the lower ecological flow left in river. The environment conservation of downstream river systems is critically influenced by upstream water supply decisions (Gupta, 2008). Contrary to the unidirectional positive nexus between hydropower generation and environment conservation proposed by Wei et al. (2022), our study reveals bidirectional feedbacks of H and E, aligning with Wu et al. (2021). The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir, Zhang et al., 2008) even in abundant water months, particularly. The increased flows for hydropower generation alleviates the pressure of ecological damage in river. However, the more flows for hydropower generation from the reservoir, the less supplied amount of available water resources (Doummar et al., 2009), and leads to negative impacts on the S component. The feedbacks of the H on S are more pronounced than on E, according to the wider range of variation in LRR_1 values compared to LRR_3 values. Negative feedbacks of the E component on S for reservoirs has been found in the scenario that main function is water supply while no significant effect on reservoirs has been found in the scenario that main function is hydropower generation (negative LRR_1 in Figure 7 (c-1)). There are both negative and positive feedbacks of the E component on H while the negative feedbacks are grown in abundant water months. Feedbacks of the E component on S are stronger than those on H, according to the values of LRR_n. The negative feedbacks between S and H, and between S and E are strong in low flow months due to the high-water supply demand. More competitions for water can be found among S, H and E in low flow months, and their negative feedbacks of the SHE nexus have found to be strengthened (Wu et al., 2021). Feedback loops of SHE nexus in reservoirs with regulation function (e.g., AK and DJK) remain stable under the varying inflow conditions. These reservoirs reasonably allocate water among S, H and E components to prevent strengthening of negative feedbacks in low flow months. Furthermore, increasing hydropower generation flow might have impacts on downstream water quality and biodiversity (Botelho et al., 2017; Martinez et al., 2019), the feedbacks of H on E are enhanced.

Inter-basin water diversion projects (IWDPs) have negative impacts on the regional water supply from DJK and upstream reservoirs with negative LRR_1, consistent with Hong et al. (2016)

and Ouyang et al. (2018). And all reservoirs have reduced their hydropower generation, but there are positive impacts on H in abundant water months with positive LRR_2 in Figure 14 (b). Many studies have highlighted the negative impacts of IWDPs on hydropower generation (Yang, et al., 2023), but the positive impacts are less frequently discussed. With the water donation for the Han-to-Wei Water Diversion Project, the Middle Route of the South-to-North Water Diversion Project and the Northern Hubei Water Resources Allocation Project, multiple algal bloom events occurred in the downstream of HRB (Tian et al., 2022), and the water donation had a significant negative impact on the environment conservation of the basin. Water receiving from the Three Gorges Reservoir to Hanjiang River are not compensate for all their negative impacts, and water receiving from the Changjiang-to-Hanjiang River Water Diversion Project benefits environment conservation for XL. It is evident that IWDPs significantly alter the feedback loops of the SHE nexus by modifying water availability. As IWDPs export or import water to or from an area, the amount of available water has to be altered. It can prompt a redistribution and re-planning of the available water (Li, et al., 2014). And the redistribution and re-planning can significantly impact on feedback loops of SHE nexus (Feng, et al., 2019). Although strong responses occur in feedback loops of SHE nexus, its positive or negative nature of feedback among these components remains stable with impacts of IWDPs. Thus, the redistribution and re-planning of available water can not alter their competitions and collaborations among the components of the SHE nexus. It is evident that water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E while receiving water has positive impacts on all these feedbacks. Water donation results in a reduction of available water (Mok et al., 2015; Wu et al., 2022) and leads to lower flow. More competition for water can be found among S, H and E, and negatively impacts on the feedbacks. Less competition is found among S, H and E in water receiving areas, and it has positive impacts on their feedbacks. The persistent feedback polarity with IWDPs suggests that simply increasing water supply (e.g., via compensation donations like Three Gorges-to-Hanjiang) cannot resolve inherent SHE conflicts—instead, adaptive allocation rules that account for these stable feedback patterns are needed.

The consistency in the signs of mean LRR_n values across seasonal as shown in Figure 9 and 13 and annual scales as shown in Supplementary material Table S1-S5 with those at the monthly scale indicates an inherent similarity and stability in SHE nexus feedback loops over different temporal resolutions. Compared with the values of LRR_n at monthly scale, the values at the seasonal scale show its stronger periodic variations. Based on the variations in LRR_n and the mathematical implications of LRR_1, LRR_2, and LRR_3, this study found that these periodic variations align closely with the runoff variations, and the temporal and spatial variations in feedback loops are primarily attributed to variations in runoff. The wavelet transform analysis has also been applied in the runoffs for HJX, AK, DJK, WFZ, and XL dam sites. And the results are in consisted with that in Hutuo River Basin (Xu et al., 2018), the periodic variations have been found at the seasonal scale. The LRR_n values at the seasonal scale can help analyze the variations in periodic feedback loops. Different from the monthly or seasonal scales, results at the annual scale reveal the long-term trends and periodic variations in the inter-annual and spatial trends of the SHE nexus from a macro perspective. The impacts of reservoir operation and the regulation on SHE nexus can be clearly simulated and observed at the monthly scale, so the immediate changes in the nexus at monthly scale can provide information for short-term decision-making in reservoirs."

Reference Number: hess-2024-399-EC

RESPONSES TO EDITOR'S COMMENTS

We would like to express our sincere appreciation for your professional and insightful remarks. The comments are valuable and helpful for us to improve the quality of the manuscript. All the concerns raised have been carefully treated and an itemized reply to the editor's comments is presented in the revision files.

<u>Point #1</u>

COMMENT: *I am generally happy about the comments made by both reviewers. One suggestion by reviewer 2, i.e. to make the results section more concise, was in fact not honoured the authors, as I could not detect any significant shortening of the results section.*

RESPONSE: We sincerely appreciate the reviewer #2's constructive feedback to enhance the conciseness of the manuscript. We apologize for not shortening this section more substantially in our initial revision – this was an oversight on our part. To address this, we have rigorously streamlined the Results and Discussion sections by retaining monthly and seasonal-scale analyses in the main text (as they directly address the core research objectives) while relocating annual-scale results to Supplementary material for transparency. Redundant descriptions of similar trends across timescales (e.g., overlapping statistical interpretations in Sections 4.3 and 4.4 of the original manuscript) were removed. Additionally, the Discussion section has been restructured as an independent chapter to strengthen logical coherence. Collectively, these revisions reduced the combined Results length by 34%, prioritized novel insights, and maintained data integrity through supplementary archiving. We believe the revised manuscript now offers a clearer narrative while preserving scientific rigor. The revised parts are:

"**4.3 Responses of indexes in feedback loops with different clusters of IWDPs in a reservoirs group**

4.3.1 Responses of indexes in feedback loops without and with IWDPs

To analyse the feedback loops of SHE nexus without (i.e., $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) across the multiple temporal (i.e., monthly, seasonal and annual) and spatial (i.e., five reservoirs) scales, the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the

S, H, and E component) between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ or between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ are determined at the time scales in a reservoirs group. Monthly differences are presented in Figures 7 and 8, while the seasonal results are shown in Figure 9. Corresponding annual-scale results can be found in Supplementary material Tables S1 and S2.

If there was no IWDPs and S-Priority was set, both the mean values of LRR_2 (i.e., -0.06, -0.09, -0.07, -0.10, and -0.02) and the mean values of LRR_3 (i.e., -0.27, -0.54, -0.07, -0.20, and -0.61) in five reservoirs remain below 0 as shown in Figure 7 (a). As there are a large number of negative values of LRR_2 in all reservoirs with S-Priority as shown in Figure 7 (a-1), the hydropower generation is found to be reduced in most months. However, there are still some positive values of LRR_2 in reservoirs. XL reservoir shows a higher occurrence of positive values of LRR_2 when there is abundant water such as July in 2007 and September in 2017 (i.e., 0.15 and 0.12, respectively). As shown in Figure 7 (a-2), all the five reservoirs exhibit a negative LRR_3 in all months. The value of LRR_3 for the DJK reservoir is closest to 0. The smallest mean values of LRR_3 for the XL and AK reservoirs are -0.61 and -0.54, respectively. The reduction of ecological flow satisfaction rates for DJK is smaller than those for other reservoirs due to its effective regulating. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. There are also differences between the results of LRR_2 and LRR_3, the range of LRR_3 value is wider, while its of LRR_2 are relatively concentrated and closer to 0.

If there was no IWDPs and H-Priority was set, the values of LRR_1 for all five reservoirs are less than zero in most months, and the mean values of LRR_3 exceed zero as shown in Figure 7 (b). The water supply for HJX, DJK, and XL is significantly decreased, with their mean values of LRR_1 are -18.35, -11.55, and -7.72, while the water supply for AK and WFZ has slight reductions (i.e., the mean values of LRR_1 are -0.17 and -0.23, respectively) as shown in Figure 7 (b-1). There are two positive values of LRR_1 for DJK reservoir occurring in January 2010 and in July 2011 (i.e., 20.32 and

0.19, respectively). In January 2010, higher water storage resulting from H-Priority increases water availability. With H-Priority, reservoirs with regulating capacity will store more water, leading to increased generation flow during dry periods (Zhang et al., 2014). While in July 2011, an increase in the discharge flow from the upstream reservoir increase the water supply. As shown in Figure 7 (b-2), the values of ecological flow satisfaction rates for HJX reservoir experiences a significant increase, with a mean value of LRR_3 of 0.92, followed by XL and AK (i.e., their mean values of LRR_3 are 0.40 and 0.14). DJK and its downstream reservoirs have negative values of LRR_3 in abundant water months because of the increased storage capacity and the reduced inflow into DJK. The water resource allocation of DJK affects the SHE system of downstream reservoirs. There are also differences between the results of LRR_1 and LRR_3, the values of LRR_3 are relatively closer to 0 than those of LRR_1. The feedbacks on S are more pronounced than on E. The extreme values of LRR_1 and LRR_3 are always found in months with small water flow in river but with high-water supply demand.

If there was no IWDP and E-Priority was set, the mean values of LRR_1 for HJX, DJK, and XL reservoirs are -6.59, -1.74, and -5.64 as shown in Figure 7 (c-1). However, the values of LRR_1 for AK and WFZ are almost zero because their increased discharge water from upstream are prioritized to be released for hydropower generation, and no excess is for water supply. Thus, the prioritizing E has less impact on S for reservoirs due to the main function of hydropower generation. DJK and XL exhibit some positive values of LRR_1 because the increased inflows from upstream. Therefore, the increased inflow to upstream reservoirs alleviates the negative feedbacks of E on S in downstream reservoirs. As shown in Figure 7 (c-2), the mean values of LRR_2 for HJX, AK, DJK, and WFZ reservoirs are 0.13, 0.05, 0.02, and 0.04. While XL has a negative mean value of LRR_2 at -0.06, it experiences more decreases in hydropower generation primarily due to its smaller installed capacity (Zhang, 2008). Negative values of LRR_2 can be found in abundant water months. The ranges of LRR_1 and LRR_2 are also different. The former one is wide while the other one is narrow and their values are closer to zero.

The differences between the $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios were determined to analyse the feedback loops with IWDPs as shown in Figure 8 (a), (b), and (c). It can be found that the positive or negative signs of the LRR_n values with IWDPs are consistent with those without IWDPs. If there are IWDPs and S-Priority was set, the mean value of LRR_3 for XL shows an increase while all the values of LRR_2 and LRR_3 for other four reservoirs are lower than those without IWDPs as shown in Figure 8 (a) and Figure 7 (a). The mean values of LRR_2 with IWDPs for the five reservoirs are -0.13, -0.11, -0.17, -0.21, and -0.07, and the mean values of LRR_3 are -0.91, -0.75, -1.25, -1.13, and -0.29. And DJK reservoir get more extreme values due to the impacts of IWDPs. The values of LRR_2 with IWDPs are lower than -0.45 (i.e., the minimum value of LRR_2 without IWDPs) in 6 % of the months while the values of LRR_3 are lower than -1.40 (i.e., the minimum value of LRR_3 without IWDPs) in 8 % of the months. It is evident that IWDPs strengthens the negative feedbacks of the S component on the other two components in HJX, AK, DJK and WFZ, while IWDPs weaken negative feedbacks of S on E for XL. As shown in Figure 8 (b-1), If there were IWDPs and H-Priority was set, the mean values of LRR_1 for HJX, AK, and XL reservoirs significantly decrease to -18.78, -0.78, and -12.24, but the mean value of LRR_1 for DJK reservoir are increased by 3.49 due to IWDPs. The differences of water supply between the $S_{3\text{-}2\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios remain negligible despite further reductions in water supply with H-Priority. As shown in Figure 8 (b-2), The values of LRR_3 for HJX, AK, DJK, and WFZ increase further than them in Figure 7 (b-2) without IWDPs. The values of LRR_3 for XL decrease slightly due to the positive feedbacks of the H component on E and the IWDPs impacts. As shown in Figure 8 (c-1), If there were IWDPs and E-Priority was set, the mean values of LRR_1 for HJX and XL decrease by 5.11 and 2.77, respectively. And the mean values of LRR_1 for AK and WFZ remain at almost zero, while the mean value of LRR_1 for DJK increases by 0.26 with IWDPs compared to without IWDPs. As shown in Figure 8 (c-2), the mean values of LRR_2 for five reservoirs increase by 0.18, 0.04, 0.03, 0.02 and 0.01 with IWDPs compared to without IWDPs. The positive feedbacks of E component on H are strengthened, while the negative feedbacks are weakened.

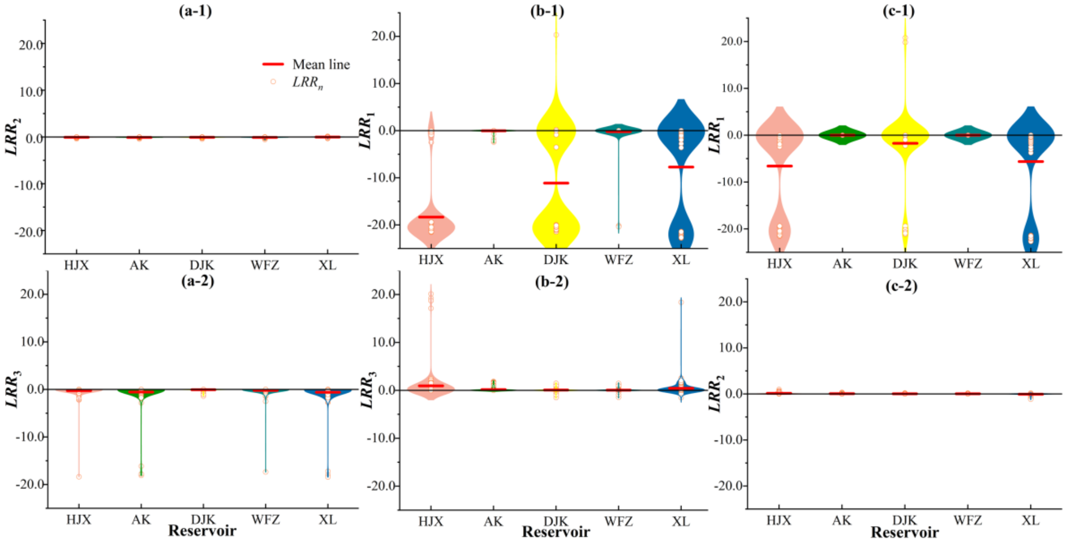

Figure 7. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) without IWDPs (i.e., between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}2}$ and $S_{0\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

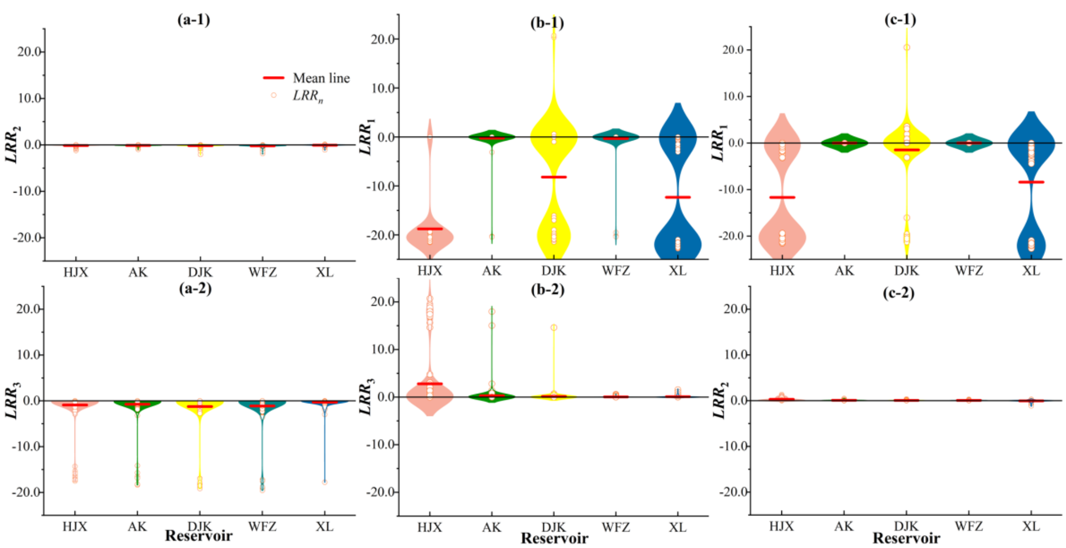

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) at the monthly scale: (a-1) is LRR_2 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$), (a-2) is LRR_3 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (b-1) is LRR_1 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (b-2) is LRR_3 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (c-1) is LRR_1 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (c-2) is LRR_2 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}2}$ and $S_{3\text{-}4\text{-}2}$).

In this study, March, April, May are taken as spring, June, July and August are taken as summer, September, October and November are taken as autumn, and December, January and February of the following year are taken as winter. The values of LRR_n for five reservoirs at seasonal scale are shown in Figure 9. If there was no IWDP but S-Priority was still set, positive values of LRR_2 for HJX and XL are found in summer, while all negative values of LRR_2 for other three reservoirs are found in all seasons as shown in Figure 9 (a). The mean values of LRR_3 for the five reservoirs are -0.12, -0.11, -0.02, -0.02, and -0.67, and all values of LRR_3 are negative in all seasons. If there were IWDPs and S-Priority was set, the mean value of LRR_3 for XL increases while the values of LRR_2 and LRR_3 for other four reservoirs are less than those without IWDPs as shown in Figure 9 (b). These negative values indicate that IWDPs significantly strengthen the negative feedbacks of the S component on H and E in reservoirs and weaken negative feedback of S on E in XL. If there was no IWDPs but H-Priority was set, negative values of LRR_1 and positive values of LRR_3 are found for the five reservoirs as shown in Figure 9 (c). For HJX, DJK and XL reservoirs, the negative values of LRR_1 are found in winter while zero values of LRR_1 are found in summer. The mean values of LRR_1 are close to zero in AK and WFZ reservoirs in all seasons. Positive values of LRR_3 are smaller in HJX, AK, DJK and WFZ reservoirs, while those in XL are greater in winter with a low flow. If there were IWDPs and H-Priority was set, the values of LRR_1 for all reservoirs are lower than those without IWDPs as shown in Figure 9 (d). Values of LRR_3 for HJX, AK, DJK and WFZ reservoirs are greater than those without IWDPs, while those for XL are close to zero. If there was no IWDPs and E-Priority was set, negative values of LRR_1 for HJX, DJK, WFZ and XL reservoirs can be found in almost every season, while zero values of LRR_1 for AK reservoir can be found in all seasons. As shown in Figure 9 (e), two positive values of LRR_1 for DJK are found in spring and in winter of 2007 due to the increased discharge water from AK reservoir. The positive values of LRR_2 for the five reservoirs are found in most seasons, but few negative values are found in summer. If there were IWDPs and E-Priority was set, more positive values of LRR_2 for five reservoirs and less negative values of LRR_1 are found in HJX, DJK, WFZ and XL reservoirs.

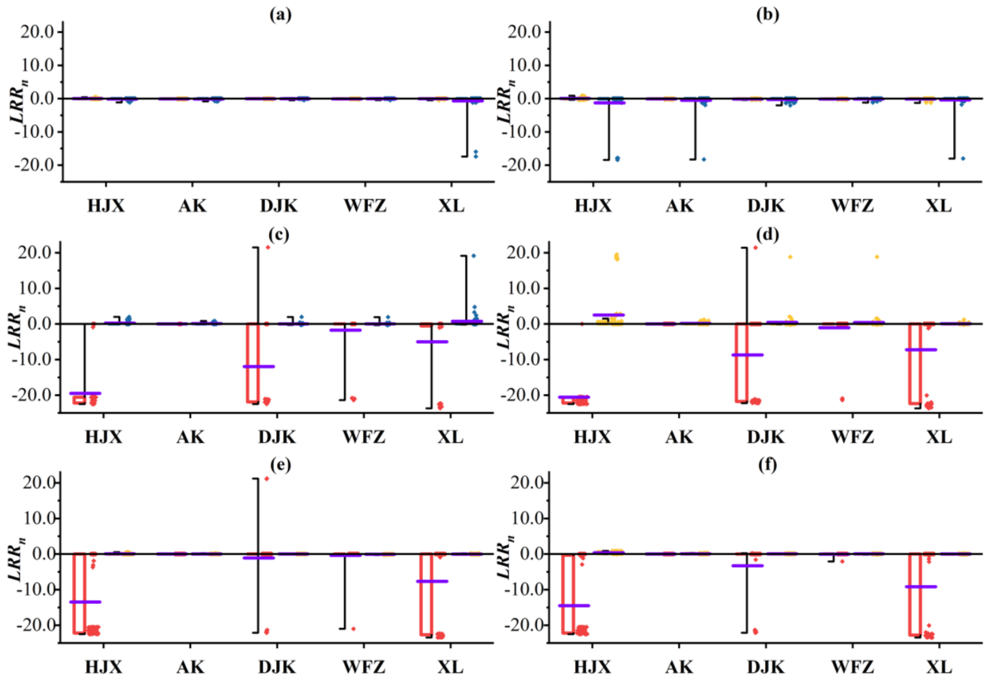

Figure 9. LRR_n with different highest priorities (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{m\text{-}4\text{-}n}$) at the seasonal scale: (a) and (b) are LRR_n with the highest priority in S without IWDPs (i.e., between $S_{0\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{3\text{-}4\text{-}n}$), (c) and (d) are LRR_n with the highest priority in H without IWDPs (i.e., between $S_{0\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}2\text{-}c}$ and $S_{3\text{-}4\text{-}n}$). (e) and (f) are LRR_n with the highest priority in E without IWDPs (i.e., between $S_{0\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{3\text{-}4\text{-}n}$).

4.3.2 Responses of indexes in feedback loops with only water donation, water receiving, and both donation and receiving

To analyse the impacts of only water donation (i.e., $S_{1\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), only water receiving (i.e., $S_{2\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), and both donation and receiving (i.e., $S_{3\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) on feedback loops of SHE nexus across the multiple temporal and spatial scales, the differences of indexes between $S_{m\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ are determined in a reservoirs group. The results of the monthly differences are shown in Figure 10-12. The seasonal results are shown in Figure 13. Corresponding annual-scale results can be found in Supplementary material Tables S3 -S5.

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 for five reservoirs are negative and lower than those without IWDPs as shown in Figure 10 (a-1) and (a-2). More small negative values are found in DJK, water donation has negative impacts on the negative feedback of S on H and E for five reservoirs. If there was only water receiving and S-Priority was set, values of LRR_2 and LRR_3 for HJX and AK are the same as those without IWDPs. Meanwhile, for DJK, WFZ, and XL, the values are close to zero. XL exhibits a lot of positive values of LRR_3 as shown in Figure 10 (b-1) and (b-2). If there were both water donation and receiving, the mean values of LRR_2 for five reservoirs are -0.59, -0.26, -0.48, -0.47 and -0.09, and mean values of LRR_3 for five reservoirs are -6.12, -1.50, -2.01, -1.60 and 0.14 as shown in Figure 10 (c-1) and (c-2). There are negative impacts on negative feedbacks of S on H and E for HJX, AK, DJK and WFZ and positive impacts of the negative feedbacks of S on E for XL.

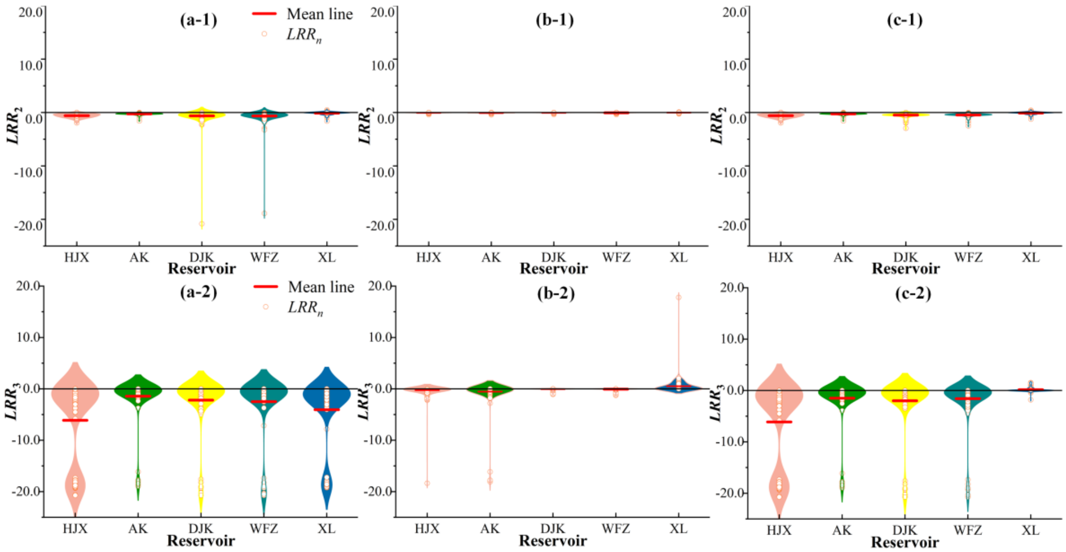

Figure 10. *LRR_n* values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR_2* and *LRR_3* when there is only water donation (i.e., between $S_{1\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR_2* and *LRR_3* when there is only water receiving (i.e., between $S_{2\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR_2* and *LRR_3* when there are both donation and receiving (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 for five reservoirs are lower than those without IWDPs as shown in Figure 11 (a-1) and (a-2). Negative values of LRR_3 for five reservoirs are found in low flow months such as November, December and January. Thus, water donation is found to have negative impacts on feedbacks of H on S and E, especially in low flow months. If there was only water receiving and H-Priority was set, values of LRR_1 and LRR_3 for DJK, WFZ and XL are greater than those without IWDPs as shown in Figure 11 (b-1) and (b-2). Water receiving has positive impacts on feedbacks of H on S and E. If there were both water donation and receiving and H-Priority was set, the mean values of LRR_1 and LRR_3 for DJK, WFZ and XL are still lower than those without IWDPs. And the mean value of LRR_3 for XL is greater than those without IWDPs as shown in Figure 11 (c-1) and (c-2).

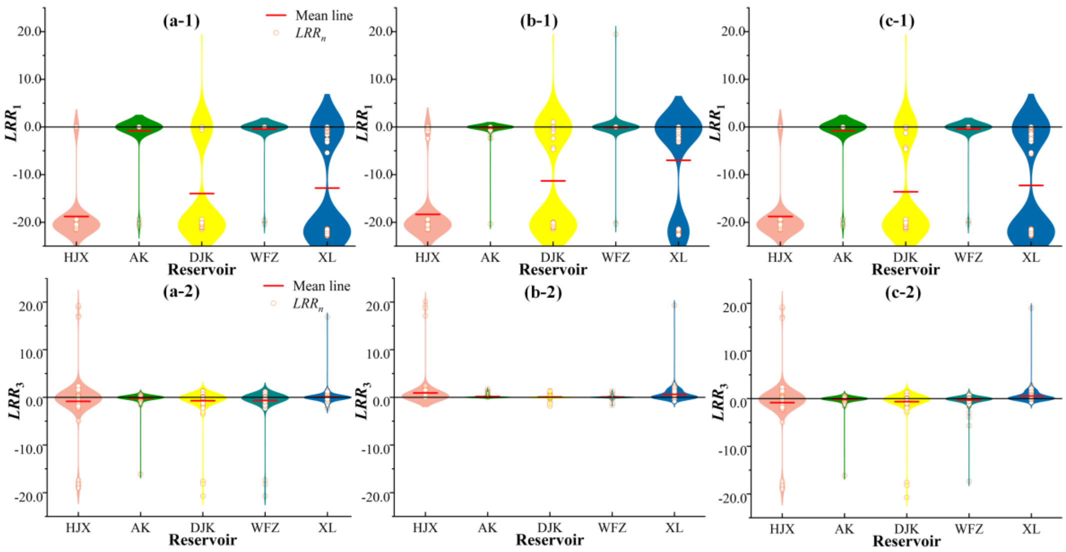

Figure 11. LRR_n values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are LRR_2 and LRR_3 when there is only water donation (i.e., between $S_{1\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are LRR_2 and LRR_3 when there is only water receiving (i.e., between $S_{2\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are LRR_2 and LRR_3 when there are both donation and receiving(i.e., between $S_{3\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and E-Priority was set, then values of LRR_1 and LRR_2 for five reservoirs are shown in Figure 12 (a-1) and (a-2). The mean values of LRR_1 for these five reservoirs are -11.70, 0, -7.23, -0.22, and -9.14, respectively. And the mean values of LRR_2 are -0.16, -0.07, -0.29, -0.30, and -0.08. All these values are lower than the those without IWDPs. Different from the values of LRR_n without IWDPs, there are no positive values of LRR_1 for DJK and few positive values of LRR_2 for five reservoirs due to the decreased inflows from upstream with water donation. If there was only water receiving and E-Priority was set, values of LRR_1 and LRR_2 for DJK, WFZ and XL are greater than those without IWDPs. If there were both water donation and receiving and E-Priority was set, the mean values of LRR_1 and LRR_2 for DJK, WFZ and XL are still lower than those without IWDPs as shown in Figure 12 (c-1) and (c-2).

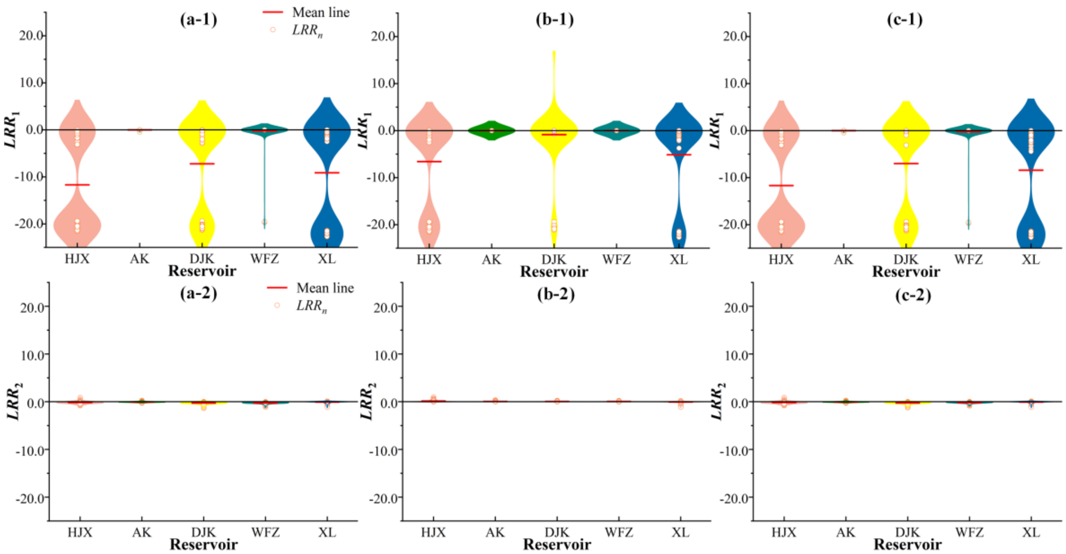

Figure 12. *LRR_n* values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are *LRR_1* and *LRR_2* when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are *LRR_1* and *LRR_2* when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are *LRR_1* and *LRR_2* when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

If there was only water donation and S-Priority was set, values of LRR_2 and LRR_3 as shown in Figure 13(a-1) are lower than those without IWDPs in all seasons as shown in Figure 9 (a). If there was only water receiving and S-Priority was set, mean values of LRR_2 and LRR_3 for DJK, WFZ and XL (i.e., -0.04, -0.05, -0.03 and -0.01, 0, 0.70) as shown in Figure 13 (a-2) are all greater than those without IWDPs. If there were both water donation and receiving and S-Priority was set, mean values of LRR_2 for five reservoirs decrease by 0.33, 0.12, 0.34, 0.36 and 0.07 compared to those without IWDPs. Mean values of LRR_3 for HJX, AK, DJK and WFZ decrease by 3.69, 0.52, 0.72, 0.55, and its for XL increases by 0.89 compared to those without IWDPs as shown in Figure 13 (a-3). If there was only water donation and H-Priority was set, values of LRR_1 and LRR_3 as shown in Figure 13(b-1) are lower than those without IWDPs. Water donation has negative impacts on feedbacks of H on S for HJX, DJK and XL. If there was only water receiving and H-Priority was set, mean values of LRR_2 for DJK, WFZ and XL increase by 0.73, 0.32 and 0.73, and mean values of LRR_3 for DJK, WFZ and XL increase by 0, 0.01 and 0.01 compared to those without IWDPs. If there were both water donation and receiving and H-Priority was set, mean values of LRR_2 for five reservoirs are -20.58, 0, -14.49, -1.75, -8.07, and mean values of LRR_3 for five reservoirs are 0.01, 0.01, -0.05, -0.02 and 0.68 as shown in Figure 13 (b-3). If there was only water donation and E-Priority was set, it can be found that values of LRR_1 and LRR_2 in all seasons are lower than those without IWDPs as shown in Figure 13(c-1). Mean values of LRR_1 for five reservoirs decrease by 14.58, 0.01, 9.39, 1.04 and 10.38, and mean values of LRR_2 for five reservoirs decrease by 0.05, 0.04, 0.28, 0.33 and 0.22. If there was only water receiving and E-Priority was set, mean values of LRR_1 and LRR_2 for DJK, WFZ and mean values of LRR_1 for XL are greater than those without IWDPs, while mean values of LRR_2 for XL get an increase as shown in Figure 13 (c-2). If there were both water donation and receiving and E-Priority was set, Values of LRR_1 and LRR_2 for DJK and WFZ and values of LRR_1 for XL as shown in Figure 13 (c-3) are greater than those with only water donation, while lower than those without IWDPs. While values of LRR_2 for XL are greater than those without IWDPs because of the reduced spilled water. Therefore, values of LRR_n at seasonal scale demonstrate a consistent conclusion with those at the monthly scale. Moreover, the values of LRR_n are relatively stable in summer, while they change greatly in winter at seasonal scale. The impacts of IWDPs on SHE nexus are more significant in low flow seasons.

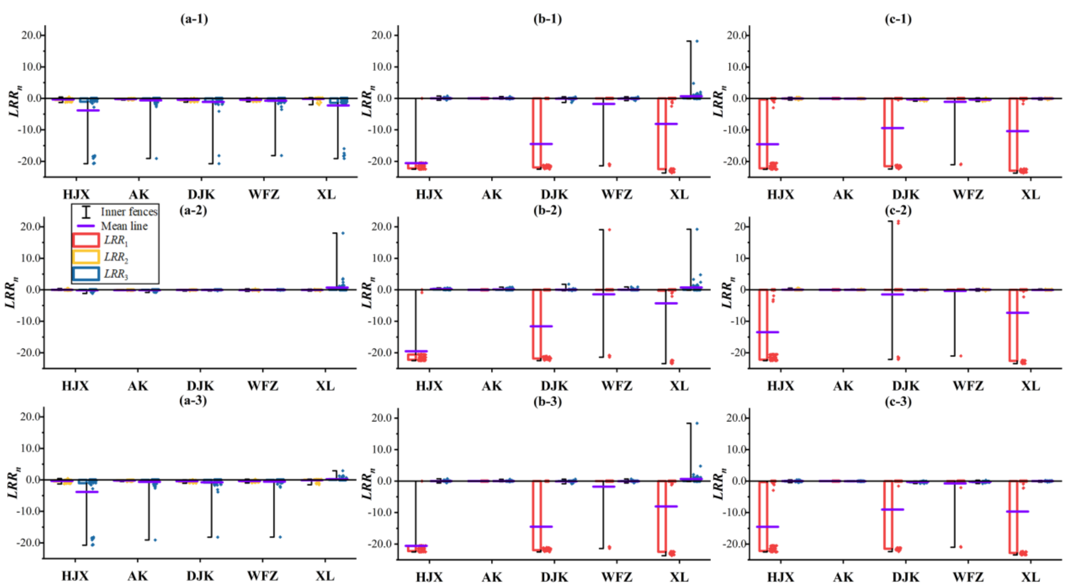

Figure 13. LRR_n values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are LRR_n when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).

4.4 Responses of the three components with IWDPs

To identify the impacts of IWDPs on S, H and E components in a reservoirs group, differences between indexes without IWDPs and with IWDPs (i.e., $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) are determined. Negative values of LRR_1 for five reservoirs are found in all months, mean values of LRR_1 for five reservoirs are 0, 0, -5.54, -0.22 and -0.01 as shown in Figure 14 (a). It is found that values of LRR_1 for DJK are significantly smaller than those for other reservoirs. Mean values of LRR_2 for five reservoirs are -0.46, -0.15, -0.32, -0.26 and -0.03 as shown in Figure 14 (b). Positive values of LRR_3 are found in XL and negative values of LRR_3 are found in HJX, AK, DJK and WFZ in all months, mean values of LRR_3 for five reservoirs are -5.21, -0.75, -0.76, -0.47 and 0.43 as shown in Figure 14 (c).

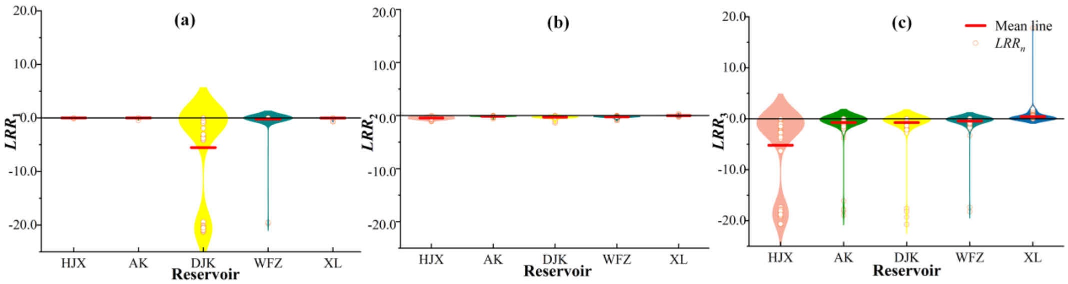

Figure 14. the differences of indexes (i.e., (a) LRR_1, (b) LRR_2, (c) LRR_3 for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale.

5 Discussion

The proposed framework reveals significant negative feedbacks of the water supply (S) on both hydropower generation (H) and environment conservation (E), as evidenced by reductions in hydropower generation (negative LRR_2 in Figure 7 (a-1)) and ecological flow satisfaction rate (negative LRR_2 in Figure 7 (a-2)) with S-Priority. The negative feedbacks of the S component on E are more pronounced than those on H, as evidenced by the wider range of variation in LRR_3 values compared to LRR_2 values. These findings are consistent with previous studies on the SHE nexus (Chen et al.,2018; Khalkhali et al., 2018). It has been found that there are a few positive feedbacks between S and H in abundant water months even the spilled water leads to a reduction in hydropower generation (Jiang et al., 2018). Thus, the increasing water storage or increasing water supply still can ensure hydropower generation. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. And Gao et al. (2023) find that the higher water supply demand, the lower ecological flow left in river. The environment conservation of downstream river systems is critically influenced by upstream water supply decisions (Gupta, 2008). Contrary to the unidirectional positive nexus between hydropower generation and environment conservation proposed by Wei et al. (2022), our study reveals bidirectional feedbacks of H and E, aligning with Wu et al. (2021). The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir, Zhang et al., 2008) even in abundant water months, particularly. The increased flows for hydropower generation alleviates the pressure of ecological damage in river. However, the more flows for hydropower generation from the reservoir, the less supplied amount of available water resources (Doummar et al., 2009), and leads to negative impacts on the S component. The feedbacks of the H on S are more pronounced than on E, according to the wider range of variation in LRR_1 values compared to LRR_3 values. Negative feedbacks of the E component on S for reservoirs has been found in the scenario that main function is water supply while no significant effect on reservoirs has been found in the scenario that main function is hydropower generation (negative LRR_1 in Figure 7 (c-1)). There are both negative and positive feedbacks of the E component on H while the negative feedbacks are grown in abundant water months. Feedbacks of the E component on S are stronger than those on H, according to the values of LRR_n. The negative feedbacks between S and H, and between S and E are strong in low flow months due to the high-water supply demand. More competitions for water can be found among S, H and E in low flow months, and their negative feedbacks of the SHE nexus have found to be strengthened (Wu et al., 2021). Feedback loops of SHE nexus in reservoirs with regulation function (e.g., AK and DJK) remain stable under the varying inflow conditions. These reservoirs reasonably allocate water among S, H and E components to prevent strengthening of negative feedbacks in low flow months. Furthermore, increasing hydropower generation flow might have impacts on downstream water quality and biodiversity (Botelho et al., 2017; Martinez et al., 2019), the feedbacks of H on E are enhanced.

Inter-basin water diversion projects (IWDPs) have negative impacts on the regional water supply from DJK and upstream reservoirs with negative LRR_1, consistent with Hong et al. (2016)

and Ouyang et al. (2018). And all reservoirs have reduced their hydropower generation, but there are positive impacts on H in abundant water months with positive LRR_2 in Figure 14 (b). Many studies have highlighted the negative impacts of IWDPs on hydropower generation (Yang, et al., 2023), but the positive impacts are less frequently discussed. With the water donation for the Han-to-Wei Water Diversion Project, the Middle Route of the South-to-North Water Diversion Project and the Northern Hubei Water Resources Allocation Project, multiple algal bloom events occurred in the downstream of HRB (Tian et al., 2022), and the water donation had a significant negative impact on the environment conservation of the basin. Water receiving from the Three Gorges Reservoir to Hanjiang River are not compensate for all their negative impacts, and water receiving from the Changjiang-to-Hanjiang River Water Diversion Project benefits environment conservation for XL. It is evident that IWDPs significantly alter the feedback loops of the SHE nexus by modifying water availability. As IWDPs export or import water to or from an area, the amount of available water has to be altered. It can prompt a redistribution and re-planning of the available water (Li, et al., 2014). And the redistribution and re-planning can significantly impact on feedback loops of SHE nexus (Feng, et al., 2019). Although strong responses occur in feedback loops of SHE nexus, its positive or negative nature of feedback among these components remains stable with impacts of IWDPs. Thus, the redistribution and re-planning of available water can not alter their competitions and collaborations among the components of the SHE nexus. It is evident that water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E while receiving water has positive impacts on all these feedbacks. Water donation results in a reduction of available water (Mok et al., 2015; Wu et al., 2022) and leads to lower flow. More competition for water can be found among S, H and E, and negatively impacts on the feedbacks. Less competition is found among S, H and E in water receiving areas, and it has positive impacts on their feedbacks. The persistent feedback polarity with IWDPs suggests that simply increasing water supply (e.g., via compensation donations like Three Gorges-to-Hanjiang) cannot resolve inherent SHE conflicts—instead, adaptive allocation rules that account for these stable feedback patterns are needed.

The consistency in the signs of mean LRR_n values across seasonal as shown in Figure 9 and 13 and annual scales as shown in Supplementary material Table S1-S5 with those at the monthly scale indicates an inherent similarity and stability in SHE nexus feedback loops over different temporal resolutions. Compared with the values of LRR_n at monthly scale, the values at the seasonal scale show its stronger periodic variations. Based on the variations in LRR_n and the mathematical implications of LRR_1, LRR_2, and LRR_3, this study found that these periodic variations align closely with the runoff variations, and the temporal and spatial variations in feedback loops are primarily attributed to variations in runoff. The wavelet transform analysis has also been applied in the runoffs for HJX, AK, DJK, WFZ, and XL dam sites. And the results are in consisted with that in Hutuo River Basin (Xu et al., 2018), the periodic variations have been found at the seasonal scale. The LRR_n values at the seasonal scale can help analyze the variations in periodic feedback loops. Different from the monthly or seasonal scales, results at the annual scale reveal the long-term trends and periodic variations in the inter-annual and spatial trends of the SHE nexus from a macro perspective. The impacts of reservoir operation and the regulation on SHE nexus can be clearly simulated and observed at the monthly scale, so the immediate changes in the nexus at monthly scale can provide information for short-term decision-making in reservoirs."

Point #2

COMMENT: *This I find this rather problematic, because although the manuscript is generally well written, the manuscript at the same time was for me tedious to read, mainly because of the complex abbreviations and terminologies used. In that sense it is not a very appealing paper, which may affect the readership. So it is in interest of the authors to try to make this paper better accessible.*

RESPONSE: We sincerely appreciate the editor's constructive feedback regarding the readability of the manuscript. We acknowledge that the excessive use of abbreviations and specialized terminology may have hindered the accessibility of the content, particularly for interdisciplinary readers. To address this concern, we have implemented the following revisions: 1) Streamlined abbreviations by retaining only those essential to the core methodology and eliminating non-critical acronyms; 2) Introduced a glossary table in Supplementary material Table S6 listing key technical terms with concise definitions to serve as a quick reference; 3) Added contextual explanations for domain-specific concepts at their first appearance to enhance narrative flow. These modifications have been systematically applied throughout the manuscript, with tracked changes highlighted in the revised version. We believe these adjustments significantly improve readability while maintaining scientific rigor, and we remain open to further suggestions to enhance the paper's accessibility and appeal to broader audiences. The Supplementary material Table S6 is follows:

Table S6. List of Abbreviations

Abbreviation	Full Term
IWDPs	Inter-basin water diversion projects
S	Water supply
H	Hydropower generation
E	Environment conservation
SHE	Water Supply-Hydropower Generation-Environment Conservation
HRB	Hanjiang River Basin
S-Priority	the highest priority is set to water supply
H-Priority	the highest priority is set to hydropower generation
E-Priority	the highest priority is set to environment conservation
the VIC model	The Variable Infiltration Capacity hydrological model
NSE	the Nash-Sutcliffe efficiency coefficient
R^2	Coefficient of determination
PBIAS	Percent bias
the MTMMHC method	The Modified Tennant Method Based on Multilevel Habitat Conditions method
the MIORG model	The Multisource Input-Output Reservoir Generalization model
*EF*s	ecological flows
LRR	log response ratio
DEM	the Inverse Distance Weighting method. Digital Elevation Model
HWSD	the Harmonized World Soil Database
SWCT	the Soil-Water Characteristics
FAO	Food and Agriculture Organization
IIASA	Institute of Internal Auditors South Africa

Point #3

COMMENT: *Acronyms used: Normally in this type of papers, comparing scenarios is among the more interesting aspects. This requires the scenarios to be clearly identifiable and understandable. But in this paper the scenarios are many, and cannot be easily understood because of the use of codes (what scenarios are meant with, e.g.* $S_{1\text{-}0\text{-}4\text{-}c}$ *and* $S_{2\text{-}1\text{-}p\text{-}c}$*?). The make things even more complex, the text is ridden with* LRR_1*,* LRR_2 *and* LRR_3*, but the meaning of n is only declared somewhere in brackets (line 306 in the original manuscript, whereas the concept of LLR is introduced much earlier, in lines 206-212).*

RESPONSE: We sincerely thank the editor for highlighting the critical need to clarify scenario labeling and parameter definitions. To improve transparency, we have restructured the scenario nomenclature and integrated explicit explanations at the first mention of each term. The revised labeling system (e.g., $S_{3\text{-}4\text{-}1}$) now adheres to a standardized three-tier format (*m*-*p*-*n*) with intuitive semantic mapping:

- *m* represents the different clusters of IWDPs:

0: without IWDPs;

1: with only water donation;

2: with only water receiving;

3: with both donation and receiving.

- *p* represents the priority types of SHE:

1: the highest priority is set to water supply;

2: the highest priority is set to hydropower generation;

3: the highest priority is set to environment conservation;

4: the component operates under the standard scheduling rules for reservoirs.

- *n* represents the performance evaluation component:

1: water supply component;

2: hydropower generation component;

3: environment conservation component.

To mitigate confusion around terms like LRR_1/ LRR_2/ LRR_3, we now explicitly define the subscript “n” in *LRR* metrics during their initial introduction (Section 2.4.3, revised lines 226-227) rather than deferring clarification to later sections. A consolidated table summarizing all scenario codes has also been added to Figure 1 and Section 2.5, ensuring readers can cross-reference labels without textual backtracking. We appreciate the editor's astute observation and welcome further suggestions to refine accessibility. The revised parts are:

"

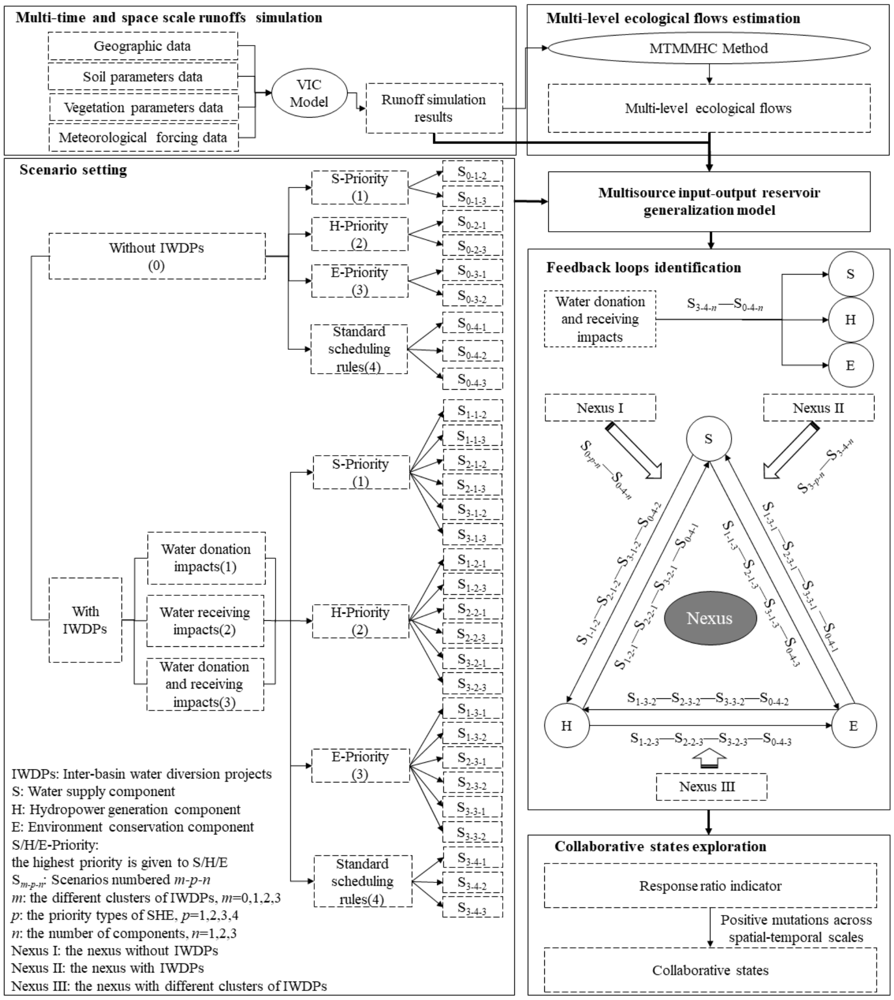

Figure 1. Framework to identify the impacts of different IWDPs on the feedback loops of SHE nexus.

2.4.3 The Log Response Ratio method

To analyse the feedback loops in Nexus I, Nexus II and Nexus III in Figure 1, the log response ratio (*LRR*) method (Patrick et al., 2022) is used to quantify the responses of S, H, and E with different clusters of IWDPs. This method captures non-linear feedback loops within complex SHE nexus systems. The formula is as follows:

$$LRR_n = \ln\left(\frac{\left(r_{c(n)} - r_n\right) + r_n}{r_n}\right) = \ln\left(\frac{r_{c(n)}}{r_n}\right) \tag{18}$$

where LRR_n is the log response ratio of the nth component; n represents the performance evaluation component (1:

water supply component; 2: hydropower generation component; 3: environmental conservation component); LRR_1 refers to the log response ratio of water supply volume between the two compared scenarios, characterizing the differences in the S component. Correspondingly, LRR_2 and LRR_3 represent the differences in the H and E components between two compared scenarios, respectively. r_n is the value of regional water supply volume or hydropower generation or ecological flow satisfaction rate in the baseline scenario. $r_{c(n)}$ is the value of the index in the compared scenario. $r_{c(n)}$ and r_n are both greater than or equal to zero. The positive LRR_n indicates $r_{c(n)} > r_n$, meaning the compared scenario improves the component relative to the baseline. The negative LRR_n indicates $r_{c(n)} < r_n$, meaning the compared scenario reduces the component relative to the baseline. The absolute value of LRR_n reflects the degree of change on a logarithmic scale. The larger the absolute value of LRR_n, the more substantial the improvement (if positive) or reduction (if negative) is when measured logarithmically.

2.5 Scenario setting

To identify the impacts of different clusters of IWDPs on the SHE nexus, scenarios are set according to the following three aspects: with or without IWDPs (i.e., two types for IWDPs), different clusters of IWDPs (i.e., four clusters for the above two types), and the priority orders of S, H, and E. As there are three components for the highest priority, six scenarios can be obtained through the combination of the three components. As all S, H, and E are determined from standard scheduling rules, there are also three types for the standard scheduling rules. Combined with the types of different clusters of IWDPs, there will be a total of 30 scenarios (i.e., 4 clusters of IWDPs ×6 types for the highest priority combinations +2 types for IWDPs ×3 types for standard scheduling rules) as listed in Table 2. Specifically, to iteratively set the priority orders of S, H, and E, all three components are all in standard scheduling rules firstly. Secondly, the highest priority is set to water supply (as denoted by S-Priority), that means all reservoirs will first meet regional water demands (i.e., domestic, industrial, and ecological), with surplus water then allocated to hydropower generation and environment conservation needs. Additionally, increasing the regional water supply to 120% enhances the observability and analytical prominence of the quantitative outcomes derived from these nexus. And thirdly, hydropower generation (H-Priority) is prioritized to achieve the maximum output during the planned period. Finally, environmental conservation (E-Priority) is addressed through ensuring that the reservoir outflow meets $OEF_{xy(\max)}$. These scenarios offer flexibility in modeling SHE nexus system behavior under different conditions.

The scenarios are named in the format $S_{m\text{-}p\text{-}n}$, where m represents the different clusters of IWDPs (0: without IWDPs; 1: with only water donation; 2: with only water receiving; 3: with both donation and receiving), p represents the priority types of S, H, and E (1: the highest priority is water supply; 2: the highest priority is hydropower generation; 3: the highest priority is environmental conservation; 4: standard reservoir scheduling rules), and n represents the performance evaluation component (1: water supply component; 2: hydropower generation component; 3: environmental conservation component).

To analyse the feedback loops of SHE nexus without IWDPs, the differences between the $S_{0\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined (i.e., the feedback loops of Nexus I as shown in Figure 1.). To analyse the feedback loops with IWDPs (i.e., the feedback loops of Nexus II as shown in Figure 1.), the differences between the $S_{3\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{3\text{-}4\text{-}n}$ scenarios are determined. Thus, the differences between Nexus I and Nexus II can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus III as shown in Figure 1.), the differences between $S_{m\text{-}p\text{-}n}$ (m=1, 2, 3; p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined. The differences between Nexus I and Nexus III can figure out the impacts of different IWDP clusters on the SHE nexus. $S_{0\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules without IWDPs) and $S_{3\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules with IWDPs), are the baseline scenarios for distinguishing Nexus I, Nexus III, and Nexus II. In the same way, to clarify the impacts of IWDPs on the three components, the differences between the $S_{0\text{-}4\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios are determined.

Table 2. The scenarios to identify the impacts of different clusters of IWDPs on the SHE nexus.

	Different clusters of IWDPs (m)	The priority orders of S, H, and E (p)			Scenarios
		S	H	E	
Without IWDPs	\ (0)		ISQ		$S_{0\text{-}4\text{-}1}$
					$S_{0\text{-}4\text{-}2}$
					$S_{0\text{-}4\text{-}3}$
		S-Priority	\	ISQ	$S_{0\text{-}1\text{-}2}$
		S-Priority	ISQ	\	$S_{0\text{-}1\text{-}3}$
		\	H-Priority	ISQ	$S_{0\text{-}2\text{-}1}$
		ISQ	H-Priority	\	$S_{0\text{-}2\text{-}3}$
		\	ISQ	E-Priority	$S_{0\text{-}3\text{-}1}$
		ISQ	\	E-Priority	$S_{0\text{-}3\text{-}2}$
With IWDPs	With water donation impacts (1)	S-Priority	\	ISQ	$S_{1\text{-}1\text{-}2}$
		S-Priority	ISQ	\	$S_{1\text{-}1\text{-}3}$
		\	H-Priority	ISQ	$S_{1\text{-}2\text{-}1}$
		ISQ	H-Priority	\	$S_{1\text{-}2\text{-}3}$
		\	ISQ	E-Priority	$S_{1\text{-}3\text{-}1}$
		ISQ	\	E-Priority	$S_{1\text{-}3\text{-}2}$

	S-Priority	\	ISQ	S_{2-1-2}
	S-Priority	ISQ	\	S_{2-1-3}
With water receiving impacts	\	H-Priority	ISQ	S_{2-2-1}
（2）	ISQ	H-Priority	\	S_{2-2-3}
	\	ISQ	E-Priority	S_{2-3-1}
	ISQ	\	E-Priority	S_{2-3-2}
				S_{3-4-1}
		ISQ		S_{3-4-2}
				S_{3-4-3}
With water donation and receiving	S-Priority	\	ISQ	S_{3-1-2}
impacts	S-Priority	ISQ	\	S_{3-1-3}
（3）	\	H-Priority	ISQ	S_{3-2-1}
	ISQ	H-Priority	\	S_{3-2-3}
	\	ISQ	E-Priority	S_{3-3-1}
	ISQ	\	E-Priority	S_{3-3-2}

* ISQ (In Status Quo) indicates that the component operates under the standard scheduling rules for reservoirs.

Point #4

COMMENT: *Figures: Graphs of findings that need to be compared would benefit from graphs with identical scales. E.g. comparing Figs 7 and 8 is not easy, as their Y-scales (I mean the scales for e.g. Fig 7a-1, 7a-2, 8a-1 and 8a-2, same for 7b-1,7b-2, 8b-1,8b-2) differ. They should be identical, so that you can better compare them. And why not include in both graphs what the a, b, c scenarios (the columns) are, and what the 1 and 2 scenarios (the rows) mean? I understand that the rows mean without and with IWD, and the column mean a = S priority, b = H priority and c= E priority. This is not even written in the caption. To confuse matters further, Figure 9 uses columns to distinguish with and without IWD, and rows to distinguish the priorities for S, H and E. And figure 10 I found even more confusing. I really failed to deduce anything interesting from it. That is either my own failure or the failure of the authors to effectively communicate their findings. For the figures 10, 15, 16 and 17 I couldn't decide whether it is critical to use identical colour units/scales, which I normally would favour. I therefore ask the authors to explain why they decided to use different scales.*

RESPONSE: We sincerely appreciate the editor's constructive feedback on improving the clarity and comparability of our figures.

1) We acknowledge that differing y-axis scales hinder direct comparison. In the revised manuscript, we have standardized the y-axis scales across all subfigures (e.g., Fig 7a-1, 7a-2, 8a-1, 8a-2) to enable visual consistency and facilitate meaningful comparisons.

2) We agree that the figure captions lack critical details about scenario labels. We explicitly defined these in all figure captions to reduce reader’s confusion.

3) We fully acknowledge the importance of uniform color scales for cross-figure comparisons. However, in preliminary attempts, we observed that unified scales would obscure critical differences between scenarios (e.g., subtle annual-scale variations in Figure 10, 15-17 became indistinguishable under fixed color bands). To balance clarity and comparability, the annual-scale results have been converted into tables for presentation, as shown in the Supplementary material (Tables S1-S5). The Figure7-14 and the Supplementary material Table S1-S5 is follows:

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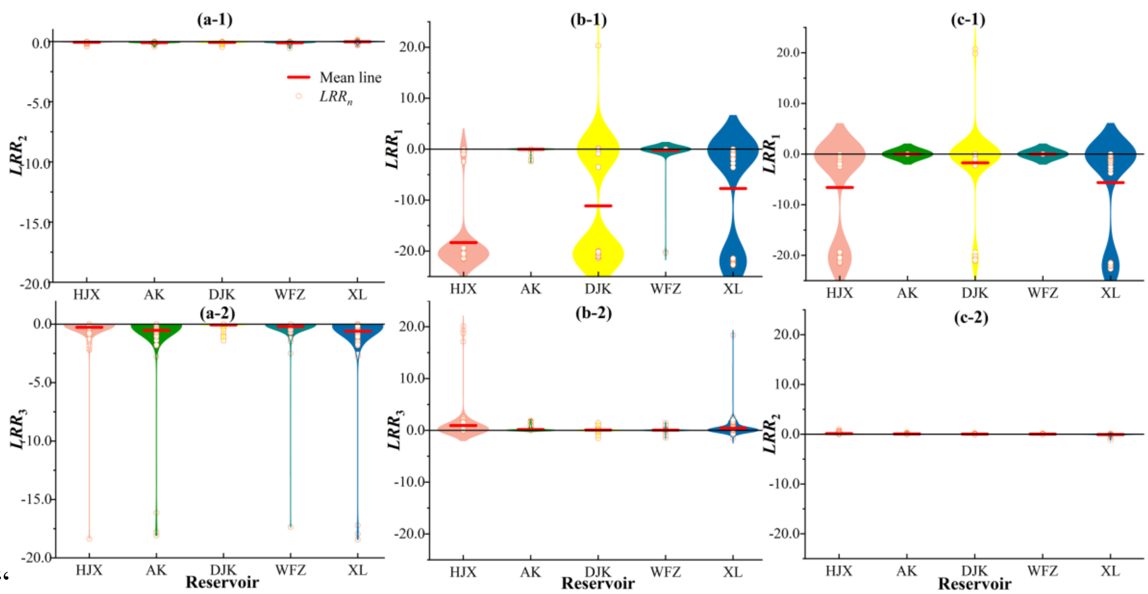

Figure 7. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) without IWDPs (i.e., between $S_{0\text{-}p\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) at the monthly scale: (a-1) are LRR_2 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}2}$ and $S_{0\text{-}4\text{-}2}$), (a-2) are LRR_3 with the highest priority in S (i.e., between $S_{0\text{-}1\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (b-1) are LRR_1 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (b-2) are LRR_3 with the highest priority in H (i.e., between $S_{0\text{-}2\text{-}3}$ and $S_{0\text{-}4\text{-}3}$), (c-1) are LRR_1 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}1}$ and $S_{0\text{-}4\text{-}1}$), (c-2) are LRR_2 with the highest priority in E (i.e., between $S_{0\text{-}3\text{-}2}$ and $S_{0\text{-}4\text{-}2}$).

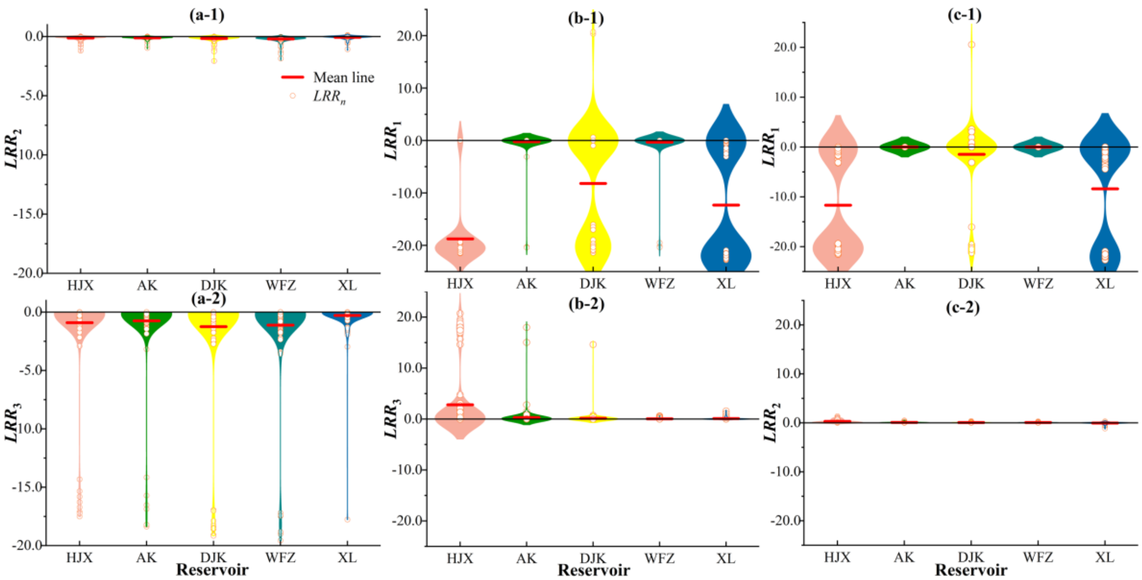

Figure 8. the differences of indexes (i.e., LRR_1, LRR_2, LRR_3 for log response ratio of the S, H, and E component) with IWDPs (i.e., between $S_{3\text{-}p\text{-}n}$ and $S_{3\text{-}4\text{-}n}$) at the monthly scale: (a-1) are LRR_2 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}2}$ and $S_{3\text{-}4\text{-}2}$), (a-2) are LRR_3 with the highest priority in S (i.e., between $S_{3\text{-}1\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (b-1) are LRR_1 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (b-2) are LRR_3 with the highest priority in H (i.e., between $S_{3\text{-}2\text{-}3}$ and $S_{3\text{-}4\text{-}3}$), (c-1) are LRR_1 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}1}$ and $S_{3\text{-}4\text{-}1}$), (c-2) are LRR_2 with the highest priority in E (i.e., between $S_{3\text{-}3\text{-}2}$ and $S_{3\text{-}4\text{-}2}$).

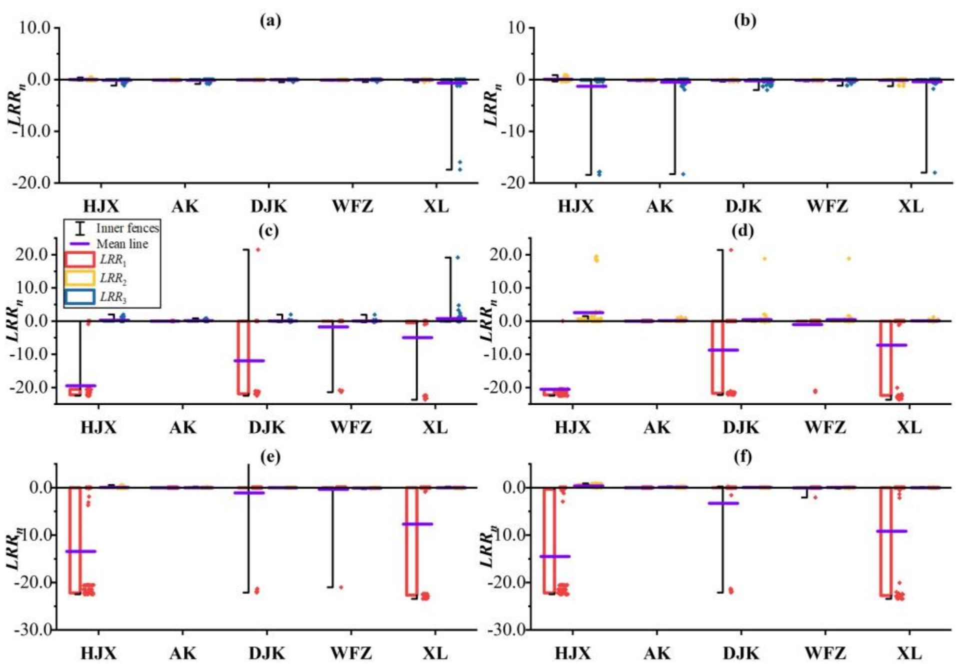

Figure 9. LRR_n with different highest priorities (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{m\text{-}4\text{-}n}$) at the seasonal scale: (a) and (b) are LRR_n with the highest priority in S without IWDPs (i.e., between $S_{0\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{3\text{-}4\text{-}n}$), (c) and (d) are LRR_n with the highest priority in H without IWDPs (i.e., between $S_{0\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}2\text{-}c}$ and $S_{3\text{-}4\text{-}n}$). (e) and (f) are LRR_n with the highest priority in E without IWDPs (i.e., between $S_{0\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$) and with IWDPs (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{3\text{-}4\text{-}n}$).

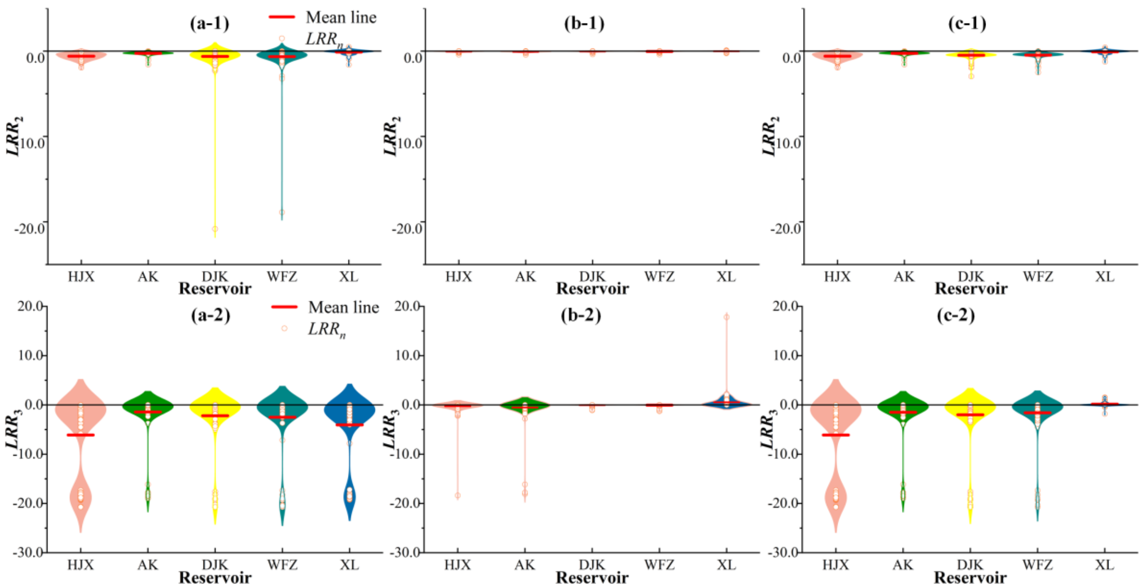

Figure 10. ***LRR_n*** **values when there are different clusters of IWDPs and S-Priority was set at the monthly scale: (a-1) and (a-2) are** ***LRR_2*** **and** ***LRR_3*** **when there is only water donation (i.e., between $S_{1\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are** ***LRR_2*** **and** ***LRR_3*** **when there is only water receiving (i.e., between $S_{2\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are** ***LRR_2*** **and** ***LRR_3*** **when there are both donation and receiving (i.e., between $S_{3\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

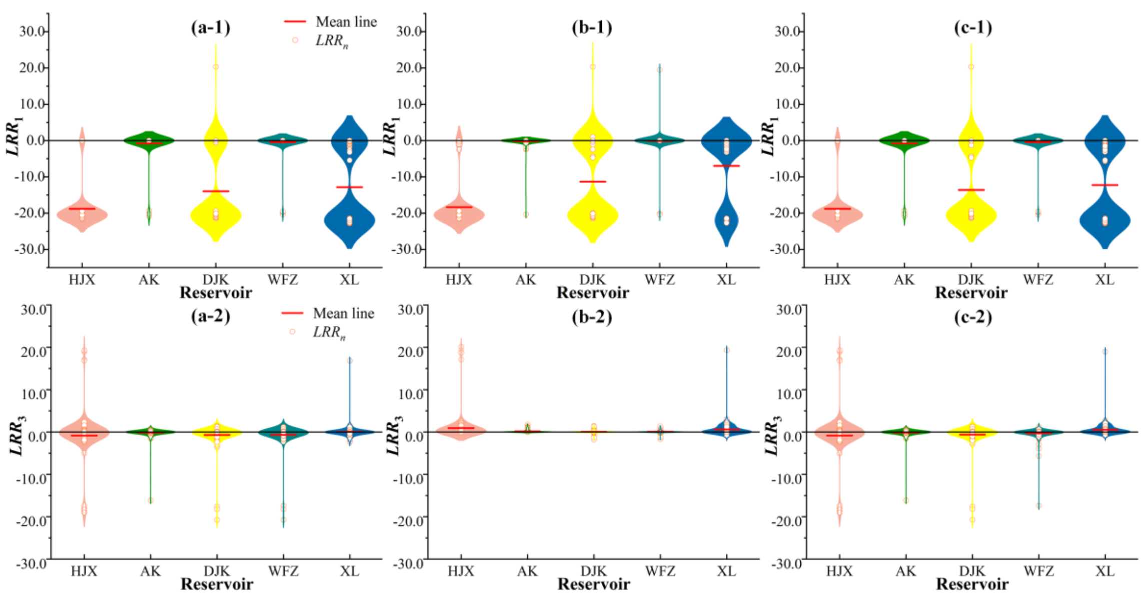

Figure 11. ***LRR_n*** **values when there are different clusters of IWDPs and H-Priority was set at the monthly scale: (a-1) and (a-2) are** ***LRR_2*** **and** ***LRR_3*** **when there is only water donation (i.e., between $S_{1\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are** ***LRR_2*** **and** ***LRR_3*** **when there is only water receiving (i.e., between $S_{2\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are** ***LRR_2*** **and** ***LRR_3*** **when there are both donation and receiving(i.e., between $S_{3\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

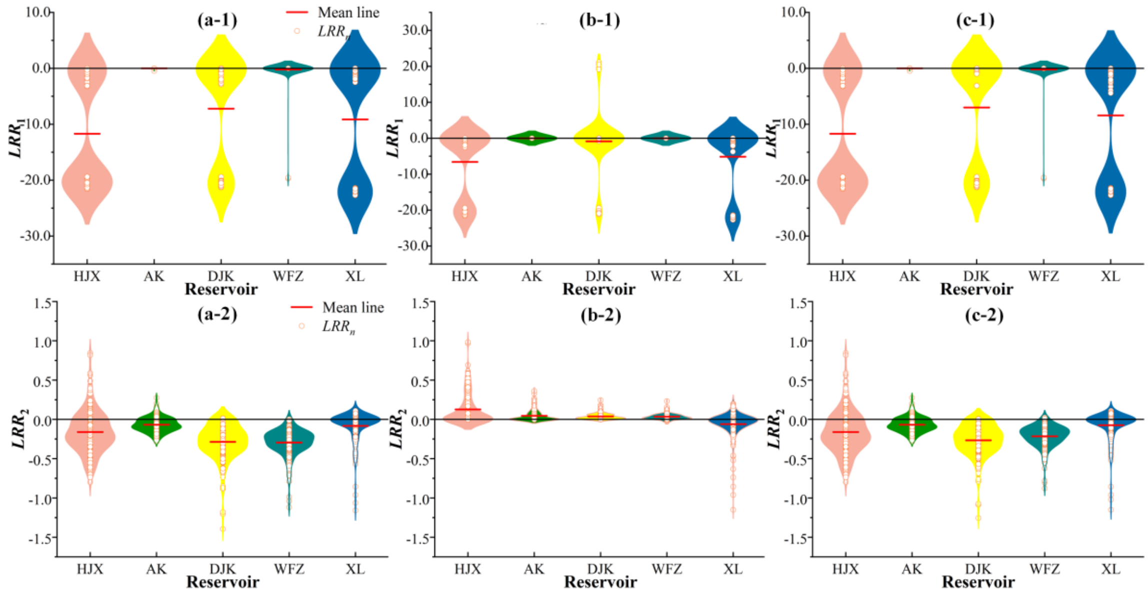

Figure 12. ***LRR_n*** **values when there are different clusters of IWDPs and E-Priority was set at the monthly scale: (a-1) and (a-2) are** ***LRR_1*** **and** ***LRR_2*** **when there is only water donation (i.e., between $S_{1\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (b-1) and (b-2) are** ***LRR_1*** **and** ***LRR_2*** **when there is only water receiving (i.e., between $S_{2\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$), (c-1) and (c-2) are** ***LRR_1*** **and** ***LRR_2*** **when there are both donation and receiving (i.e., between $S_{3\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

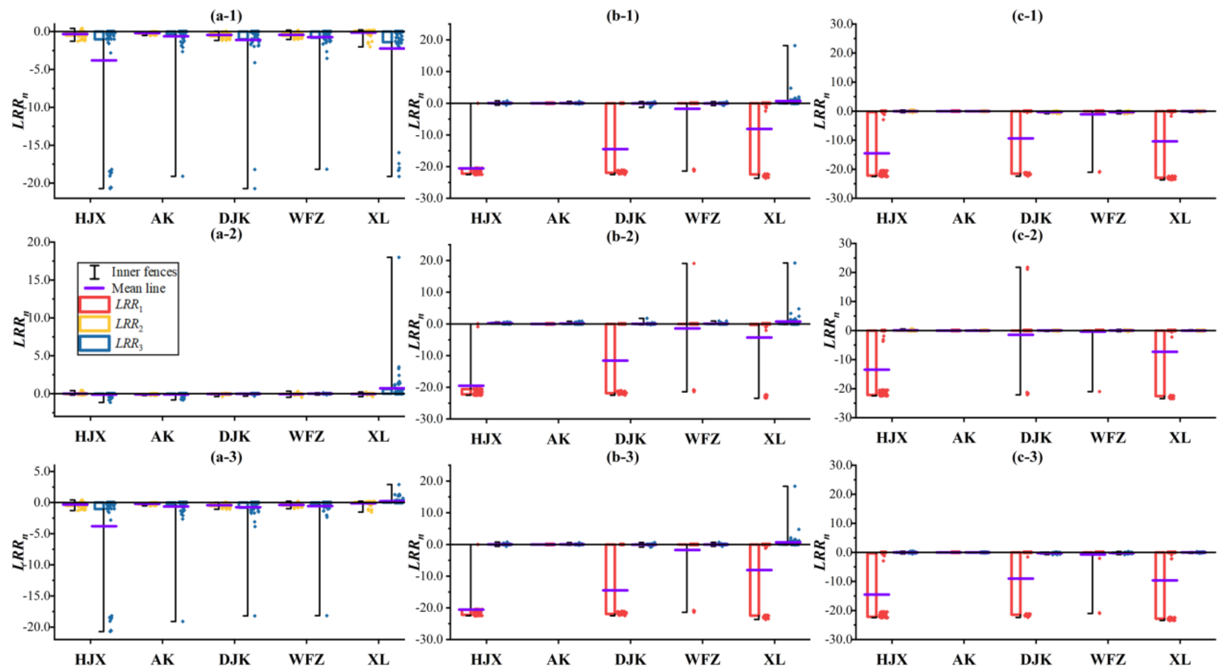

Figure 13. ***LRR_n*** **values when there are different clusters of IWDPs at the seasonal scale: (a-1), (a-2) and (a-3) are** ***LRR_n*** **when there was only water donation, when there was only water receiving, when there were both donation and receiving and S-Priority was set (i.e., between $S_{m\text{-}1\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (b-1), (b-2) and (b-3) are those when H-Priority was set (i.e., between $S_{m\text{-}2\text{-}n}$ and $S_{0\text{-}4\text{-}n}$); (c-1), (c-2) and (c-3) are those when E-Priority was set (i.e., between $S_{m\text{-}3\text{-}n}$ and $S_{0\text{-}4\text{-}n}$).**

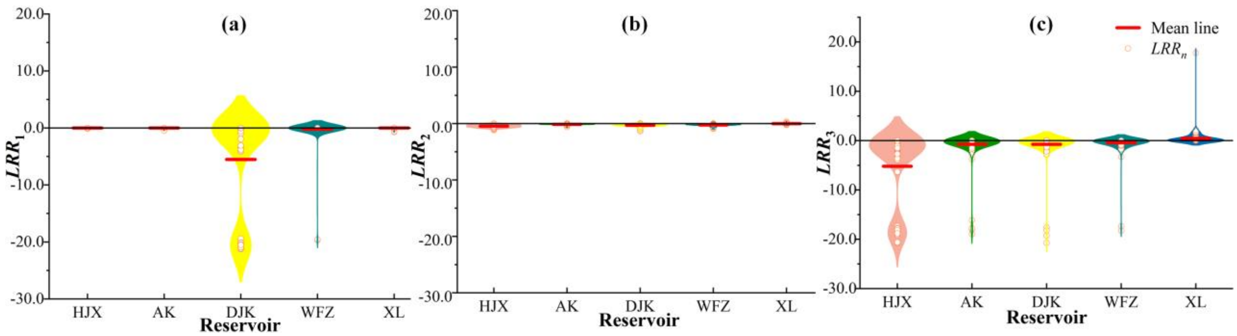

Figure 14. the differences of indexes (i.e., (a) LRR_1, (b) LRR_2, (c) LRR_3 for log response ratio of the S, H, and E component) between $S_{3\text{-}4\text{-}n}$ and $S_{0\text{-}4\text{-}n}$ at the monthly scale."

"**Table S1**. LRR_n values when there are no IWDPs and different priority orders are set at the annual scale.

	The Log Response Ratio	Reservoirs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
If there was no IWDPs and S-Priority was set	LRR_2	HJX	-0.08	-0.07	-0.08	-0.07	-0.05	-0.04	-0.05	-0.06	-0.06	-0.06	-0.08	-0.06	-0.06	-0.05	-0.05
		AK	-0.09	-0.08	-0.10	-0.08	-0.06	-0.05	-0.05	-0.07	-0.07	-0.08	-0.11	-0.07	-0.08	-0.07	-0.07
		DJK	-0.05	-0.05	-0.06	-0.06	0.00	-0.03	-0.04	-0.06	-0.06	-0.06	-0.06	-0.01	0.00	-0.06	-0.06
		WFZ	-0.07	-0.06	-0.08	-0.08	-0.05	-0.07	-0.06	-0.08	-0.08	-0.08	-0.08	-0.05	-0.05	-0.07	-0.07
		XL	-0.18	-0.02	-0.02	-0.02	-0.02	-0.06	-0.02	-0.05	-0.02	-0.05	-0.02	-0.02	-0.02	-0.02	0.06
	LRR_3	HJX	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	-0.06	0.00	0.00	0.00	-0.09	0.00	-0.05	-0.05
		AK	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	-0.10	0.00	0.00	0.00	-0.11	0.00	-0.06	-0.06
		DJK	0.00	0.00	0.00	0.00	-0.09	-0.24	0.00	0.00	0.00	0.00	0.00	-0.13	-0.06	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-0.14	-0.43	0.00	0.00	0.00	0.00	0.00	-0.19	-0.12	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-0.14	-0.43	-0.06	0.00	0.00	0.00	0.00	-0.17	0.00	0.00	-0.12
If there was no IWDPs and H-Priority was set	LRR_1	HJX	-23.25	-23.26	-23.29	-23.30	-23.26	-23.27	-23.29	-23.29	-23.28	-23.29	-23.29	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-0.67	-1.89	0.00	-23.00	-23.09	-23.14	-23.05	-1.07	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	-24.63	0.00	0.00	0.00	0.00	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LRR_3	HJX	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.13	0.00	0.00	0.00	0.20	0.00	0.08	0.08
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
		DJK	0.00	0.00	0.00	0.00	-0.31	-0.10	0.00	0.00	0.00	0.00	0.00	-0.29	0.05	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-0.28	-0.14	0.00	0.00	0.00	0.00	0.00	-0.23	0.05	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-0.19	0.05	0.00	0.00	0.00	0.00	0.00	-0.15	0.00	0.00	0.18

If there was no IWDPs and E-Priority was set	*LRR*$_1$	HJX	0.00	0.00	0.00	0.00	-0.44	0.00	-23.29	-23.29	-23.28	0.00	0.00	-23.31	-23.31	-23.28	-0.39
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	0.00	0.00	0.00	-23.00	-23.09	-23.14	-23.05	0.00	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-24.44	-0.25	0.00	0.00	0.00	0.00	0.00	-24.42	0.00	0.00	-24.43
	LRR$_2$	HJX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.00	0.00	0.02	0.02
		XL	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table S2. *LRR*$_n$ values when there are IWDPs and different priority orders are set at the annual scale.

	The Log Response Ratio	Reservoirs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
If there was IWDPs and S-Priority was set	*LRR*$_2$	HJX	-0.18	-0.18	-0.19	-0.18	-0.20	-0.28	-0.24	-0.20	-0.19	-0.19	-0.19	-0.20	-0.19	-0.21	-0.21
		AK	-0.11	-0.09	-0.12	-0.10	-0.07	-0.05	-0.06	-0.08	-0.08	-0.09	-0.13	-0.08	-0.10	-0.08	-0.08
		DJK	-0.07	-0.07	-0.17	-0.18	-0.05	-0.08	-0.06	-0.08	-0.08	-0.08	-0.08	-0.05	-0.05	-0.08	-0.08
		WFZ	-0.10	-0.09	-0.18	-0.19	-0.06	-0.09	-0.08	-0.11	-0.10	-0.11	-0.10	-0.07	-0.06	-0.11	-0.10
		XL	-0.29	-0.02	-0.02	-0.04	-0.02	-0.18	-0.12	-0.15	-0.06	-0.16	-0.05	-0.02	-0.11	-0.12	-0.02
	LRR$_3$	HJX	-0.07	-0.26	-0.24	-0.52	-0.27	0.00	-0.05	-0.26	0.00	-0.10	-0.28	-0.11	-0.11	-0.27	-0.26
		AK	0.00	0.00	0.00	0.00	-0.10	0.00	0.00	-0.15	0.00	0.00	-1.40	-0.22	0.00	-0.12	-0.12
		DJK	-0.12	-0.09	0.00	0.00	-0.10	-0.19	0.00	0.00	0.00	0.00	0.00	-0.12	-0.30	0.00	-0.14
		WFZ	-0.17	-0.03	0.00	0.00	-0.28	-0.27	0.00	0.00	0.00	0.00	0.00	-0.17	-0.42	0.00	-0.08
		XL	0.00	0.00	0.00	0.00	-0.28	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	-0.03

If there was IWDPs and H-Priority was set	*LRR*$_1$	HJX	-23.25	-23.26	-23.29	-23.30	-23.26	-23.27	-23.29	-23.29	-23.28	-23.29	-23.29	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-0.67	-1.89	0.00	-23.00	-23.09	-23.14	-23.05	-1.07	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	-24.63	0.00	0.00	0.00	0.00	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LRR$_3$	HJX	0.00	0.34	0.00	0.71	0.59	0.00	0.03	0.78	0.00	0.01	0.01	0.97	0.04	0.58	0.56
		AK	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.12	0.00	0.00	0.00	0.13	0.00	0.10	0.10
		DJK	0.06	0.00	0.00	0.00	-0.18	0.06	0.00	0.00	0.00	0.00	0.00	-0.07	0.33	0.00	0.06
		WFZ	0.00	0.00	0.00	0.00	-0.29	0.05	0.00	0.00	0.00	0.00	0.00	-0.06	0.30	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.32
If there was IWDPs and E-Priority was set	*LRR*$_1$	HJX	0.00	0.00	0.00	0.00	-0.44	0.00	-23.29	-23.29	-23.28	0.00	0.00	-23.31	-23.31	-23.28	-0.39
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	0.00	0.00	0.00	-23.00	-23.09	-23.14	-23.05	0.00	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-24.44	-0.25	0.00	0.00	0.00	0.00	0.00	-24.42	0.00	0.00	-24.43
	LRR$_2$	HJX	-0.01	0.16	-0.01	0.24	0.20	0.01	0.16	0.21	0.22	0.00	-0.01	0.22	0.26	0.20	0.20
		AK	0.00	0.06	0.00	0.09	0.08	0.00	0.06	0.08	0.09	0.00	0.00	0.09	0.10	0.08	0.08
		DJK	0.06	0.09	0.00	0.07	0.06	0.17	0.10	0.09	0.10	0.10	0.09	0.09	0.07	0.12	0.12
		WFZ	0.05	0.07	0.00	0.06	0.05	0.14	0.09	0.08	0.08	0.08	0.08	0.07	0.05	0.10	0.10
		XL	0.04	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.40

Table S3. *LRR*$_n$ values when there are only water donation and different priority orders are set at the annual scale.

	The Log Response Ratio	Reservoirs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

If there was only water donation and S-Priority was set	LRR_2	HJX	-0.61	-0.52	-0.63	-0.55	-0.44	-0.43	-0.43	-0.45	-0.46	-0.48	-0.64	-0.46	-0.49	-0.44	-0.44
		AK	-0.26	-0.22	-0.28	-0.23	-0.16	-0.12	-0.13	-0.18	-0.19	-0.21	-0.29	-0.19	-0.21	-0.17	-0.17
		DJK	-0.42	-0.46	-0.52	-0.53	-0.18	-0.32	-0.38	-0.40	-0.41	-0.41	-0.40	-0.26	-0.13	-0.48	-0.48
		WFZ	-0.40	-0.42	-0.49	-0.50	-0.26	-0.33	-0.36	-0.39	-0.39	-0.40	-0.38	-0.27	-0.26	-0.45	-0.43
		XL	-0.37	-0.02	-0.02	-0.05	-0.03	-0.20	-0.14	-0.16	-0.07	-0.17	-0.06	-0.02	-0.13	-0.13	0.06
	LRR_3	HJX	-0.07	-0.60	-0.24	-1.23	-0.92	0.00	-0.08	-1.10	0.00	-0.11	-0.29	-1.17	-0.15	-0.92	-0.88
		AK	0.00	0.00	0.00	0.00	-0.21	0.00	0.00	-0.30	0.00	0.00	-1.40	-0.38	0.00	-0.23	-0.22
		DJK	-0.18	-0.14	0.00	0.00	-1.10	-1.21	0.00	0.00	0.00	0.00	0.00	-1.09	-1.06	0.00	-0.20
		WFZ	-0.24	-0.14	0.00	0.00	-1.12	-1.28	0.00	0.00	0.00	0.00	0.00	-1.12	-1.11	0.00	-0.14
		XL	-1.74	0.00	0.00	-0.41	-0.64	-1.61	-1.44	0.00	0.00	0.00	0.00	-0.58	0.00	0.00	-0.58
cIf there was only water donation and H-Priority was set	LRR_1	HJX	-23.25	-23.26	-23.29	-23.30	-23.26	-23.27	-23.29	-23.29	-23.28	-23.29	-23.29	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-23.22	-24.43	-23.20	-23.00	-23.09	-23.14	-23.05	-23.04	-23.05	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	-24.63	0.00	0.00	0.00	-0.49	-24.47	-2.02	-1.07	0.00	-1.07	0.00	0.00	-1.66	0.00	0.00
	LRR_3	HJX	0.00	0.00	0.00	0.00	-0.07	0.00	0.00	-0.06	0.00	0.00	0.00	-0.09	0.00	-0.06	-0.07
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.03	0.00	0.00	0.00
		DJK	0.00	0.00	0.00	0.00	-1.18	-0.96	0.00	0.00	0.00	0.00	0.00	-1.04	-0.39	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-1.14	-0.93	0.00	0.00	0.00	0.00	0.00	-1.01	-0.42	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-0.47	-0.31	-0.03	0.00	0.00	0.00	0.00	-0.44	0.00	0.00	-0.13
If there was only water donation and	LRR_1	HJX	0.00	-0.80	0.00	-1.47	-23.26	0.00	-23.29	-23.29	-23.28	-0.02	-0.01	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-23.22	-24.43	-23.20	-23.00	-23.09	-23.14	-23.05	-23.04	-23.05	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	-0.90	0.00	0.00	0.00	-24.44	-3.44	-3.81	0.00	0.00	0.00	0.00	-24.42	0.00	0.00	-24.43

E-Priority was set		HJX	-0.44	-0.18	-0.46	-0.12	-0.04	-0.15	-0.02	-0.04	-0.04	-0.29	-0.46	-0.04	-0.04	-0.04	-0.04
		AK	-0.16	-0.07	-0.16	-0.05	-0.02	-0.07	-0.01	-0.02	-0.02	-0.11	-0.16	-0.02	-0.02	-0.02	-0.02
	LRR_2	DJK	-0.29	-0.30	-0.34	-0.28	-0.07	-0.07	-0.22	-0.23	-0.23	-0.23	-0.23	-0.12	0.00	-0.27	-0.27
		WFZ	-0.25	-0.25	-0.29	-0.24	-0.14	-0.08	-0.19	-0.20	-0.20	-0.20	-0.19	-0.13	-0.13	-0.23	-0.22
		XL	-0.02	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.32

Table S4. LRR_n values when there are only water receiving and different priority orders are set at the annual scale.

	The Log Response Ratio	Reservoirs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
If there was only water receiving and S-Priority was set	LRR_2	HJX	-0.08	-0.07	-0.08	-0.07	-0.05	-0.04	-0.05	-0.06	-0.06	-0.06	-0.08	-0.06	-0.06	-0.05	-0.05
		AK	-0.09	-0.08	-0.10	-0.08	-0.06	-0.05	-0.05	-0.07	-0.07	-0.08	-0.11	-0.07	-0.08	-0.07	-0.07
		DJK	-0.04	-0.03	-0.04	-0.06	0.00	-0.03	-0.02	-0.05	-0.05	-0.05	-0.05	0.00	0.01	-0.05	-0.05
		WFZ	-0.04	-0.02	-0.03	-0.05	-0.03	-0.05	-0.03	-0.05	-0.05	-0.05	-0.05	-0.04	-0.02	-0.05	-0.05
		XL	-0.16	-0.02	-0.02	-0.02	-0.02	-0.05	-0.02	-0.04	-0.02	-0.05	-0.02	-0.02	-0.02	-0.02	0.06
	LRR_3	HJX	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	-0.06	0.00	0.00	0.00	-0.09	0.00	-0.05	-0.05
		AK	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	-0.10	0.00	0.00	0.00	-0.11	0.00	-0.06	-0.06
		DJK	0.00	0.00	0.00	0.00	-0.09	-0.24	0.00	0.00	0.00	0.00	0.00	-0.13	-0.04	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-0.09	-0.31	0.00	0.00	0.00	0.00	0.00	-0.12	-0.04	0.00	0.00
		XL	0.00	0.00	0.00	0.00	0.55	0.08	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.45
If there was only water receiving	LRR_1	HJX	-23.25	-23.26	-23.29	-23.30	-23.26	-23.27	-23.29	-23.29	-23.28	-23.29	-23.29	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	0.00	-1.06	0.00	-23.00	-23.09	-23.14	-23.05	-1.07	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

and H-Priority was set		XL	-24.63	0.00	0.00	0.00	0.00	-0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LRR_3	HJX	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.13	0.00	0.00	0.00	0.20	0.00	0.08	0.08
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
		DJK	0.00	0.00	0.00	0.00	-0.27	-0.07	0.00	0.00	0.00	0.00	0.00	-0.11	0.07	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-0.20	-0.02	0.00	0.00	0.00	0.00	0.00	-0.04	0.09	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-0.14	0.05	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.25
If there was only water receiving and E-Priority was set	LRR_1	HJX	0.00	0.00	0.00	0.00	-0.44	0.00	-23.29	-23.29	-23.28	0.00	0.00	-23.31	-23.31	-23.28	-0.39
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	0.00	0.00	0.00	-23.00	-23.09	-23.14	-23.05	0.00	0.00	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	0.00	0.00	0.00	0.00	-24.44	-0.08	0.00	0.00	0.00	0.00	0.00	-24.42	0.00	0.00	-24.43
	LRR_2	HJX	-0.08	-0.07	-0.08	-0.07	-0.05	-0.04	-0.05	-0.06	-0.06	-0.06	-0.08	-0.06	-0.06	-0.05	-0.05
		AK	-0.09	-0.08	-0.10	-0.08	-0.06	-0.05	-0.05	-0.07	-0.07	-0.08	-0.11	-0.07	-0.08	-0.07	-0.07
		DJK	-0.05	-0.05	-0.06	-0.06	0.00	-0.03	-0.04	-0.06	-0.06	-0.06	-0.06	-0.01	0.00	-0.06	-0.06
		WFZ	-0.07	-0.06	-0.08	-0.08	-0.05	-0.07	-0.06	-0.08	-0.08	-0.08	-0.08	-0.05	-0.05	-0.07	-0.07
		XL	-0.18	-0.02	-0.02	-0.02	-0.02	-0.06	-0.02	-0.05	-0.02	-0.05	-0.02	-0.02	-0.02	-0.02	0.06

Table S5. LRR_n values when there are both water donation and receiving and different priority orders are set at the annual scale.

	The Log Response Ratio	Reservoirs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
If there are both water donation	LRR_2	HJX	-0.61	-0.52	-0.63	-0.55	-0.44	-0.43	-0.43	-0.45	-0.46	-0.48	-0.64	-0.46	-0.49	-0.44	-0.44
		AK	-0.26	-0.22	-0.28	-0.23	-0.16	-0.12	-0.13	-0.18	-0.19	-0.21	-0.29	-0.19	-0.21	-0.17	-0.17
		DJK	-0.41	-0.43	-0.48	-0.53	-0.18	-0.32	-0.36	-0.40	-0.40	-0.40	-0.40	-0.25	-0.10	-0.47	-0.47

and receiving and S-Priority was set		WFZ	-0.37	-0.36	-0.41	-0.45	-0.24	-0.30	-0.32	-0.36	-0.35	-0.36	-0.35	-0.25	-0.23	-0.41	-0.39
		XL	-0.35	-0.02	-0.02	-0.04	-0.02	-0.18	-0.12	-0.15	-0.06	-0.16	-0.05	-0.02	-0.11	-0.12	0.06
	LRR$_3$	HJX	-0.07	-0.60	-0.24	-1.23	-0.92	0.00	-0.08	-1.10	0.00	-0.11	-0.29	-1.17	-0.15	-0.92	-0.88
		AK	0.00	0.00	0.00	0.00	-0.21	0.00	0.00	-0.30	0.00	0.00	-1.40	-0.38	0.00	-0.23	-0.22
		DJK	-0.18	-0.09	0.00	0.00	-1.10	-1.21	0.00	0.00	0.00	0.00	0.00	-1.09	-0.99	0.00	-0.20
		WFZ	-0.17	-0.03	0.00	0.00	-1.07	-1.20	0.00	0.00	0.00	0.00	0.00	-1.07	-1.03	0.00	-0.08
		XL	0.00	0.00	0.00	0.00	0.19	0.08	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.09
If there are both water donation and receiving and H-Priority was set	*LRR*$_1$	HJX	-23.25	-23.26	-23.29	-23.30	-23.26	-23.27	-23.29	-23.29	-23.28	-23.29	-23.29	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-23.22	-24.43	-23.20	-23.00	-23.09	-23.14	-23.05	-23.04	-1.24	-23.03	-23.01
		WFZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		XL	-24.63	0.00	0.00	0.00	-0.27	-24.47	-0.94	-0.70	0.00	-0.72	0.00	0.00	-0.95	0.00	0.00
	LRR$_3$	HJX	0.00	0.00	0.00	0.00	-0.07	0.00	0.00	-0.06	0.00	0.00	0.00	-0.09	0.00	-0.06	-0.07
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.03	0.00	0.00	0.00
		DJK	0.00	0.00	0.00	0.00	-1.18	-0.96	0.00	0.00	0.00	0.00	0.00	-1.04	-0.36	0.00	0.00
		WFZ	0.00	0.00	0.00	0.00	-1.09	-0.88	0.00	0.00	0.00	0.00	0.00	-0.96	-0.31	0.00	0.00
		XL	0.00	0.00	0.00	0.00	0.28	0.08	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.45
If there are both water donation and	*LRR*$_1$	HJX	0.00	-0.80	0.00	-1.47	-23.26	0.00	-23.29	-23.29	-23.28	-0.02	-0.01	-23.31	-23.31	-23.28	-23.26
		AK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		DJK	-23.04	-23.05	-23.18	-23.13	-23.22	-24.43	-23.20	-23.00	-23.09	-23.14	-23.05	-23.04	-1.24	-23.03	-23.01
		WF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

receiving and E-Priority was set		Z														
		XL	-0.63	0.00	0.00	0.00	-24.44	-1.74	-1.27	0.00	0.00	0.00	0.00	-24.42	0.00	0.00	-24.43
	LRR_2	HJX	-0.44	-0.18	-0.46	-0.12	-0.04	-0.15	-0.02	-0.04	-0.04	-0.29	-0.46	-0.04	-0.04	-0.04	-0.04
		AK	-0.16	-0.07	-0.16	-0.05	-0.02	-0.07	-0.01	-0.02	-0.02	-0.11	-0.16	-0.02	-0.02	-0.02	-0.02
		DJK	-0.29	-0.27	-0.31	-0.28	-0.07	-0.07	-0.20	-0.23	-0.22	-0.22	-0.22	-0.11	0.01	-0.26	-0.26
		WFZ	-0.22	-0.20	-0.23	-0.21	-0.13	-0.06	-0.15	-0.18	-0.17	-0.17	-0.17	-0.11	-0.11	-0.20	-0.20
		XL	-0.02	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.40	-0.02	-0.02	-0.32

Point #5

COMMENT: *To come back to my initial point: the results section could focus on only two of the three result schemes: monthly, seasonal and annual. Decide on which two of these three are the most pertinent and clear. And present the third one as supplementary material. The result session should therefore be reduced by one third from 330 lines to only 220 lines.*

RESPONSE: We are grateful for your perceptive feedback, which has significantly strengthened the manuscript's conceptual clarity and structural precision. In response to your comment, we have made revisions to the results section. We have decided to focus on the monthly and seasonal scales as they provide the most pertinent and clear insights for the main discussion. The annual scale has been moved to the supplementary material, reducing the length of the Results section by 34%. This revision ensures a more concise presentation while still retaining the comprehensive analysis in the supplementary section for those interested in the full data.

Point #6

COMMENT: *In addition, and this is a completely separate comment, and aligns with reviewer #1: you now have called section 4 "Results and discussion", but there is hardly any discussion. I would recommend you to include a new "Discussion" section, in which you (critically) discuss the value of your work by referring to what other experts have done. That can be perhaps be done in half a page.*

RESPONSE: We gratefully acknowledge the editor's guidance and have comprehensively restructured the manuscript to address this concern. We fully agree that expanding the critical discussion will strengthen the contextualization of our findings. The original "Results and Discussion" section (Section 4) has been bifurcated into distinct "4 Results" (Page 13-22) and "5 Discussion" (Page 22-23), achieving enhanced focus through strategic revisions. In Section 4, we streamlined results presentation by 34%, relocating annual-scale analyses to Supplementary material. The new Discussion section (Section 5) is:

"5 Discussion

The proposed framework reveals significant negative feedbacks of the water supply component

(S) on both hydropower generation (H) and environment conservation (E), as evidenced by reductions in hydropower generation (negative LRR_2 in Figure 7 (a-1)) and ecological flow satisfaction rate (negative LRR_2 in Figure 7 (a-2)) with S-Priority. The negative feedbacks of the S component on E are more pronounced than those on H, as evidenced by the wider range of variation in LRR_3 values compared to LRR_2 values. These findings are consistent with previous studies on the SHE nexus (Chen et al.,2018; Khalkhali et al., 2018). It has been found that there are a few positive feedbacks between S and H in abundant water months even the spilled water leads to a reduction in hydropower generation (Jiang et al., 2018). Thus, the increasing water storage or increasing water supply still can ensure hydropower generation. The values of ecological flow satisfaction rates for XL and AK significantly decrease due to their greater reductions of ecological flow and their higher ecological flow standards at the two reservoirs dam sites. The extreme values (e.g., lower than 90 % months values) of LRR_3 for HJX, AK, WFZ, and XL reservoirs occur in the higher water supply demand months such as June to September of each year. And Gao et al. (2023) find that the higher water supply demand, the lower ecological flow left in river. The environment conservation of downstream river systems is critically influenced by upstream water supply decisions (Gupta, 2008).

Contrary to the unidirectional positive nexus between hydropower generation and environment conservation proposed by Wei et al. (2022), our study reveals bidirectional feedbacks of H and E, aligning with Wu et al. (2021). The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir, Zhang et, al., 2008) even in abundant water months, particularly. The increased flows for hydropower generation alleviates the pressure of ecological damage in river. However, the more flows for hydropower generation from the reservoir, the less supplied amount of available water resources (Doummar et al., 2009), and leads to negative impacts on the S component. The feedbacks of the H on S are more pronounced than on E, according to the wider range of variation in LRR_1 values compared to LRR_3 values.

Negative feedbacks of the E component on S for reservoirs has been found in the scenario that main function is water supply while no significant effect on reservoirs has been found in the scenario that main function is hydropower generation (negative LRR_1 in Figure 7 (c-1)). There are both negative and positive feedbacks of the E component on H while the negative feedbacks are grown in abundant water months. Feedbacks of the E component on S are stronger than those on H, according to the values of LRR_n. The negative feedbacks between S and H, and between S and E are strong in low flow months due to the high-water supply demand. More competitions for water can be found among S, H and E in low flow months, and their negative feedbacks of the SHE nexus have found to be strengthened. Feedback loops of SHE nexus in reservoirs with regulation function (e.g., AK and DJK) remain stable under the varying inflow conditions. These reservoirs reasonably allocate water among S, H and E components to prevent strengthening of negative feedbacks in low flow months. Furthermore, increasing hydropower generation flow might have impacts on downstream water quality and biodiversity (Botelho et al., 2017; Martinez et al., 2019), the feedbacks of H on E are enhanced.

Inter-basin Water Diversion Projects (IWDPs) have negative impacts on the regional water supply from DJK and upstream reservoirs with negative LRR_1, consistent with Hong et al. (2016) and Ouyang et al. (2018). And all reservoirs have reduced their hydropower generation, but there are positive impacts on H in abundant water months with positive LRR_2 in Figure 14 (b). Many studies have highlighted the negative impacts of IWDPs on hydropower generation (Yang, et al., 2023), but the positive impacts are less frequently discussed. With the water donation for the Han-to-Wei Water Diversion Project, the Middle Route of the South-to-North Water Diversion Project and the Northern Hubei Water Resources Allocation Project, multiple algal bloom events occurred in the downstream of HRB (Tian et al., 2022), and the water donation had a significant negative impact on the environment conservation of the basin. Water receiving from the Three Gorges Reservoir to Hanjiang River are not compensate for all their negative impacts, and water receiving from the Changjiang-to-Hanjiang River Water Diversion Project benefits environment conservation for XL.

It is evident that IWDPs significantly alter the feedback loops of the SHE nexus by modifying water availability. As IWDPs export or import water to or from an area, the amount of available water has to be altered. It can prompt a redistribution and re-planning of the available water (Li, et al., 2014). And the redistribution and re-planning can significantly impact on feedback loops of SHE nexus (Feng, et al., 2019). Although strong responses occur in feedback loops of SHE nexus, its positive or negative nature of feedback among these components remains stable with impacts of IWDPs. Thus, the redistribution and re-planning of available water can not alter their competitions and collaborations among the components of the SHE nexus. It is evident that water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E while receiving water has positive impacts on all these feedbacks. Water donation results in a reduction of available water (Mok et al., 2015; Wu et al., 2022) and leads to lower flow. More competition for water can be found among S, H and E, and negatively impacts on the feedbacks. Less competition is found among S, H and E in water receiving areas, and it has positive impacts on their feedbacks. The persistent feedback polarity with IWDPs suggests that simply increasing water supply (e.g., via compensation donations like Three Gorges-to-Hanjiang) cannot resolve inherent SHE conflicts—instead, adaptive allocation rules that account for these stable feedback patterns are needed.

The consistency in the signs of mean LRR_n values across seasonal as shown in Figure 9 and annual scales as shown in Supplementary material Table S1-S5 with those at the monthly scale indicates an inherent similarity and stability in SHE nexus feedback loops over different temporal resolutions. Compared with the values of LRR_n at monthly scale, the values at the seasonal scale show its stronger periodic variations. Based on the variations in LRR_n and the mathematical implications of LRR_1, LRR_2, and LRR_3, this study found that these periodic variations align closely with the runoff variations, and the temporal and spatial variations in feedback loops are primarily attributed to variations in runoff. The wavelet transform analysis has also been applied in the runoffs for HJX, AK, DJK, WFZ, and XL dam sites. And the results are in consisted with that in Hutuo River Basin (Xu et al., 2018), the periodic variations have been found at the seasonal scale. The LRR_n values at the seasonal scale can help analyze the variations in periodic feedback loops. Different from the monthly or seasonal scales, results at the annual scale reveal the long-term trends and periodic variations in the inter-annual and spatial trends of the SHE nexus from a macro perspective. The impacts of reservoir operation and the regulation on SHE nexus can be clearly simulated and observed at the monthly scale, so the immediate changes in the nexus at monthly scale can provide information for short-term decision-making in reservoirs. Water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E, while receiving water has positive impacts on these feedbacks across different time scales. Compared with the values of LRR_n at monthly scale, the values of LRR_n at seasonal and annual scales are stable and changes can be found in low flow periods."

Point #7

COMMENT: *It would be useful to mention somewhere in the beginning of the paper that the concept of IWDP is identical to what many other authors call inter-basin water transfers (IBWTs).*

RESPONSE: Thank you for this constructive suggestion. As recommended, we have explicitly clarified the equivalence between IWDPs and IBWTs in the introduction section (Page 2, Line 63-64). A statement now reads: "Inter-basin water diversion projects (IWDPs), also commonly referred to as inter-basin water transfers (IBWTs, Dong et al., 2023; Sheng et al., 2024), have been widely implemented to solve the imbalance (Siddik et al., 2023) through transferring water resources from water-rich areas (i.e., water donating area) to water-deficient regions (i.e., water receiving area) through channels and other hydraulic engineering works. (**On Line 63-64 of the revised manuscript**)" Additionally, relevant references adopting the IBWTs terminology have been cited to align our work with related researches. This revision enhances terminological consistency and avoids potential confusion for readers familiar with different nomenclature.

Relevant references:

Dong, J., Chen, X., Li, Y., Gao, M., Wei, L., Tangdamrongsu, N., Crow, T.W.: Inter-Basin Water Transfer Effectively Compensates for Regional Unsustainable Water Use. Water Resour. Res., 59(12), https://doi.org/10.1029/2023WR035129, 2023.

Sheng, J., Zhang, R., and Yang, H.: Inter-basin water transfers and water rebound effects: The South-North water transfer Project in China. J. Hydrol., 638, 131516, https://doi.org/10.1016/J.JHYDROL.2024.131516, 2024.

Point #8

COMMENT: *Line 107-109: you write "It has been widely application in runoff simulations across various basins worldwide, consistently yielding outstanding results." Give references.*

RESPONSE: Thank you for highlighting the need for supporting references in this section. The statement has been revised to include citations of key studies demonstrating the global applicability and performance of the method in runoff simulations. The revised part is:

> "The VIC model has been widely applied in runoff simulations across various basins worldwide, consistently yielding outstanding results (Yeste et al., 2024; Su et al., 2024; Wang et al., 2012). (**On Line 114-115 of the revised manuscript**)"

Relevant references:

Yeste, P., Ojeda, G.M., Gámiz-Fortis, R.S., Castro-Díez, Y., Bronstert, A., and Esteban-Parra, J.M.: A large-sample modelling approach towards integrating streamflow and evaporation data for the Spanish catchments, Hydrol. Earth Syst. Sci., 28, 5331–5352, https://doi.org/10.5194/hess-28-5331-2024, 2024.

Su, L., Lettenmaier, P.D., Pan, M., and Bass, B. Improving runoff simulation in the Western United States with Noah-MP and VIC models, Hydrol. Earth Syst. Sci., 28, 3079–3097, https://doi.org/10.5194/hess-28-3079-2024, 2024.

Wang, G., Zhang, J., Jin, J., Pagano, T.C., Calow, R., Bao, Z., Liu, C., Liu, Y., Yan, X.: Assessing water resources in China using PRECIS projections and a VIC model. Hydrol. Earth Syst. Sci., 16(150):231-240, https://doi.org/10.5194/hess-16-231-2012, 2012.

Point #9

COMMENT: *Line 119: PBLAS Do you mean PBIAS?; see also lines 126 and 127.*

RESPONSE: Thank you very much for your meticulous review and constructive feedback. You are absolutely correct—the term "PBLAS" in lines 119, 126, and 127 is indeed a error, and it should be replaced with "PBIAS" We sincerely apologize for this oversight during the editing process. We have now corrected all instances in the revised manuscript and conducted an additional thorough check to ensure consistency and accuracy of terminology throughout the paper. Your keen attention to detail has been invaluable in preventing potential misunderstandings related to this key metric, and we deeply appreciate the time and expertise you have dedicated to improving our work. Thank you once again for your guidance. The revised part is:

"In order to verify the accuracy of the runoff simulation results, the simulations need to be compared with the observations. Three widely used quantitative indices of numerical differences are selected, and they are the Nash-Sutcliffe efficiency coefficient (*NSE*, Nash and Sutcliffe, 1970), Coefficient of determination (R^2, Rousseeuw and Leroy, 1987), and Percent bias (*PBIAS*, Bland and Altman, 1986):

$$NSE = 1 - \frac{\sum_{t=1}^{T}\left(Q_t^o - Q_t^s\right)^2}{\sum_{t=1}^{T}\left(Q_t^o - \overline{Q^o}\right)^2} \tag{1}$$

$$R^2 = \frac{\left[\sum_{t=1}^{T}\left(Q_t^o - \overline{Q^o}\right)\left(Q_t^s - \overline{Q^s}\right)\right]^2}{\sum_{t=1}^{T}\left(Q_t^o - \overline{Q^o}\right)^2 \sum_{t=1}^{T}\left(Q_t^s - \overline{Q^s}\right)^2} \tag{2}$$

$$PBIAS = \frac{\sum_{t=1}^{T}\left(Q_t^o - Q_t^s\right)\times 100}{\sum_{t=1}^{T} Q_t^o} \tag{3}$$

where, Q_t^o and Q_t^s are the observed and simulated runoff results at *t*th month, m^3/s. $\overline{Q^o}$ and $\overline{Q^s}$ are the average of the observed and simulated runoff results over the whole period *T*, m^3/s. *NSE* $\in (-\infty, 1]$, the closer *NSE* is to 1, the better the simulations are. The *NSE* of the simulations greater than 0.5 is acceptable. $R^2 \in [0,1]$, R^2 approaching 1 means the simulations are equal to the observations. *PBIAS* is utilized to quantify the cumulative deviation between the simulations and observations. *PBIAS* lager than 0 meant that the simulations are generally small, and vice versa, the simulations are generally large. When $|PBIAS| < 25\%$, the runoff simulation results are acceptable. (**On page 5 of the revised manuscript**)"

Point #10

COMMENT: *Line 163: the parameter EF is introduced, with without any definition. What does EF mean? In what unit is it expressed?*

RESPONSE: Thank you for your careful review. The term "EF" refers to ecological flows, defined as the minimum flow threshold required to sustain river ecosystem integrity. We have revised the text to explicitly state this definition: "...ecological flows (EFs, m^3/s)" in Section 2.3. The revised part is:

"In order to establish a multi-level ecological flow standard to aid in evaluating river ecological health, the multi-level ecological flows are estimate by the MTMMHC method. There are over 200 methods for ecological flows (EFs, m^3/s) estimation worldwide, typically categorized into four types: hydrological, hydraulic, habitat simulation, and holistic methods (Tharme, 2003). The Tennant method, which determines EFs based on predetermined percentages of average annual flow, is the most widely used hydrological method (Tharme, 2003). The MTMMHC method (Li and Kang, 2014) modifies the Tennant method based on three parameters: average periodic flow, water period, and percentage. It can solve four key problems existed in the current ecological flow standards: spatial transferability, monthly variability, inter-annual variability and scalability (Li, et al., 2015). Indeed, the MTMMHC method can avoid the impacts of extreme inter-annual flow events and uneven intra-annual distribution. This enables the calculation of different guarantee rates for various river sections, water years (e.g., wet, normal, and dry years), and months. It reflects the temporal and spatial variability of EFs, and provides a comprehensive and reasonable multi-level ecological flows standards. The steps of the MTMMHC method are as follows. (**On page 6 of the revised manuscript**)"

Point #11

COMMENT: *Eq. 13: the factors g (gravitational acceleration) and rho (density of water) are missing.*

RESPONSE: Thank you for your careful review and insightful feedback regarding Eq. 13

(N=KQH). Your observation about the omission of gravitational acceleration (g) and water density (ρ) is entirely valid. We acknowledge that the original formulation lacked clarity in defining the constant K, which may have caused confusion about its physical meaning and dimensional consistency. To address this, we have revised Eq. 13 to explicitly incorporate ρ and g, aligning it with the standard hydropower equation:

$$E_{i,t} = \sum_{t=1}^{T} N_{i,t} \Delta t \qquad N_{i,t} = K_i Q_{e,i,t} H_{i,t} \qquad K_i = \eta_i g \rho$$

where, $E_{i,t}$ is the hydropower generation of the ith reservoir, kW·h; $N_{i,t}$ is the output of the ith reservoir in the tth period, kW; K_i is the comprehensive hydropower coefficient of the ith reservoir, kg/(s²·m²); η_i is the hydropower generation efficiency; g is the gravitational acceleration, m/s^2; ρ is the density of water, kg/m³; $Q_{e,i,t}$ and $H_{i,t}$ are the release discharge for hydropower generation, m^3/s, and the average hydropower head of the ith reservoir in period t, m, respectively.

The revised part is:

"② Hydropower generation:

$$E_{i,t} = \sum_{t=1}^{T} N_{i,t} \Delta t \qquad N_{i,t} = K_i Q_{e,i,t} H_{i,t} \qquad K_i = \eta_i g \rho \tag{14}$$

where, $E_{i,t}$ is the hydropower generation of the ith reservoir, kW·h; $N_{i,t}$ is the output of the ith reservoir in the tth period, kW; K_i is the comprehensive hydropower coefficient of the ith reservoir, kg/(s²·m²); η_i is the hydropower generation efficiency; g is the gravitational acceleration, m/s^2; ρ is the density of water, kg/m³; $Q_{e,i,t}$ and $H_{i,t}$ are the release discharge for hydropower generation, m^3/s, and the average hydropower head of the ith reservoir in period t, m, respectively. (**On page 7 of the revised manuscript**)"

Point #12

COMMENT: *Lines 191-192: " … and ecological water supply for the outside of the river)… ???? I do not understand this sentence.*

RESPONSE: Thank you for highlighting the lack of clarity in the original phrasing of Lines 191-192. We agree that the phrase "ecological water supply for the outside of the river" was ambiguous and could lead to misinterpretation. To resolve this, we have revised the sentence to explicitly categorize the model outputs and remove redundant terminology. The modified sentence has been integrated into Section 2.4.2 (Page 8) of the revised manuscript:

"The outputs from this MIORG model refer to regional water supply (i.e., domestic, industrial, and ecological water supply), water donation for IWDPs, evaporation and seepage losses, water release from the reservoir. (**On page 8 of the revised manuscript**)"

Point #13

COMMENT: *Figure 2: 1) what about precipitation on the lake; is that ignored? 2) what does "abandoned water" mean? Why are releases for other uses than hydropower and "abandoned water" apparently excluded?*

RESPONSE:

1) We appreciate the reviewer's insightful comment regarding precipitation on lakes and reservoirs. In this study, while direct precipitation on water surfaces was not explicitly modeled due to the default configuration of VIC model (which focuses on terrestrial hydrological processes and requires explicit land cover classification of water bodies to partition precipitation), we rigorously calibrated key model parameters (e.g., soil infiltration, baseflow recession, and routing coefficients) against observed streamflow data from six hydrological stations along the main river channel. This calibration process implicitly accounted for unmodeled contributions, including precipitation effects on lakes/reservoirs, by aligning simulated and observed outflow dynamics, as evidenced by strong validation metrics ($NSE > 0.650$, $R^2 > 0.700$). While this simplification may slightly underestimate localized storage, the robust agreement between modeled and observed streamflow suggests that the omission did not substantially bias our core conclusions.

2) We sincerely thank the reviewer for highlighting the ambiguity in the term "abandoned water," which was used in our original manuscript to describe reservoir releases not utilized for hydropower or water supply. Upon reflection and editorial guidance, we recognize that "abandoned water" could misleadingly imply intentional neglect of water resources, whereas the intended meaning aligns with the widely accepted term "spilled water" in reservoir operations literature. This term, defined as "water released from reservoirs without passing through turbines or diversion systems, often to prevent overtopping or meet downstream environmental needs", more accurately reflects the operational context. In the revised manuscript, we have replaced all instances of "abandoned water" with "spilled water" and clarified that such releases are explicitly included in our modeled reservoir outflow calculations. We apologize for any

confusion caused and appreciate the opportunity to align our terminology with established hydrological conventions.

Point #14

COMMENT: *Line 206: "quantization method": explain*

RESPONSE: Thank you for raising this important point. We have revised the phrase "the log response ratio quantization method" to "the log response ratio method" throughout the manuscript to align with standard terminology and avoid potential misinterpretation. The term "quantization" typically refers to discretizing continuous data into categories or bins (e.g., digitizing analog signals), which is unrelated to the log response ratio methodology. The log response ratio method calculates the logarithmic proportional difference between scenarios, quantifying how much a component (e.g., water supply) increases or decreases in the compared scenario relative to the baseline. This approach, widely recognized in ecological and environmental studies (e.g., Patrick et al., 2022), ensures symmetry in interpreting proportional changes without implying discretization. We appreciate your feedback and hope this revision enhances clarity.

Relevant references:

Patrick, C.J., Kominoski, J.S., McDowell, W.H., Branoff, B., Lagomasino, D., Leon, M., Hensel, E., Hensel, M.J.S., Strickland, B.A., Aide, T.M., Armitage, A., Campos-Cerqueira, M., Congdon, V.M., Crowl, T.A., Devlin, D.J., Douglas, S., Erisman, B.E., Feagin, R.A., Geist, S.J., Hall, N.S., Hardison, A.K., Heithaus, M.R., Hogan, J.A., Hogan, J.D., Kinard, S., Kiszka, J.J., Lin, T., Lu, K., Madden, C.J., Montagna, P.A., O'Connell, C.S., Proffitt, C.E., Reese, B.K., Reustle, J.W., Robinson, K.L., Rush, S.A., Santos, R.O., Schnetzer, A., Smee, D.L., Smith, R.S., Starr, G., Stauffer, B.A., Walker, L.M., Weaver, C.A., Wetz, M.S., Whitman, E.R., Wilson, S.S., Xue, J., and Zou, X.: A general pattern of trade-offs between ecosystem resistance and resilience to tropical cyclones, Sci. Adv., 8(9), eabl9155, https://doi.org/10.1126/sciadv.abl9155, 2022.

Point #15

COMMENT: *Line 209-210: you write "rn is the value of the nth index, and rc(n) is the value of the nth index need to be compared. " This is an unintelligible sentence.*

RESPONSE: We sincerely appreciate your thoughtful comment. We agree with your point and will revise the sentence accordingly for clarity. r_n represents the value of one of the three indices: regional water supply volume, hydropower generation, or ecological flow satisfaction rate in the baseline scenario. Correspondingly, $r_{c(n)}$ denotes the value of the same index in the scenario being compared. For example, if r_n refers to hydropower generation in the baseline, $r_{c(n)}$ would represent hydropower generation in the comparison scenario. In the manuscript, we give a reviser as:

> "r_n represents the value of regional water supply volume or hydropower generation or ecological flow satisfaction rate in the baseline scenario. $r_{c(n)}$ represents the value of the index in the compared scenario. (**On page 9 of the revised manuscript**)"

Point #16

COMMENT: *Lines 210-211: Can you explain better what the value of LRR mean? If they are positive, what does it mean if values differ from e.g. 0.5 to e.g. 15?*

RESPONSE: Thank you very much for your question, and we apologize for the lack of clarity in the manuscript. The positive LRR_n indicates $r_{c(n)} > r_n$, meaning the compared scenario improves the component relative to the baseline. The negative LRR_n indicates $r_{c(n)} < r_n$, meaning the compared scenario reduces the component relative to the baseline. The absolute value of LRR_n reflects the degree of change on a logarithmic scale. The larger the absolute value of LRR_n, the more substantial the improvement (if positive) or reduction (if negative) is when measured logarithmically. The revised part is:

> "where LRR_n is the log response ratio of the nth component; n denotes the component identifier (1: water supply, 2: hydropower generation, 3: environment conservation). LRR_1, LRR_2, LRR_3 quantify differences in the S, H, and E components, respectively, between two scenarios. r_n represents the value of regional water supply volume or hydropower generation or ecological flow satisfaction rate in the baseline scenario. $r_{c(n)}$ represents the value of the index in the compared scenario. $r_{c(n)}$ and r_n are both greater than or equal to zero. The positive LRR_n indicates $r_{c(n)} > r_n$, meaning the compared scenario improves the component relative to the baseline. The negative LRR_n indicates $r_{c(n)} < r_n$,

meaning the compared scenario reduces the component relative to the baseline. The absolute value of LRR_n reflects the degree of change on a logarithmic scale. (**On page 9 of the revised manuscript**)"

Point #17

COMMENT: *Lines 219-224: the priority for S is expressed by simply increasing it by 20%. But that is in my view not a normal or conventional way of dealing with prioritization of water allocation. Please justify this approach.*

RESPONSE: Thank you for raising this important point. We sincerely appreciate your insightful feedback regarding the unconventional approach to prioritizing water allocation by increasing the water supply (S) by 20%, and we appreciate the opportunity to clarify our rationale. In this study, the highest priority is set to water supply (as denoted by S-Priority), that means all reservoirs will first meet regional water demands (i.e., domestic, industrial, and ecological), with surplus water then allocated to hydropower generation and environment conservation needs. The 20% increase in regional water supply (to 120%) was not intended to represent a prioritization mechanism but rather a sensitivity-oriented adjustment to amplify the observability of impacts within the SHE nexus framework. By artificially elevating the water supply target, we aimed to enhance the discernibility of nexus between S, H, and E in quantitative modeling. This approach allows us to better characterize nexus that might otherwise remain obscured with actual water supply. The revised part is:

"To identify the impacts of different clusters of IWDPs on the SHE nexus, scenarios are set according to the following three aspects: with or without IWDPs (i.e., two types for IWDPs), different clusters of IWDPs (i.e., four clusters for the above two types), and the priority orders of S, H, and E. As there are three components for the highest priority, six scenarios can be obtained through the combination of the three components. As all S, H, and E are determined from standard scheduling rules, there are also three types for the standard scheduling rules. Combined with the types of different clusters of IWDPs, there will be a total of 30 scenarios (i.e., 4 clusters of IWDPs ×6 types for the highest priority combinations +2 types for IWDPs ×3 types for standard scheduling rules) as listed in Table 2. Specifically, to iteratively set the priority orders of S, H, and E, all three components are all in standard scheduling rules firstly. Secondly, the highest priority is set to water supply (as denoated by S-Priority), that means all reservoirs will first meet regional water demands (i.e., domestic, industrial, and ecological), with surplus water then allocated to hydropower generation and environment conservation needs. Additionally, increasing the regional water supply to 120% enhances the observability and analytical prominence of the quantitative outcomes derived from these nexus. And thirdly, hydropower generation (H-Priority) is prioritized to achieve the maximum output during the planned period. Finally, environmental conservation (E-Priority) is addressed through ensuring that the reservoir outflow meets $OEF_{xy(\max)}$. These scenarios offer flexibility in modeling SHE nexus system behavior under different conditions. (**On page 9-10 of the revised manuscript**)"

Point #18

COMMENT: *Lines 227-230: you write "Thus, the differences between Nexus Ⅰ and Nexus Ⅱ can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus Ⅲ as shown in Figure 1.), the differences between* $S_{2\text{-}m\text{-}p\text{-}c}$ *and* $S_{1\text{-}0\text{-}4\text{-}c}$ *scenarios are determined. Thus, the differences between Nexus Ⅰ and Nexus Ⅲ can figure out the impacts of IWDPs on the SHE nexus." The above text consists of three sentences of which the first and the last are identical. There must be something wrong here.*

RESPONSE: We sincerely appreciate the editor's thoughtful comment. We deeply apologize for the misrepresentation. The revised part is:

"To analyse the feedback loops of SHE nexus without IWDPs, the differences between the $S_{0\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined (i.e., the feedback loops of Nexus I as shown in Figure 1.). To analyse the feedback loops with IWDPs (i.e., the feedback loops of Nexus II as shown in Figure 1.), the differences between the $S_{3\text{-}p\text{-}n}$ (p=1, 2, 3) and $S_{3\text{-}4\text{-}n}$ scenarios are determined. Thus, the differences between Nexus I and Nexus II can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus III as shown in Figure 1.), the differences between $S_{m\text{-}p\text{-}n}$ (m=1, 2, 3; p=1, 2, 3) and $S_{0\text{-}4\text{-}n}$ scenarios are determined. The differences between Nexus I and Nexus III can figure out the impacts of different IWDP clusters on the SHE nexus. $S_{0\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules without IWDPs) and $S_{3\text{-}4\text{-}n}$ (i.e., the scenarios with standard scheduling rules with IWDPs), are the baseline scenarios for distinguishing Nexus I, Nexus III, and Nexus II. In the same way, to clarify the impacts of IWDPs on the three components, the differences between the $S_{0\text{-}4\text{-}n}$ and $S_{3\text{-}4\text{-}n}$ scenarios are determined. (**On page 10 of the revised manuscript**)"

Point #19

COMMENT: *Table 2: Explain the difference between scenarios $S_{1\text{-}0\text{-}4\text{-}1}$, $S_{1\text{-}0\text{-}4\text{-}2}$ and $S_{1\text{-}0\text{-}4\text{-}3}$; and between $S_{2\text{-}3\text{-}4\text{-}1}$, $S_{2\text{-}3\text{-}4\text{-}2}$ and $S_{2\text{-}3\text{-}4\text{-}3}$. Table 2: You could simplify the scenario number by one level by simply removing the first digit of the scenario name (1-0 becomes 0, 2-1 becomes 1, 2-2 becomes 2 and 2-3 becomes 3). For me simpler and therefore clearer.*

RESPONSE: We sincerely appreciate your valuable suggestions for enhancing the clarity of scenario nomenclature in Table 2. Below, we provide a systematic explanation of the differences between the specified scenarios and our implementation of your proposed simplification.

Following your recommendation, we reduced hierarchical complexity by truncating the first digit of scenario labels. The revised format $S_{m\text{-}p\text{-}n}$ now encodes.

- *m* represents the different clusters of IWDPs:

0: without IWDPs;

1: with only water donation;

2: with only water receiving;

3: with both donation and receiving.

- *p* represents the priority types of SHE:

1: the highest priority is set to water supply;

2: the highest priority is set to hydropower generation;

3: the highest priority is set to environment conservation;

4: the component operates under the standard scheduling rules for reservoirs.

- *n* represents the performance evaluation component:

1: water supply component;

2: hydropower generation component;

3: environment conservation component.

For instance:

$S_{0\text{-}4\text{-}1}$ (originally labeled $S_{1\text{-}0\text{-}4\text{-}1}$) represents the standard scheduling rules (p=4) without IWDPs, (m=0), evaluating water supply component (n=1).

$S_{3\text{-}4\text{-}1}$ (originally labeled $S_{2\text{-}3\text{-}4\text{-}1}$) represents the standard scheduling rules (p=4) with both water donation and receiving (m=3), evaluating water supply component (n=1).

Parallel nomenclature applies to $S_{0\text{-}4\text{-}2}$, $S_{0\text{-}4\text{-}3}$ and $S_{3\text{-}4\text{-}2}$, $S_{3\text{-}4\text{-}3}$, which respectively evaluate hydropower generation (n=2) and environmental conservation (n=3) with identical policy configurations.

This revised labeling system achieves enhanced parsimony while preserving critical information about scenario configurations through systematic parameter encoding. Scenario numbers are explained in Figure 1 and further detailed in Section 2.5. The revised and relevant parts are:

"

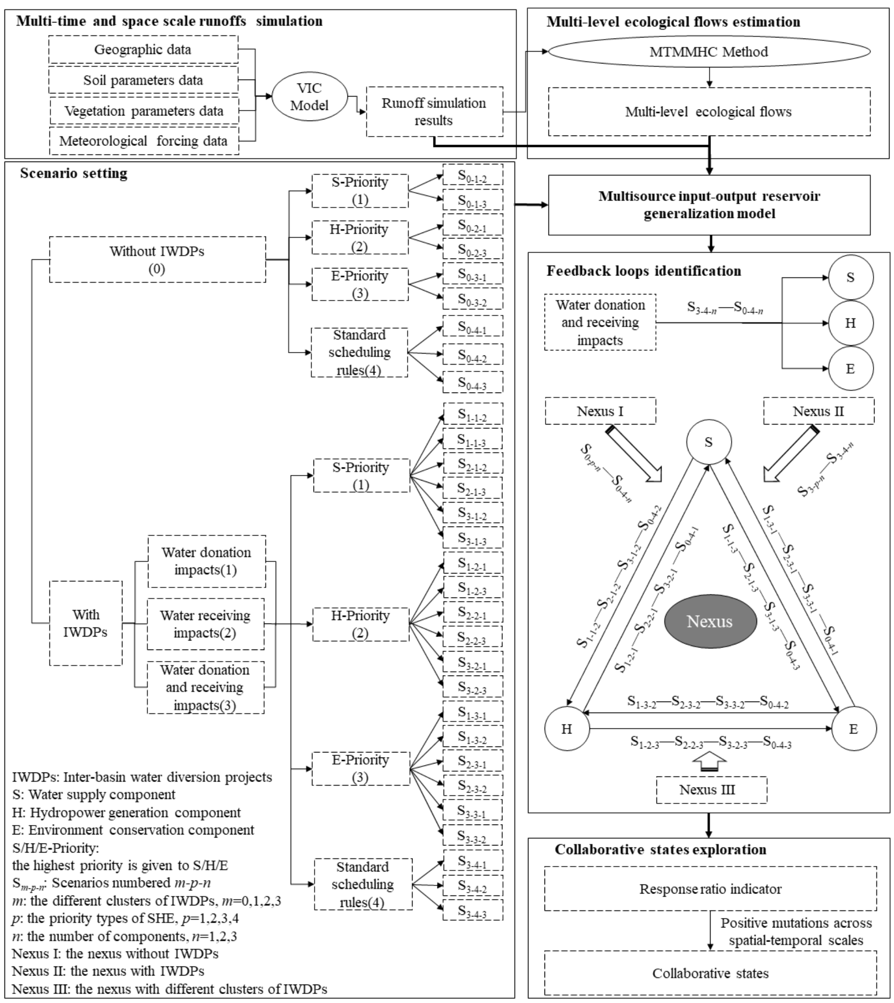

Figure 1. Framework to identify the impacts of different IWDPs on the feedback loops of SHE nexus."

"2.5 Scenario setting

To identify the impacts of different clusters of IWDPs on the SHE nexus, scenarios are set according to the following three aspects: with or without IWDPs (i.e., two types for IWDPs), different clusters of IWDPs (i.e., four clusters for the above two types), and the priority orders of S, H, and E. As there are three components for the highest priority, six scenarios can be obtained through the combination of the three components. As all S, H, and E are determined from standard scheduling rules, there are also three types for the standard scheduling rules. Combined with the types of different clusters of IWDPs, there will be a total of 30 scenarios (i.e., 4 clusters of IWDPs ×6 types for the highest priority combinations +2 types for IWDPs ×3 types for standard scheduling rules) as listed in Table 2. Specifically, to iteratively set the priority orders of S, H, and E, all three components are all in standard scheduling rules firstly. Secondly, the highest priority is set to water supply (as denoated by S-Priority), that means all reservoirs will first meet regional water demands (i.e., domestic, industrial, and ecological), with surplus water then allocated to hydropower generation and environment conservation needs. Additionally, increasing the regional water supply to 120% enhances the observability and analytical prominence of the quantitative outcomes derived from these nexus. And thirdly, hydropower generation (H-Priority) is prioritized to achieve the maximum output during the planned period. Finally, environmental conservation (E-Priority) is addressed through ensuring that the reservoir outflow meets $OEF_{xy(\max)}$. These scenarios offer flexibility in modeling SHE nexus system behavior under different conditions.

The scenarios are named in the format S_{m-p-n}, where *m* represents the different clusters of IWDPs (0: without IWDPs; 1: with only water donation; 2: with only water receiving; 3: with both donation and receiving), *p* represents the priority types of S, H, and E (1: the highest priority is water supply; 2: the highest priority is hydropower generation; 3: the highest priority is environmental conservation; 4: standard reservoir scheduling rules), and *n* represents the performance evaluation component (1: water supply component; 2: hydropower generation component; 3: environmental conservation component).

To analyse the feedback loops of SHE nexus without IWDPs, the differences between the S_{0-p-n} and S_{0-4-n} scenarios are determined (i.e., the feedback loops of Nexus I as shown in Figure 1.). To analyse the feedback loops with IWDPs (i.e., the feedback loops of Nexus II as shown in Figure 1.), the differences between the S_{3-p-n} and S_{3-4-n} scenarios are determined. Thus, the differences between Nexus I and Nexus II can figure out the impacts of IWDPs on the SHE nexus. To identify the SHE nexus with different clusters of IWDPs (i.e., the feedback loops of Nexus III as shown in Figure 1.), the differences between S_{m-p-n} and S_{0-4-n} scenarios are determined. Thus, the differences between Nexus I and Nexus III can figure out the impacts of different IWDP clusters on the SHE nexus. S_{0-4-n} (i.e., the scenarios with standard scheduling rules without IWDPs) and S_{3-4-n} (i.e., the scenarios with standard scheduling rules with IWDPs), are the baseline scenarios for distinguishing Nexus I, Nexus III, and Nexus II. In the same way, to clarify the impacts of IWDPs on the three components, the differences between the S_{0-4-n} and S_{3-4-n} scenarios are determined.

Table 2. The scenarios to identify the impacts of different clusters of IWDPs on the SHE nexus.

Different clusters of IWDPs (*m*)		The priority orders of S, H, and E (*p*)			Scenarios
		S	H	E	
Without IWDPs	\ (0)		ISQ		S_{0-4-1}
					S_{0-4-2}
					S_{0-4-3}
		S-Priority	\	ISQ	S_{0-1-2}
		S-Priority	ISQ	\	S_{0-1-3}

		\	H-Priority	ISQ	S_{0-2-1}
		ISQ	H-Priority	\	S_{0-2-3}
		\	ISQ	E-Priority	S_{0-3-1}
		ISQ	\	E-Priority	S_{0-3-2}
With IWDPs	With water donation impacts (1)	S-Priority	\	ISQ	S_{1-1-2}
		S-Priority	ISQ	\	S_{1-1-3}
		\	H-Priority	ISQ	S_{1-2-1}
		ISQ	H-Priority	\	S_{1-2-3}
		\	ISQ	E-Priority	S_{1-3-1}
		ISQ	\	E-Priority	S_{1-3-2}
	With water receiving impacts (2)	S-Priority	\	ISQ	S_{2-1-2}
		S-Priority	ISQ	\	S_{2-1-3}
		\	H-Priority	ISQ	S_{2-2-1}
		ISQ	H-Priority	\	S_{2-2-3}
		\	ISQ	E-Priority	S_{2-3-1}
		ISQ	\	E-Priority	S_{2-3-2}
	With water donation and receiving impacts (3)				S_{3-4-1}
			ISQ		S_{3-4-2}
					S_{3-4-3}
		S-Priority	\	ISQ	S_{3-1-2}
		S-Priority	ISQ	\	S_{3-1-3}
		\	H-Priority	ISQ	S_{3-2-1}
		ISQ	H-Priority	\	S_{3-2-3}
		\	ISQ	E-Priority	S_{3-3-1}
		ISQ	\	E-Priority	S_{3-3-2}

* ISQ (In Status Quo) indicates that the component operates under the standard scheduling rules for reservoirs. (**On page 9-11 of the revised manuscript**)”

Point #20

COMMENT: *Line 238: acronym HR not explained.*

RESPONSE: We apologize for not explaining the abbreviation “HR” earlier. To ensure clarity and avoid unnecessary abbreviations, we have replaced it with the full term “Hanjiang River” (**On Line 272 of the revised manuscript**). This makes the explanation a bit smoother and more professional.

Point #21

COMMENT: *Figure 5: The IWDPs are not very clear in this figure. Fig 5 and Table 3: The link between Fig 5 and Table 3 is not easy because of the naming of the reservoirs. Try to make things easily understandable for the reader, if you want your paper to have impact!*

RESPONSE: We greatly appreciate your insightful comments and apologize for the lack of clarity. To enhance the clarity of the IWDPs in Figure 5, we have changed the names of the IWDPs to blue font and separately displayed the water donation nodes and water receiving nodes in the legend. Regarding the connection between Figure 5 and Table 3, we understand that the naming of the reservoirs may have caused some confusion. We have adjusted the naming conventions in both the figure and the table to ensure a clearer link between them. These changes should help make the content more accessible and comprehensible for readers. the revised part are:

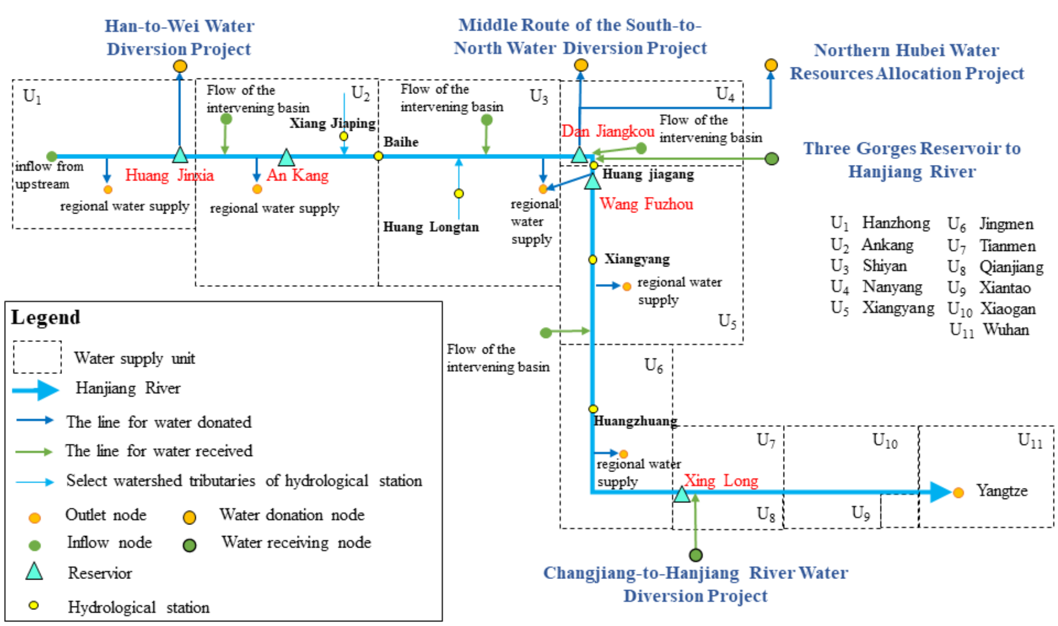

Figure 5. The sketch graphic of the Hanjiang River Basin (adapted from Zeng et al., 2023).

Table 3. List of characteristic parameter values of reservoirs.

Characteristic parameter	Unit	Huang Jinxia	An Kang	Dan Jiangkou	Wang Fuzhou	Xing Long
Operational year	year	2023	1992	2013	2003	2013
Normal water level	m	450	330	170	86.23	36.2

Usable storage	$10^8 m^3$	0.92	14.95	163.6	1.495	0.246
Dead water level	m	440	305	150	85.48	35.7
Installed capacity	MW	135	800	900	109	40
Annual generation	billion kW·h	0.25	2.80	3.83	0.58	0.23
Comprehensive hydropower coefficient	$kg/(s^2 \cdot m^2)$	8.4	8.4	7.7	8.5	8.4
Regulation ability	time	Daily	Yearly	Multi-year	Daily	Daily

Point #22

COMMENT: *Table 3: 1) why haven't you included the year in which each reservoir was put into operation? 2) What is the unit for hydropower generation efficiency? 3) What is the unit for regulation ability: residence time? If so, the unit is time.*

RESPONSE: Thank you for your thoughtful comments. We address each of your concerns as follows:

1) Regarding the year each reservoir was put into operation, we have not included this information in Table 3. We acknowledge its importance and will revise the table to include the operational year for each reservoir to provide a more comprehensive context. However, it must be clarified that the objective of this manuscript is to address the feedback loops of the SHE nexus and the impacts of IWDPs on these feedback loops. Due to the relatively short operational history of real-world reservoirs, it is challenging to conduct multi-temporal and spatial scale analyses. Therefore, this manuscript constructs a Multisource Input-Output Reservoir Generalization model based on the reservoir parameters and their scheduling rules, with long-term scale runoff inputs, to address the different impacts of IWDPs on the dynamic SHE nexus with multiple scenarios. Moreover, we compared the results relevant studies (Wei et al., 2022; Liu et al., 2019; Zhang et, al., 2008; Zeng et al., 2023, etc.), government-published statistical yearbooks, and reports related to reservoirs.

2) The unit for comprehensive hydropower coefficient is "$kg/(s^2 \cdot m^2)$". We will update Table 3 to make this unit explicit for clarity.

3) Thank you for your correction, we have updated Table 3 to reflect this change, with the unit for regulation ability now specified as time.

"**Table 3**. List of characteristic parameter values of reservoirs.

Characteristic parameter	Unit	Huang Jinxia	An Kang	Dan Jiangkou	Wang Fuzhou	Xing Long
Operational year	year	2023	1992	2013	2003	2013
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Regulation ability	time	Daily	Yearly	Multi-year	Daily	Daily

”

Relevant references:

Wei, N., Yang, F.L., Lu, K.M., Xie, J.C., Zhang, S.F.: A Method of Multi-Objective Optimization and Multi-Attribute Decision-Making for Huangjinxia Reservoir, Appl. Sci., 12(13):6300, https://doi.org/10.3390/APP12136300, 2022.

Liu Z., Lyu, J., Jia Z., Wang, L., Xu, B.: Risks Analysis and Response of Forecast-Based Operation for Ankang Reservoir Flood Control, Water, 11(6): 1134, https://doi.org/10.3390/w11061134, 2019.

Zeng, Y., Liu, D., Guo, S., Xiong, L., Liu, P., Chen, J., Yin, J., Wu, Z., and Zhou, W.: Assessing the effects of water resources allocation on the uncertainty propagation in the water-energy-food-society (WEFS) nexus. Agric, Water Manag., 282, https://doi.org/10.1016/j.agwat.2023.108279, 2023.

Zhang, B.H.M.M.: Selection of installed capacity of Xinglong Hydropower Station, Hydropower and New Energy, (01), 66-68, https://doi.org/10.13622/j.cnki.cn42-1800/tv.2008.01.020, 2008.

Point #23

COMMENT: *Results section: you give many values for LRRn, and all with three decimals, suggesting a very high accuracy, although you have only in a very summary way (lines 210-211) explained what these values really mean. Improve this.*

RESPONSE: Thank you for your guidance and suggestions. Your comments have significantly strengthened our manuscript. In Section 2.4.3, we have supplemented explanations regarding the LRR_n values and clarified the significance of their magnitude to facilitate readers' comprehension. The original retention of three decimal places for LRR_n was intended to thoroughly demonstrate variations between scenarios, where LRR_n = 0.001 corresponds to an approximate 0.1% change on a linear scale. However, considering water supply volume, hydropower generation, and ecological flow satisfaction rates, such a refined scale appears unnecessary, as a 1% variation has been identified as more appropriate. Consequently, we have modified the presentation of LRR_n in the manuscript to retain two decimal places instead. For the modifications to the number of decimal places, please refer to the revised manuscript, and the revised part in Section 2.4.3 is：

> "where LRR_n is the log response ratio of the nth component; n is the number of components; LRR_1 refers to the log response ratio of water supply volume between the two compared scenarios, characterizing the differences in the S component. Correspondingly, LRR_2 and LRR_3 represent the differences in the H and E components between two compared scenarios, respectively. r_n is the value of regional water supply volume or hydropower generation or ecological flow satisfaction rate in the baseline scenario. $r_{c(n)}$ is the value of the index in the compared scenario. $r_{c(n)}$ and r_n are both greater than or equal to zero. The positive LRR_n indicates $r_{c(n)} > r_n$, meaning the compared scenario improves the component relative to the baseline. The negative LRR_n indicates $r_{c(n)} < r_n$, meaning the compared scenario reduces the component relative to the baseline. The absolute value of LRR_n reflects the degree of change on a logarithmic scale. The larger the absolute value of LRR_n, the more substantial the improvement (if positive) or reduction (if negative) is when measured logarithmically. (**On page 24 of the revised manuscript**)"

Point #24

COMMENT: *Lines 614-615: you conclude: "All feedback loops are strengthened in low flow periods accompanied by their greater or smaller values of LRR_n than other periods. If there was only water donation, all values of LRR_n for the reservoirs are lower than those without IWDPs, while all values of LRR_n for reservoirs are greater than those without IWDPs." A very straightforward conclusion, but as I do not know what the value of LRR means, it doesn't resonate with me and I will not remember what it really means. So it would be much better to simply state what these changes in value imply in the real world.*

RESPONSE: We sincerely appreciate your valuable feedback regarding the clarity of our conclusions. We acknowledge that the original version inadvertently emphasized numerical data over conceptual insights, which could obscure the core scientific contributions for readers. In response, we have substantially restructured the Conclusion section. In the revised manuscript, we have avoided describing numerical results in the conclusion and instead focused on the phenomena and findings revealed. The specific changes are as follows:

“A framework was proposed to address the different impacts of IWDPs on the dynamic SHE nexus across the multiple temporal and spatial scales in reservoirs group with different priority functions, and to explore collaborative states in feedback loops. The HRB was taken as case study to verify the feasibility and reliability of this framework. Negative feedbacks can be found between S and H, and between S and E while positive feedbacks can be found between H and E in a reservoirs group without IWDPs. The negative feedbacks of S on H and the positive feedbacks of E on H are weakened or even broken in abundant water periods. All feedback loops are strengthened in low flow periods due to heightened competition for water resources. Water donation has negative impacts on the negative feedbacks between S and H, on the negative feedbacks between S and E, and on the positive feedbacks between H and E. While water receiving has positive impacts on these feedbacks. Less positive feedbacks are found with IWDPs than without them. Feedback loops of SHE nexus exhibit intrinsic similarity and stability across different time scales. The impact of reservoir operation and regulation on SHE nexus are clearer at the monthly scale. The seasonal scale offers the variations in periodic feedback loops. And the annual scale offers inter-annual and spatial trends of the SHE nexus from a macro perspective. Feedback loops in reservoirs with regulation function (e.g., AK and DJK) can remain stable under the varying inflow conditions at monthly scale. The positive feedbacks between H and E are weakened or even turn to be negative in the small installed hydropower generation capacity reservoirs (e.g., the XL reservoir) even in abundant water periods. Feedback loops for downstream reservoirs are influenced by their upstream reservoirs, especially in low flow periods. Thus, water donation or regional water supply can be increasing in abundant water periods to reduce spilled water and increase hydropower generation efficiency. In dry periods, it is necessary to consider the priority order of S, H, and E, and determine water utilization threshold for each component to maximize the benefits.

This framework offers a systematic and quantitative approach to examining the spatiotemporal variations of SHE nexus with external perturbations. It elucidates the existence and nature of collaborative states among S, H, and E. However, more work should be done to enrich the representation of every component such as the E component. This component should be reflected by a comprehensive set of water quality indicators. Then more details of the mechanism of the SHE nexus will be figured out.”

Generally, we are deeply grateful to the editor for his insightful and careful review. The provided comments and suggestions have greatly helped improve the manuscript. We also expressed our gratitude in the "**Acknowledgments**" section of the revised manuscript.