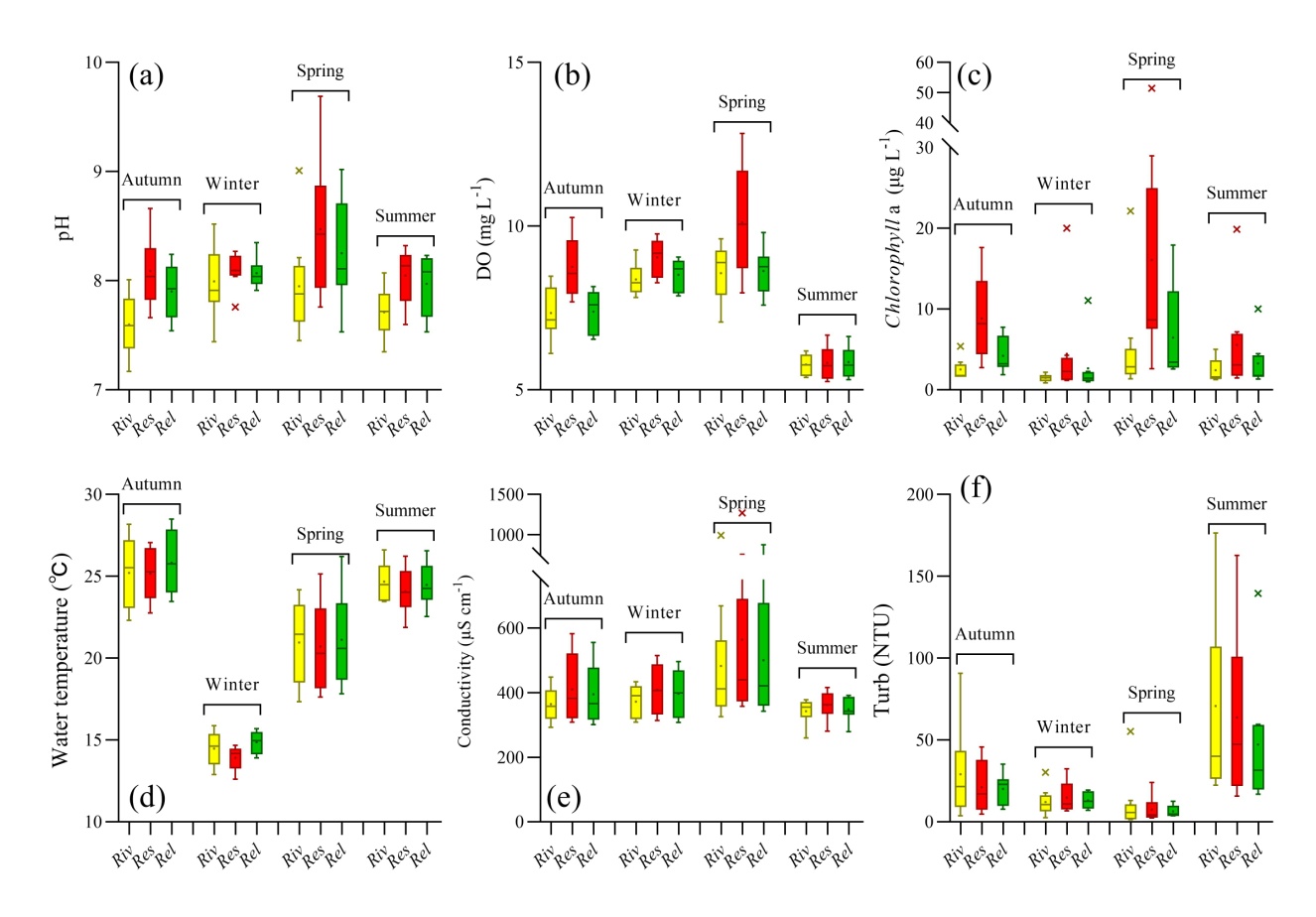
Supplementary Material

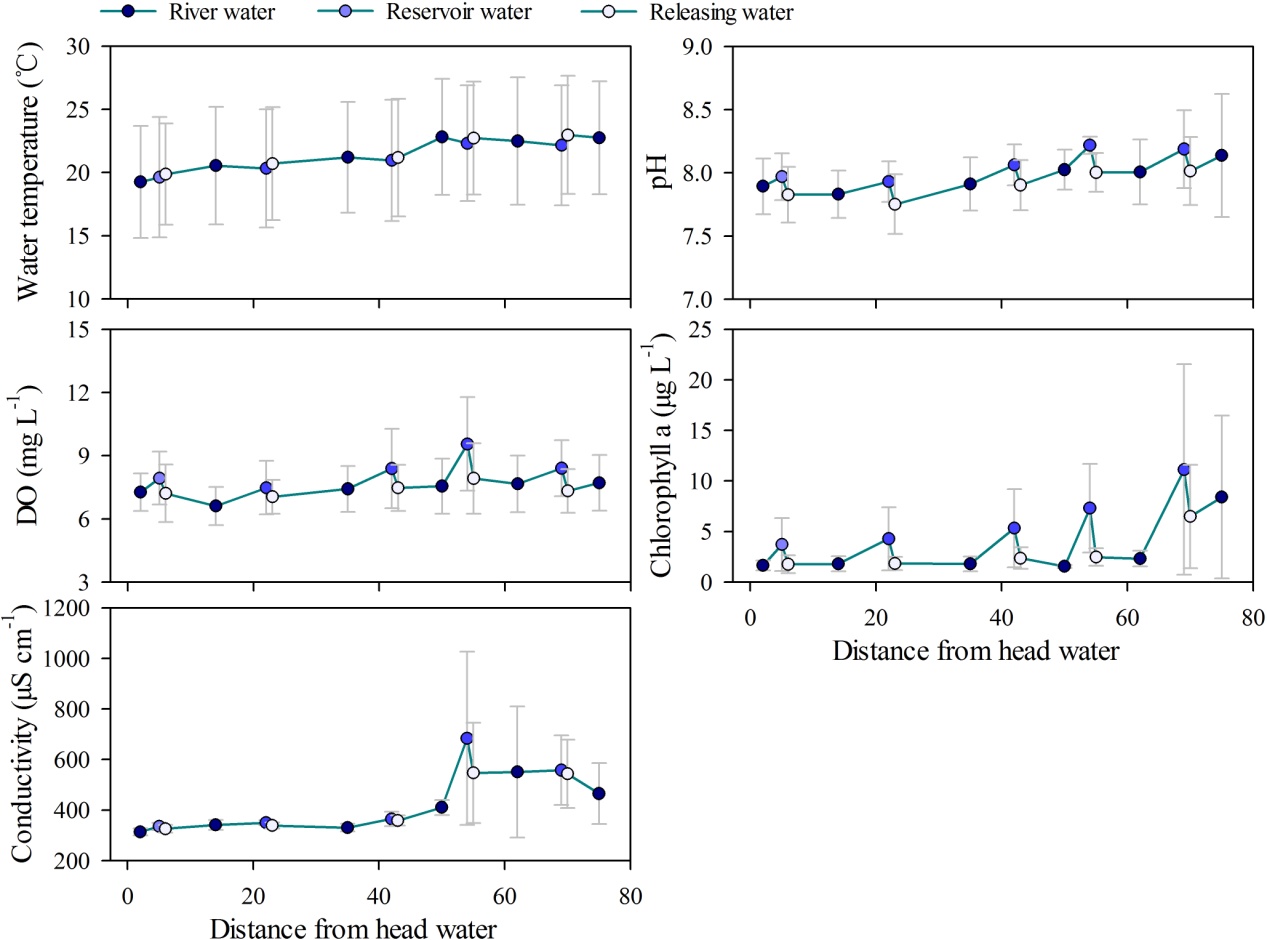
# Supplementary Figures and Tables

For more information on Supplementary Material and for details on the different file types accepted, please see [here](http://home.frontiersin.org/about/author-guidelines#SupplementaryMaterial). Figures, tables, and images will be published under a Creative Commons CC-BY licence and permission must be obtained for use of copyrighted material from other sources (including re-published/adapted/modified/partial figures and images from the internet). It is the responsibility of the authors to acquire the licenses, to follow any citation instructions requested by third-party rights holders, and cover any supplementary charges.

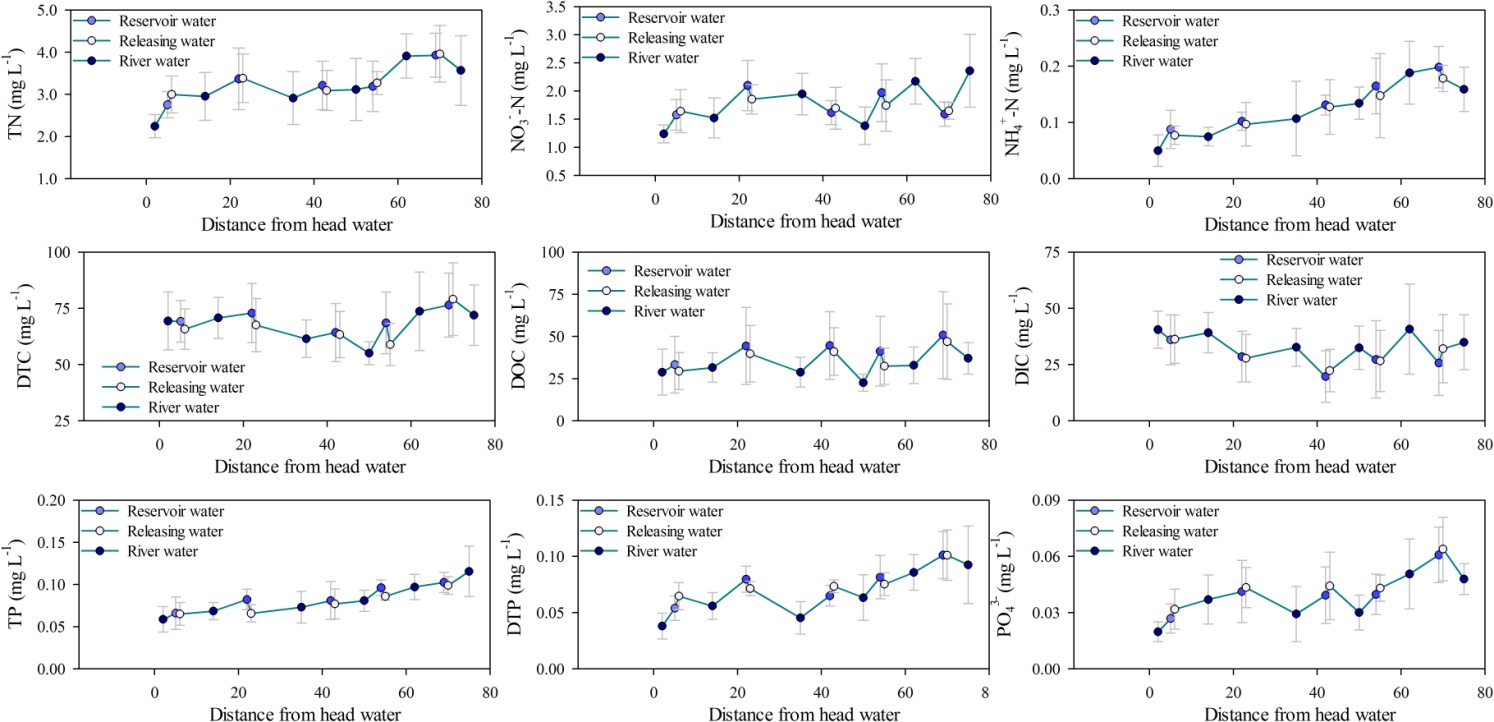
## Supplementary Figures



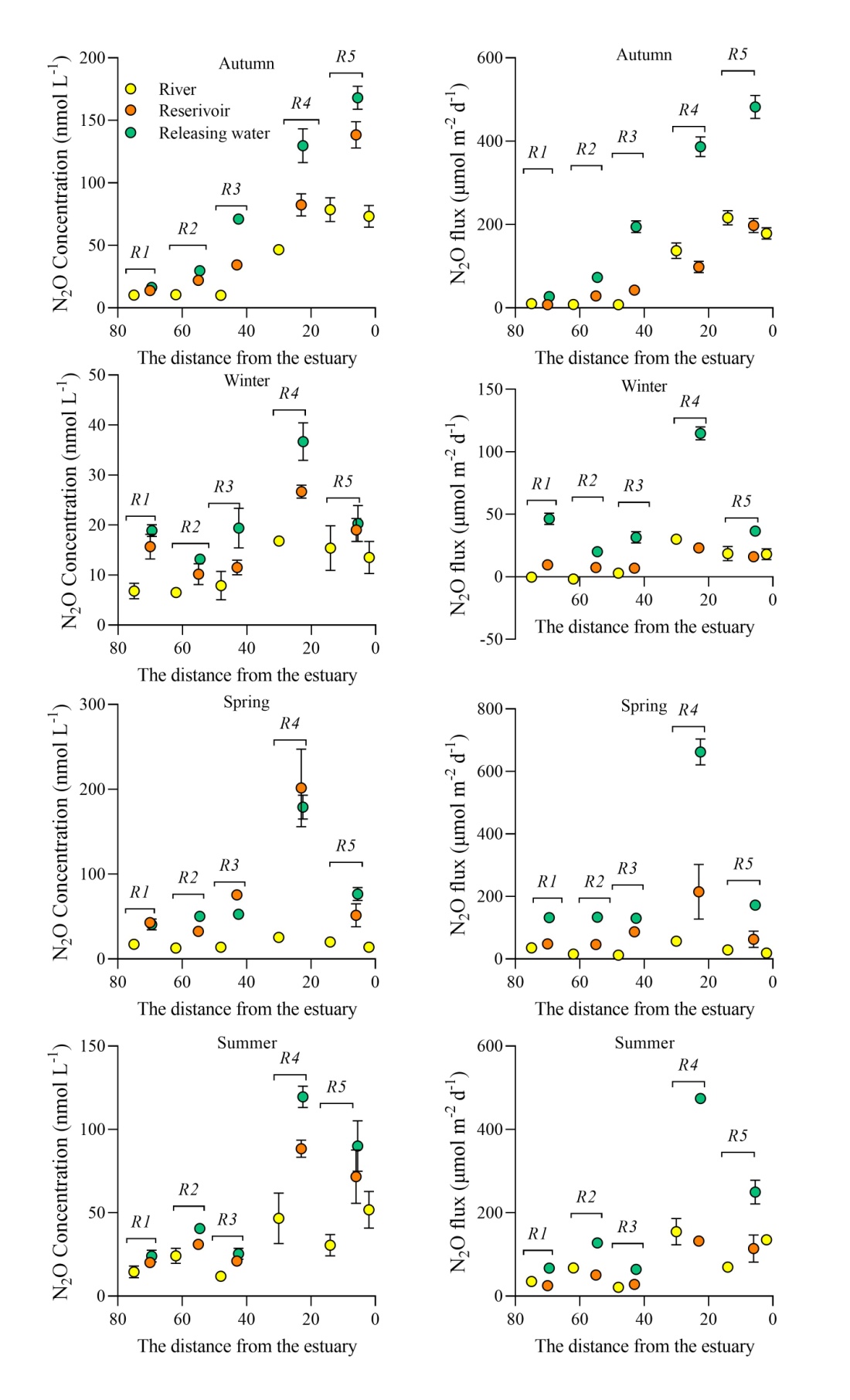
**Supplementary Figure 1.** Seasonal and spatial variability of the water temperature, pH, dissolved oxygen (DO), conductivity, turbidity (Turb) and chlorophyll a (*chl-a*) in the water samples of the river (*Ri*), reservoir (*Res*) and released (*Rel*) sections. Reservoir sections have a generally higher *chl-a*, DO and pH compare with river sections.



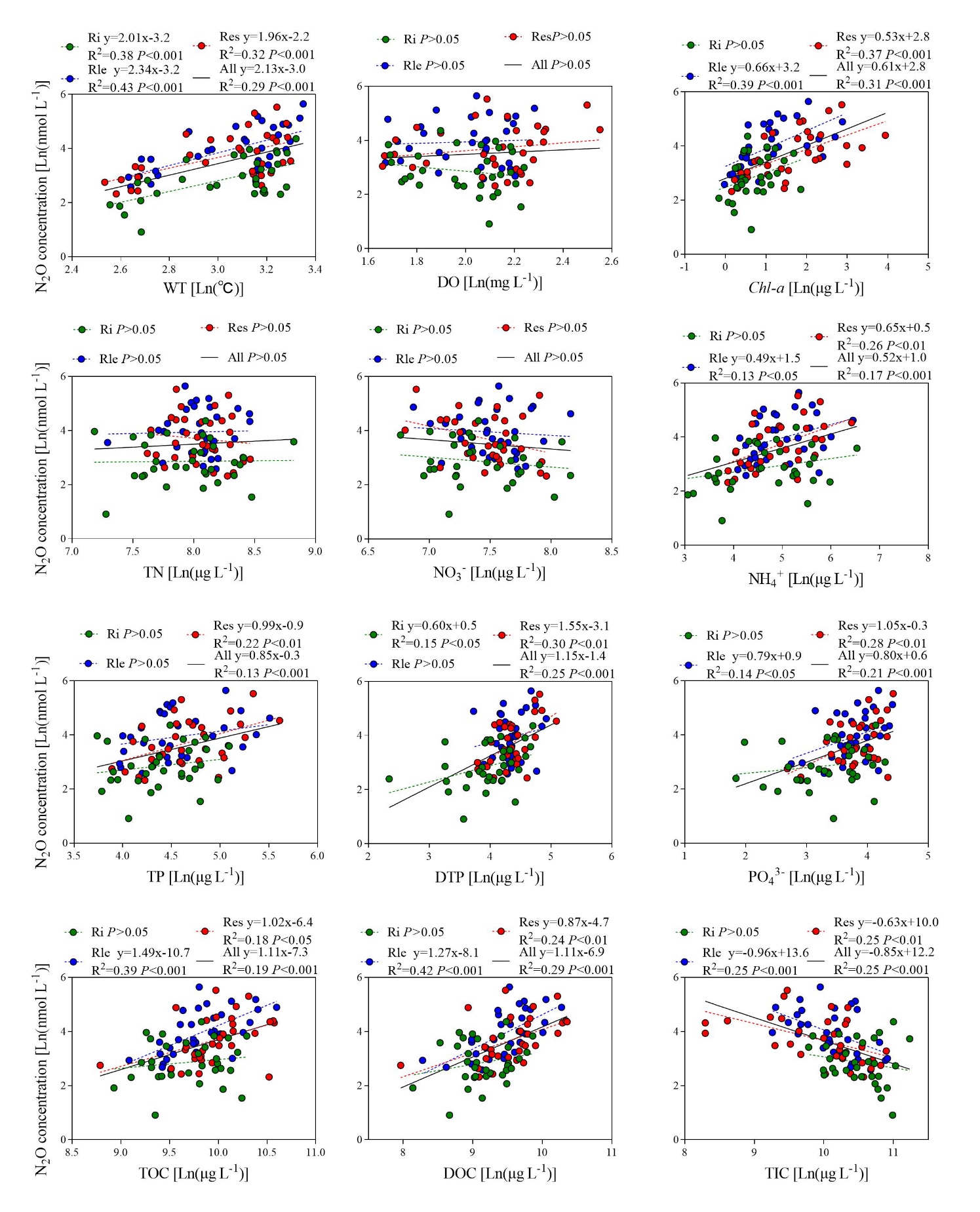
**Supplementary Figure 2** The longitudinal spatial variations in water temperature, pH, DO, *chl-a*, and conductivity along Wubu River mainstream.



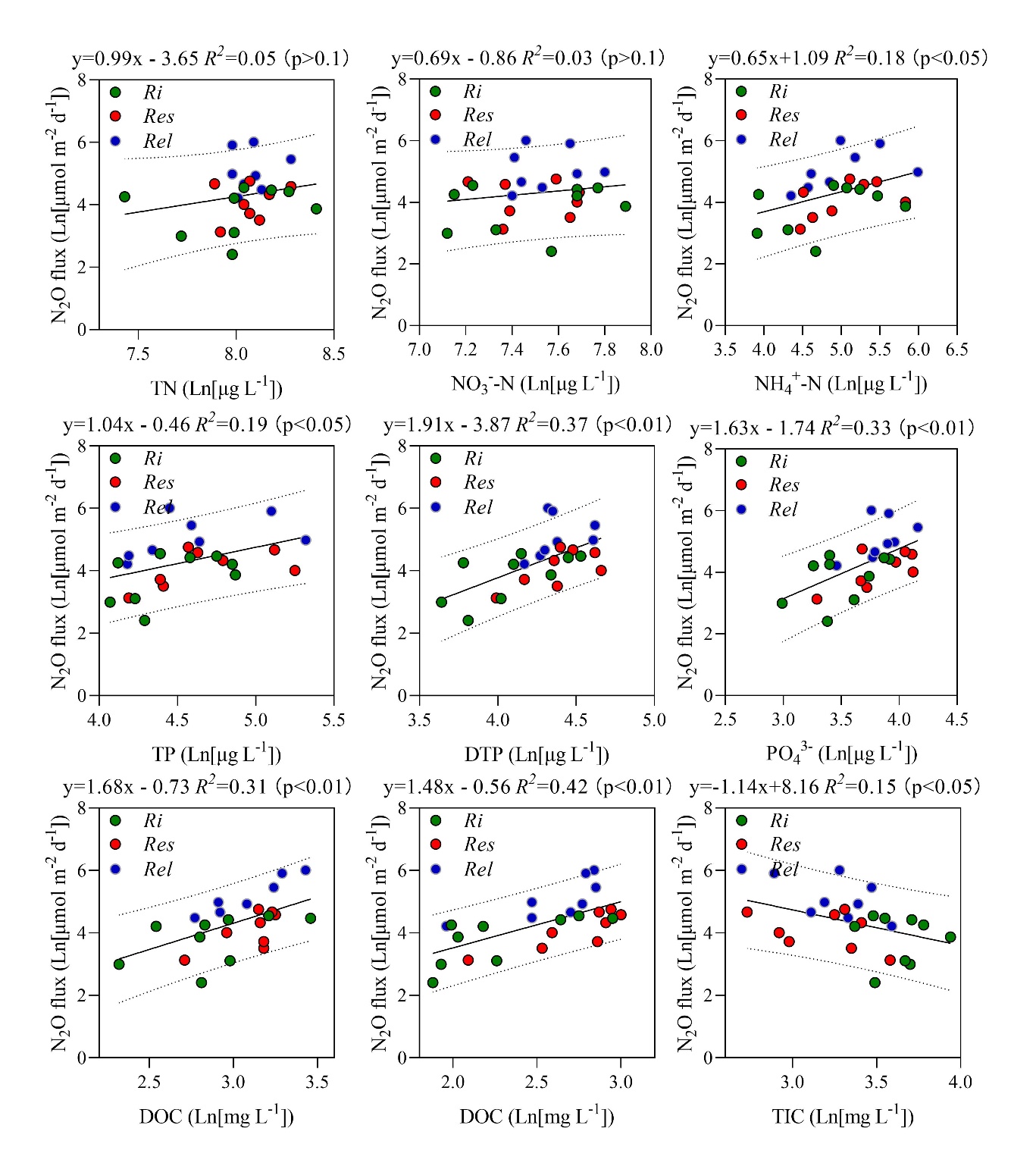
**Supplementary Figure 3** The longitudinal spatial variations in TN, NO3--N, NH4+-N, TP, DTP, PO43-, TOC, DOC, and TIC (c) in the water of the Wubu River mainstream.



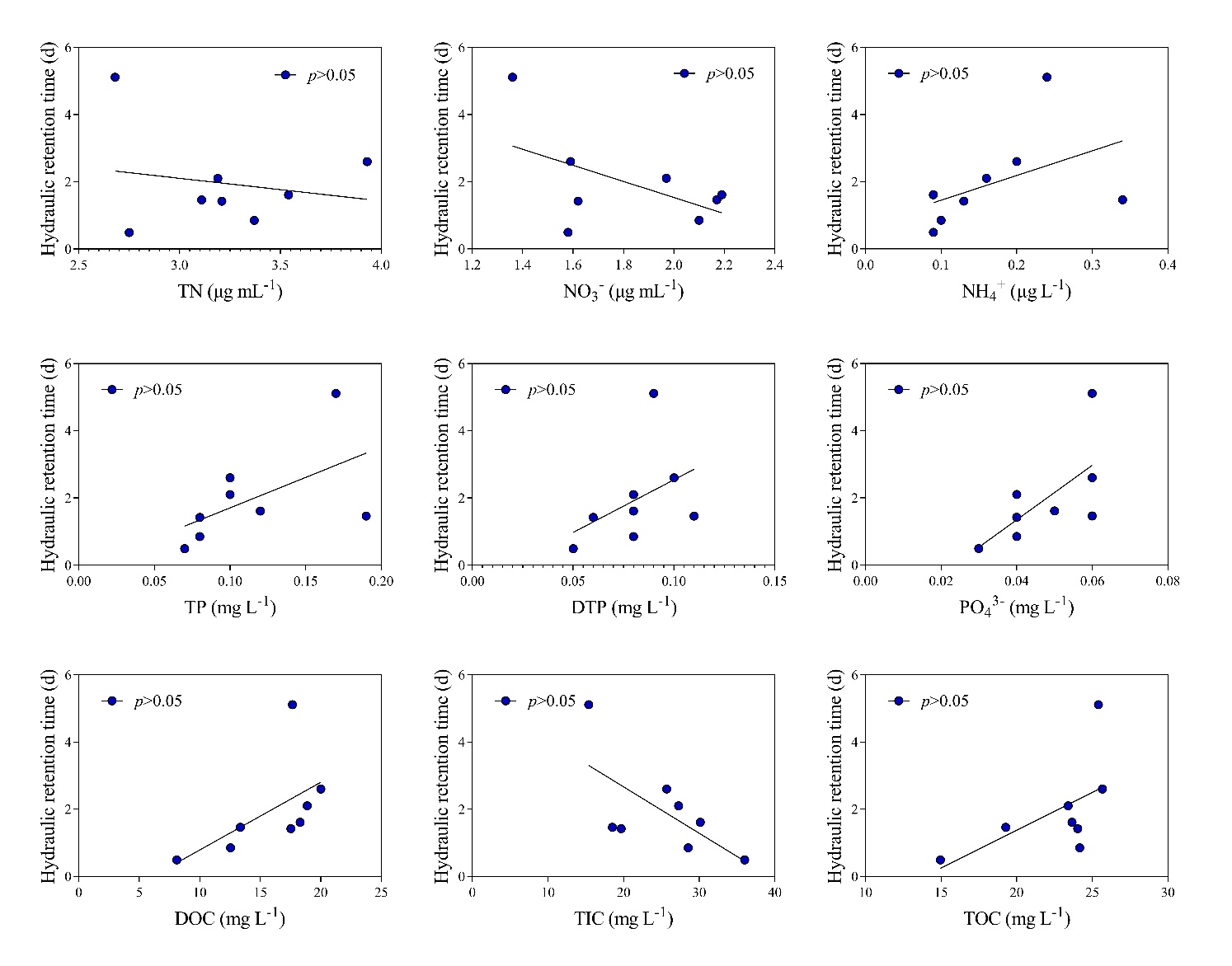
**Supplementary Figure 4** The longitudinal spatial variation in water N2O concentration and flux along the upstream section to estuary section of the Wubu River in different seasons.



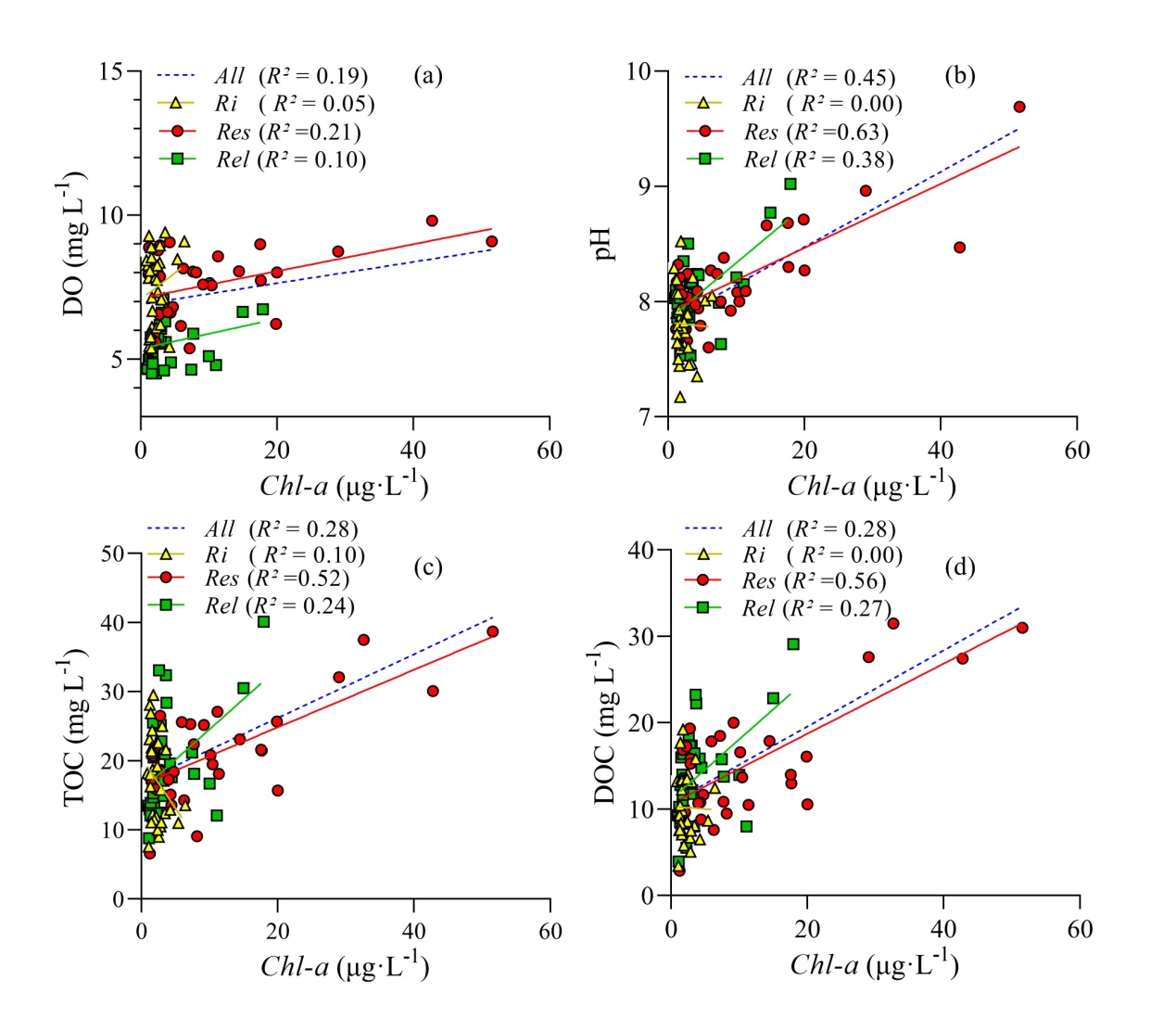
**Supplementary Figure 5.** Regression analysis of the N2O concentrations with WT, DO, *Chl-a*, C, N and P measured in the river-reservoir-release system in Wubu River basin.



**Supplementary Figure 6.** Predict relationships of annual averaged N2O fluxes and C, N and P measured in the river-reservoir-release system in Wubu River Basin.



**Supplementary Figure 7.** relationships of hydraulic retention time and C, N and P measured in the reservoir sections in Wubu River Basin.



**Supplementary Figure 8.** Regression relationship of *chl-a* with DO, pH, TOC and DOC for river, reservoir and released water sections.

## Supplementary Tables

**Supplementary Table 1** Flow velocity, depth, riverway width, open water width, discharge and dominant sediment types of each sampling site.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sampling sites | State | Flow velocity  (m s-1) | Depth (m) | Riverway width (m) | Open water width (m) | Discharge (m3 s-1) | Wind speed (m s-1) | | | | Air temperature (℃) | | | | Sediment type |
| Sep-14 | Dec-14 | Mar-15 | Jun-15 | Sep-14 | Dec-14 | Mar-15 | Jun-15 |
| w1 | River | 1.60 | 2.5 | 14 | 7.0 | 4.76 | 1.00 | 0.94 | 1.16 | 1.16 | 19.6 | 14 | 17.7 | 30.7 | boulder |
| w2 | Reservoir | 0.51 | 5.6 | 36 | 24.5 | 5.03 | 0.95 | 0.88 | 1.32 | 1.12 | 20.3 | 13.9 | 18.3 | 31.3 | fine sand |
| w3 | Released water | 1.30 | 1.7 | 11 | 17.8 | 4.84 | 0.92 | 0.93 | 1.20 | 1.02 | 21.20 | 14.20 | 18.60 | 32.00 | bed rock |
| w4 | River | 1.18 | 2.5 | 23 | 5.2 | 5.01 | 0.94 | 0.84 | 1.30 | 1.19 | 21.3 | 14.5 | 18.2 | 31.1 | fine sand |
| w5 | Reservoir | 0.63 | 3.4 | 50 | 71.5 | 6.14 | 1.09 | 0.94 | 1.33 | 1.16 | 22.30 | 15.90 | 18.20 | 30.10 | silt |
| w6 | Released water | 1.08 | 1.7 | 41 | 17.2 | 5.87 | 0.93 | 1.02 | 1.31 | 1.07 | 23.40 | 16.00 | 18.90 | 31.20 | cobble |
| w7 | River | 0.93 | 3.1 | 29 | 12.0 | 6.76 | 1.00 | 0.88 | 1.29 | 0.98 | 24.6 | 17.1 | 18.3 | 32.2 | grait |
| w8 | Reservoir | 0.56 | 5.0 | 65 | 52.8 | 6.63 | 0.98 | 0.98 | 1.31 | 1.07 | 25.40 | 17.60 | 19.30 | 32.20 | silt |
| w9 | Released water | 0.92 | 2.0 | 17 | 7.4 | 6.64 | 1.07 | 1.02 | 1.24 | 1.12 | 26.60 | 17.90 | 19.60 | 32.00 | fine sand |
| w10 | River | 1.70 | 3.0 | 54 | 11.8 | 7.11 | 1.10 | 0.98 | 1.26 | 1.03 | 29.7 | 18.50 | 21 | 31.9 | fine sand |
| w11 | Reservoir | 0.58 | 6.9 | 84 | 54.9 | 9.91 | 1.05 | 1.02 | 1.22 | 1.20 | 28.40 | 19 | 20.80 | 31.80 | silt |
| w12 | Released water | 0.99 | 1.3 | 43 | 17.5 | 9.19 | 1.05 | 1.07 | 1.28 | 1.06 | 29.00 | 17.60 | 20.30 | 32.70 | grait |
| w13 | River | 0.76 | 2.3 | 69 | 19.4 | 11.46 | 1.02 | 1.17 | 1.23 | 1.07 | 30.8 | 15 | 19.8 | 34.5 | bed rock |
| w14 | Reservoir | 0.51 | 4.6 | 90 | 90 | 14.05 | 1.10 | 1.12 | 1.29 | 1.10 | 29.30 | 14.50 | 19.80 | 33.70 | silt |
| w15 | Released water | 0.86 | 2.0 | 77 | 24.3 | 13.47 | 1.00 | 1.17 | 1.22 | 1.02 | 29.40 | 14.7 | 20.10 | 35.20 | silt |
| w16 | Estuary | 1.35 | 4.1 | 64 | 42.4 | 14.77 | 1.07 | 1.22 | 1.14 | 1.01 | 30.8 | 14.4 | 21.5 | 34 | silt |
| e1 | River | 0.85 | 1.4 | 31 | 2.9 | 1.72 | 0.83 | 0.54 | 1.26 | 1.03 | 28.5 | 15.7 | 21.7 | 32.3 | silt |
| e2 | Reservoir | 0.60 | 9.8 | 50 | 18.8 | 2.78 | 0.83 | 0.88 | 1.22 | 1.20 | 29.2 | 16.2 | 21.9 | 32 | silt |
| e3 | Released water | 1.15 | 2.2 | 15 | 4.9 | 2.59 | 0.97 | 0.86 | 1.28 | 1.06 | 29.70 | 20.3 | 21 | 32.1 | bed rock |
| y1 | River | 0.67 | 1.9 | 47 | 3.0 | 1.83 | 1.02 | 0.75 | 1.11 | 1.02 | 29.2 | 19.9 | 19.3 | 31.1 | silt |
| y2 | Reservoir | 0.58 | 5.0 | 66 | 37.7 | 2.66 | 0.91 | 0.71 | 1.08 | 1.11 | 29.30 | 18.50 | 19.50 | 31.30 | silt |
| y3 | Released water | 0.70 | 1.1 | 38 | 6.2 | 2.27 | 0.93 | 0.67 | 1.11 | 1.20 | 29.70 | 18.50 | 20.00 | 32.00 | bed rock |
| L1 | River | 0.56 | 1.0 | 27 | 4.2 | 1.15 | 0.85 | 0.68 | 1.16 | 1.00 | 29.7 | 14.7 | 21.3 | 32.3 | bed rock |
| L2 | Reservoir | 0.53 | 5.9 | 79 | 22.7 | 3.34 | 0.82 | 0.59 | 1.08 | 1.11 | 28.90 | 14.9 | 21.1 | 32.1 | fine sand |
| L3 | Released water | 0.59 | 3.3 | 49 | 3.0 | 2.80 | 1.01 | 0.59 | 1.08 | 1.20 | 28.90 | 14.20 | 21.50 | 32.00 | grait |

**Supplementary Table 2** The average and range of water temperature (℃), pH, conductivity (μS cm-1), DO (mg L-1), turbidity (NTU) and *chl-a* (μg L-1) in the cascade river-reservoir system along the Wubu River. The average are presented as mean ± standard error.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sampling  Rivers | State | Sampling  sites | Water temperature  (℃) | pH | Conductivity  (μS cm-1) | DO  (mg L-1) | Turbidity  (NTU) | *chl-a*  (μg L-1) |
| Wubu River | River | *w1* | 19.3±5.1  (12.9-23.5) | 7.9±0.2  (7.6-8.1) | 314±17  (293-329) | 7.3±1.0  (5.9-8.3) | 20.4±14.4  (7.7-40.1) | 1.7±0.6  (1.1-2.4) |
| Reservoir | *w2* | 19.6±5.5  (12.6-24.0) | 8.1±0.2  (7.9-8.3) | 335±17  (318-358) | 7.9±1.4  (5.9-9.3) | 25.9±15.6  (4.9-42.2) | 3.7±3  (1.3-7.7) |
| Released water | *w3* | 19.9±4.6  (13.9-23.6) | 7.9±0.3  (7.5-8.2) | 326±17  (302-342) | 7.2±1.6  (5.3-8.9) | 19.1±12.5  (4.7-35.2) | 2.3±1.2  (1.1-3.3) |
| River | *w4* | 20.5±5.4  (13.4-25.0) | 7.6±0.2  (7.4-7.9) | 341±23  (312-360) | 6.6±1.0  (5.4-7.8) | 21.0±15.0  (5.7-40.5) | 1.8±0.9  (1.2-3.1) |
| Reservoir | *w5* | 20.3±5.4  (13.2-25.0) | 7.9±0.1  (7.8-8.1) | 350±12  (341-368) | 7.5±1.5  (5.3-8.3) | 16.7±11.1  (2.9-27.3) | 4.3±3.6  (1.2-9.2) |
| Released water | *w6* | 20.7±5.1  (14.0-24.8) | 7.9±0.1  (7.8-8.0) | 339±14  (322-355) | 7.1±0.9  (5.9-7.9) | 17.2±9.1  (3.8-23.9) | 1.8±0.7  (1-2.8) |
| River | *w7* | 21.2±5.1  (14.6-26.0) | 7.9±0.3  (7.6-8.3) | 331±18  (315-356) | 7.4±1.3  (5.7-8.4) | 14.3±11.9  (2.1-30.4) | 1.8±0.8  (0.9-2.5) |
| Reservoir | *w8* | 21.0±5.5  (14.1-27.1) | 8.2±0.1  (8.1-8.4) | 365±33  (335-411) | 8.4±2.2  (5.3-10.2) | 11.5±7.0  (3.9-19) | 5.3±4.5  (1.4-10.1) |
| Released water | *w9* | 21.2±5.4  (14.5-27.0) | 8.0±0.2  (7.9-8.2) | 359±23  (341-390) | 7.5±1.3  (5.7-8.6) | 16.9±11.3  (3.7-28.2) | 3.1±1.4  (1.2-4.5) |
| River | *w10* | 22.8±5.3  (15.0-26.7) | 7.8±0.2  (7.6-7.9) | 411±34  (368-452) | 7.6±1.5  (5.4-8.9) | 9.3±13.3  (1.8-29.2) | 1.6±0.2  (1.4-1.8) |
| Reservoir | *w11* | 22.3±5.3  (14.7-26.7) | 8.2±0.2  (8.0-8.5) | 684±396  (416-1272) | 9.6±2.6  (6.0-12.2) | 9.8±7.5  (3.2-20.5) | 8.3±4.3  (2.8-12.8) |
| Released water | *w12* | 22.7±5.2  (15.2-26.8) | 7.9±0.3  (7.5-8.2) | 547±229  (343-875) | 7.9±1.9  (5.4-9.8) | 11.1±6.3  (4.7-19.5) | 2.5±1.0  (1.5-3.6) |
| River | *w13* | 22.5±5.8  (14.4-27.7) | 7.8±0.4  (7.2-8.2) | 551±300  (338-995) | 7.7±1.6  (6.1-9.4) | 31.2±53.2  (1.4-110.9) | 2.3±0.9  (1.6-3.6) |
| Reservoir | *w14* | 22.2±5.5  (14.5-26.6) | 8.1±0.6  (7.6-9.0) | 558±159  (376-758) | 8.4±1.5  (6.7-10.2) | 20.1±29.6  (2.4-64.3) | 10.1±12.7  (2.8-29) |
| Released water | *w15* | 23.0±5.4  (15.7-28.1) | 8.1±0.5  (7.5-8.8) | 543±156  (374-748) | 7.3±1.2  (6.1-8.7) | 17.1±14.2  (4.5-35.1) | 5.7±6.2  (1.7-15) |
| Estuary | *w16* | 22.8±5.2  (15.9-28.2) | 7.9±0.8  (7.3-9.0) | 465±139  (356-668) | 7.7±1.5  (6.0-9.6) | 51.2±83.6  (7.1-176.4) | 7.6±9.8  (1.5-22.1) |
| Ersheng River | River | *e1* | 22.2±4.5  (15.6-25.5) | 7.7±0.3  (7.3-8.0) | 322±44  (260-363) | 7.4±1.5  (5.4-9.1) | 39.9±42.1  (13.0-102.5) | 4.1±1.8  (2.2-6.4) |
| Reservoir | *e2* | 21.7±5.2  (14.3-25.6) | 8.6±0.7  (8.2-9.7) | 324±49  (281-395) | 8.7±3.0  (5.5-12.8) | 66.2±65.0  (24.0-162.8) | 27.3±16.2  (17.6-51.5) |
| Released water | *e3* | 23.0±6.1  (14.7-28.5) | 8.3±0.6  (7.6-9.0) | 319±42  (279-379) | 7.8±1.2  (6.2-9.1) | 43.3±64.2  (9.5-139.5) | 11.7±4.4  (7.7-17.9) |
| Yalu stream | River | *y1* | 19.3±4.5  (13.7-23.5) | 7.9±0.2  (7.6-8.2) | 383±23  (358-412) | 8.2±1.4  (6.2-9.3) | 58.0±30.3  (30.2-100.8) | 3.1±1.7  (1.2-5.4) |
| Reservoir | *y2* | 19.7±4.4  (14.5-23.6) | 8.3±0.3  (8.0-8.7) | 436±38  (397-480) | 8.9±1.7  (6.3-9.9) | 37.6±46.2  (14.0-106.9) | 7.6±4.9  (4.0-14.4) |
| Released water | *y3* | 20.2±4.4  (15.2-24.0) | 8.2±0.2  (8.0-8.5) | 418±34  (389-458) | 8.2±1.1  (6.6-9.1) | 22.0±25.1  (7.8-59.6) | 3.6±2.6  (1.7-7.5) |
| Lugou stream | River | *L1* | 21.4±5.0  (14.7-26.6) | 7.9±0.5  (7.5-8.5) | 395±16  (378-412) | 7.8±1.4  (5.8-8.9) | 30.5±41.1  (2.1-90.8) | 1.9±0.6  (1.5-2.8) |
| Reservoir | *L2* | 20.9±5.4  (13.5-26.2) | 8.0±0.3  (7.8-8.3) | 434±31  (397-469) | 8.2±1.8  (5.5-9.2) | 25.9±37.3  (4.5-81.7) | 3.2±2.1  (1.7-6.3) |
| Released water | *L3* | 21.9±4.7  (15.5-26.6) | 8.0±0.3  (7.6-8.2) | 426±27  (392-452) | 7.8±1.5  (5.6-8.8) | 26.7±21.6  (7.2-57.0) | 2.5±1.3  (1.4-4.2) |

**Supplementary Table 3** The average and range of N2O concentration (nmol L-1), *k0* (cm h-1), and N2O flux (μmol·m-2·d-1) in the cascade river-reservoir system along the Wubu River. The average is presented as mean ± standard error.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sampling  Rivers | State | Sampling  sites | N2O concentration (nmol L-1) | | *k0* (cm h-1) | N2O (μmol·m-2·d-1) | |
| Average | Range | Average | Range |
| Wubu River | River | *w1* | 12.3±4.5 | 5.5~19.2 | 14.2±0.4 | 20.1±15.6 | -0.2~35.4 |
| Reservoir | *w2* | 23.2±11.9 | 12.4~47.3 | 5.4±0.8 | 22.8±16.4 | 7.8~48.6 |
| Released water | *w3* | 25±10.2 | 15.2~49.8 | 15.6±0.8 | 68.2±39.4 | 27.5~132 |
| River | *w4* | 13.5±7 | 6~29.2 | 12±1.6 | 22.5±26.8 | -1.7~67.7 |
| Reservoir | *w5* | 24±9.2 | 7.4~36.1 | 7.7±0.2 | 33.4±17.1 | 7.5~50.8 |
| Released water | *w6* | 33.4±14 | 12.2~58.2 | 13.9±0.7 | 88.6±46 | 20.1~133.6 |
| River | *w7* | 11±3 | 4~15.1 | 9.6±1.9 | 11.1±6.7 | 2.9~21.2 |
| Reservoir | *w8* | 35.6±24.6 | 10.4~83.1 | 6±0.8 | 41.4±29.4 | 6.9~87.3 |
| Released water | *w9* | 42.2±21.3 | 16.4~74.3 | 12±1.1 | 105.2±62.8 | 31.5~194.9 |
| River | *w10* | 33.8±15.3 | 16.4~66.6 | 13.2±1.4 | 94.7±52.4 | 30.1~154.6 |
| Reservoir | *w11* | 99.7±67.7 | 25~262.5 | 5.3±0.8 | 117±68.9 | 23.1~214.9 |
| Released water | *w12* | 116.2±52.2 | 33.9~198.6 | 15.6±1.5 | 409.5±197.1 | 114.7~662.2 |
| River | *w13* | 36.2±25.9 | 10.1~88 | 10±1.8 | 83.4±79 | 18.6~216.2 |
| Reservoir | *w14* | 70.1±45.2 | 16.4~153 | 6.1±0.7 | 97.8±67.4 | 16.2~197.9 |
| Released water | *w15* | 88.7±53.6 | 15.4~178.5 | 11.6±0.9 | 235.2±161.9 | 36.5~482.4 |
| Estuary | *w16* | 38.2±26.6 | 8.9~82.2 | 10.5±1 | 87.8±70.8 | 18.1~178.7 |
| Ersheng River | River | *e1* | 25.9±17.2 | 8.8~57.8 | 0±0 | 67.7±53 | 14.4~133 |
| Reservoir | *e2* | 104.2±88.6 | 27.1~272 | 13.6±1.5 | 107.1±92.5 | 23.8~263.4 |
| Released water | *e3* | 131.2±95.9 | 33.6~325.6 | 4.6±0.3 | 369±266.4 | 99.8~805.6 |
| Yalu stream | River | *y1* | 25.2±15 | 4.3~45.1 | 12.8±1.2 | 47.7±36.2 | -4.5~90.8 |
| Reservoir | *y2* | 44.4±32 | 8.9~102 | 10.5±0.5 | 54.9±40.2 | 7.1~113.3 |
| Released water | *y3* | 51.7±35 | 12.4~128.5 | 6.1±0.7 | 144.8±94.3 | 28.5~286.4 |
| Lugou stream | River | *L1* | 28±20.9 | 2.4~55.7 | 14.1±1 | 71±64.9 | -11.8~148.3 |
| Reservoir | *L2* | 65.2±46.6 | 14.1~159.6 | 13.3±0.6 | 75.9±54.7 | 13.6~156.6 |
| Released water | *L3* | 80.4±62.3 | 17.2~204.7 | 5.4±0.3 | 138.1±109.8 | 26.2~269.9 |

**Supplementary Table 4** Relations among environmental variables in Wubu River watershed, China (tested by Non-parametric correlations using Pearson).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | TN | NO3- | NH4+ | TP | DTP | PO43- | DOC | TIC | TOC | WT | pH | Con | DO | Turb | *Chl-a* |
| TN | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| NO3- | 0.658\*\* | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| NH4+ | 0.433\*\* | 0.46\*\* | 1 |  |  |  |  |  |  |  |  |  |  |  |  |
| TP | 0.165 | 0.378\*\* | 0.653\*\* | 1 |  |  |  |  |  |  |  |  |  |  |  |
| DTP | 0.365\*\* | 0.241\* | 0.482\*\* | 0.506\*\* | 1 |  |  |  |  |  |  |  |  |  |  |
| PO43- | 0.094 | -0.031 | 0.259\*\* | 0.345\*\* | 0.738\*\* | 1 |  |  |  |  |  |  |  |  |  |
| DOC | 0.171 | 0.002 | 0.247\* | 0.153 | 0.26\*\* | 0.339\*\* | 1 |  |  |  |  |  |  |  |  |
| TIC | 0.106 | 0.174 | -0.276\*\* | -0.318\*\* | -0.249\* | -0.463\*\* | -0.515\*\* | 1 |  |  |  |  |  |  |  |
| TOC | 0.244\* | 0.1 | 0.242\* | 0.128 | 0.23\* | 0.263\*\* | 0.831\*\* | -0.402\*\* | 1 |  |  |  |  |  |  |
| WT | -0.405\*\* | -0.448\*\* | -0.058 | 0.073 | 0.061 | 0.276\*\* | 0.276\*\* | -0.408\*\* | 0.149 | 1 |  |  |  |  |  |
| pH | 0.132 | 0.117 | 0.347\*\* | 0.314\*\* | 0.114 | 0.085 | 0.415\*\* | -0.314\*\* | 0.332\*\* | -0.163 | 1 |  |  |  |  |
| Con | 0.347\*\* | 0.207 | 0.312\*\* | 0.008 | 0.365\*\* | 0.355\*\* | 0.509\*\* | -0.175 | 0.419\*\* | 0.056 | 0.298\*\* | 1 |  |  |  |
| DO | 0.259\*\* | 0.205\* | 0.42\*\* | 0.113 | 0.195\* | 0.042 | 0.37\*\* | -0.06 | 0.36\*\* | -0.377\*\* | 0.542\*\* | 0.44\*\* | 1 |  |  |
| Turb | -0.297\*\* | -0.209\* | -0.131 | 0.206\* | -0.024 | 0.161 | -0.153 | -0.125 | -0.141 | 0.241\* | -0.119 | -0.287\*\* | -0.268\*\* | 1 |  |
| *Chl-a* | -0.037 | -0.114 | 0.347\*\* | 0.35\*\* | 0.191 | 0.221\* | 0.53\*\* | -0.459\*\* | 0.446\*\* | 0.163 | 0.691\*\* | 0.198\* | 0.512\*\* | 0.065 | 1 |

**Supplementary Table 5** Relations between hydrodynamic conditions and environmental variables in reservoir sections of Wubu River watershed, China (tested by Non-parametric correlations using Pearson).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | TN | NO3- | NH4+ | TP | DTP | PO43- | DOC | TIC | TOC | WT | pH | Con | DO | Turb | *Chl-a* | HRT | HL |
| HRT | -0.191 | -0.536 | 0.451 | 0.556 | 0.428 | 0.661 | 0.571 | -0.659 | 0.572 | 0.636 | 0.205 | 0.034 | 0.414 | 0.726\* | 0.962\*\* | 1 |  |
| HL | -0.435 | 0.131 | -0.108 | -0.178 | -0.411 | -0.532 | -0.919\*\* | 0.509 | -0.977\*\* | -0.840\*\* | -0.234 | -0.333 | -0.291 | -0.101 | -0.508 | -0.678 | 1 |