## Supplementary Materials

**Supplementary Table S1.** Spatial heterogeneities of water quality parameters during 2002-2020, along with range, average, and standard error (SE).

| Category | Parameter (unit) | Rz | | Tz | | Lz | |
|---|---|---|---|---|---|---|---|
| | | Mean±SE | (Range) | Mean±SE | (Range) | Mean±SE | (Range) |
| Physical factors | WT(°C) | 16.79±0.59 | (1-33.9) | 15.9±0.55 | (2.2-30.5) | 16.15±0.56 | (1.7-30.2) |
| | EC (µS/cm) | 558.81±38.59 | (109-3422) | 923.92±52.81 | (100-4726) | 1139.26±53.73 | (100-5855) |
| | TSS (mg/L) | 24.26±1.51 | (1.6-223.6) | 18.73±0.99 | (1.9-138.7) | 11.51±0.63 | (1.2-91.4) |
| | SD (m) | 0.52±0.02 | (0.0-2) | 0.65±0.03 | (0.0-2.5) | 1.02±0.05 | (0.0-4.5) |
| | $K_{na}$ ($m^{-1}$) | 1.19±0.11 | (0.65-1.72) | 1.35±0.15 | (0.74-2.1) | 0.91±0.13 | (0.37-1.62) |
| Chemical factors | pH | 7.84±0.04 | (6.0-9.6) | 7.63±0.03 | (6.4-9.2) | 7.74±0.03 | (6.6-9.3) |
| | DO (mg/L) | 10.02±0.21 | (3.6-21.1) | 8.78±0.2 | (2.8-18.5) | 9.61±0.19 | (3.9-17.2) |
| | BOD (mg/L) | 2.67±0.09 | (0.3-8.2) | 2.01±0.07 | (0.2-7.9) | 1.59±0.07 | (0.3-8.8) |
| | COD (mg/L) | 6.6±0.11 | (2.9-12.5) | 6.03±0.08 | (3.1-9.4) | 5.77±0.07 | (2.6-9.9) |
| | TN (mg/L) | 3.92±0.1 | (0.86-10.17) | 3.63±0.09 | (1.2-9.26) | 3.48±0.09 | (1.09-8.35) |
| | TDN (mg/L) | 3.52±0.09 | (0.57-9.69) | 3.25±0.08 | (1.09-8.14) | 3.11±0.08 | (1.02-6.88) |
| | $NH_4$-N (mg/L) | 0.42±0.03 | (0.0-2.8) | 0.32±0.02 | (0.0-2.55) | 0.25±0.02 | (0.0-2.71) |
| | $NO_3$-N (mg/L) | 2.32±0.07 | (0.0-5.5) | 2.25±0.06 | (0.05-5.79) | 2.2±0.06 | (0.05-5.34) |
| | TP (µg/L) | 129.91±5.43 | (14-676) | 107.91±4.33 | (17-487) | 92.04±5.14 | (16-920) |
| | TDP (µg/L) | 82.78±4.08 | (7-542) | 76.63±5.37 | (7-264) | 65.93±3.15 | (3-291) |
| | $PO_4$-P (µg/L) | 64.4±3.9 | (0.0-515) | 56.36±3.05 | (0-249) | 51.07±2.91 | (0-259) |
| | TN:TP | 39.1±1.72 | (5.8-134.5) | 45.1±2.01 | (9.6-148.7) | 55.9±2.82 | (5.0-264.4) |
| Biological factors | FCB (col/100ml) | 190.7±43.6 | (0-4967) | 186.7±48.9 | (0-5861) | 110.2±28.1 | (0-3467) |
| | CHL-a (µg/L) | 21.87±1.61 | (0.0-173.4) | 12.37±0.94 | (0.01-99.2) | 9.56±0.64 | (0.1-60.8) |

Rz – riverine zone, Tz – transition zone, Lz – lacustrine zone

**Supplementary Table S2.** Spatial-seasonal variations of water quality parameters during 2020, along with ranges, averages, and standard error (SE).

| | Parameter (unit) | Rz | | | | Tz | | | | Lz | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter |
| | | Mean±SE (Range) | | | | Mean±SE (Range) | | | | Mean±SE (Range) | | | |
| Physical factors | WT (°C) | 14.25±0.69 (4.3-23.8) | 26.95±0.47 (14-33.9) | 20.51±0.65 (12-29) | 5.45±0.32 (1-12.9) | 12.6±0.62 (4-20.7) | 24.66±0.44 (16.8-30.5) | 20.54±0.63 (13-29) | 5.81±0.35 (2.2-12) | 12.74±0.65 (4-20.5) | 25.38±0.38 (19.1-30.2) | 20.69±0.62 (11.4-29.3) | 5.78±0.37 (1.7-11.9) |
| | EC (µS/cm) | 798.5±93.8 (141-3422) | 272±23.9 (109-1186) | 311.9±30.4 (110-1209) | 852.8±93.4 (236-3379) | 1379±132.1 (190-4726) | 613.4±83.6 (100-2513) | 469±52.2 (109-1769) | 1233.5±85.0 (255-2799) | 1513.6±92.5 (220-3661) | 706.12±74.6 (108-2740) | 798.7±96.2 (100-5127) | 1538±112.5 (449-5855) |
| | TSS (mg/L) | 17.17±1.56 (2-62.8) | 28.81±3.1 (8.8-161.6) | 36.06±4.25 (2.4-223.6) | 15.01±1.22 (1.6-63.6) | 12.08±1.31 (3.7-70.9) | 24.41±2.64 (8-138.7) | 26.18±1.81 (6-64.3) | 12.24±0.88 (1.9-35.3) | 6.78±0.52 (2.2-28.6) | 13.98±1.85 (2.5-91.4) | 15.17±1.1 (2.4-52.4) | 7.79±0.53 (1.2-20.4) |
| | SD (m) | 0.68±0.06 (0.2-2) | 0.44±0.03 (0.0-1.2) | 0.35±0.03 (0.1-1.2) | 0.6±0.04 (0.2-1.4) | 0.87-0.07 (0.2-2.5) | 0.52±0.04 (0.0-1.3) | 0.47±0.04 (0.1-1.5) | 0.74±0.04 (0.2-1.5) | 1.57±0.13 (0.3-4.5) | 0.87±0.1 (0.1-4) | 0.63±0.04 (0.1-1.3) | 1.01±0.05 (0.2-2) |
| | Kna ($m^{-1}$) | 0.87±0.07 (0.75-0.99) | 1.28±0.2 (0.96-1.66) | 1.61±0.07 (1.48-1.72) | 1.01±0.23 (0.65-1.43)) | 0.89±0.04 (0.82-0.96) | 1.67±0.26 (1.2-2.1) | 1.85±0.08 (1.74-2.01) | 0.99±0.19 (0.74-1.35) | 0.41±0.02 (0.37-0.44) | 1.17±0.2 (0.6-1.62) | 1.42±0.05 (1.36-1.52) | 0.77±0.15 (0.62-1.07) |
| Chemical factors | pH | 7.89±0.06 (6.8-9.2) | 8.03±0.1 (6.0-9.6) | 7.63±0.07 (6.5-9.2) | 7.83±0.08 (6.1-9.4) | 7.78±0.05 (6.8-8.7) | 7.59±0.07 (6.6-9.1) | 7.43±0.05 (6.4-8.7) | 7.72±0.07 (6.4-9.2) | 7.94±0.05 (7.3-9.3) | 7.74±0.08 (6.7-9.2) | 7.52±0.04 (6.8-8.5) | 7.75±0.06 (6.6-8.9) |
| | DO (mg/L) | 10.69±0.28 (6.1-14.9) | 7.21±0.25 (3.9-12.7) | 7.98±0.21 (4.9-12.4) | 12.57±0.26 (7.8-17.2) | 9.92±0.3 (5-14.6) | 6.08±0.24 (2.8-11.3) | 7.01±0.19 (4.5-11.3) | 12.11±0.29 (6.8-18.5) | 10.42±0.32 (4.1-17.8) | 8.24±0.33 (3.6-14.7) | 7.98±0.22 (5.1-12.2) | 13.42±0.38 (5.9-21.1) |
| | BOD (mg/L) | 2.68±0.18 (0.5-6.1) | 3.27±0.22 (0.9-8.2) | 2.16±0.11 (0.9-4) | 2.55±0.15 (0.3-5) | 2.18±0.16 (0.2-6.3) | 2.19±0.15 (0.7-7.9) | 1.78±0.11 (0.5-4.2) | 1.9±0.12 (0.5-4.6) | 2.11±0.21 (0.3-8.8) | 1.65±0.13 (0.3-6.8) | 1.1±0.07 (0.3-2.5) | 1.52±0.11 (0.3-3.6) |
| | COD (mg/L) | 6.59±0.18 (4.3-10.3) | 7.38±0.24 (3.4-12.5) | 6.08±0.19 (2.9-9.1) | 6.37±0.22 (3-10.6) | 6.03±0.12 (4.2-8.2) | 6.58±0.18 (3.1-9.4) | 5.72±0.16 (3.1-8.8) | 5.79±0.15 (3.5-9.3) | 5.82±0.12 (2.7-7.8) | 6.41±0.17 (2.6-9.9) | 5.4±0.14 (2.7-7.8) | 5.46±0.12 (3.8-8.3) |
| | TN (mg/L) | 4.82±0.21 (1.27-10.17) | 3.21±0.14 (0.86-5.54) | 2.84±0.11 (1.67-5.95) | 4.79±0.19 (2.82-9.45) | 4.61±0.17 (1.2-8.63) | 3.26±0.14 (1.36-6.46) | 2.56±0.1 (1.43-5.41) | 4.08±0.19 (2.21-9.26) | 4.54±0.17 (1.09-8.35) | 3.25±0.15 (1.4-7.05) | 2.42±0.11 (1.24-5.63) | 3.73±0.17 (1.74-6.79) |
| | TDN (mg/L) | 4.48±0.19 (1.22-9.69) | 2.86±0.13 (0.57-5.04) | 2.42±0.07 (1.36-3.83) | 4.33±0.17 (2.49-8.6) | 4.29±0.15 (1.09-8.06) | 2.9±0.11 (1.16-5.44) | 2.19±0.06 (1.27-3.22) | 3.6±0.16 (2.11-8.14) | 4.2±0.13 (1.02-6.88) | 2.89±0.11 (1.12-5.71) | 2.09±0.06 (1.22-3.69) | 3.28±0.13 (1.61-6.41) |
| | $NH_4$-N (mg/L) | 0.74±0.09 (0.01-2.8) | 0.22±0.03 (0.00-1.04) | 0.17±0.02 (0.00-0.7) | 0.55±0.07 (0.00-2.49) | 0.58±0.06 (0.03-2.55) | 0.18±0.03 (0.01-0.91) | 0.15±0.03 (0.00-1.16 | 0.36±0.04 (0.00-1.82) | 0.49±0.06 (0.03-2.71) | 0.14±0.03 (0.00-1.17) | 0.1±0.02 (0.00-0.83) | 0.28±0.04 (0.00-1.52) |
| | $NO_3$-N (mg/L) | 2.98±0.12 (1.52-5.5) | 1.66±0.11 (0.00-4.33) | 1.78±0.08 (0.1-3.32) | 2.85±0.11 (0.03-5.39) | 2.99±0.12 (0.81-5.79) | 1.94±0.11 (0.07-3.95) | 1.56±0.06 (0.1-2.76) | 2.49±0.11 (0.05-5.4) | 3.02±0.1 (1.12-5.34) | 1.95±0.1 (0.05-3.6) | 1.54±0.06 (0.08-2.71) | 2.29±0.11 (0.1 - 4.78) |
| | TP (µg/L) | 124.4±10 (14-380) | 127.6±6.76 (25-228) | 126.7±5.92 (54-250) | 140.9±17.16 (32-676) | 94.5±7.68 (17-264) | 118.1±8.79 (28-428) | 113.7±6.1 (43-250) | 105.4±11.17 (27-487) | 81.2±8.36 (16-303) | 93.9±6.79 (20-194) | 97.5±6.46 (31-271) | 95.5±16.37 (23-920) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TDP (µg/L) | 81.4±7.9 (11-210) | 85.6±6.51 (7-195) | 74.7±4.95 (21-172) | 89.5±4.14 (8-542) | 83.6±18.31 (12-240) | 80.4±5.91 (7-213) | 69.7±4.91 (21-154) | 72.8±8.37 (12-264) | 66.6±8.14 (10-291) | 68.6±5.88 (3-189) | 67.8±4.14 (15-148) | 60.8±6.51 (12-217) |
| | $PO_4$-P (µg/L) | 63.7±7.75 (1-200) | 65.7±6.24 (0.00-185) | 60.5±4.83 (0.00-159) | 67.8±11.11 (0.00-515) | 52.9±6.48 (0.00-192) | 62.5±5.3 (3-210) | 55.2±4.52 (4-126) | 54.9±7.74 (0.00-249) | 48.6±7.22 (0.00-259) | 53.3±5.48 (1-184) | 54.8±4.03 (0.00-132) | 47.6±6.21 (0.00-175) |
| | TN:TP | 49.2±3.44 (17.1-134.5) | 30.8±2.58 (5.8-108.3) | 24.7±1.26 (10.5-53.4) | 51.9±4.14 (7.8-134.2) | 64.7±4.53 (23.-148.7) | 35.5±2.89 (9.9-114.2) | 25.45±1.47 (10.9-74.7 | 54.8±4.16 (9.6-146.2) | 84.2±7.12 (16.5-264.4) | 50.7±5.22 (10.8-189.4) | 28.1±1.35 (8.9-55.3) | 60.4±4.47 (5.0-149.5) |
| **Biological factors** | FCB (col/100ml) | 98.1±48.61 (0-2283) | 238±98.39 (0-4000) | 270.8±94.02 (0-3467) | 155.2±98.7 (0-4967) | 69±43.31 (0-2395) | 263.5±126.9 (0-5861 | 284.5±108.1 (0-3800) | 128.7±91.8 (0-5069) | 39.8±24.9 (0-1376) | 140.6±61.4 (0-1947) | 167.9±65.2 (0-2400) | 92.3±63.3 (0-3467) |
| | CHL-a (µg/L) | 18.7±3 (1.6-112.8) | 26.9±3.31 (0.7-109.8) | 15.56±1.59 (0.2-53.7) | 26.3±4.24 (0.0-173.4) | 10.29±1.27 (0.7-47.4) | 12.85±1.69 (0.3-60.2) | 11.05±1.26 (0.01-57.3) | 15.29±2.82 (0.1-99.2) | 9.28±1.23 (0.5-40.7) | 11.37±1.64 (0.2-60.8) | 8.08±0.89 (0.1-29.3) | 9.49±1.21 (0.2-44.7) |

Rz – riverine zone, Tz – transition zone, Lz – lacustrine zone.

**Supplementary Table S3.** Spatial and spatial-seasonal comparisons of water quality parameters in the reservoir during 2002 – 2020.

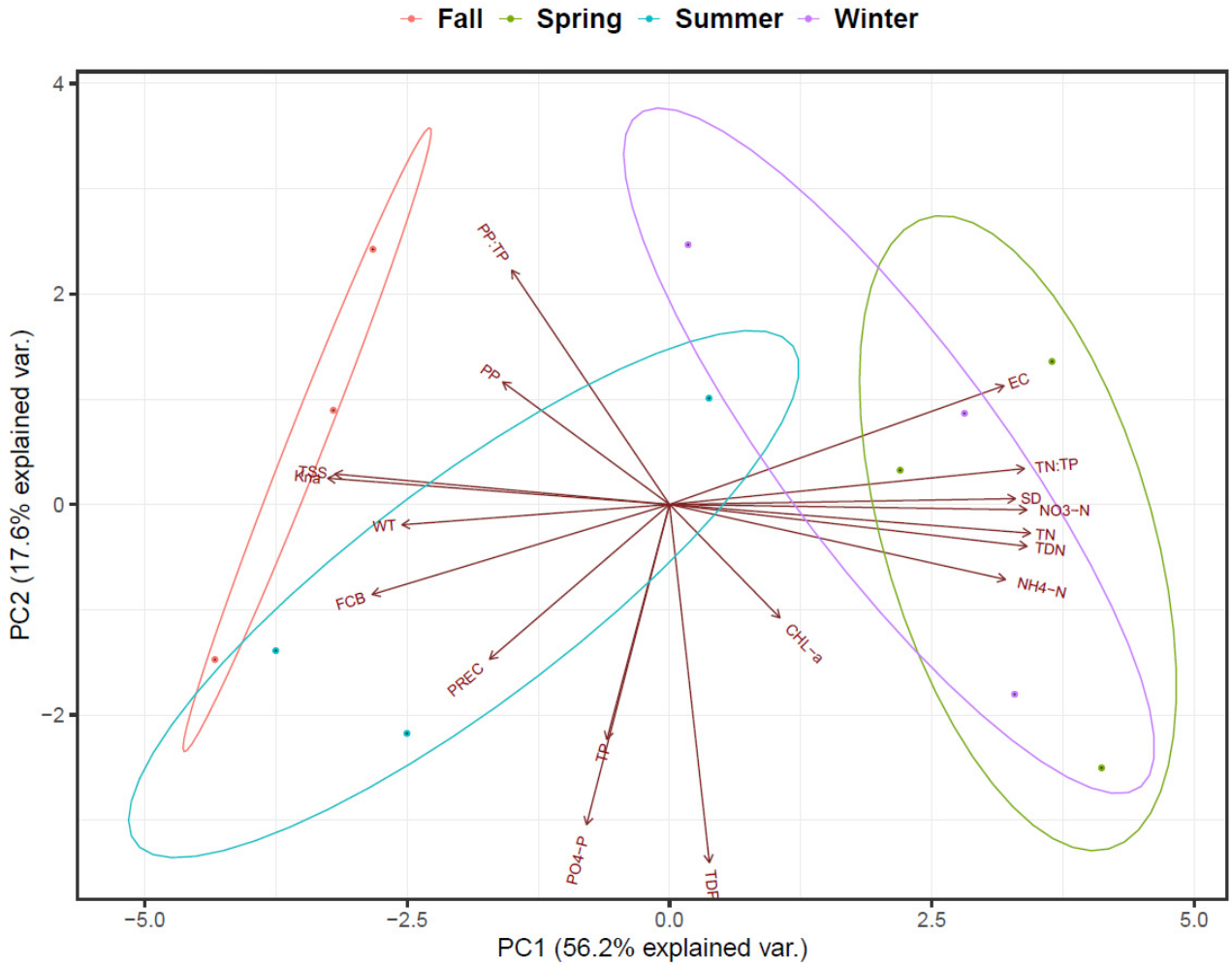
| | | Parameter (unit) | WT | EC | TSS | SD | $K_{na}$ | pH | DO | BOD | COD | TN | TDN | $NH_4$-N | $NO_3$-N | TP | TDP | $PO_4$-P | TN:TP | FCB | CHL-a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Spatial Comparison** | ANOVA on Ranks | ***H value*** | 1.23 | 94.09 | 113.05 | 100.2 | 81.82 | 20.97 | 17.57 | 112.66 | 37.05 | 11.49 | 10.18 | 19.02 | 1.37 | 48.45 | 10.06 | 5.32 | 20.94 | 10.87 | 58.06 |
| | | ***p-value*** | >0.05 | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.01** | **<0.01** | **<0.001** | >0.05 | **<0.001** | **<0.01** | >0.05 | **<0.001** | **<0.01** | **<0.001** |
| | t-test (*p<0.05**) | Rz vs Tz | | * | * | * | * | | * | * | * | | | | | * | | | | | * |
| | | Rz vs Lz | | * | * | * | * | * | | * | * | * | * | * | | * | * | | * | * | * |
| | | Tz vs Lz | | * | * | * | * | * | * | * | * | | | * | | * | | | * | | * |
| **Seasonal Comparison on each site** | | | | | | | | | | | | | | | | | | | | | |
| **Lz** | ANOVA on Ranks | ***H value*** | 176.08 | 76.53 | 73.35 | 60.88 | 44.78 | 32.89 | 134.26 | 22.49 | 29.61 | 90.46 | 114.24 | 61.13 | 96.85 | 9.78 | 6.59 | 6.85 | 67.54 | 11.23 | 1.33 |
| | | ***p-value*** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.05** | >0.05 | >0.05 | **<0.001** | **<0.05** | >0.05 |
| | t-test (*p<0.05**) | S vs Su | * | * | * | * | * | * | * | | | * | * | * | * | | | | * | | |
| | | Su vs F | * | | | | | | | * | * | * | * | | * | | | | * | | |
| | | F vs W | * | * | * | * | * | * | * | * | | * | * | * | * | | | | * | | |
| | | W vs S | * | | | * | * | | * | | | * | * | * | * | | | | | | |
| | | S vs F | * | * | * | * | * | * | * | * | | * | * | * | * | * | | | * | * | |
| | | W vs Su | * | * | * | | | | * | | * | | | * | | | | | | | |
| **Tz** | ANOVA on Ranks | ***H value*** | 173.36 | 73.98 | 77.65 | 40.12 | 21.12 | 27.58 | 138.56 | 5.75 | 25.93 | 96.7 | 114.96 | 58.47 | 90.81 | 10.66 | 6.14 | 6.48 | 75.14 | 17.21 | 1.51 |
| | | ***p-value*** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | >0.05 | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.05** | >0.05 | >0.05 | **<0.001** | **<0.001** | >0.05 |
| | t-test (*p<0.05**) | S vs Su | * | * | * | * | * | * | * | | | * | * | * | * | | | | * | | |
| | | Su vs F | * | | | | | | | | * | * | * | | * | | | | | | |
| | | F vs W | * | * | * | * | * | * | * | | | * | * | * | * | | | | * | * | |
| | | W vs S | * | | | | | | * | | | | * | | | | | | | | |
| | | S vs F | * | * | * | * | * | * | * | | | * | * | * | * | | | | * | * | |
| | | W vs Su | * | * | * | * | | | * | | * | * | * | * | * | | | | * | | |
| **Rz** | ANOVA on Ranks | ***H value*** | 178.26 | 94.03 | 53.31 | 40.73 | 22.94 | 15.39 | 103.32 | 14.36 | 53.02 | 98.12 | 110.64 | 56.57 | 93.72 | 2.39 | 1.39 | 1.39 | 54.71 | 20.03 | 6.16 |
| | | ***p-value*** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.01** | **<0.001** | **<0.01** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | >0.05 | >0.05 | >0.05 | **<0.001** | **<0.001** | >0.05 |
| | t-test (*p<0.05**) | S vs Su | * | * | * | * | | | * | | * | * | * | * | * | | | | * | | |
| | | Su vs F | * | | | | | * | | * | * | | | | | | | | | | |
| | | F vs W | * | * | * | * | * | | * | | | * | * | * | * | | | | * | * | |
| | | W vs S | * | | | | | | * | | | | | | | | | | | | |
| | | S vs F | * | * | * | * | * | * | * | | | * | * | * | * | | | | * | * | |
| | | W vs Su | * | * | * | * | | | * | | * | * | * | * | * | | | | * | | |

Lz-lacustrine zone, Tz–transition zone, Rz–riverine zone; S–spring, Su-summer, F-fall, W-winter; *p<0.05.

**Supplementary Table S4.** The variations in the TSID of the estuarine reservoir altered by the construction of new upper weirs.

| | TSID plot statement | Whole year (%) | BWCs(%) | AWCs (%) |
|---|---|---|---|---|
| P-I | Smaller particles predominate (P - limitation) | 4.73 | 0.31 | 8.71 |
| P-II | Larger particles predominate (Blue green algae) | 5.62 | 1.56 | 9.27 |
| P-III | Non-algal light limitation | 82.99 | 87.81 | 78.65 |
| P-IV | Zooplankton grazing | 6.66 | 10.31 | 3.37 |

BWCs-before upper weir constructions, AWCs –after upper weir constructions




**Supplementary Figure S1.** Biplot showing interrelation among water quality parameters in the estuarine reservoir (PP-particulate phosphorus, PREC-precipitation).