Supplementary Materials for

**Sediment phosphorus release in boreal lakes: the role of trophic state and humic substances**

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**SM Table 1** Key water quality (soluble reactive phosphorus, total phosphorus, dissolved iron) and environmental variables (water temperature, dissolved oxygen concentration, pH) on sampling in August 2018

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Lake** | **Site** | **Depth, m** | **Temp, °C** | **DO,**  **mg/l** | **pH** | **SRP,**  **μg/l** | **TP,**  **μg/l** | **Fe,**  **μg/l** |
| **Matjärvi** | IF | 0.0 | 17.88 | 9.47 | 7.85 | 32 | 160 | 230 |
|  | IF | 1.5 | 17.43 | 7.7 | 7.38 | 32 | 160 | 230 |
|  | CE | 0.0 | 17.82 | 10.07 | 8.34 | 30 | 150 | 250 |
|  | CE | 1.7 | 17.63 | 9.01 | 7.92 | 33 | 150 | 240 |
|  | OF | 0.0 | 17.85 | 10.41 | 8.65 | 32 | 140 | 210 |
|  | OF | 1.4 | 17.65 | 9.48 | 8.12 | 33 | 140 | 230 |
| **Kutajärvi** | IF | 0.0 | 17.12 | 10.71 | 8.24 | 17 | 60 | 86 |
|  | IF | 0.7 | 16.94 | 10.72 | 8.25 | 17 | 56 | 77 |
|  | CE | 0.0 | 17.54 | 10.79 | 8.48 | 17 | 56 | 80 |
|  | CE | 0.5 | 16.68 | 10.86 | 8.31 | 16 | 56 | 76 |
|  | OF | 0.0 | 16.26 | 10.59 | 8.13 | 16 | 54 | 86 |
|  | OF | 0.4 | 16.10 | 10.64 | 8.16 | 17 | 58 | 89 |
| **Enonselkä** | ST33 | 0.0 | 17.65 | 9.02 | 7.54 | 6 | 35 | Na |
|  | ST33 | 13.5 | 15.90 | 0.26 | 6.54 | 7 | 38 | Na |
|  | ST9 | 0.0 | 17.63 | 8.93 | 7.46 | 7 | 39 | Na |
|  | ST9 | 7.5 | 17.29 | 8.16 | 7.29 | 7 | 39 | Na |
|  | ST11 | 0.0 | 17.45 | 8.71 | 7.54 | 8 | 39 | Na |
|  | ST11 | 6.3 | 17.23 | 7.97 | 7.39 | 7 | 43 | Na |
| **Kymijärvi** | IF | 0.0 | 18.55 | 10.08 | 8.07 | 9 | 33 | Na |
|  | IF | 8.3 | 8.67 | 0.14 | 6.39 | 7 | 26 | Na |
|  | CE | 0.0 | 19.00 | 9.60 | 7.67 | 9 | 32 | Na |
|  | CE | 2.2 | 17.81 | 8.06 | 7.29 | 8 | 41 | Na |
|  | OF | 0.0 | 18.62 | 10.31 | 7.88 | 7 | 30 | Na |
|  | OF | 8.9 | 16.76 | 0.28 | 4.90 | 11 | 51 | Na |

Na – not available

**SM Table 2** Literature data for the lakes worldwide. Humic lakes are defined so by their geographical location (source: ”Finnish”,” Dillon”, ”Nürnberg”). Methods for release rate determination are indicated by 1 (hypolimnetic TP accumulation, in situ TP increases; RR\_in situ), 2 (anaerobic core incubations), 3 (diffusion), 4 (mass balance), 5 (others).





**SM Table 3**  Release rate (RR) as a function of water quality variables (TP, DOC concentration) and/ or sediment variables (sediment TP concentration TPsed, LOI) of literature data for the lakes worldwide. Also, relationships between TP and DOC, and LOI and DOC are shown for the dataset. Some of the relationships are studied separately for oligotrophic (Oligo), mesotrophic (Meso), eutrophic (Eutr) and Hypertrophic (Hyper) lakes. Only significant effects are shown, different levels of significance are indicated with asterix (\* <0.05; \*\*<0.01; \*\*\*<0.001). Analyses are presented for three separate datasets: all data (group A), potentially humic lakes (group B), and lakes with consistently determined RR (i.e., calculated from hypolimnetic TP accumulation or core incubations; group C). The RR values were log-transformed, log(RR+1). Effect (E) indicates either positive (+) or negative effect (-).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factors | *Group A* | | | | *Group B* | | | | *Group C* | | | |
|  | *All lakes* | | | | *Humic lakes* | | | | *Lakes with consistently determined RR* | | | |
|  | **E** | ***R2*** | ***p*** | ***n*** | **E** | ***R2*** | ***p*** | ***n*** | **E** | ***R2*** | ***p*** | ***n*** |
| **RR ~ log(TP) + log(DOC)** |  | 0.178 | \*\*\* |  |  | 0.249 | \*\* |  |  | 0.218 | \*\*\* |  |
| Log(TP) | + |  | \*\*\* |  | + |  | \* |  | + |  | \*\*\* |  |
| Log(DOC) |  |  | ns |  | - |  | \* |  |  |  | ns |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(DOC)** |  |  |  |  |  |  |  |  |  |  |  |  |
| Oligo: DOC | + | 0.306 | \* | 15 | + | 0.790 | \* | 5 |  |  | ns |  |
| Meso: log(DOC) | - | 0.214 | \* | 20 | - | 0.360 | \* | 9 | - | 0.248 | \* | 21 |
| Eutr: log(DOC) |  |  | ns |  | - | 0.255 | \* | 12 |  |  | ns |  |
| Hyper: log(DOC) |  |  | ns |  |  | na |  |  |  |  | ns |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(TP) + log(TPsed) + LOI** |  | 0.292 | \*\* | 45 |  | 0.554 | \*\*\* | 24 |  | 0.322 | \*\* | 31 |
| Log(TP) | + |  | \*\* |  | + |  | \*\* |  |  |  |  |  |
| Log(TPsed) | + |  | \* |  | + |  | \*\* |  |  |  |  |  |
| LOI |  |  | ns |  | - |  | \* |  | - |  | \* |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(TPsed) + LOI** |  | 0.141 | \* | 48 |  | 0.522 | \*\*\* | 25 |  | 0.310 | \*\* | 32 |
| Log(TPsed) |  |  | ns |  | + |  | \*\* |  |  |  | ns |  |
| LOI | - |  | \* |  | - |  | \*\*\* |  | - |  | \*\* |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(TPsed)** |  |  | ns | 52 |  | 0.230 | \* | 26 |  |  | ns | 36 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(TP) + log(TPsed)** |  | 0.246 | \*\* |  |  | 0.424 | \*\* | 25 |  | 0.198 | \* | 34 |
| Log(TP) | + |  | \*\* |  | + |  | \* |  | + |  | \* |  |
| Log(TPsed) | + |  | \* |  | + |  | \*\* |  |  |  | ns |  |
| Oligo: log(TPsed) |  |  |  |  |  |  |  |  |  |  | ns |  |
| Meso: log(TPsed) |  |  |  |  |  |  |  |  |  |  | ns |  |
| Eutr: log(TPsed) |  |  |  |  | + | 0.619 | \*\* |  |  |  | ns |  |
| Hyper: log(TPsed) | + | 0.389 | \*\* | 16 |  |  | na |  |  |  | ns |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ LOI** | - | 0.091 | \* | 53 |  | 0.397 | \*\*\* | 28 |  | 0.259 | \*\*\* | 37 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ log(TP) + LOI** |  |  |  |  |  | 0.418 | \*\*\* |  |  | 0.265 | \*\* |  |
| Log(TP) | + |  | \*\* |  | + |  | \*\* |  | + |  | \* |  |
| LOI |  |  | ns |  | - |  | \*\* |  | - |  | \* |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **RR ~ LOI** |  |  | ns |  |  |  | ns |  |  |  | ns |  |
| Oligo: |  |  | ns |  |  |  | ns |  |  |  | ns |  |
| Meso: |  |  | ns |  |  |  | ns |  |  |  | ns |  |
| Eutr: |  |  | ns |  |  |  | ns |  |  | 0.231 | \* |  |
| Hyper: |  |  | ns |  |  |  | na |  |  |  | ns |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Log(TP) ~ log(DOC)** | + | 0.258 | \*\*\* | 93 | + | 0.384 | \*\*\* | 40 | + | 0.260 | \*\*\* | 72 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **LOI ~ log(DOC)** |  |  |  | 51 | - | 0.315 | \*\* | 28 | - | 0.160 | \* | 37 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

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