**Ecological value of gravel pit ponds for floodplain wetland fish**

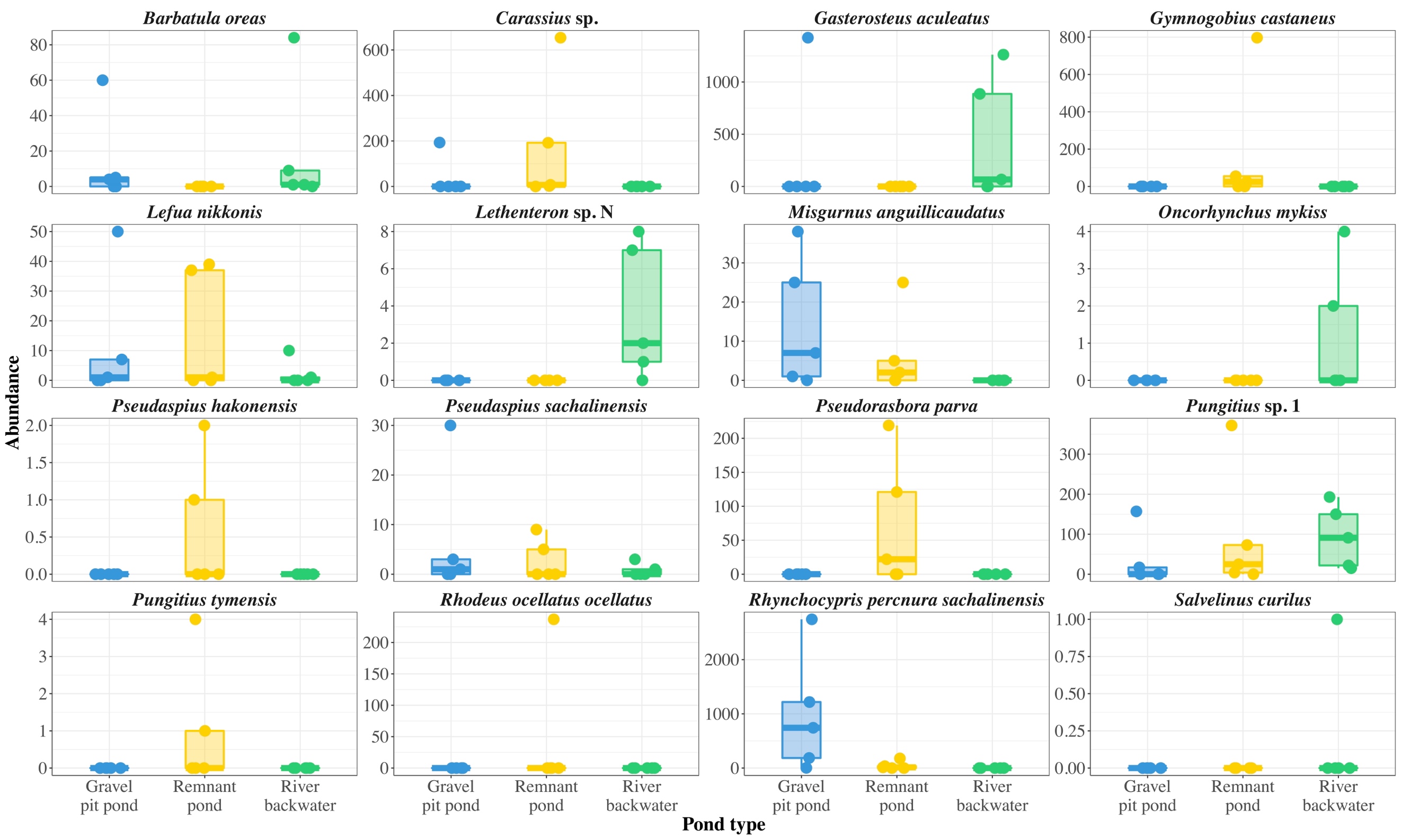
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**SUPPORTING INFORMATION**

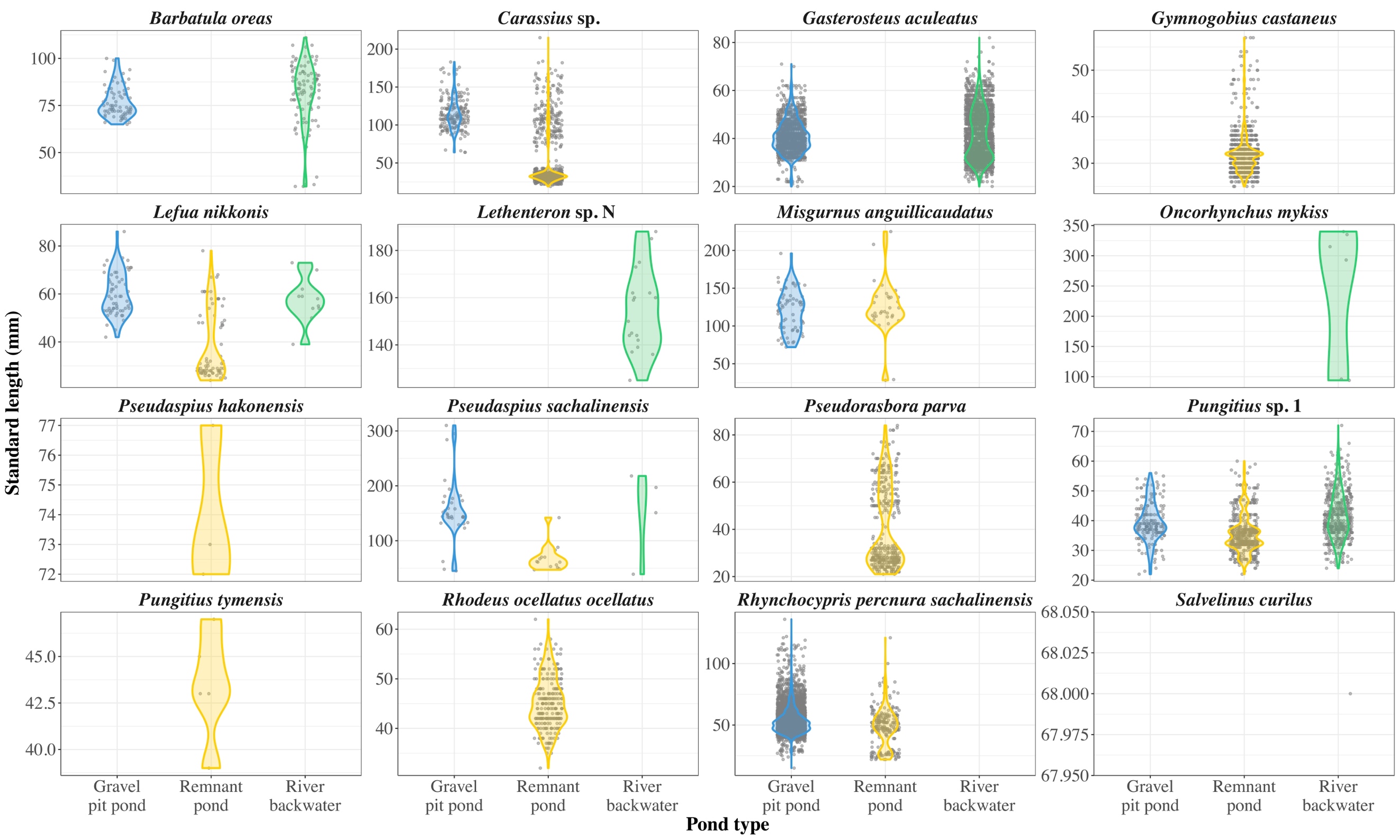
**ダイアグラム

自動的に生成された説明**

**Figure S1** Individual-based rarefaction curves estimating the species richness of each pond (black lines) and the plateau species richness extrapolated from the curves (blue lines). Abbreviation and number represent pond ID: GPP, gravel pit pond; RB, river backwater; RP, remnant pond. The confidence intervals (95%) are shown as shaded areas.



**Figure S2** Abundance of each species in each pond type.

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**Figure S3** Standard length of each individual of each species in each pond type.

**Table S1** Results of GLMMs testing the effects of pond type (gravel pit pond, remnant pond, and river backwater) on each environmental factor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Response variable** | **Intercept** | | |  | **Remnant pond** | | |  | **River backwater** | | | **df** | **AIC** |
| **Estimate** | **SE** | ***p*** |  | **Estimate** | **SE** | ***p*** |  | **Estimate** | **SE** | ***p*** |
| Dissolved oxygen (mg/L) | 2.04 | 0.24 | < 0.001 |  | -0.63 | 0.34 | 0.07 |  | -0.09 | 0.34 | 0.79 | 12 | 82.3 |
| pH | 2.03 | 0.03 | < 0.001 |  | -0.08 | 0.04 | < 0.05 |  | -0.09 | 0.04 | < 0.05 | 12 | 23.8 |
| Electrical conductivity (µs/cm) | 2.73 | 0.22 | < 0.001 |  | 0.23 | 0.31 | 0.46 |  | -0.40 | 0.31 | 0.20 | 12 | 102.1 |
| Turbidity (NTU) | 3.08 | 0.37 | < 0.001 |  | -0.72 | 0.53 | 0.18 |  | -1.21 | 0.53 | < 0.05 | 12 | 108.0 |
| Water temperature (C°) | 3.19 | 0.09 | < 0.001 |  | 0.09 | 0.13 | 0.49 |  | -0.43 | 0.13 | < 0.001 | 12 | 92.8 |
| Distance from the main channel (m) | 5.76 | 0.22 | < 0.001 |  | 0.49 | 0.31 | 0.12 |  | -2.14 | 0.31 | < 0.001 | 12 | 189.0 |
| Depth in the centre (m) | 0.54 | 0.29 | 0.06 |  | -0.06 | 0.41 | 0.88 |  | -0.66 | 0.41 | 0.10 | 12 | 41.5 |
| Depth near shore (m) | -0.64 | 0.19 | < 0.001 |  | 0.10 | 0.26 | 0.71 |  | -0.40 | 0.26 | 0.12 | 12 | -2.6 |

**Table S2** Results of multiple comparisons testing the difference in environmental factors among the pond types.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Contrast** | | **Estimate** | **SE** | **t-ratio** | ***p*** |
| Dissolved oxygen (mg/L) | |  |  |  |  |
|  | GPP vs. Remnant pond | 0.63 | 0.34 | 1.84 | 0.27 |
|  | GPP vs. River backwater | 0.09 | 0.34 | 0.27 | 0.80 |
|  | Remnant pond vs. River backwater | -0.54 | 0.34 | -1.57 | 0.28 |
| pH | |  |  |  |  |
|  | GPP vs. Remnant pond | 0.08 | 0.04 | 2.09 | 0.15 |
|  | GPP vs. River backwater | 0.09 | 0.04 | 2.18 | 0.15 |
|  | Remnant pond vs. River backwater | 0.00 | 0.04 | 0.09 | 0.93 |
| Electrical conductivity (µs/cm) | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.23 | 0.31 | -0.74 | 0.47 |
|  | GPP vs. River backwater | 0.40 | 0.31 | 1.27 | 0.45 |
|  | Remnant pond vs. River backwater | 0.63 | 0.31 | 2.01 | 0.20 |
| Turbidity (NTU) | |  |  |  |  |
|  | GPP vs. Remnant pond | 0.72 | 0.53 | 1.36 | 0.40 |
|  | GPP vs. River backwater | 1.21 | 0.53 | 2.29 | 0.12 |
|  | Remnant pond vs. River backwater | 0.49 | 0.53 | 0.93 | 0.40 |
| Water temperature (C°) | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.09 | 0.13 | -0.70 | 0.50 |
|  | GPP vs. River backwater | 0.43 | 0.13 | 3.36 | < 0.05 |
|  | Remnant pond vs. River backwater | 0.52 | 0.13 | 4.05 | < 0.01 |
| Distance from the main channel (m) | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.49 | 0.31 | -1.57 | 0.14 |
|  | GPP vs. River backwater | 2.14 | 0.31 | 6.81 | < 0.001 |
|  | Remnant pond vs. River backwater | 2.63 | 0.31 | 8.38 | < 0.001 |
| Depth in the centre (m) | |  |  |  |  |
|  | GPP vs. Remnant pond | 0.06 | 0.41 | 0.15 | 0.88 |
|  | GPP vs. River backwater | 0.66 | 0.41 | 1.63 | 0.39 |
|  | Remnant pond vs. River backwater | 0.60 | 0.41 | 1.48 | 0.39 |
| Depth near shore (m) | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.10 | 0.26 | -0.38 | 0.71 |
|  | GPP vs. River backwater | 0.40 | 0.26 | 1.54 | 0.30 |
|  | Remnant pond vs. River backwater | 0.50 | 0.26 | 1.92 | 0.24 |

**Table S3** Species list and mean and standard deviation of abundance for each species

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | | **Red list status** |  | **Gravel pit pond** | |  | **Remnant pond** | |  | **River backwater** | |
|  | **Mean** | **SD** |  | **Mean** | **SD** |  | **Mean** | **SD** |
| **Native species** | |  |  |  |  |  |  |  |  |  |  |
|  | *Barbatula oreas* |  |  | 13.8 | 25.9 |  | 0.0 | 0.0 |  | 19.0 | 36.5 |
|  | *Carassius* sp. |  |  | 38.6 | 86.3 |  | 171.0 | 282.1 |  | 0.0 | 0.0 |
|  | *Gasterosteus aculeatus* |  |  | 284.8 | 636.8 |  | 0.0 | 0.0 |  | 443.0 | 591.8 |
|  | *Gymnogobius castaneus* | NT |  | 0.0 | 0.0 |  | 175.4 | 348.2 |  | 0.0 | 0.0 |
|  | *Lefua nikkonis* | EN |  | 11.6 | 21.7 |  | 15.4 | 20.6 |  | 2.2 | 4.4 |
|  | *Lethenteron* sp. N | VU |  | 0.0 | 0.0 |  | 0.0 | 0.0 |  | 3.6 | 3.6 |
|  | *Pseudaspius hakonensis* |  |  | 0.0 | 0.0 |  | 0.6 | 0.9 |  | 0.0 | 0.0 |
|  | *Pseudaspius sachalinensis* |  |  | 6.8 | 13.0 |  | 2.8 | 4.1 |  | 0.8 | 1.3 |
|  | *Pungitius* sp. 1 |  |  | 34.8 | 68.7 |  | 94.8 | 157.7 |  | 94.2 | 78.1 |
|  | *Pungitius tymensis* | VU |  | 0.0 | 0.0 |  | 1.0 | 1.7 |  | 0.0 | 0.0 |
|  | *Rhynchocypris percnura sachalinensis* | NT |  | 979.0 | 1096.3 |  | 45.2 | 75.6 |  | 0.0 | 0.0 |
|  | *Salvelinus curilus* | VU |  | 0.0 | 0.0 |  | 0.0 | 0.0 |  | 0.2 | 0.4 |
| **Nonnative species** | |  |  |  |  |  |  |  |  |  |  |
|  | *Misgurnus anguillicaudatus* | NT |  | 14.2 | 16.7 |  | 6.4 | 10.6 |  | 0.0 | 0.0 |
|  | *Oncorhynchus mykiss* |  |  | 0.0 | 0.0 |  | 0.0 | 0.0 |  | 1.2 | 1.8 |
|  | *Pseudorasbora parva* |  |  | 0.0 | 0.0 |  | 72.4 | 96.0 |  | 0.0 | 0.0 |
|  | *Rhodeus ocellatus ocellatus* |  |  | 0.0 | 0.0 |  | 47.4 | 106.0 |  | 0.0 | 0.0 |

**Table S4** Results of GLMMs testing the effects of pond type (gravel pit pond, remnant pond, and river backwater) on the species richness and abundance of native and nonnative species.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Response variable** | **Intercept** | | |  | **Remnant pond** | | |  | **River backwater** | | | **df** | **AIC** |
| **Estimate** | **SE** | ***p*** |  | **Estimate** | **SE** | ***p*** |  | **Estimate** | **SE** | ***p*** |
| Richness of native fishes | 1.28 | 0.24 | < 0.001 |  | 0.25 | 0.31 | 0.44 |  | 0.15 | 0.32 | 0.63 | 12 | 63.1 |
| Abundance of native fishes | 7.22 | 0.46 | < 0.001 |  | -1.00 | 0.65 | 0.12 |  | -0.89 | 0.65 | 0.17 | 12 | 235.8 |
| Richness of nonnative fishes | -0.22 | 0.50 | 0.66 |  | 0.56 | 0.63 | 0.37 |  | -0.69 | 0.87 | 0.42 | 12 | 36.9 |
| Abundance of nonnative fishes | 2.65 | 0.75 | < 0.001 |  | 2.18 | 1.06 | < 0.05 |  | -2.47 | 1.13 | < 0.05 | 12 | 110.9 |

**Table S5** Results of multiple comparisons testing the difference in fish species richness and abundance among the pond types.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Contrast** | | **Estimate** | **SE** | **z-ratio** | ***p*** |
| Richness of native fishes | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.25 | 0.31 | -0.78 | 1.00 |
|  | GPP vs. River backwater | -0.15 | 0.32 | -0.48 | 1.00 |
|  | Remnant pond vs. River backwater | 0.09 | 0.30 | 0.30 | 1.00 |
| Abundance of native fishes | |  |  |  |  |
|  | GPP vs. Remnant pond | 1.00 | 0.65 | 1.54 | 0.37 |
|  | GPP vs. River backwater | 0.89 | 0.65 | 1.37 | 0.37 |
|  | Remnant pond vs. River backwater | -0.11 | 0.65 | -0.16 | 0.87 |
| Richness of nonnative fishes | |  |  |  |  |
|  | GPP vs. Remnant pond | -0.56 | 0.63 | -0.89 | 0.74 |
|  | GPP vs. River backwater | 0.69 | 0.87 | 0.80 | 0.74 |
|  | Remnant pond vs. River backwater | 1.25 | 0.80 | 1.56 | 0.35 |
| Abundance of nonnative fishes | |  |  |  |  |
|  | GPP vs. Remnant pond | -2.18 | 1.06 | -2.06 | 0.06 |
|  | GPP vs. River backwater | 2.47 | 1.13 | 2.18 | 0.06 |
|  | Remnant pond vs. River backwater | 4.66 | 1.13 | 4.13 | < 0.001 |

**Table S6** Results of permutation tests used to determine the significance of correlation of the variables with nonmetric multidimensional scaling (NMDS) axes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Metrics** | **NMDS1** | **NMDS2** | ***R*2** | ***p*** |
| pH | -0.32 | -0.95 | 0.25 | 0.18 |
| Dissolved oxygen (mg/L) | 0.43 | -0.90 | 0.14 | 0.39 |
| Electrical conductivity (μs/cm) | -0.96 | -0.28 | 0.17 | 0.31 |
| Turbidity (NTU) | -0.39 | -0.92 | 0.52 | < 0.05 |
| Water temperature (C°) | -0.99 | 0.10 | 0.67 | < 0.01 |
| Depth near shore (m) | -0.96 | -0.27 | 0.49 | < 0.05 |
| Distance from the main channel (m) | -1.00 | 0.09 | 0.57 | < 0.01 |