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ABSTRACT

This is the abstract.

Keywords: Keyword1; Keyword2; Keyword3

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APPENDIX

0.1 Study design and setup

In 2019, 12 glacial lakes ($N = 12$) were chosen for an experiment near Narsarsuaq, Greenland (61.1567°N, -45.4254°E). These glacial lakes vary in area (0.21 to 1.82 hectares) and maximum depth (2 to 8 m), but are all clustered within a few kilometers of each other. All lakes were fishless at the beginning of the experiment. Six lakes were subsequently introduced with three-spined sticklebacks (*Gasterosteus aculeatus*) from nearby lakes. Lake B1P1, B2P2, and B3P3 were introduced with *Gasterosteus aculeatus* from a single population (lake L26, 61.253333°N, -45.529141°E), while lake B2P3, B3P1, and B3P2 were introduced with *Gasterosteus aculeatus* from two populations (lake L26, 61.253333°N, -45.529141°E and lake ERL33, 61.118369°N, -45.580845°E). The remaining six lakes B1P4, B2P4, B3P0, ERL85, ERL122, and ERL152 were used as fishless control. For the purpose of this study, the origin of the introduced *Gasterosteus aculeatus* is of minor importance, as they all originate from the same area (Supplementary Table S1).

In 2021, 2022, and 2023, all 12 lakes were monitored over several days. For that purpose, EXO2 multiparameter sondes were installed (YSI, Yellow Springs, OH, USA), tracking ecosystem parameters with high frequency (2-minute intervals in 2021 and 2022, 5-minute intervals in 2023 with the exception of ERL122, which was monitored in 15-minute intervals). For the purpose of this study, only dissolved oxygen and temperature measurements yielded from these sondes are relevant. The sensors were situated at a water depth of approximately 1-1.5 m in each lake. All optical sensors were wiped clean before every measurement with a built-in wiper. The monitoring period was 16 September-24 September in 2021, 22 June-3 July in 2022, and 22 June-17 July in 2023.

Supplementary Table S1. Lakes included in the experiment, along with treatment and general characteristics.

Lake	Treatment	Latitude (°N)	Longitude (°E)	Altitude (m)	Area (hectare)	Maximum Depth (m)
B1P1	Fish	61.15338	-45.57081	272	0.21	4.00
B2P2	Fish	61.12299	-45.55988	255	0.50	3.00
B3P3	Fish	61.13385	-45.57556	258	0.30	5.00
B2P3	Fish	61.12275	-45.55696	261	0.41	4.25
B3P1	Fish	61.13130	-45.51195	180	0.40	2.00
B3P2	Fish	61.12788	-45.51031	201	0.53	4.50
B1P4	No Fish	61.16552	-45.56801	304	0.44	2.20
B2P4	No Fish	61.12192	-45.55497	261	0.51	7.00
B3P0	No Fish	61.13210	-45.51416	177	0.81	4.00
ERL85	No Fish	61.14171	-45.59328	120	1.82	8.00
ERL122	No Fish	61.14182	-45.53623	111	1.10	5.00
ERL152	No Fish	61.14646	-45.59235	156	0.73	4.50

0.2 Data sources

Dissolved oxygen and water temperature measurements were yielded from EXO2 multiparameter sondes, as described in section Study design and setup. For the purpose of estimating ecosystem metabolism, wind and irradiation data were yielded from the Programme for Monitoring of the Greenland Ice Sheet (PROMICE), providing automatic weather station data (Fausto et al., 2021). The dataset named `QAS_L_hour.csv` originating from the QAS_L automated weather station near Narsarsuaq was downloaded from a public database provided by PROMICE (How et al., 2022).

0.3 Data preparation

The data preparation for estimating lake metabolism was done separately for each monitoring period (16 September-24 September 2021, 22 June-3 July 2022, and 22 June-17 July 2023).

Sonde data

First, the raw sonde data from each lake were imported and merged into one dataset for a given monitoring period. The variables needed for lake metabolism estimation were water temperature (°C) and dissolved oxygen (mg/L). Next, an outlier analysis was performed by removing values higher than three times the median absolute deviation of all values in a sliding window of one day window size (Lürig et al., 2021). After outlier removal, the time series of water temperature and dissolved oxygen were subsequently investigated for larger data gaps due to potential lack of sensor measurements over certain periods.

To ensure overlapping estimation of lake metabolism, the data was subsequently cut to achieve equal starting and ending time points for all lakes during a given observation period. Due to large data gaps during the period of 2022, we chose to keep as much complete days as possible in order to estimate the maximum amount of days, rather than selecting the longest common monitoring period for all lakes.

After cutting, missing values were replaced by a weighted moving average, where the weights of observations around the central value decrease exponentially (Moritz and Bartz-Beielstein, 2017). For larger data gaps spanning over several hours, we chose to not estimate lake metabolism for the affected days, rather than imputing these values.

Weather data

0.4 Statistical analysis

0.5 Implementation