

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☒ ☐ The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
- ☒ ☐ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☒ ☐ The statistical test(s) used AND whether they are one- or two-sided
Only common tests should be described solely by name; describe more complex techniques in the Methods section.
- ☒ ☐ A description of all covariates tested
- ☒ ☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☒ ☐ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☒ ☐ For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
Give P values as exact values whenever suitable.
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☒ ☐ Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection No software was used for data collection for this manuscript.

Data analysis Custom code for data processing and analysis used in Python, version 3.8. GSAS-II software for XRD analysis is open source at Argonne National Lab (<https://subversion.xray.aps.anl.gov/trac/pyGSAS>).

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

All data are available in the main text or supplementary information, or in the figshare repository (doi:10.6084/m9.figshare.23907951).

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research](#).

Reporting on sex and gender	Not applicable.
Population characteristics	Not applicable.
Recruitment	Not applicable.
Ethics oversight	Not applicable.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Various field measurements and experiments were employed to understand high phosphate concentrations in soda lakes. These included various geochemical measurements in lake sediments, water, and evaporites, as described in the Methods section. Lake water and sediments were incubated to determine nitrogen fixation rates as described in the Methods section. Lake water was incubated to determine the effect of fertilization with different nutrients as described in the Methods section. Details on the various measurements and experiments can be found in the Methods section of the study.
Research sample	The rationale for lake sampling was to cover different seasons (dry = September, wet = June, winter = November) to determine seasonal trends and to cover different parts of the lakes in each season to account for any spatial variation across each lake.
Sampling strategy	Sample sizes are sufficient because clear effects of treatment can be seen in the fertilization experiment, the range of nitrogen fixation rates is sufficient to compare them between the two studied lakes and other environments, geochemical measurements show clear and significant trends (e.g., Fig. 2, Fig. S4).
Data collection	Data collection and recording (notebooks, spreadsheets) was overseen in all cases by Sebastian Haas with assistance by the co-authors of this study and additional people mentioned in the Acknowledgements section. Data were collected by different methods as described in the Methods section of the manuscript.
Timing and spatial scale	Sampling was performed in different seasons with the rational to understand how phosphate and associated biology behaves across the seasonal wet-dry cycle in the lakes. The first samples and data were collected between November 11-13, 2021, more were collected between June 14-17, 2022, and the final samples and data were collected between September 12-16, 2022.
Data exclusions	Low-quality datapoints due to analytical challenges in the ICP-MS measurements caused by the extremely high salinity were excluded from analysis.
Reproducibility	Accurate description of experimental setup assures reproducibility.
Randomization	Random.
Blinding	Not applicable.
Did the study involve field work?	☒ Yes ☐ No

Field work, collection and transport

Field conditions	Temperatures cold (around 0 celsius) in November 2021, warm (around 15-20 celsius) in June and September 2022. Several rain events during the June 2022 campaign but not while actively sampling. One big rain event on the last day and the preceding night of the September 2022 campaign as noted in the manuscript.
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Location	Location: Cariboo Plateau, near Clinton, British Columbia. 51°19'44 N, 121°38'18 W. Elevation: ~1080m.
Access & import/export	No permits or import/export restrictions apply.
Disturbance	Lake bed disturbed during wading of researchers for sampling. Minimized by only wading for necessary sampling.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging