nature portfolio

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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	The dataRetrieval R package for downloading discharge and water quality data in the US is available at the GitHub: https://github.com/USGS-R/dataRetrieval.
Data analysis	The deep learning code and instruction are available from the GitHub website at https://github.com/WeiZhiWater/DeepWater. The streamMetabolizer R package for calculating DO saturation concentration is from the GitHub at https://github.com/USGS-R/streamMetabolizer. The bestNormalize R package for transforming model inputs is from the GitHub at https://github.com/cran/bestNormalize.

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

Discharge and water quality data in the US were downloaded from the USGS National Water Information System (NWIS) at the web https://waterdata.usgs.gov/nwis. The historical meteorological datasets in the US are available from the NLDAS-2 (https://ldas.gsfc.nasa.gov/nldas/v2/forcing) and DAYMET (https://daymet.ornl.gov). Basin characteristics in the US is from the GAGES-II that archived at the website of https://water.usgs.gov/GIS/metadata/usgswrd/XML/gagesII_Sept2011.xml. The new CE dataset including meteorological forcing, discharge, and basin attributes were obtained from https://doi.org/10.5194/essd-13-4529-2021. Due to limits in sharing raw water quality data from CE providers, we recommend accessing data from their websites: water quality data in Austria was obtained from the Federal Ministry of Agriculture, Regions and Tourism at https://wasser.umweltbundesamt.at/h2odb/fivestep/abfrageQdPublic.xhtml. Water quality data in Switzerland was obtained from the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) & Federal Office for the Environment (FOEN) at https://doi.org/10.25678/0004AV. Water quality data in Germany was obtained from the State Agency for the Environment Baden-Württemberg at https://udo.lubw.baden-wuerttemberg.de/public/pages/home/welcome.xhtml, and the Bavarian State Office for the Environment at https://www.gkd.bayern.de/en/rivers/chemistry. Supporting data are deposited at https://github.com/LiReactiveWater/DO-dataset-US-CE. The projected downscaled forcing data from the NEX-GDDP-CMIP6 database can be found at https://doi.org/10.7917/OFSG3345.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	n/a
Population characteristics	n/a
Recruitment	n/a
Ethics oversight	n/a

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	n/a
Research sample	n/a
Sampling strategy	n/a
Data collection	n/a
Timing and spatial scale	n/a
Data exclusions	n/a
Reproducibility	n/a
Randomization	n/a
Blinding	n/a

Did the study involve field work? ☐ Yes ☒ No

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