EGU 2021
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ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Metabarcoding of modern sedimentary DNA from the Tibetan Plateau and Siberia as a training dataset for vegetation reconstructions

Weihan Jia, Kathleen R. Stoof-Leichsenring, Sisi Liu, Kai Li, Sichao Huang, Xingqi Liu, Jian Ni, Xianyong Cao, Luidmila A. Pestryakova, Steffen Mischke, and Ulrike Herzschuh

Contact information:

Weihan Jia (weihan.jia@awi.de) and **Ulrike Herzschuh** (ulrike.herzschuh@awi.de)

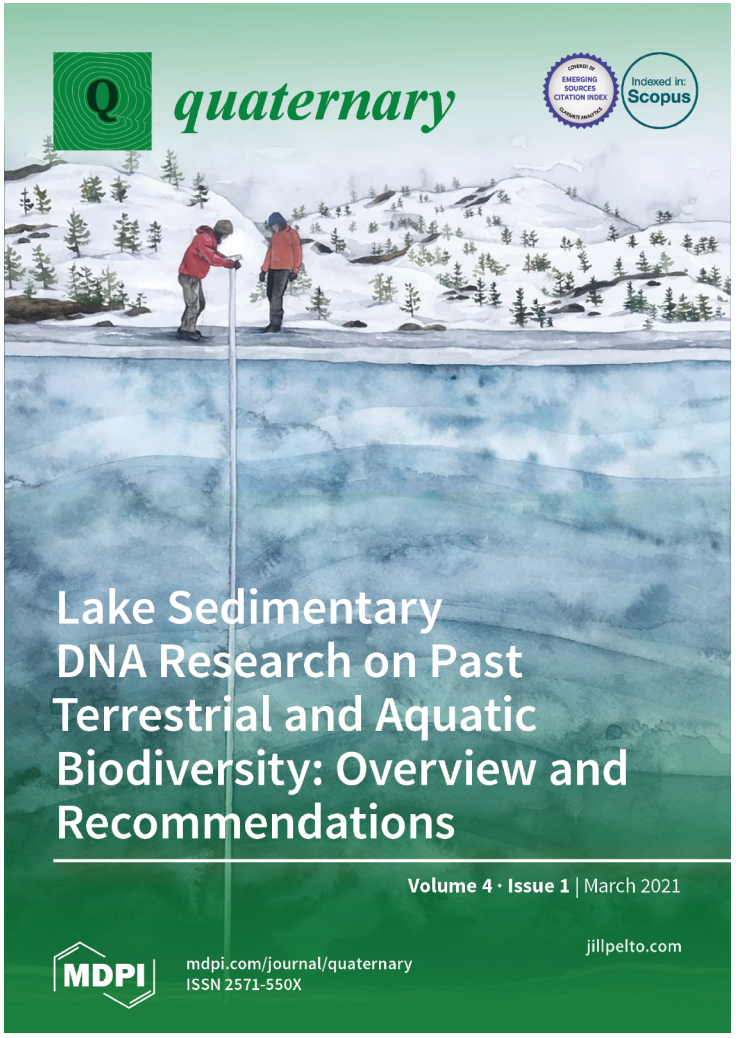
Polar Terrestrial Environmental Systems Research Group
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research
Telegrafenberg A45, 14473 Potsdam, Germany

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Introduction



Little is known about the modern processes of lake sedimentary DNA !

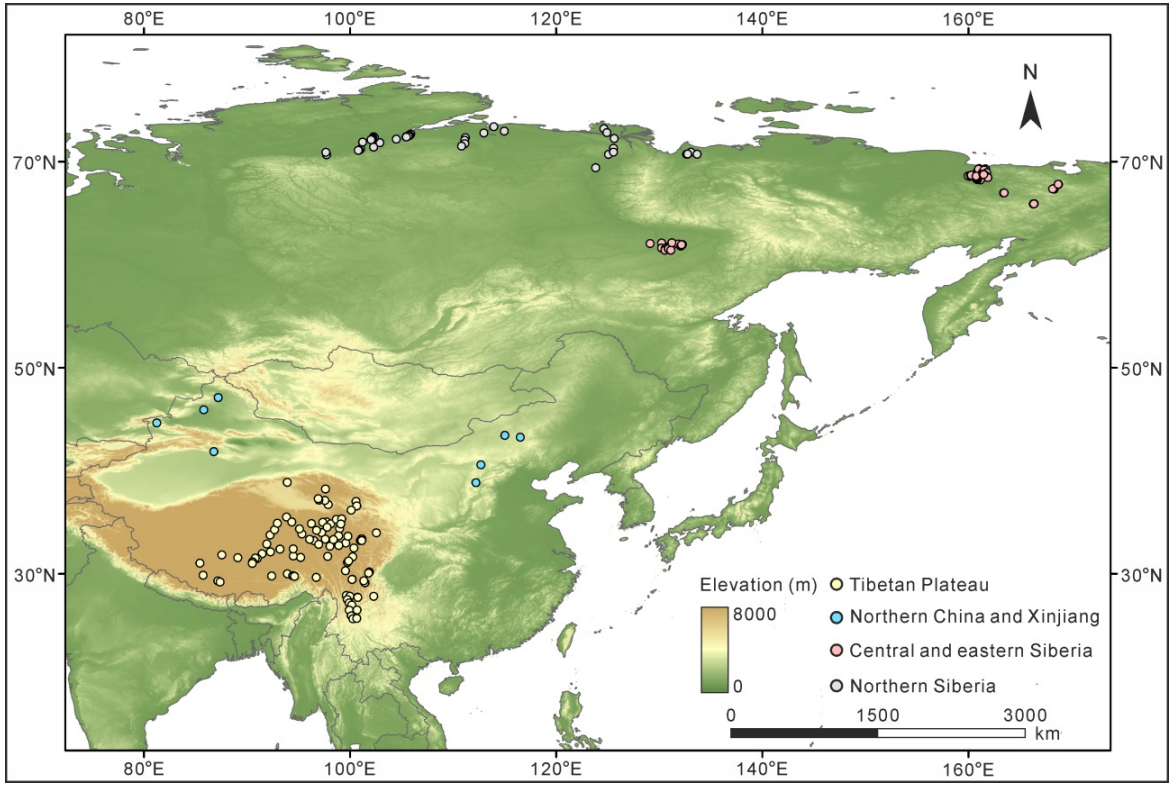
In this study, we investigate:

- The relationships between the preservation of sedimentary plant DNA and different environmental variables.
- The modern analogue of ancient plant DNA assemblages archived in lake sediments.
- The usability of sedimentary plant DNA for characterization of terrestrial and aquatic plant composition and diversity.

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Working programs





259 lake surface sediments sampled from 2003 to 2018

...

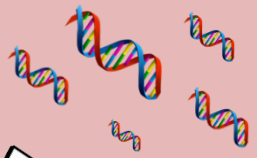
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Working programs

Surface sediment sampling



DNA extraction



PCR amplification



Next-generation sequencing



Bioinformatics Data analyses





DNeasy PowerMax Soil Kit
(Qiagen, Germany)



PowerMax Soil DNA Isolation Kit
(MoBio Laboratories, Inc., USA)

5-10 g sediment

Primer

The *g-h* primers
(Taberlet et al., 2007)

Polymerase

Platinum Taq High Fidelity
DNA Polymerase (Invitrogen)

Program

50 cycles

At least two PCR replicates for each sediment sample.



FASTERIS

Four independent runs
Illumina paired-end sequencing
Fasteris SA, Switzerland

Working programs



OBITools
(Boyer et al.,2016) +

Biodiversity Data Journal 8: e57089
doi: 10.3897/BDJ.8.e57089
open access

Data Paper

Plant diversity in sedimentary DNA obtained from high-latitude (Siberia) and high-elevation lakes (China)

Kathleen Rosmarie Stoof-Leichsenring[‡], Sisi Liu[‡,§], Weihan Jia[‡,|], Kai Li[‡,¶], Luidmila A. Pestryakova[#], Steffen Mischke[¤], Xianyong Cao[«], Xingqi Liu[|], Jian Ni[¶], Stefan Neuhaus[»], Ulrike Herzschuh[‡,§,˄]

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| College of Resource Environment and Tourism, Capital Normal University, Beijing, China
¶ College of Chemistry and Life Sciences, Zhejiang Normal University, Jinhua, China
Department for Geography and Biology, North-Eastern Federal University of Yakutsk, Yakutsk, Russia
¤ Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland
« Alpine Paleoecology and Human Adaptation Group (ALPHA), Key Laboratory of Alpine Ecology, Institute of Tibetan Plateau Research, Beijing, China
» Computing and Data Centre, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
˄ Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Germany

Reference libraries:

- *ArcBorBryo*
  Sønstebø et al., 2010
  Willerslev et al., 2014
  Soininen et al., 2015
- *EMBL-138*

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Four research papers based on the big dataset

- **Jia, W** et al. (2021). Preservation of sedimentary plant DNA is related to lake-water chemistry. *Environmental DNA*, in revision.

- **Liu, S** et al. (2021). Vegetation reconstruction from Siberia and the Tibetan Plateau using modern analogue technique -comparing sedimentary ancient DNA (sedaDNA) and pollen data. *Frontiers in Ecology and Evolution*, in press.

- **Li, K** et al. (2021). Plant sedimentary DNA as a proxy for vegetation reconstruction in eastern and northern Asia. *Ecological Indicators*, in revision.

- **Stoof-Leichsenring, KR** and **Huang, S** et al. (2021). Sedimentary DNA identifies modern and past water plant diversity and its environmental drivers in high latitude and altitude lakes in Siberia and China. In preparation.

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Paper 1

Preservation of sedimentary plant DNA is related to lake-water chemistry

First author: Weihan Jia (weihan.jia@awi.de; whjia@cnu.edu.cn)
Correspondences: Xingqi Liu and Ulrike Herzschuh



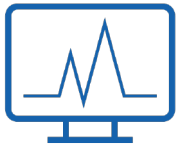
Four DNA preservation proxies:

- The percentage of sequence counts with the best identity ≥95% ($PCT_{id\geq95\%}$)
- Weighted average identity (WAI)
- Weighted average DNA fragment length (WAFL)
- Rarefied richness of terrestrial seed plants

Five environmental variables:

- Lake-water conductivity
- Lake-water pH
- July mean air temperature
- Lake size
- Sampling depth

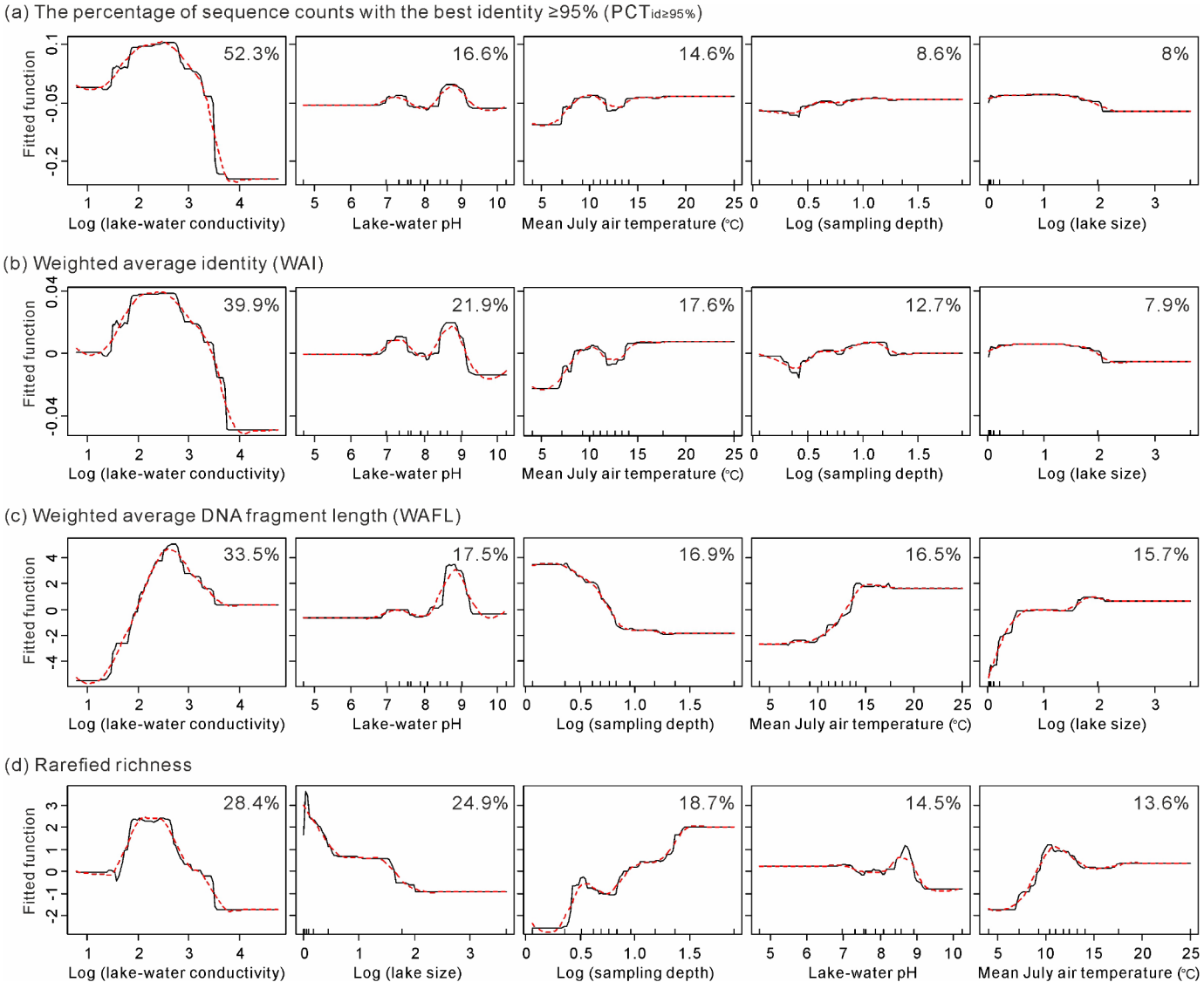


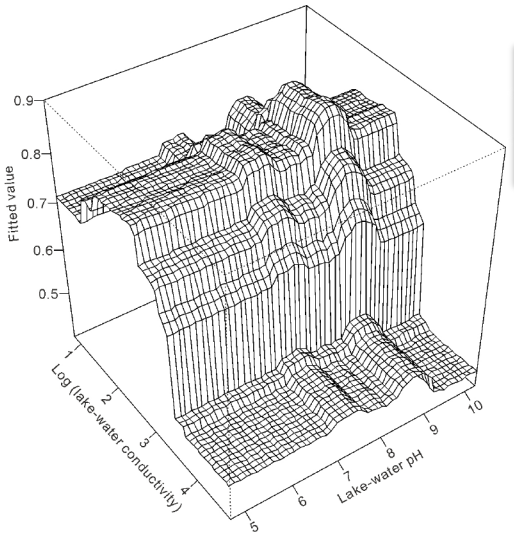


Boosted regression tree models
(Elith et al., 2008)

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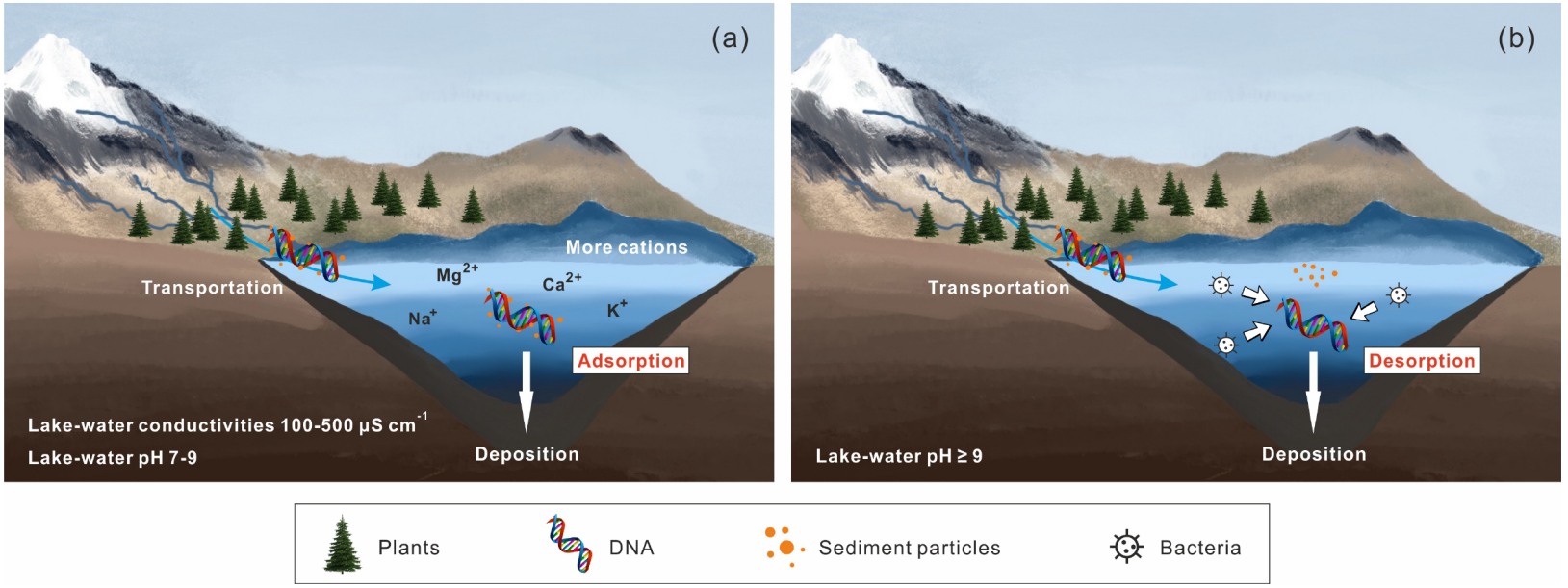
Paper 1 - BRT results





Lake-water conductivity and **pH** are the most important variables for the preservation of sedimentary plant DNA.

Paper 1 - Conclusions



a) The electrical conductivity and pH of lake water are the two most important variables for the preservation of sedimentary plant DNA. **Lakes with intermediate water conductivities (100–500 µS cm^{-1}) and neutral to slightly alkaline water pH (7–9) are suitable for sedimentary (ancient) DNA studies.**

b) Deep lakes seem to support plant DNA preservation as indicated by relatively high rarefied richness. The relationship between rarefied richness and lake size requires further assessment.

c) Air temperature does not appear to be a key variable to limit the preservation of plant DNA in lake sediments.

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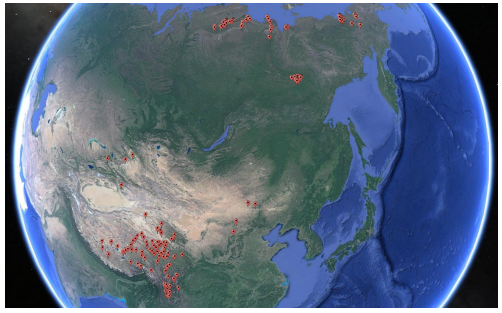
Paper 2

Vegetation reconstruction from Siberia and the Tibetan Plateau using modern analogue technique -comparing sedimentary ancient DNA (sedaDNA) and pollen data

First author: Sisi Liu (sisi.liu@awi.de)

Correspondences: Sisi Liu and Ulrike Herzschuh





Surface dataset

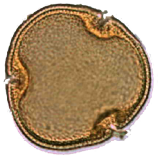
+



Two lake cores

Lakes Naleng and Omoloy

- Analogue matching
- Ordination
- Procrustes of taxa ordination scores



Pollen

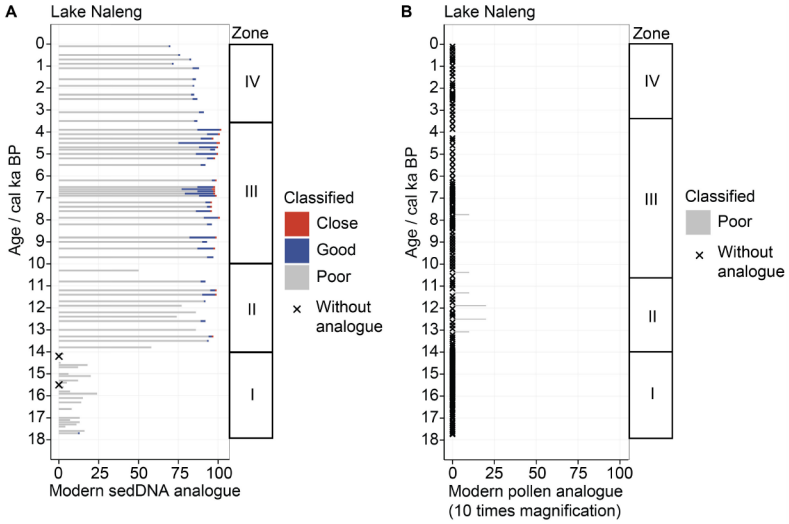
VS

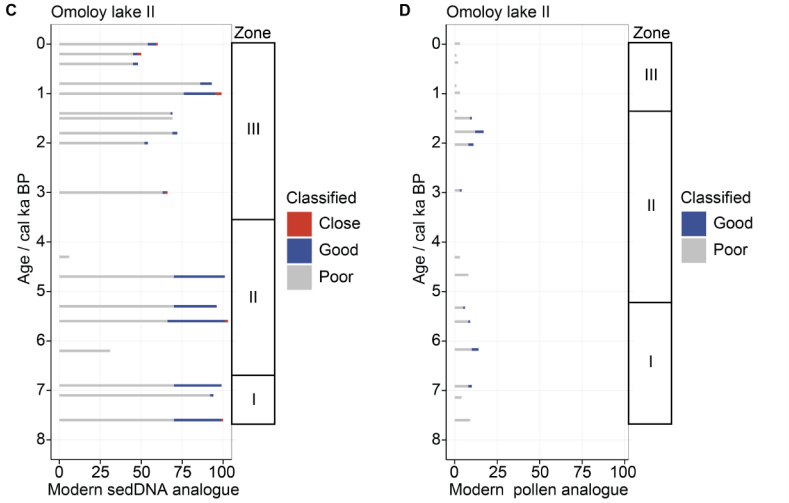


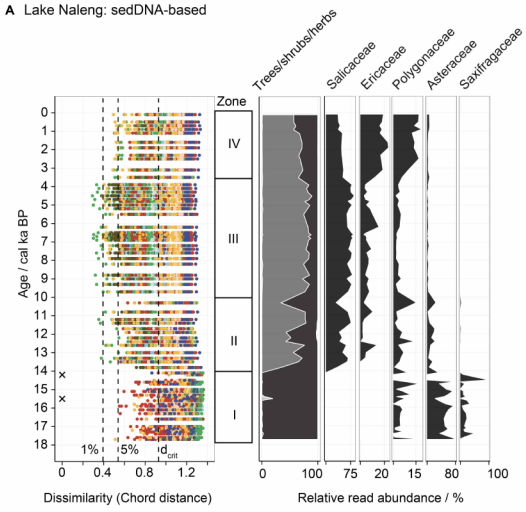
SedaDNA

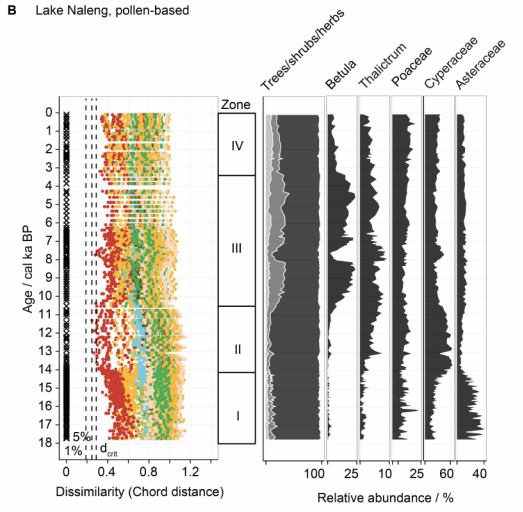
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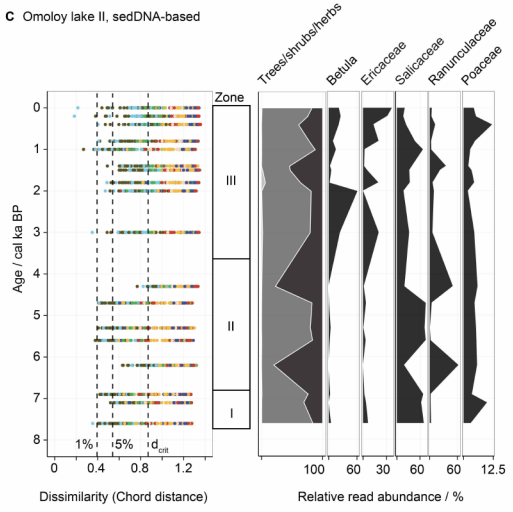
Paper 2 - The modern analogues

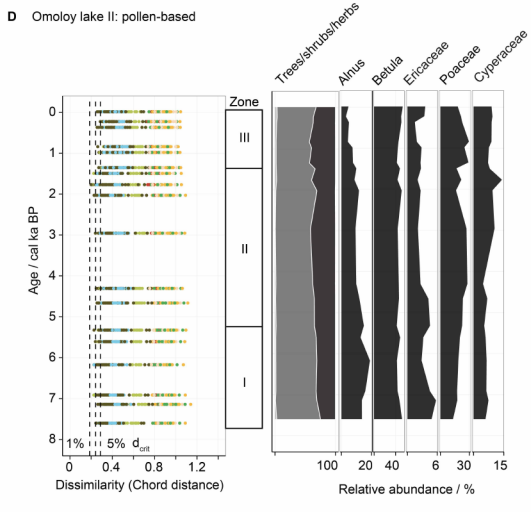








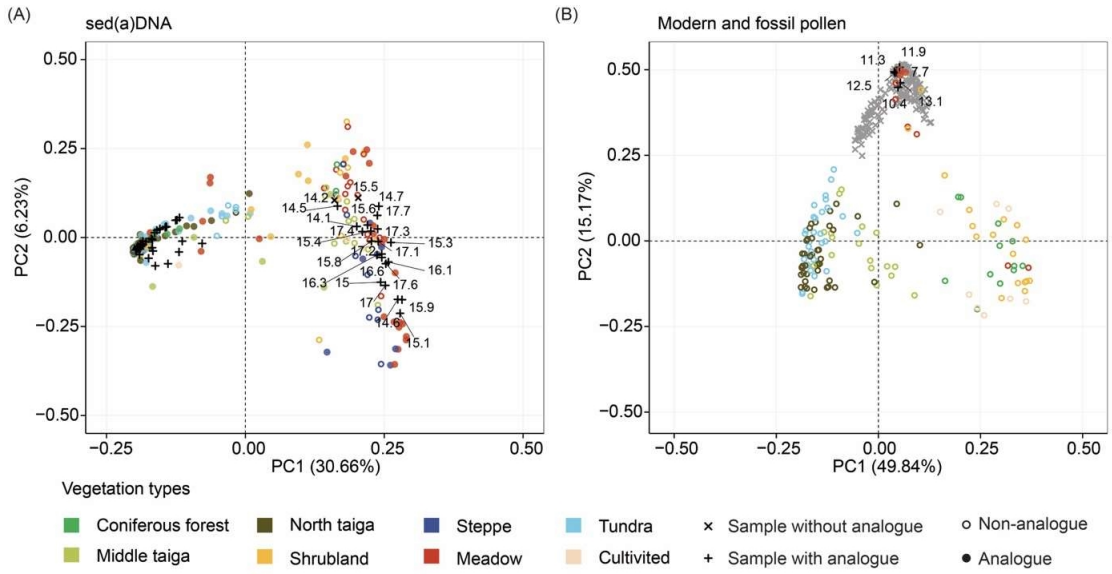




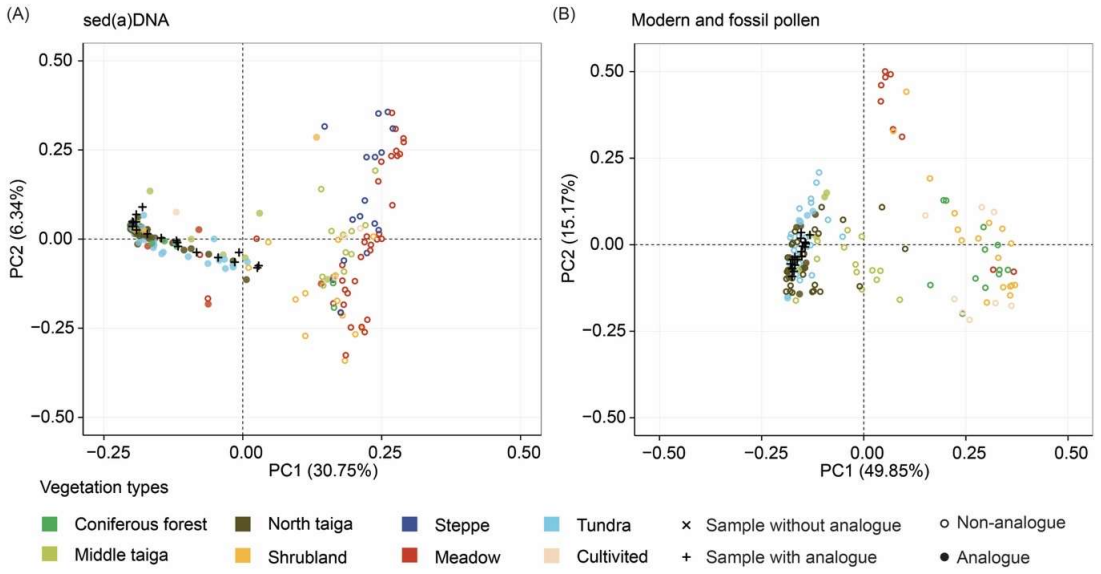


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Paper 2 - PCA results



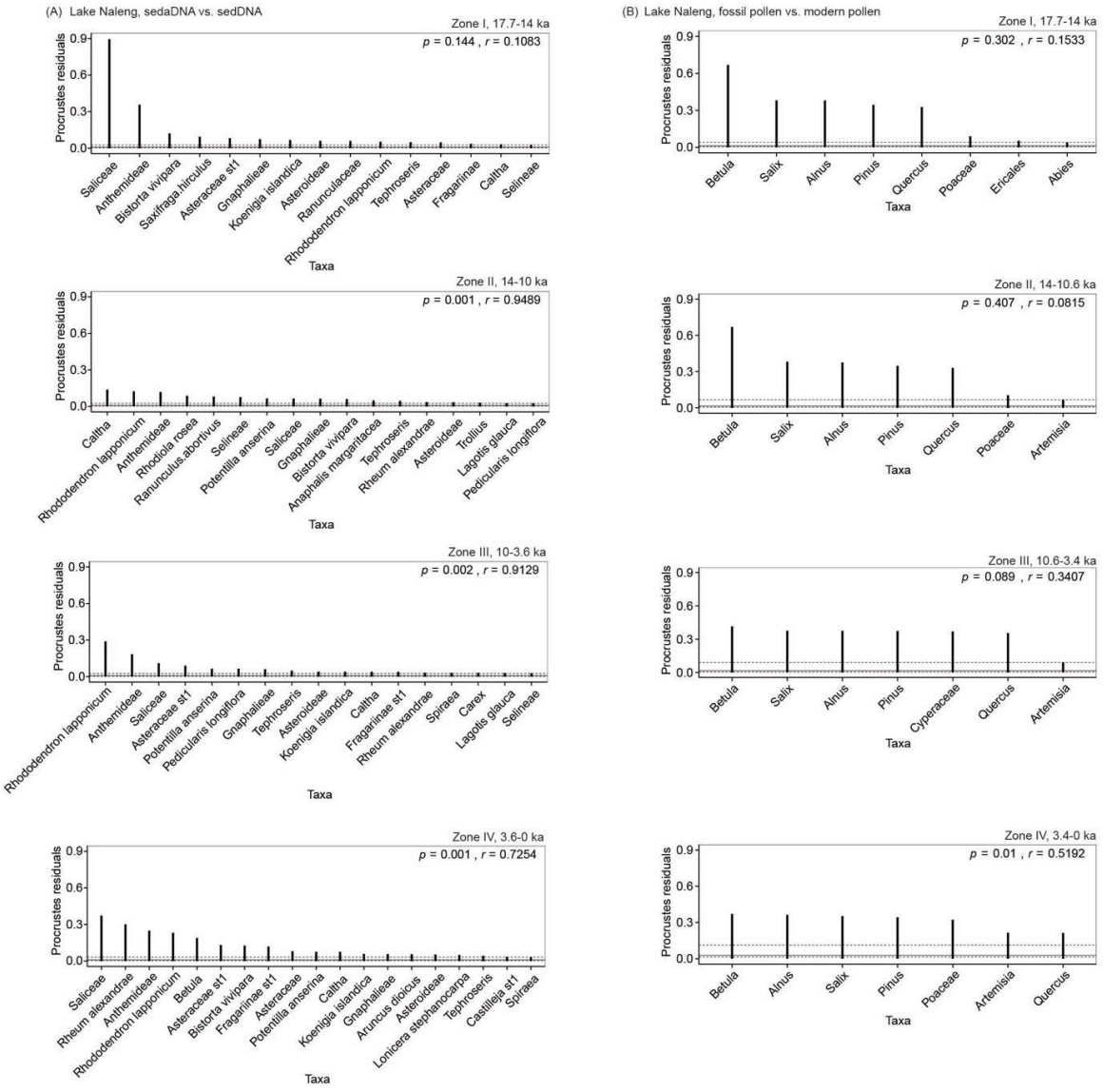
Lake Naleng



Lake Omoloy

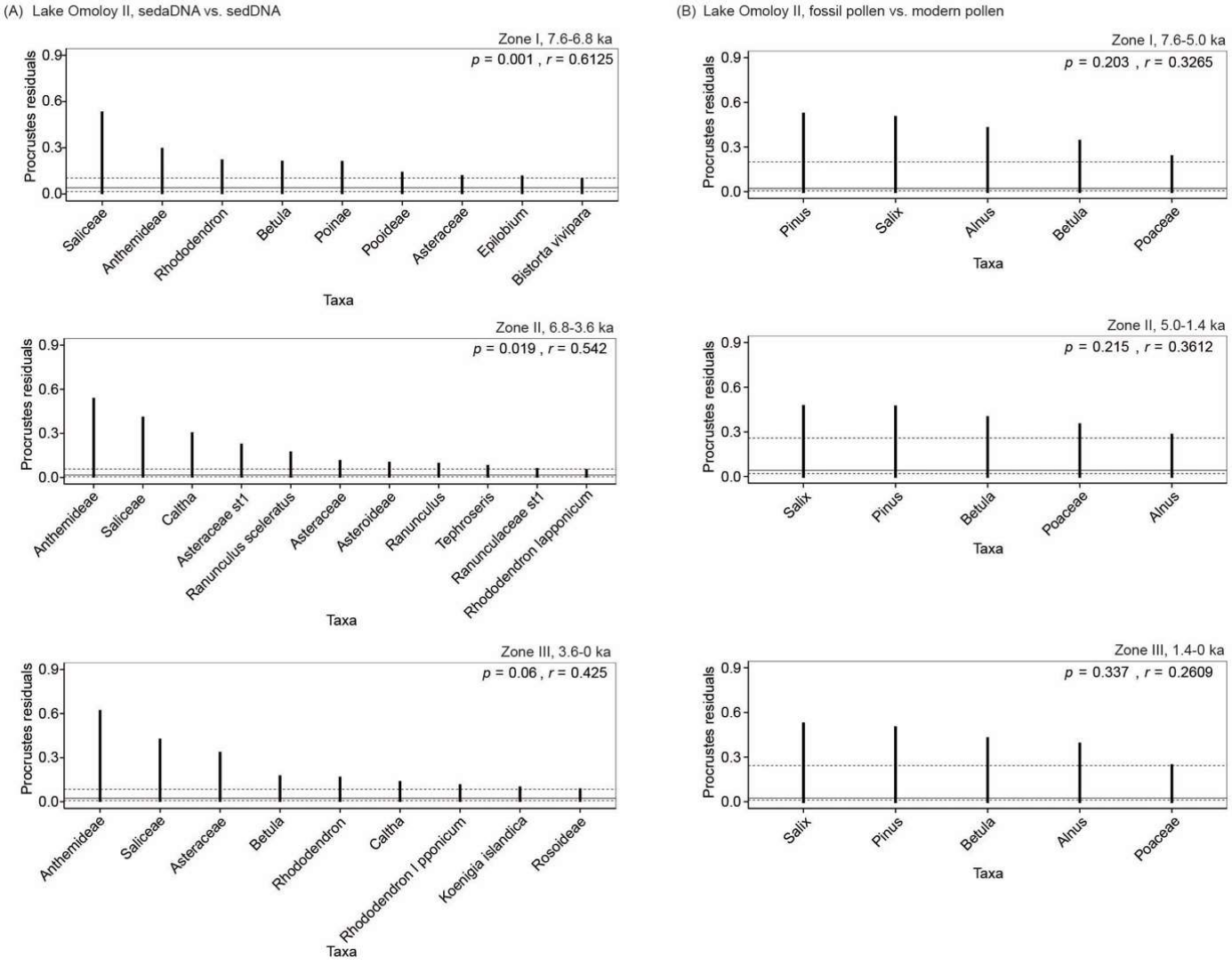
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Paper 2 - Procrustes analysis of Lake Naleng



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Paper 2 - Procrustes analysis of Lake Omoloy



Paper 2 – Conclusions

a) SedDNA is promising for palaeovegetation reconstruction in the high mountain regions, where shifts in vegetation are solely captured by the sedDNA-based analogue matching and fossil pollen generally has poor modern analogues.

b) Although we find some modern sedDNA analogues in pre-14 ka, most of them are not statistically significant. The poor-quality analogues should be carefully considered when quantitative climate reconstruction is an objective.

c) The advance and retreat of woody plants are recorded by sedDNA in the alpine area since post-14 ka. We did not find a clear retreat in the forests in the arctic tundra during the late Holocene.

d) The biases in the relative abundance of taxa (e.g., Salicaceae in sedDNA data, *Pinus*, *Betula* and *Alnus* in pollen data) have to be taken into account when both data are used for vegetation reconstruction.

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Paper 3

Plant sedimentary DNA as a proxy for vegetation reconstruction in eastern and northern Asia

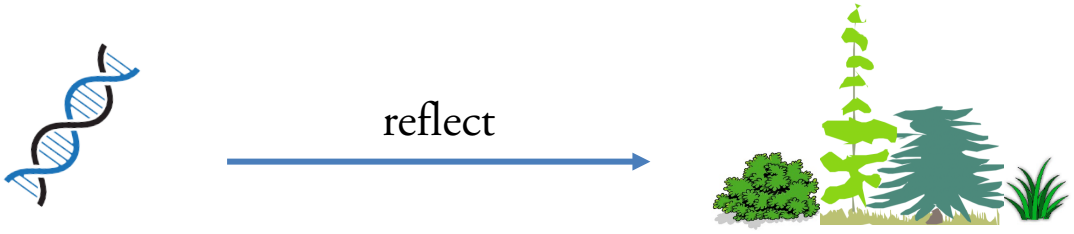
First author: Kai Li (likai@zjnu.edu.cn)

Correspondence: Ulrike Herzschuh

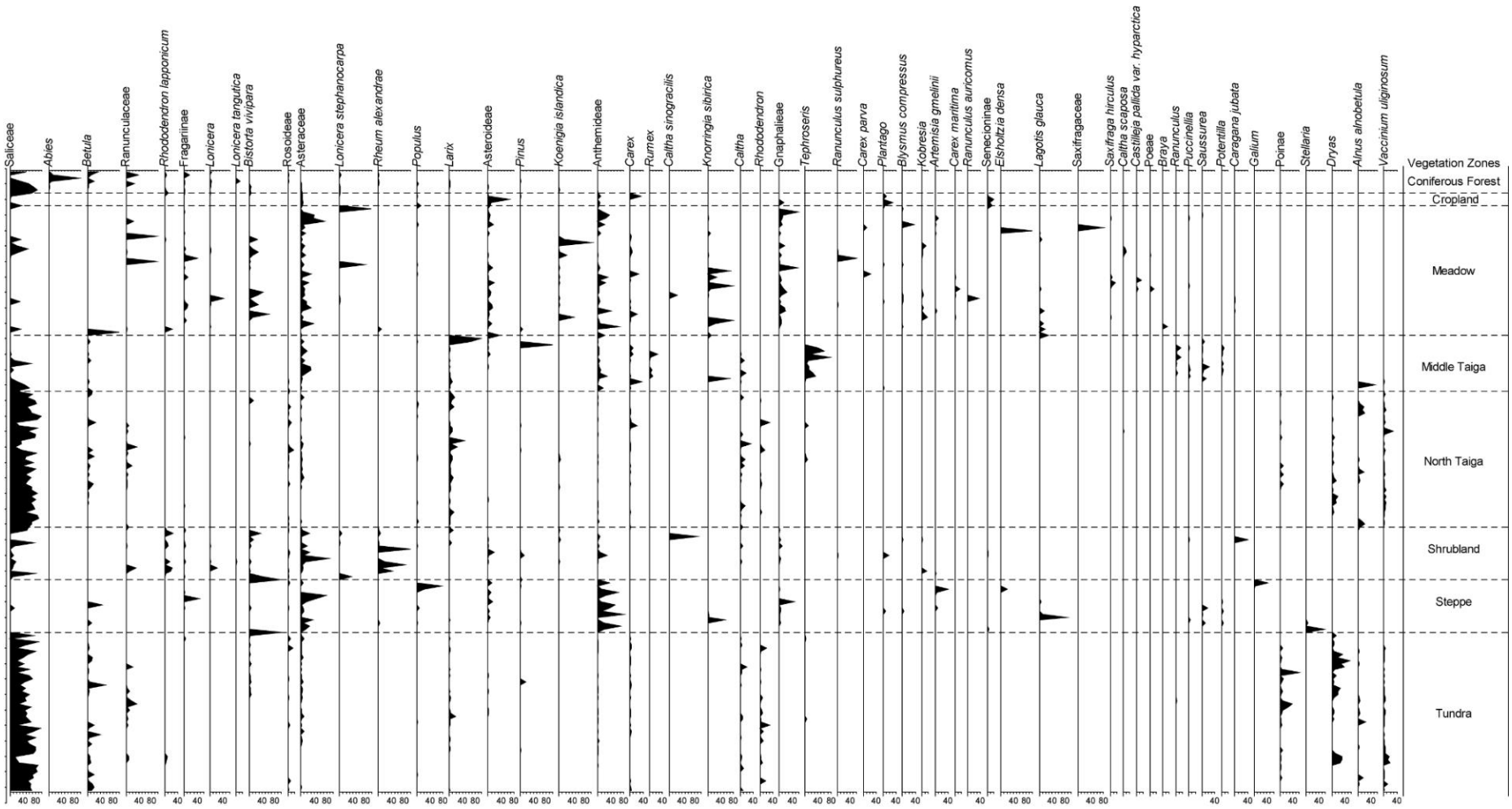


Scientific questions:

- How well does plant sedDNA reflect the dominant terrestrial plant taxa and general vegetation composition?
- The applicability and limitations of plant sedDNA metabarcoding for palaeovegetation studies.



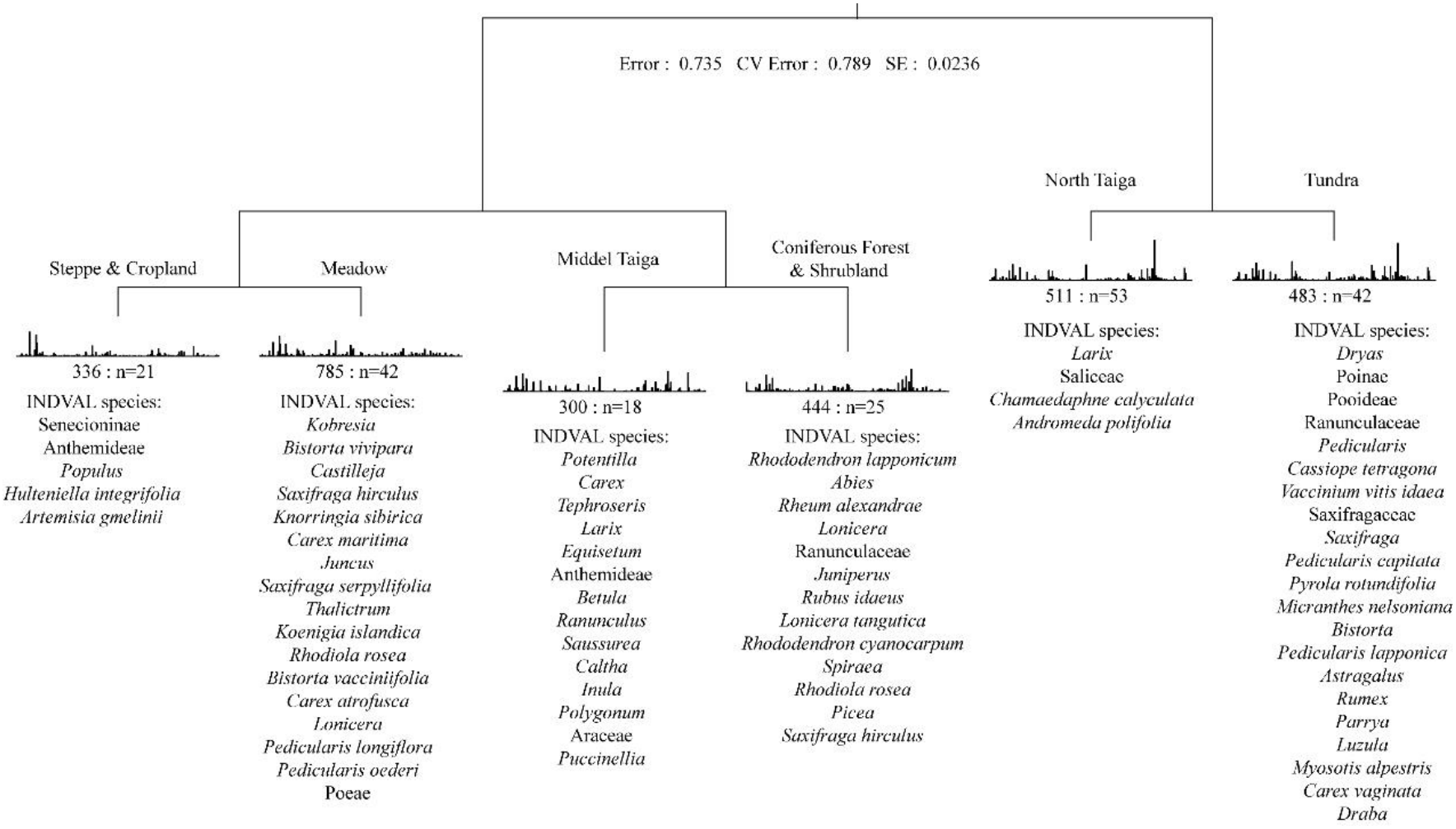
Paper 3 - Composition of plant sedDNA taxa for selected samples



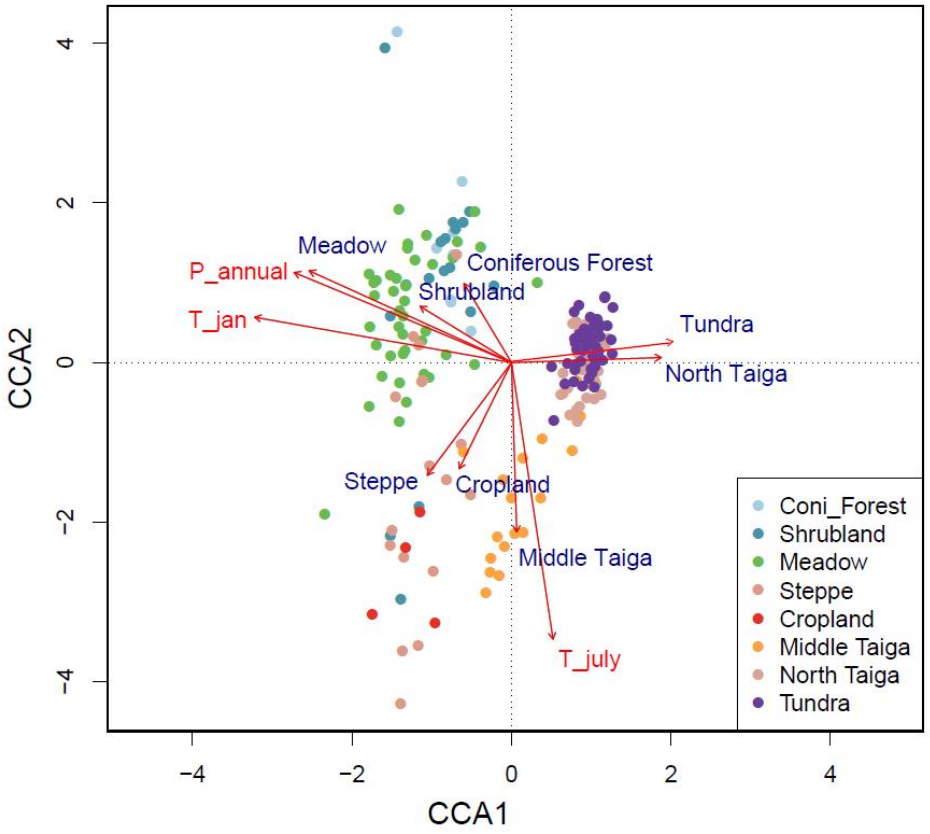
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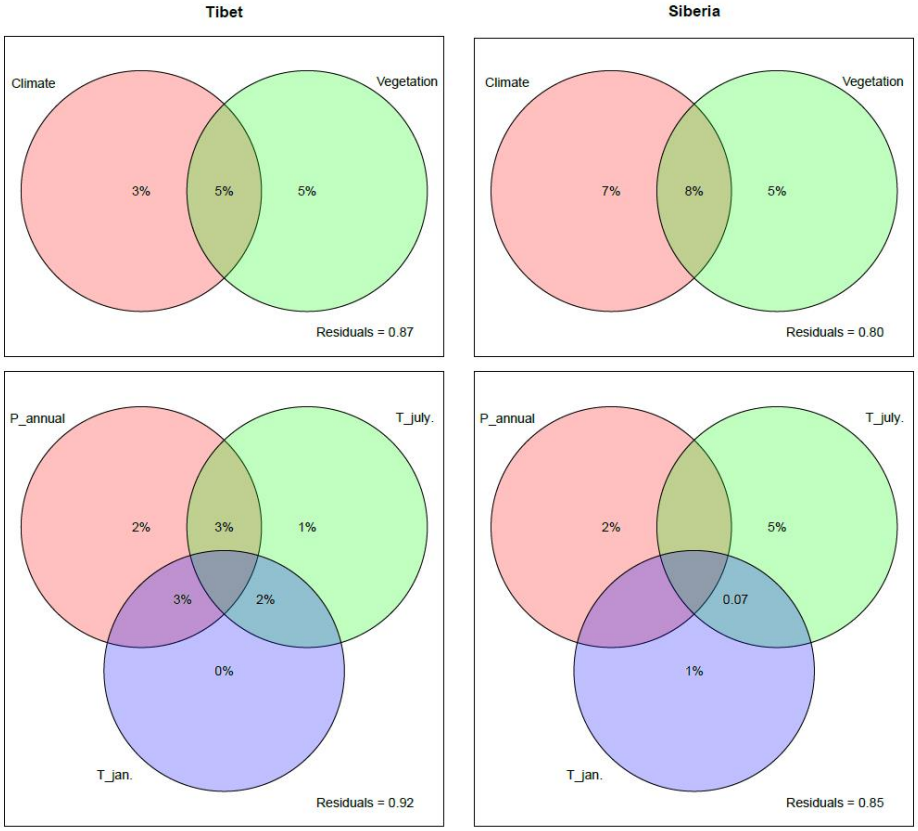
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Paper 3 – Multivariate regression trees (MRT) results



Paper 3 – CCA results





P_annual: mean annual precipitation
T_jan: mean temperature of January
T_july: mean temperature of July

Modern vegetation types and three climate parameters significantly influence the compositional variation in the plant sedDNA dataset.

Paper 3 – Conclusions

a) Plant sedDNA is a reliable proxy to reflect modern vegetation types and climate characteristics at a sub-continental scale. In addition, most of the dominant species can be recognized in our sedDNA signals, which matches our expectation that dominant species have high biomass, and their DNA has more chances of being deposited and preserved in lake sediments.

b) However, the resolution of the *trn*L P6 loop marker, the incompleteness of the reference libraries, and the unknowns of taphonomic processes are still the main limitations of this method.

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Paper 4

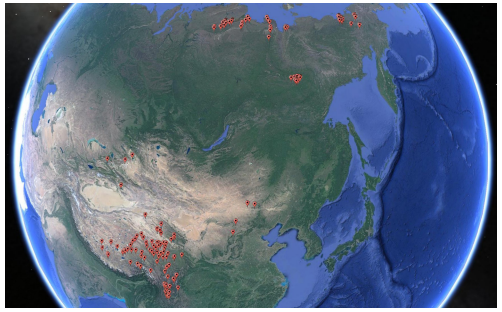
Sedimentary DNA identifies modern and past water plant diversity and its environmental drivers in high latitude and altitude lakes in Siberia and China

First authors: Kathleen R. Stoof-Leichsenring (Kathleen.Stoof-Leichsenring@awi.de) and Sichao Huang (sichao.huang@awi.de)

Correspondence: Kathleen R. Stoof-Leichsenring







Surface dataset

+



Three lake cores

Lakes Naleng, Omoloy, and Ilirney

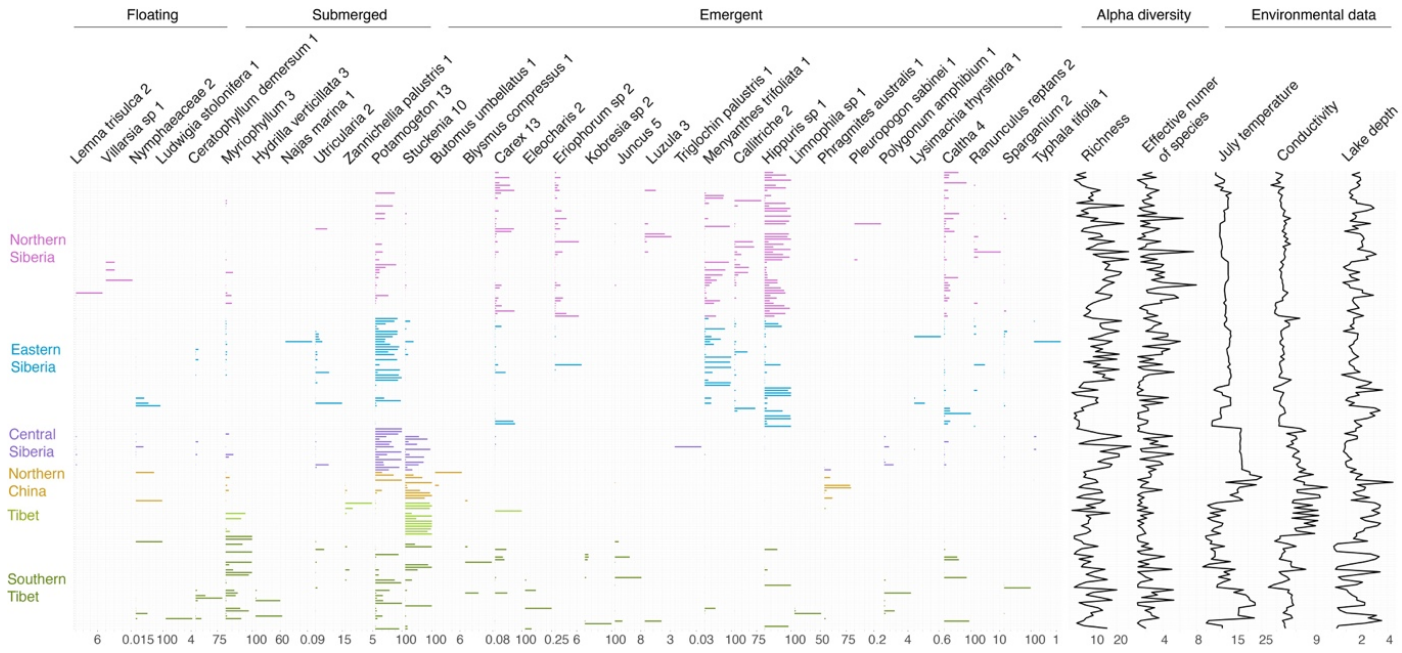
Scientific questions:

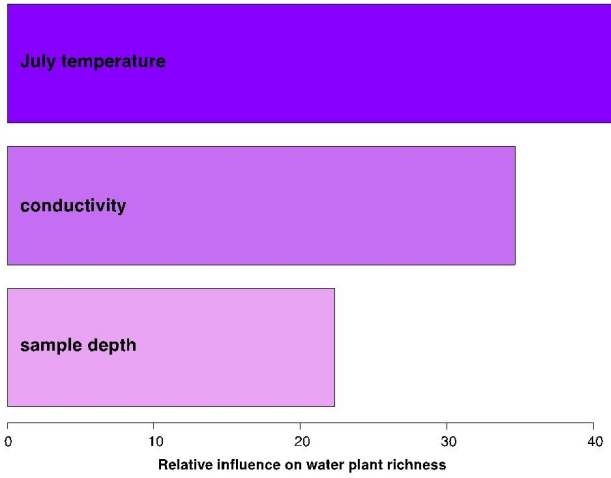
- The usability of plant sedDNA for characterization of macrophyte diversity.
- Which environmental drivers best explain modern macrophyte diversity and composition?
- How did macrophyte diversity change through climate transition from the late Pleistocene to Holocene?

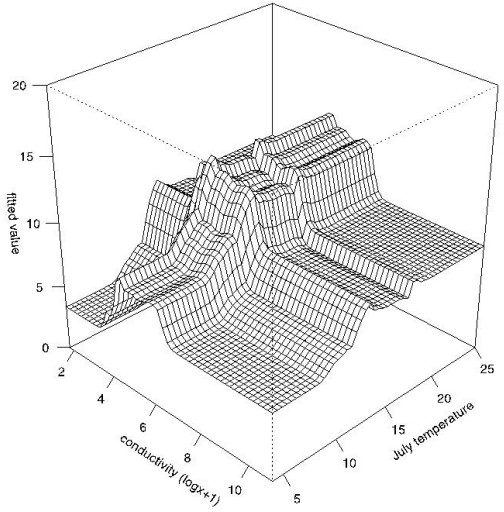
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Paper 4 – Main results



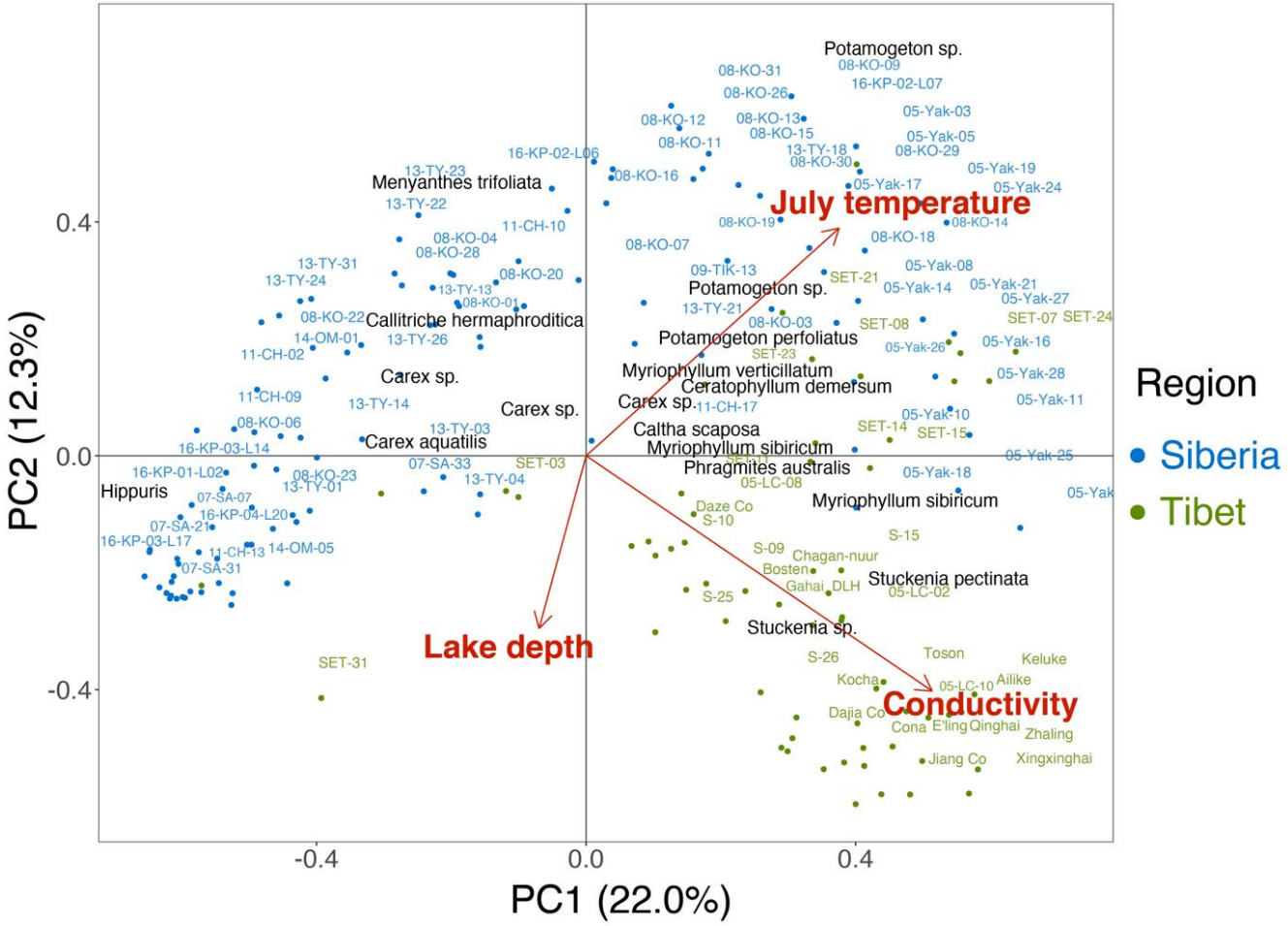




July temperature and **lake-water conductivity** are the most important variables for modern aquatic plant diversity.

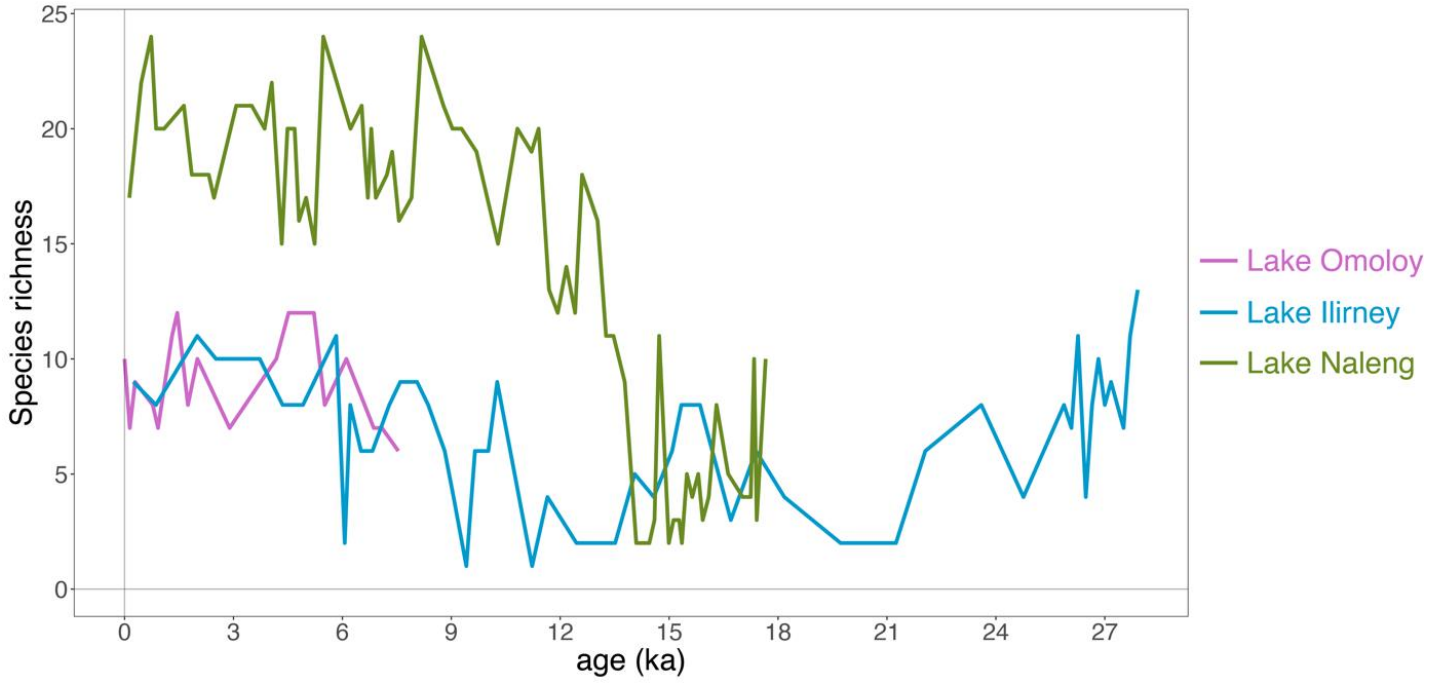
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Paper 4 – PCA results



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Paper 4 – Past macrophyte richness changes



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Paper 4 – Conclusions

a) Modern macrophyte diversity and composition are mostly affected by July temperature and lake-water conductivity.

b) Macrophyte diversity increased during the late Pleistocene-Holocene transition due to climate warming. Until now, global warming has increased the diversity and biomass of macrophyte in arctic lakes, which is assumed to be a carbon sink that can balance excess greenhouse gases.

c) Further warming may lead to a decrease and putatively loss of macrophyte taxa, which will eventually threaten the health of these important freshwater ecosystems.

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Affiliation of all authors

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[4] College of Chemistry and Life Sciences, Zhejiang Normal University, Jinhua, China

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