Understanding spatiotemporal changes in biodiversity by combining eDNA and machine learning

Niamh Eastwood[1], Jiarui Zhou[1], Arron Watson[1,2], William Stubbings[3], Mohamed Abou-Elwafa Abdallah[3], Jono Warren[4], Jo-Anne Pitt[4], Kerry Walsh[4], Henner Hollert[5], Luisa Orsini[1,5]

1 School of Biosciences, University of Birmingham; 2 Analysis and Reporting, Environment Agency; 3 School of Geography Earth & Environmental Sciences; 4 Chief Scientist's Group, Environment Agency ; 5 Goethe University Frankfurt

The Biodiversity Time Machine: Biodiversity across time

Eastwood and Zhou et al, eLife, 2023

We applied our 'time machine framework' (Eastwood et al, TREE, 2021) to a Danish lake with a documented history of anthropogenic impact. We obtain long term biological and chemical data by extracting environmental DNA (eDNA) and biocide residues from a date lake sediment core spanning the past century (fig 1) combined with historical biocide usage and weather records. The lake had 4 historical phases: semi-pristine (1915-1950, eutrophic (1950-1975), pesticide (1975-1985) and recovery (1990 onwards). By applying multi-marker metabarcoding, we captured the change in biodiversity across the past century (fig 2). Biodiversity did not return to its original state, despite improvement in water quality. By applying explainable network models with multimodal learning we identify individual and joint correlations between lake taxa, biocides and climate. Insecticides and fungicides, as well as minimum temperatures were correlated with the most number of families (fig 3).

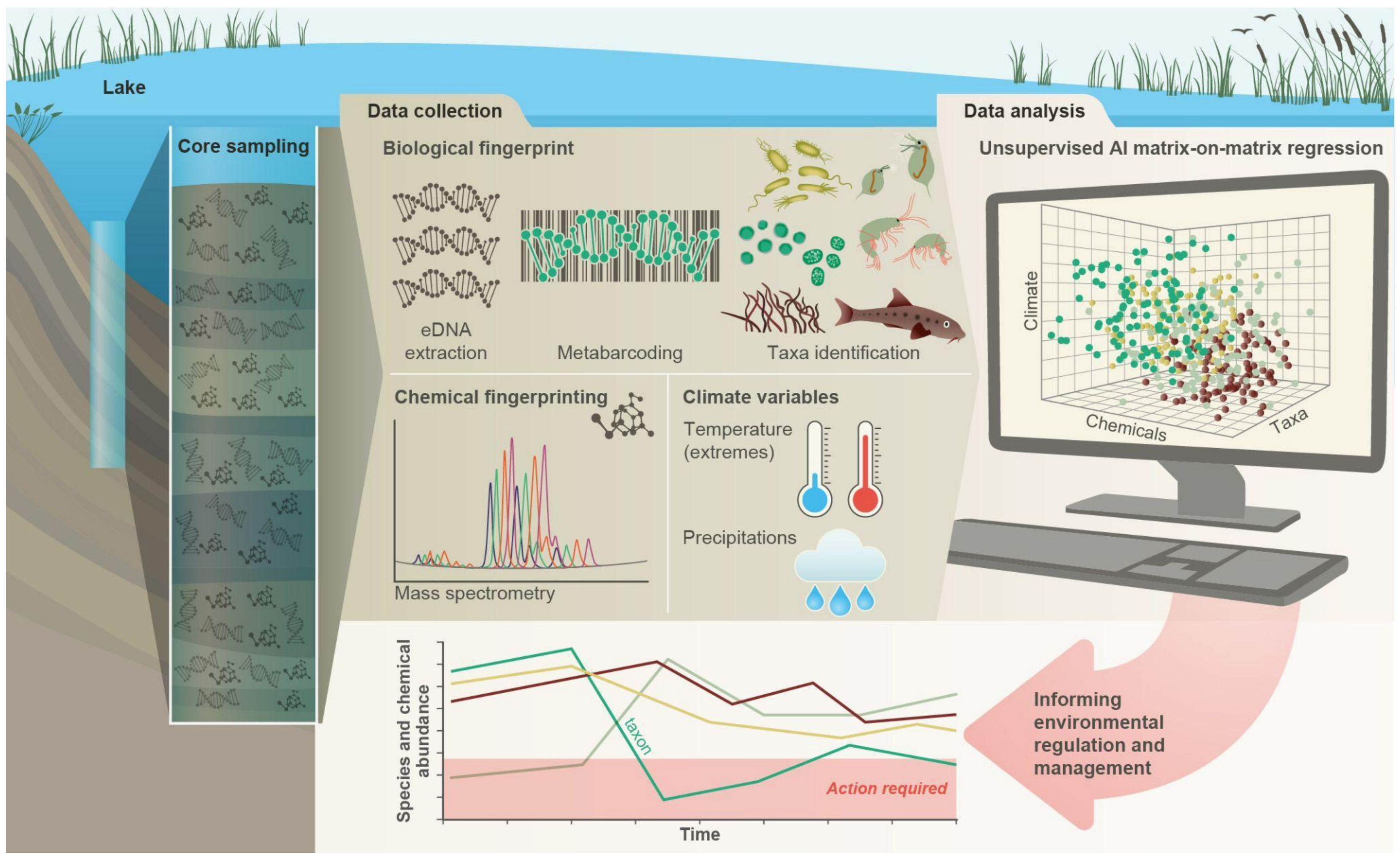

Fig 1 Conceptual Framework Biological data (eDNA) and chemical data are measured from a dated lake sediment core. Machine learning identifies significant correlations, identifying priorities for further study and intervention

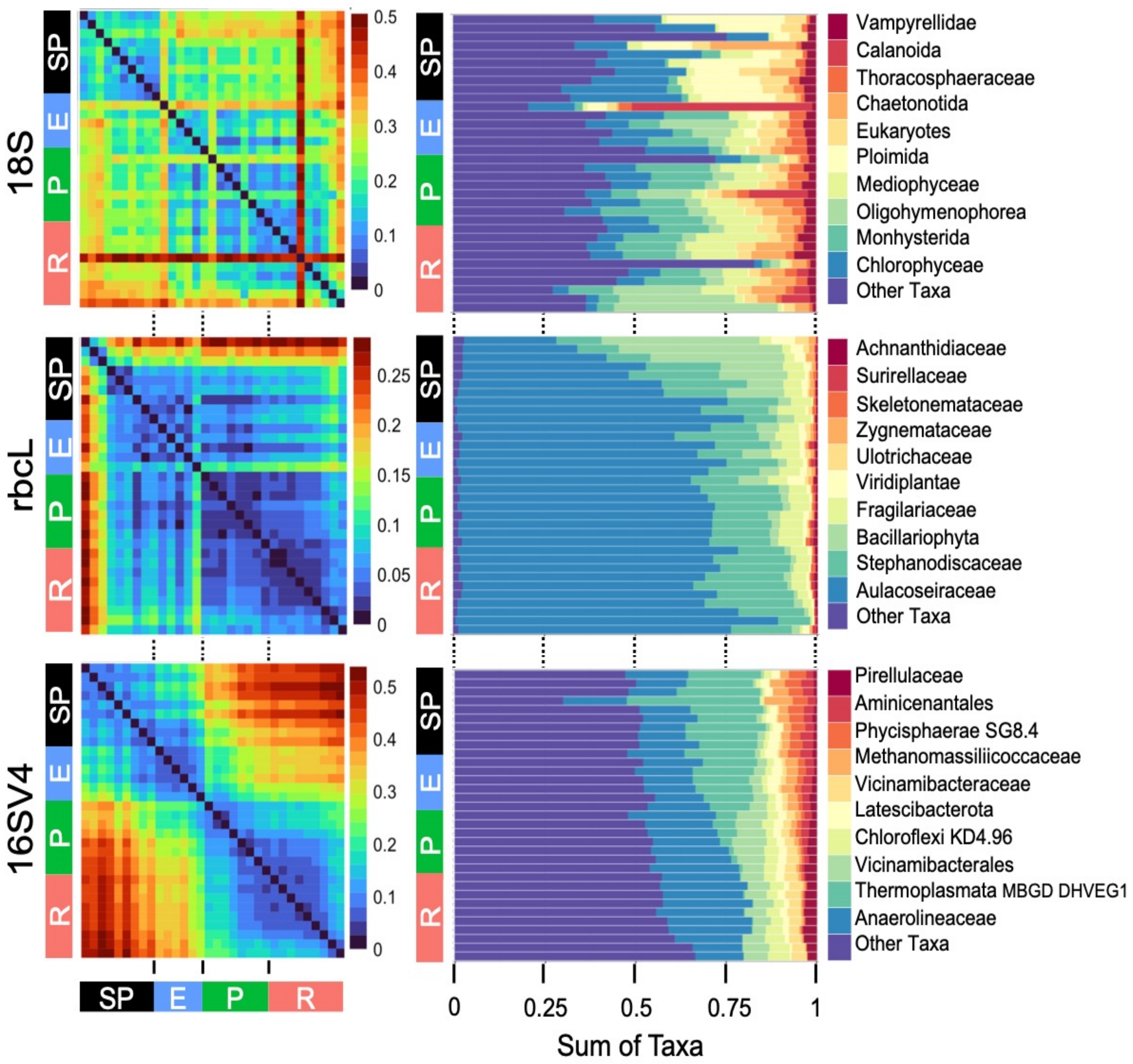

Fig 2 Community composition varies over time Beta diversity heatmaps and taxonomy bar plots to family level for three eDNA barcodes

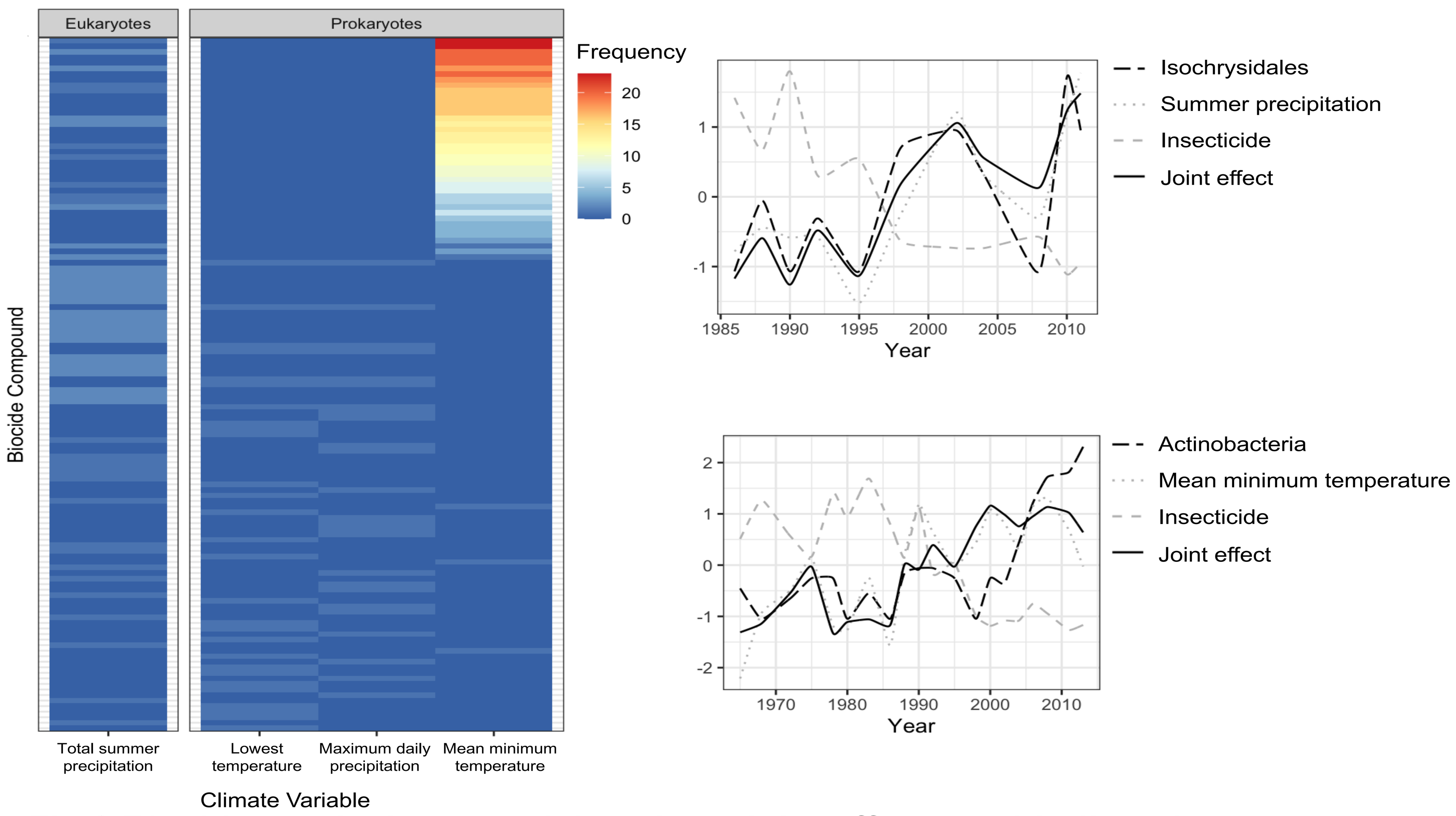

Fig 3 Biocides and climate variables have joint effects on biodiversity. Temporal correlations with 2 families are shown

Biodiversity across space

Drivers of biodiversity change are spatially heterogenous, however the links between environmental pressures and biodiversity change are typically non-linear and can involve multiple factors.

Here, we capture community biodiversity using multi-marker metabarcoding of water samples from lakes across England which are monitored in the water framework directive. The community composition significantly (PERMANOVA $p<0.05$) varies across regions (fig 5).

Physico-chemical data and pesticide usage records will be combined with biodiversity changes to understand drivers of biodiversity variance.

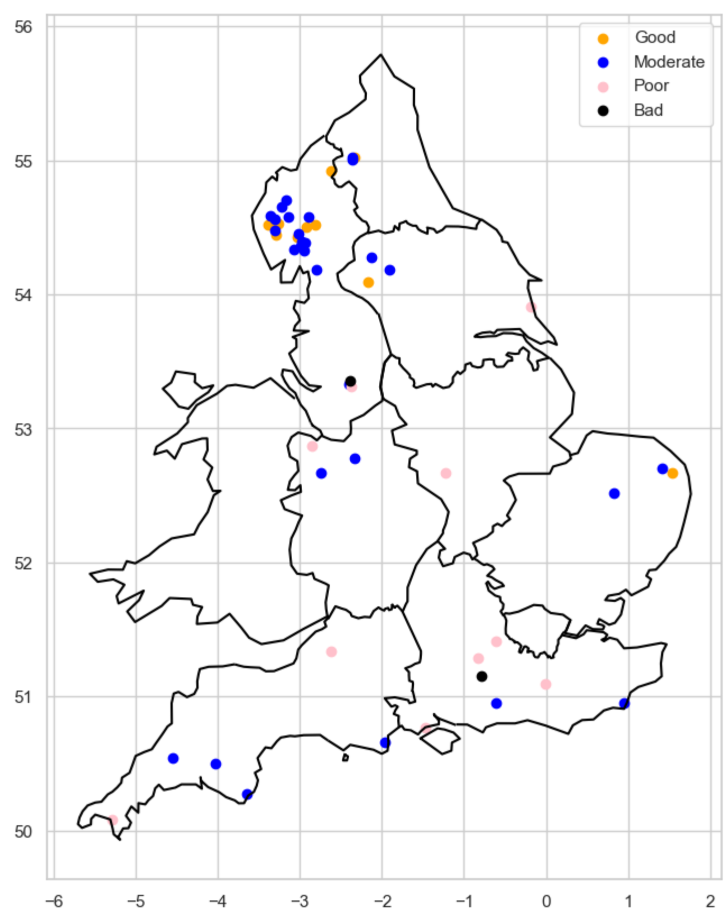

Fig 4 Spatial distribution of study lakes and their water framework directive ecological quality scores in the study

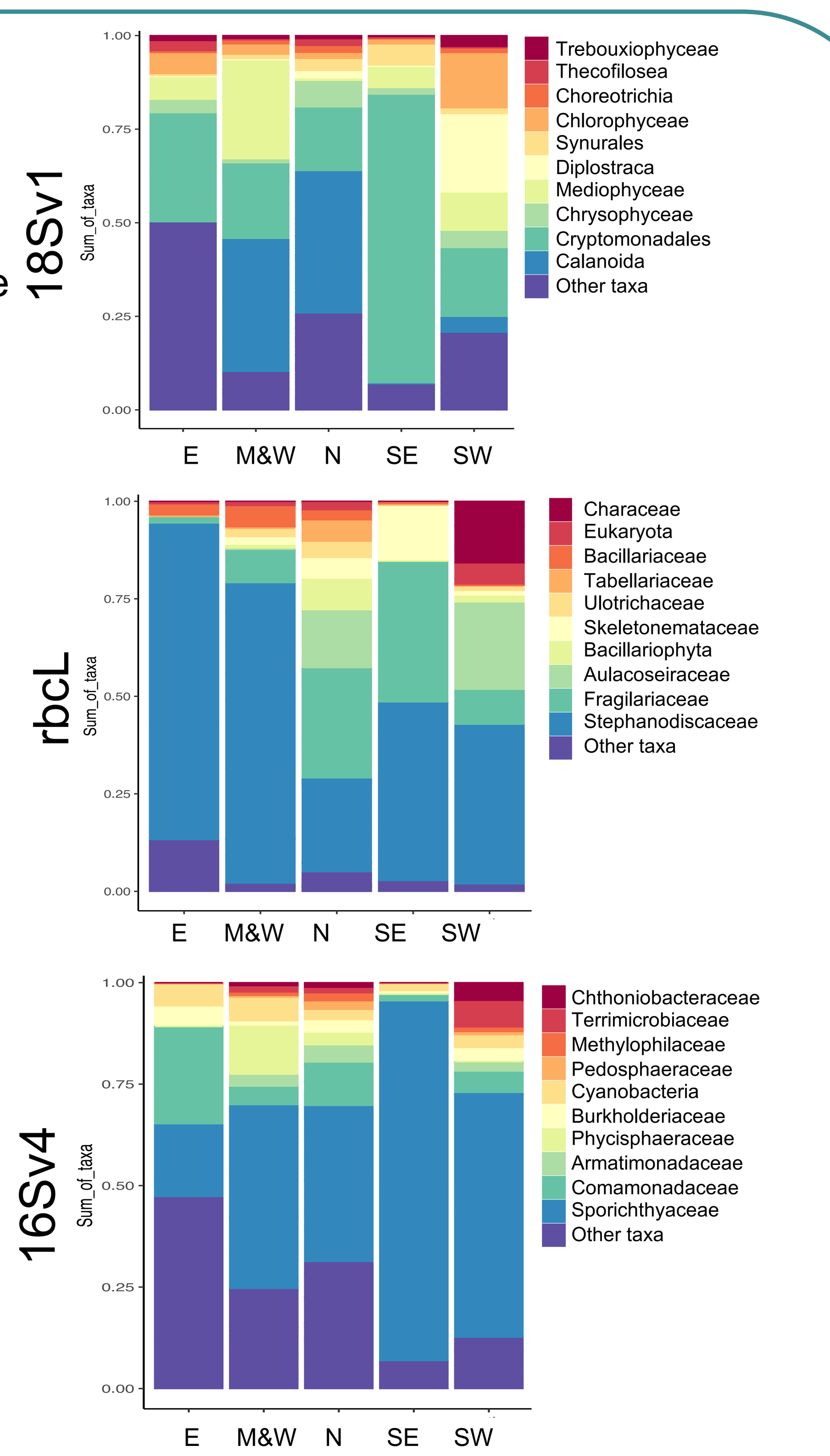

Fig 5 Taxonomic composition varies across space Taxonomy bar plots to family level across East, Midlands&Western, North, South East and South West regions of England.

Trends across space and time

Our future work aims to understand the drivers of biodiversity change across both space and time and identify commonalities in biodiversity dynamics in response to environmental pressures.

We will use sediment cores from 9 lakes across England and Wales subject to varying land use pressures (fig 6). We will use machine learning to understand the interrelations between whole-communtiy change over time and historical environmental change (climate, land use, industrial chemical despoition, biocide usage)

Fig 6 Lakes across England and Wales