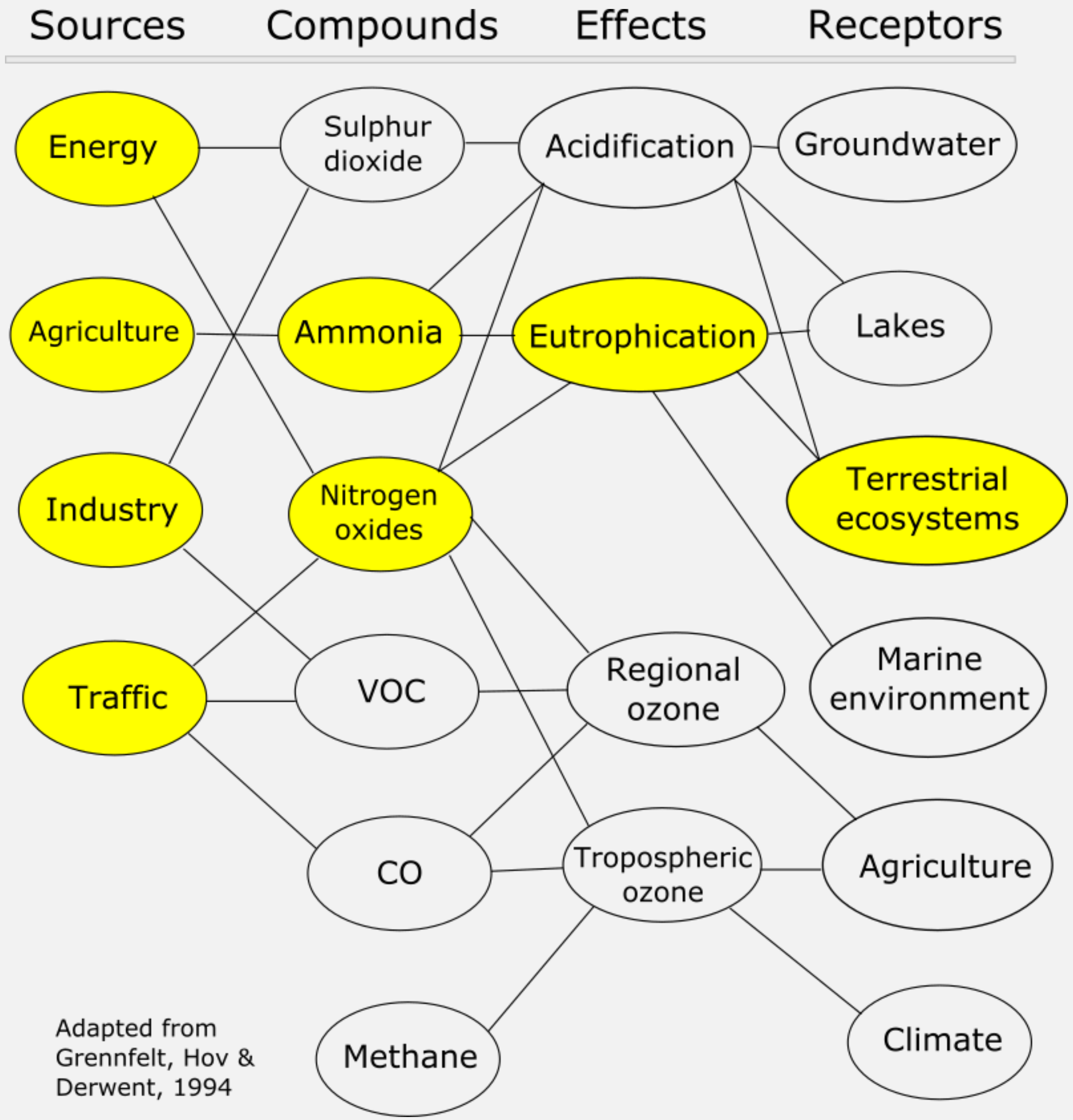

SLU
SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

NITROGEN DEPOSITION CAUSES DISTINCT EUTROPHICATION IN BRYOPHYTE COMMUNITIES IN CENTRAL AND NORTHERN EUROPEAN FORESTS

James Weldon (SLU), Julian Merder (Carnegie Institution, Stanford University), Marco Ferretti (WSL, Switzerland), Ulf Grandin (SLU)

SLU

Airborne pollutants



Adapted from Grennfelt, Hov & Derwent, 1994

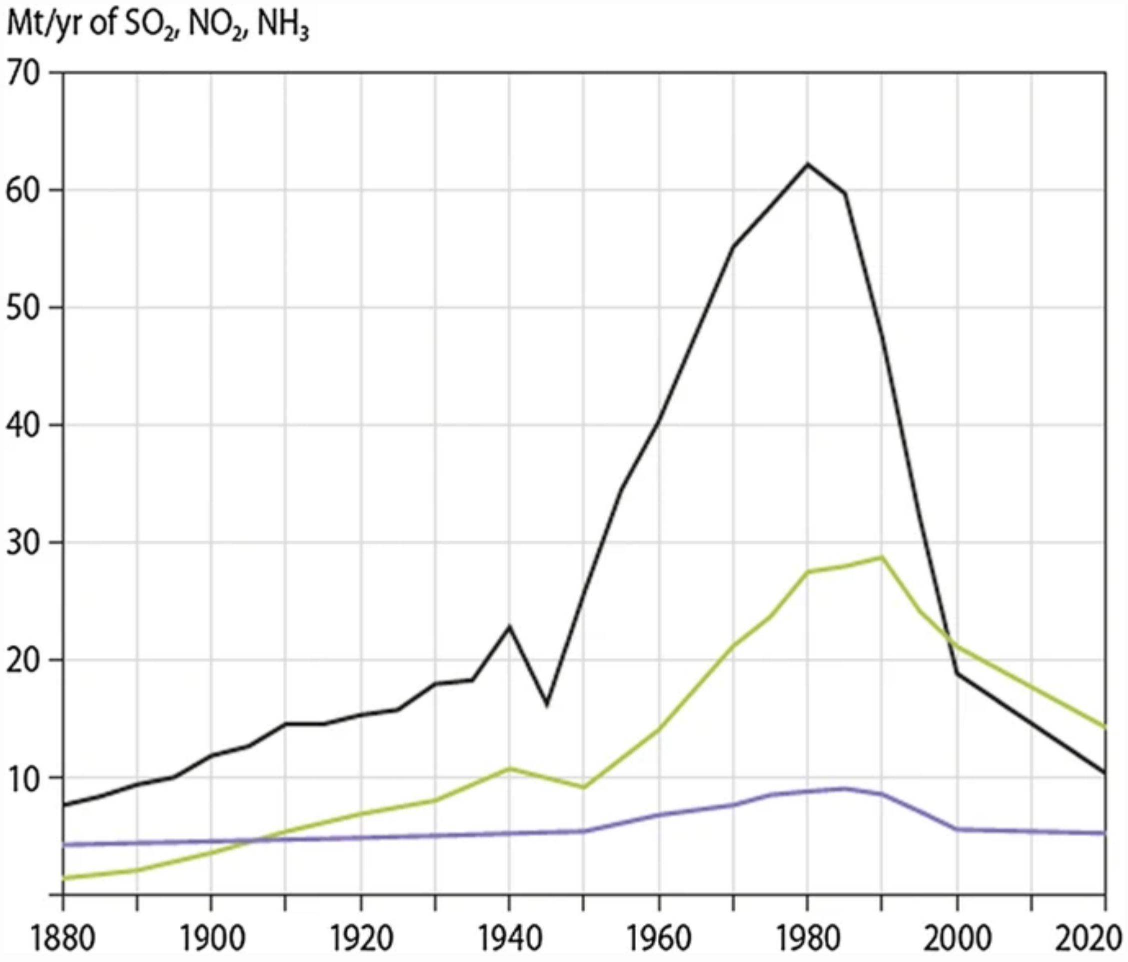
Why bryophytes?

- Hard to find clear eutrophication signals in vascular understorey at large spatial scales.
- More sensitive than vascular plants to chemical composition of rainwater.
- Generally shade tolerant, may be easier to find eutrophication signal despite increased shading

Sphagnum fallax. Photo by Bernd Haynold CC BY-SA 3.0

SLU

Fig. 1



European emissions of sulphur dioxide (SO_2—black), nitrogen oxides (NO_x, calculated as NO_2—green) and ammonia (NH_3—blue) 1880–2020 (updated from Fig. 2 in Schöpp et al. 2003)

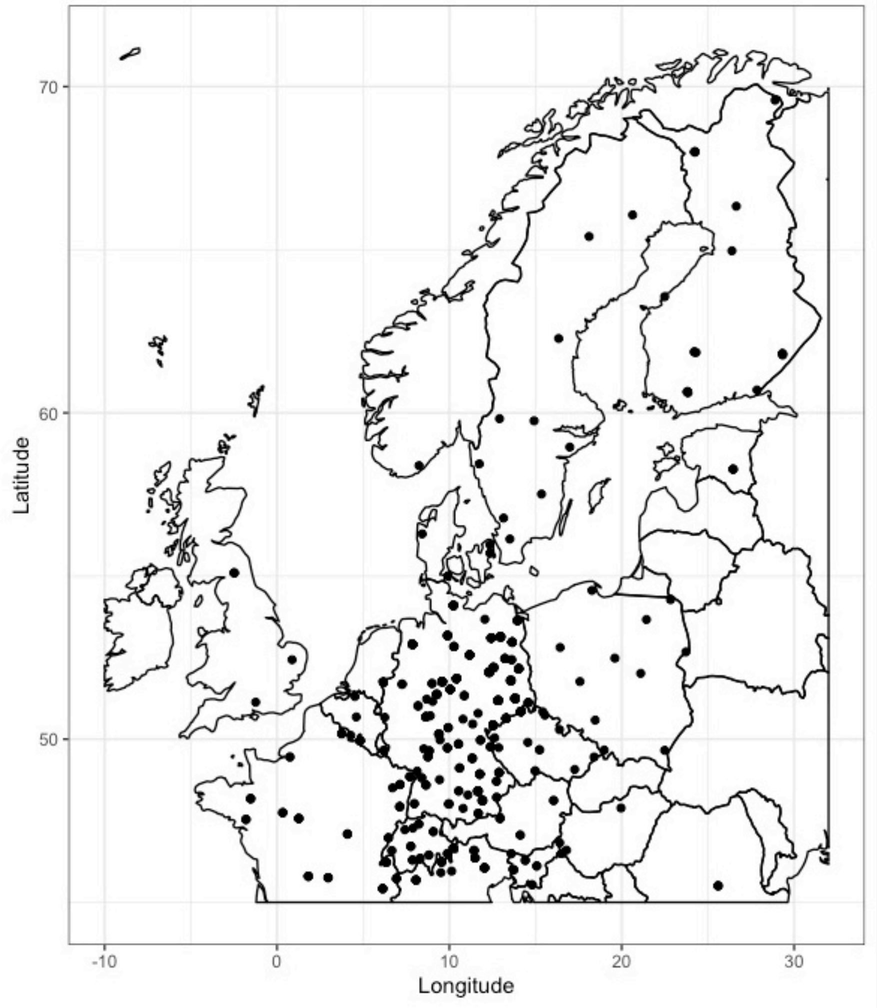
Peak emissions and declines

- Sulphur dioxide emissions peaked in Europe in the early 1980s
- Nitrogen oxide emissions peaked around 1990
- Ammonia emissions also peaked in the 1980's, but less dramatic changes
- Strong declining trend since, particularly in sulphur, less so in nitrogen

SLU

Monitoring data from ICP sites across Europe

- Data from 164 plots (mostly ICP Forests) in central/northern Europe (Mediterranean excluded)
- Not all sites record bryophytes, other gaps in data. Not all plots have data for all years (1994-2016). Data quality?
- Total of 594 plot/year combinations with available data
- Strong N deposition gradient



What were we expecting to find?

- We hypothesized that N deposition would be associated with a shift in bryophyte community composition towards more nitrophilous species
- And that N deposition would be associated with a decrease in taxonomic and functional diversity

Methods

- Community weighted mean preference for nitrogen with Ellenberg values ranging from oligotrophic (1) to eutrophic (9)
- Simpson diversity index values for each site/year combination
- Rao’s quadratic entropy as a measure of functional diversity for each site/year combination, based on three broad morphological traits (growth form, life form, and life strategy)
- These 3 response variables are related to N deposition, annual mean temperature and precipitation, light availability, forest age and forest type, as well as location and year of survey.

SLU

Methods: analyses

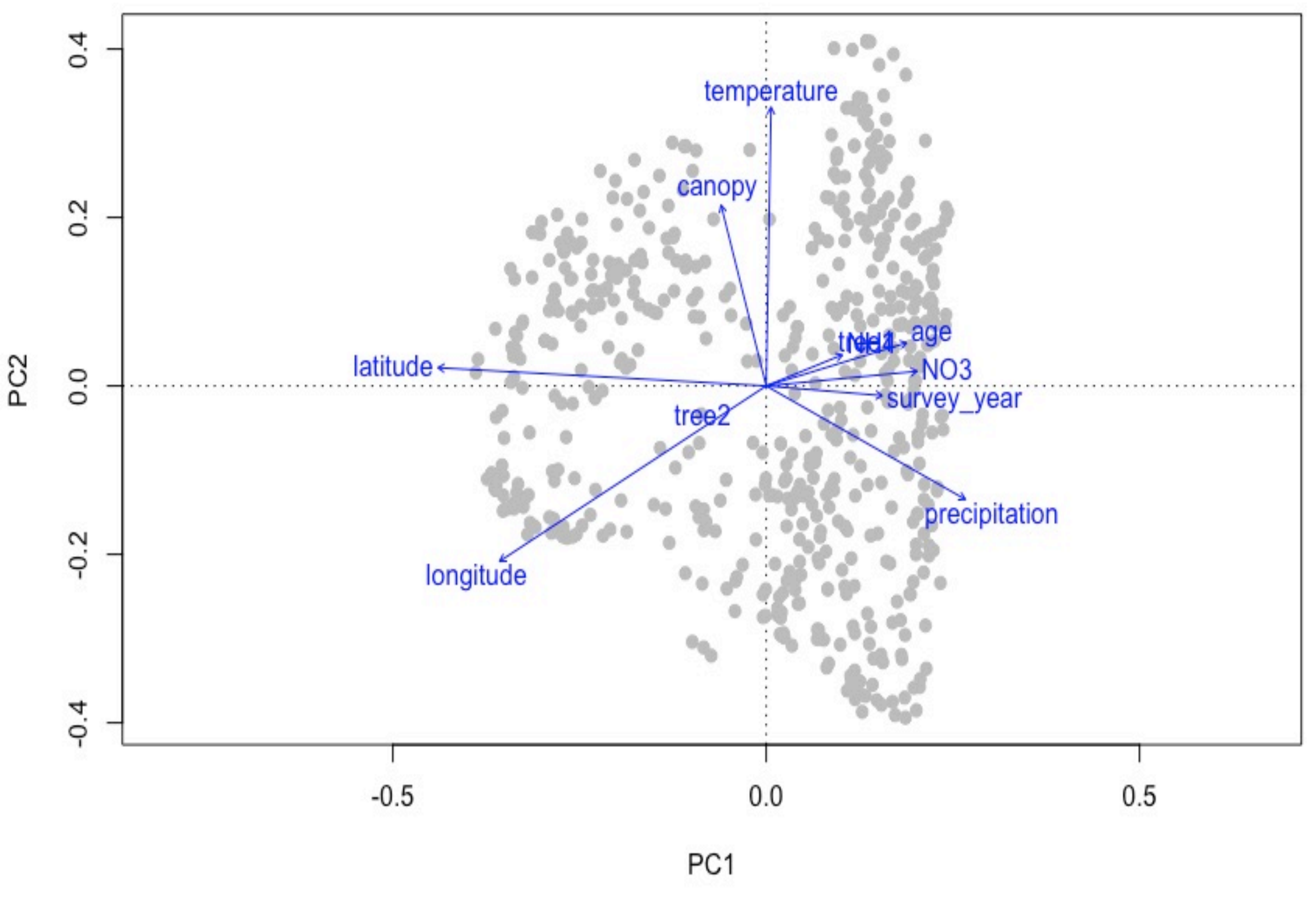
- Principal components analysis (PCA) to investigate relationships between bryophyte community and environmental variables
- N preference, taxonomic and functional diversity modelled separately using smooth additive quantile regression models (qGAMs)
- An extension of generalised linear models (GLMs) that allow “wiggly” fits
- These models allow non-linear responses and high flexibility in model specification, do not require a pre-set error distribution, and are robust to outliers.

Methods: analyses

- We allow interaction of ammonium and nitrate, and include a spatio-temporal term to account for autocorrelation.
- Model checking/ variable selection
- $q_{0.5}(N_i) \sim f_1\left(NH_{4_i}, NO_{3_i}\right) + f_2(Long_i, Lat_i, Year_i) + f_3(precip_i) + f_4(temp_i) + f_5(canopy_i) + f_6(age_i) + \psi tree_{k_i}$
- Not all variables are included in the final models after selection procedure

Results- PCA

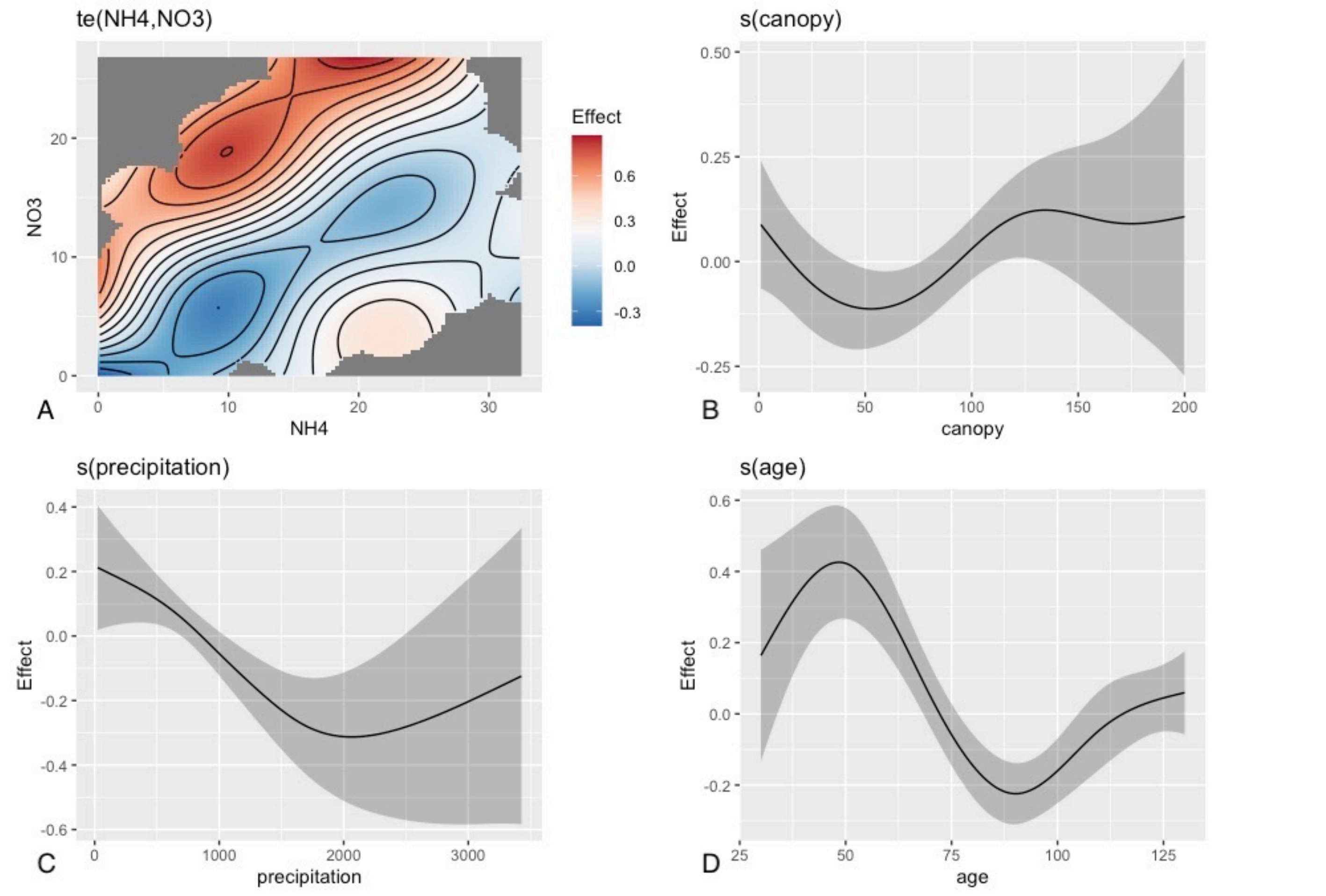
- Geographic gradient in N deposition
- Several variables close to one another
- Location largely defines first axis, temperature the second



N preference

- The CWM mean N preference changes significantly with deposition levels of NH_4 and NO_3
- Stronger effect when NH_4 and NO_3 are acting in relative isolation than when combined
- NH_4 had a weaker effect overall than NO_3

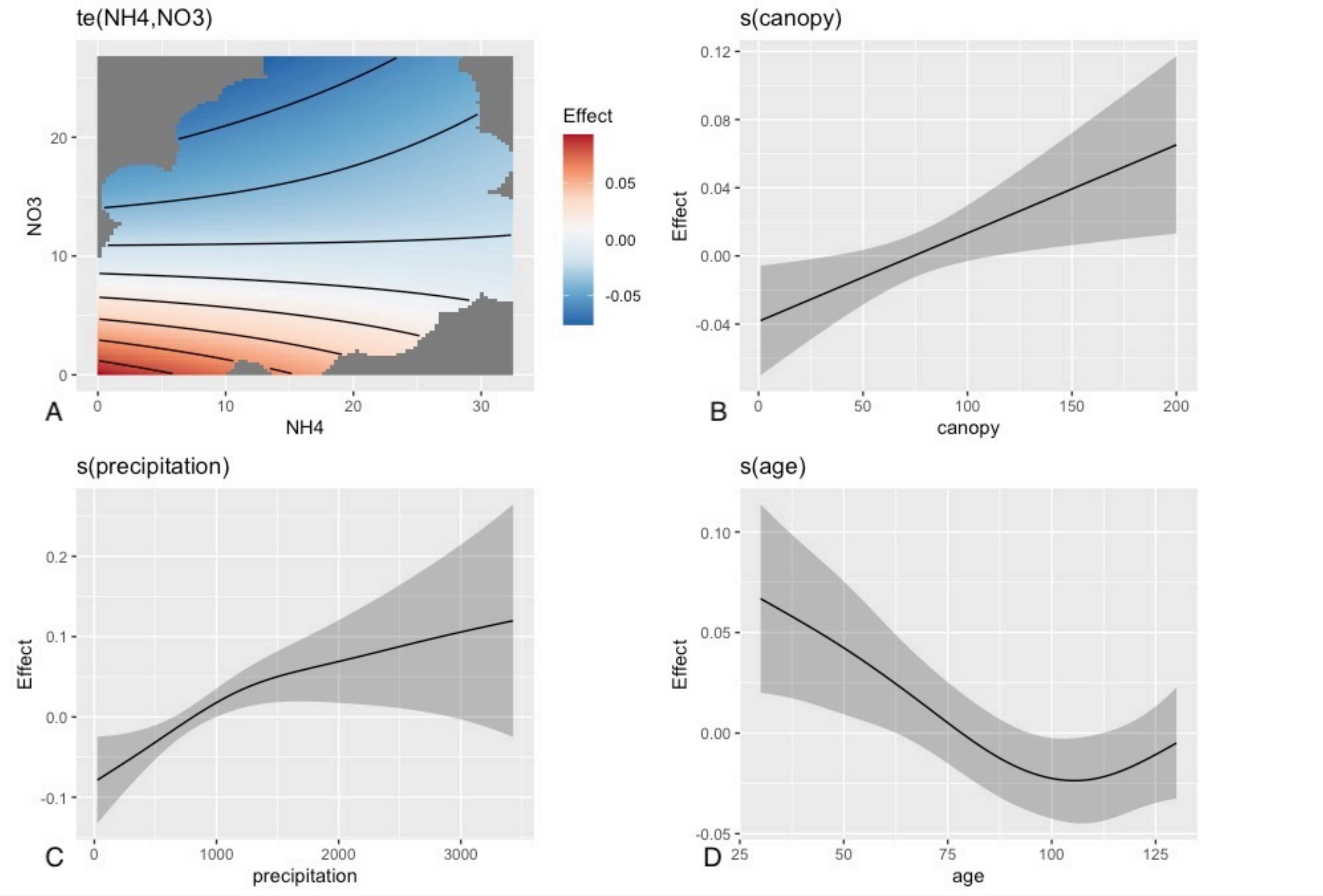
Predictor	edf	Chi.sq	p-value
NH4,NO3	11.45	93.77	**<0.001**
Canopy	3.12	11.55	**0.003**
Precipitation	2.19	16.95	**<0.001**
Age	3.63	42.82	**<0.001**



Taxonomic diversity

- Taxonomic diversity shows a significant decline with increasing levels of NH_4 and NO_3
- This effect is focussed on the NO_3 gradient

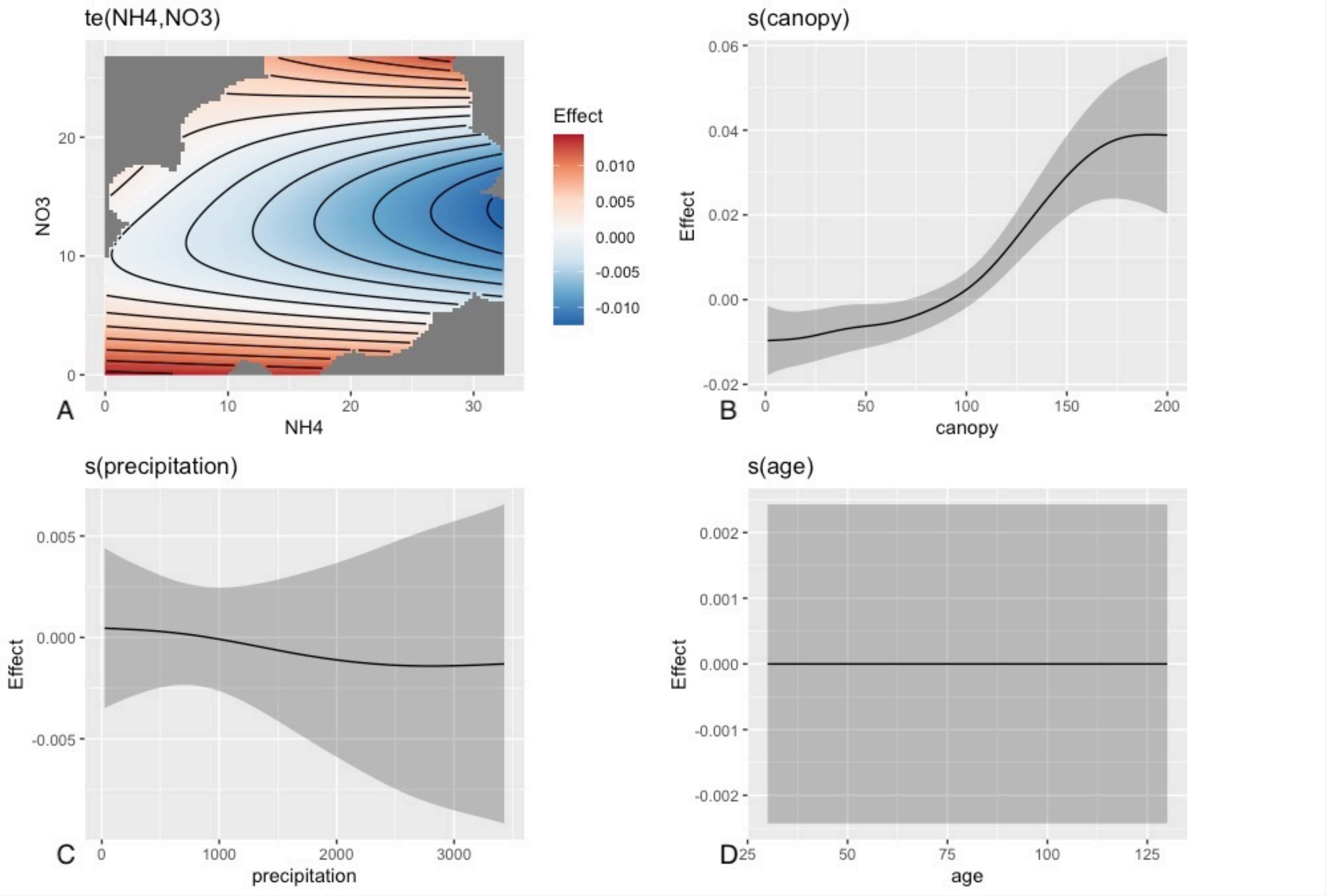
Predictor	edf	Chi.sq	p-value
NH4,NO3	3.00	14.62	**<0.001**
Canopy	0.88	7.38	**0.002**
Precipitation	1.89	13.98	**<0.001**
Age	1.81	9.81	**0.002**



Functional diversity

- Strongest negative effect on functional diversity is seen at high levels of both NH_4 and NO_3
- Some plots that show above median diversity at high levels of NO_3 combined with moderate to high levels of NH_4

Predictor	edf	Chi.sq	p-value
NH4,NO3	2.53	12.10	**0.001**
Canopy	3.27	46.04	**<0.001**
Precipitation	0.24	0.29	0.25
Age	0.00	0.00	0.72



Summary

- N deposition is significantly associated with increased bryophyte community mean Ellenberg N values, decreased taxonomic diversity and changes in functional diversity, on a European scale

- The effect sizes are modest, with a decline of at most ca.15% in both taxonomic and functional diversity attributable to N deposition. The impact of N deposition on mean Ellenberg N preference is at most a ca.25% increase.

SLU

Thank you for listening

SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE