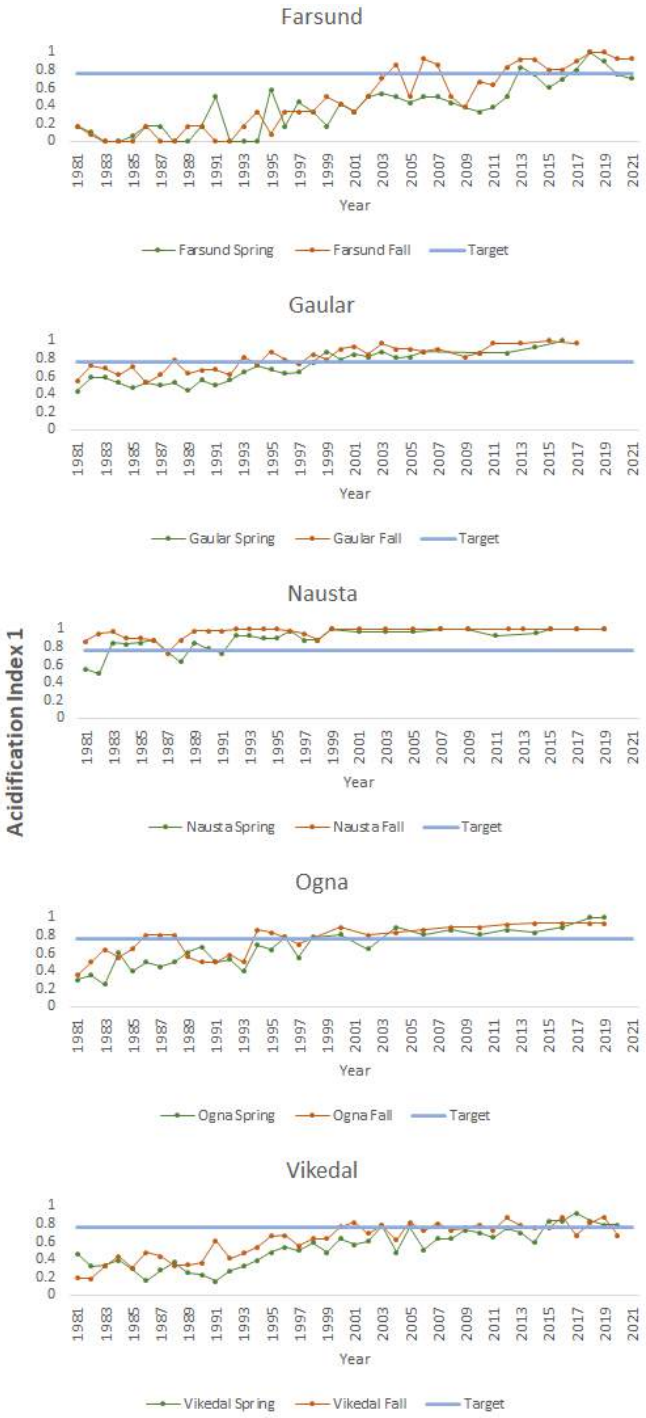
ICP Waters

Responses of benthic invertebrates to chemical recovery from acidification

Report consists of two sections:

1. **National** (Italy, Switzerland, Sweden, Norway, UK)
2. **International** (Czech Republic, Germany, Italy, Sweden, Norway, UK



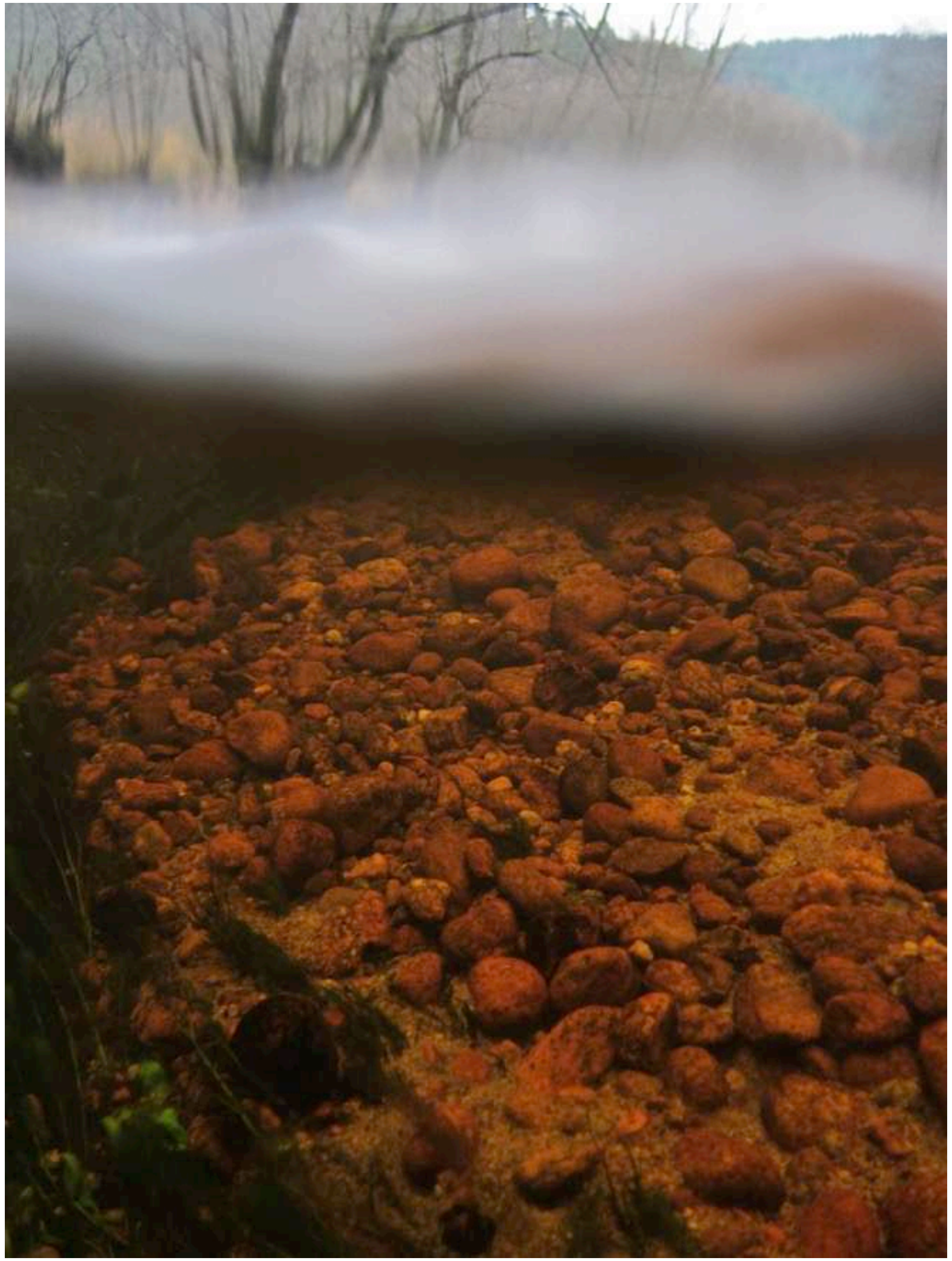
Objectives

Use benthic invertebrates to:

(1) Assess temporal changes in biological diversity as determined by the number of EPT- species

(2) Assess temporal changes in functional traits

(3) Examine whether observations of biological change can be interpreted as biological recovery from acidification



Benthic invertebrates

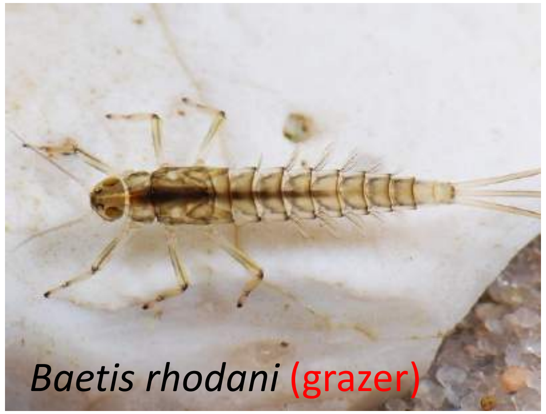
We focus on species of Ephemeroptera, Plecoptera, and Trichoptera (EPT) because:

Function

Functional group	Trait group	Description
Feeding mode	Gatherers/Collectors	Feed on fine particulate detritus on stream bottom
	Filterers	Filter suspended particulate material from water column
	Predators	Consume other animals and engulf whole prey or suck body fluids
	Grazers/Scrapers	Feed on periphytic algae and associated material on mineral or organic substrate
	Shredders	Feed on living or decomposing vascular plant tissue, coarse particulate organic material by chewing large pieces
	Other	Other modes of feeding
Movement mode	Swimming	Swim through water
	Burrowing/Boring	Burrow in soft substrates or bore in hard substrates
	Sprawling/Walking	Move actively over surfaces with legs, pseudopods or on mucus
	Semi (Sessile)	Fasten to hard substrates, plants or other animals
	Others	Other modes of locomotion

A component of biodiversity that concerns what organisms do

Need to distinguish species by functional traits


Baetis rhodani (grazer)


Limnephilus sp. (shredder)


Diura nanseni (predator)

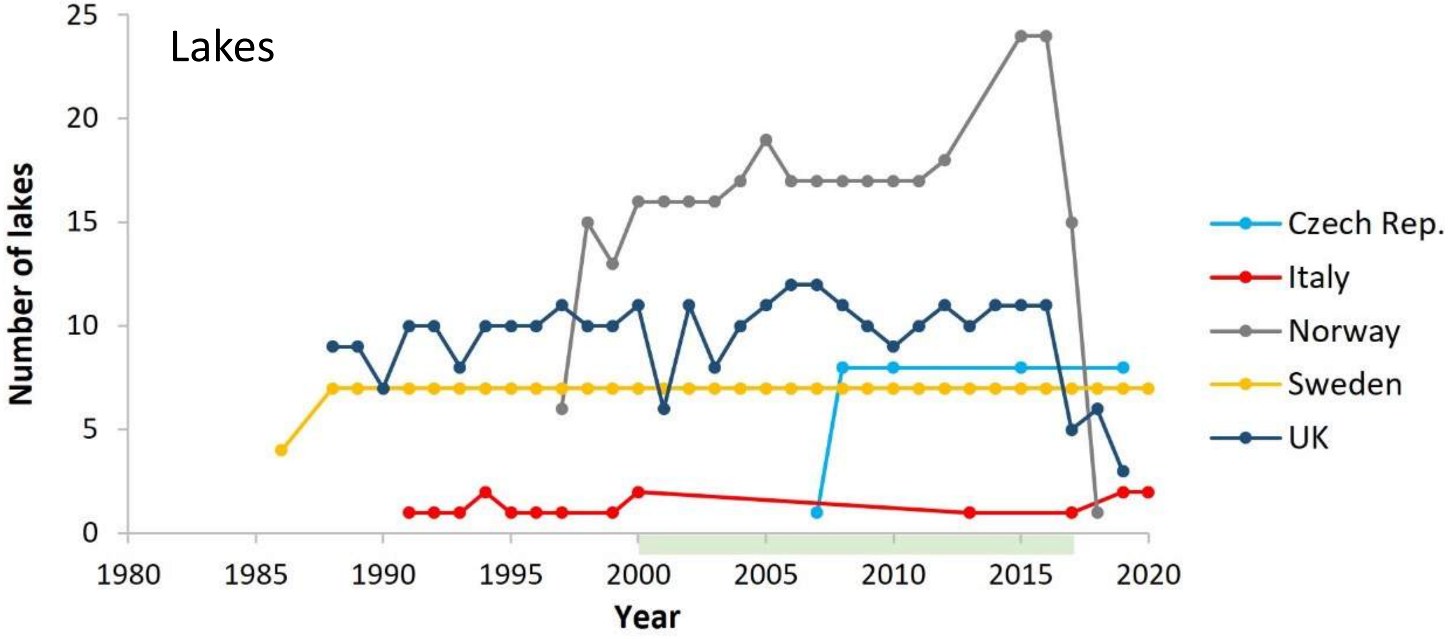
Methods

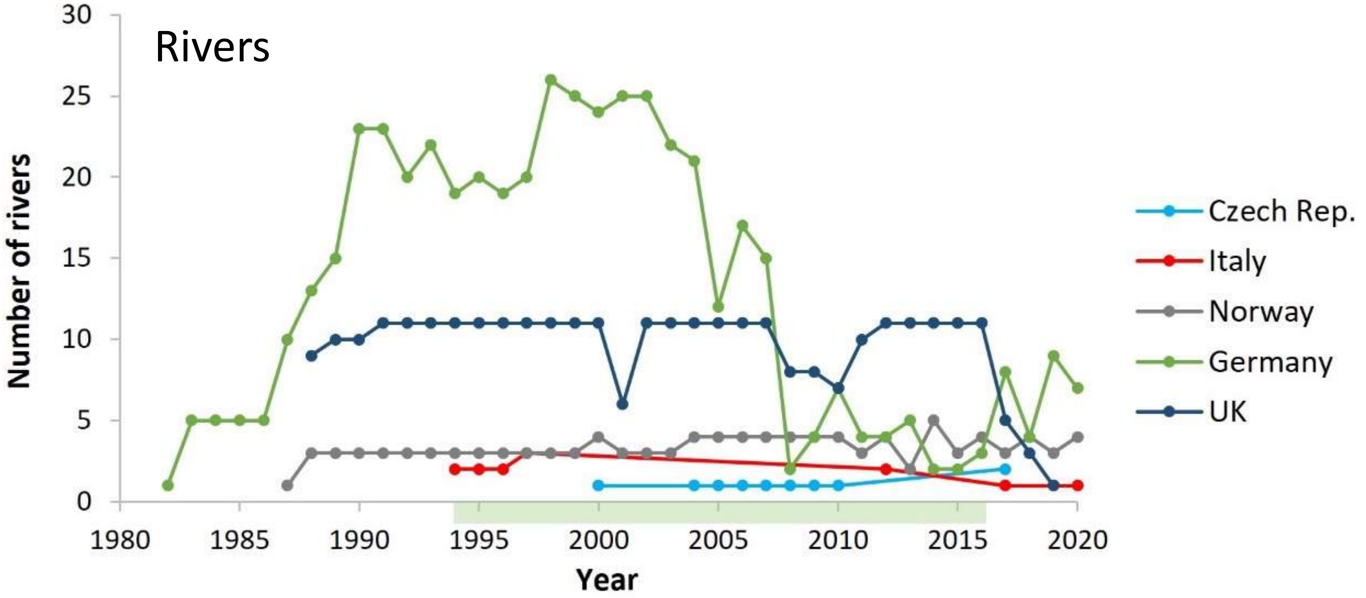
1. Enforce inclusion criteria for sites in analysis of temporal change

Inclusion criteria

i. Lakes with records covering 2000-2018, with at least one year of data in 2000-2003 and at least one year of data in 2015-2018

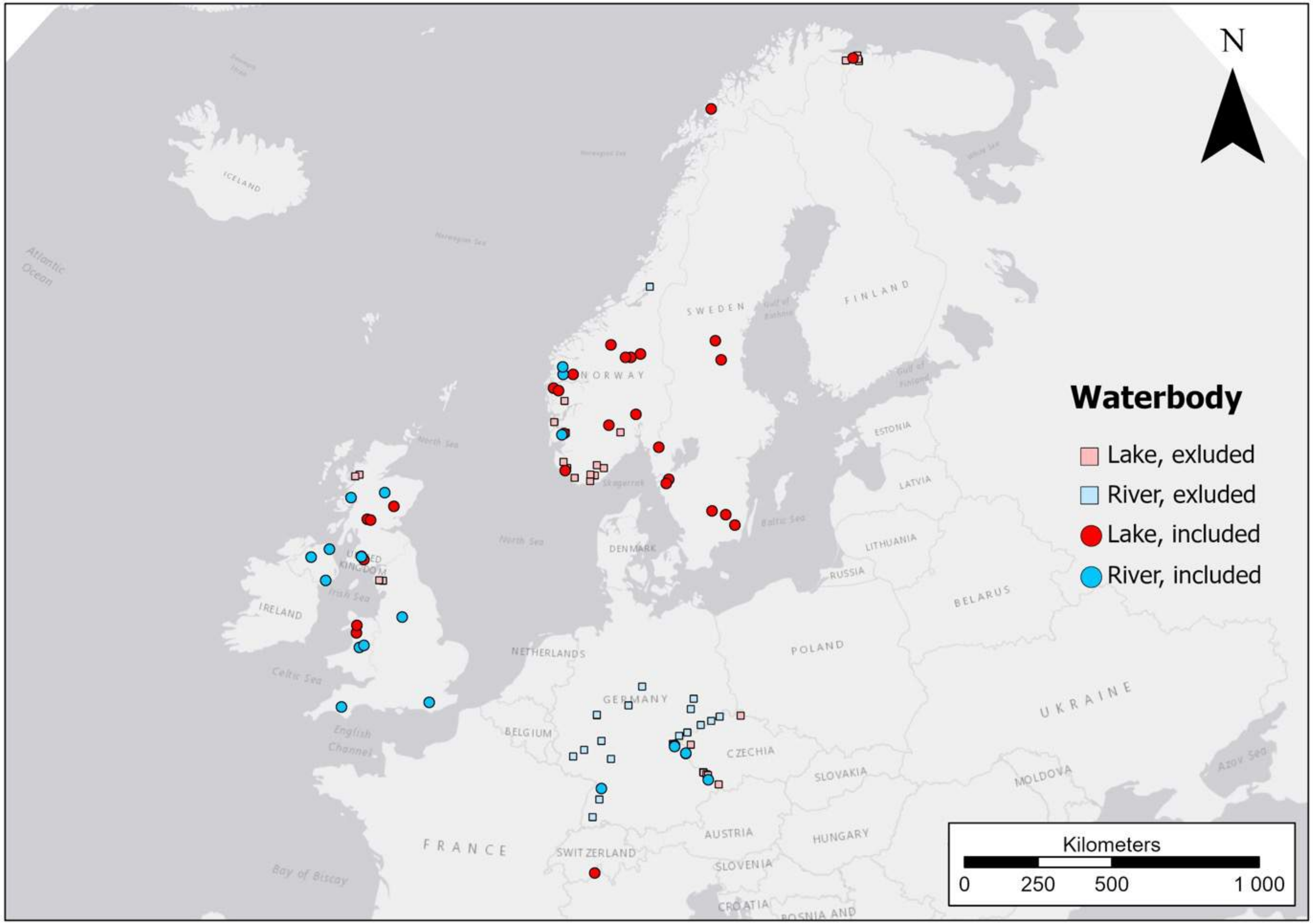
ii. Rivers covering the period 1994-2018, with at least one year of data in 1994-1997 and at least one year of data in 2015-2018





Total: 61 lakes and 46 rivers

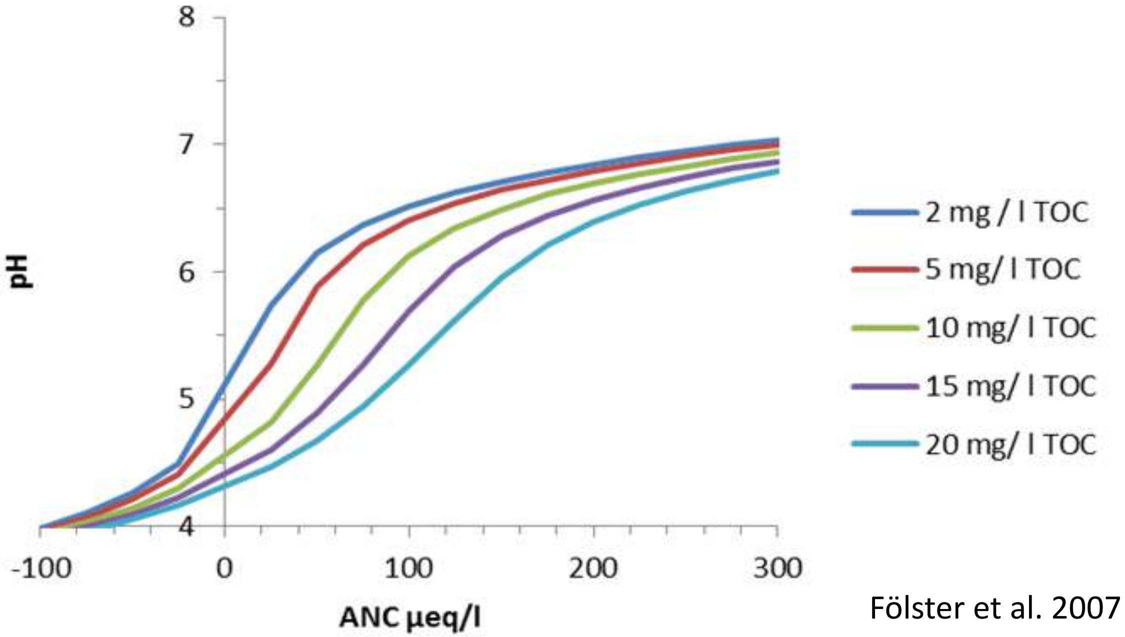
Included in analyses of temporal change: 33 lakes and 19 rivers



Methods

1. Enforce inclusion criteria for sites in analysis of temporal change
2. Testing for temporal changes in water chemistry, species richness, and proportion of functional traits:
    - Average of seasonal quartile for single sites
    - Non-parametric estimation of slope and using Mann-Kendall to test for trends
3. Testing correlations between species richness and pH, ANC, and SO_4
    - Compiled a combined data set: paired invertebrate samples and chemistry samples taken within the same seasonal quartile
    - Using Pearson correlations to find the strength of the relationship between two variables
4. Grouping of sites

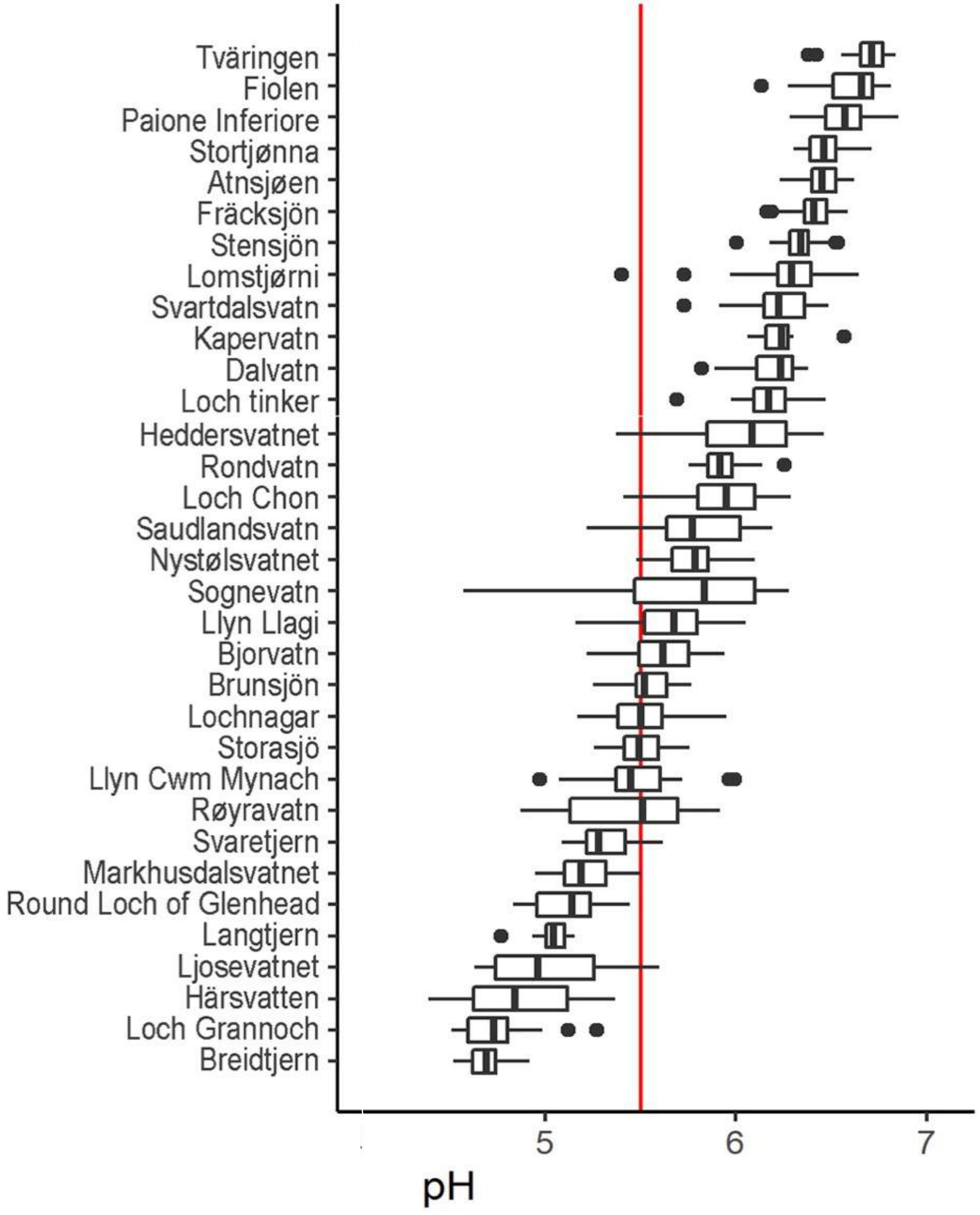
Grouping of sites according to site-specific sensitivity to acidification



Fölster et al. 2007

Group 1. All sites
Group 2. Sites where water pH has always remained above 5.5 (less acidified sites)
Group 3. Sites where water pH range from less than to greater than 5.5 (medium acidified/ sensitive)
Group 4. Sites where water pH has always remained below 5.5 (most acidified)

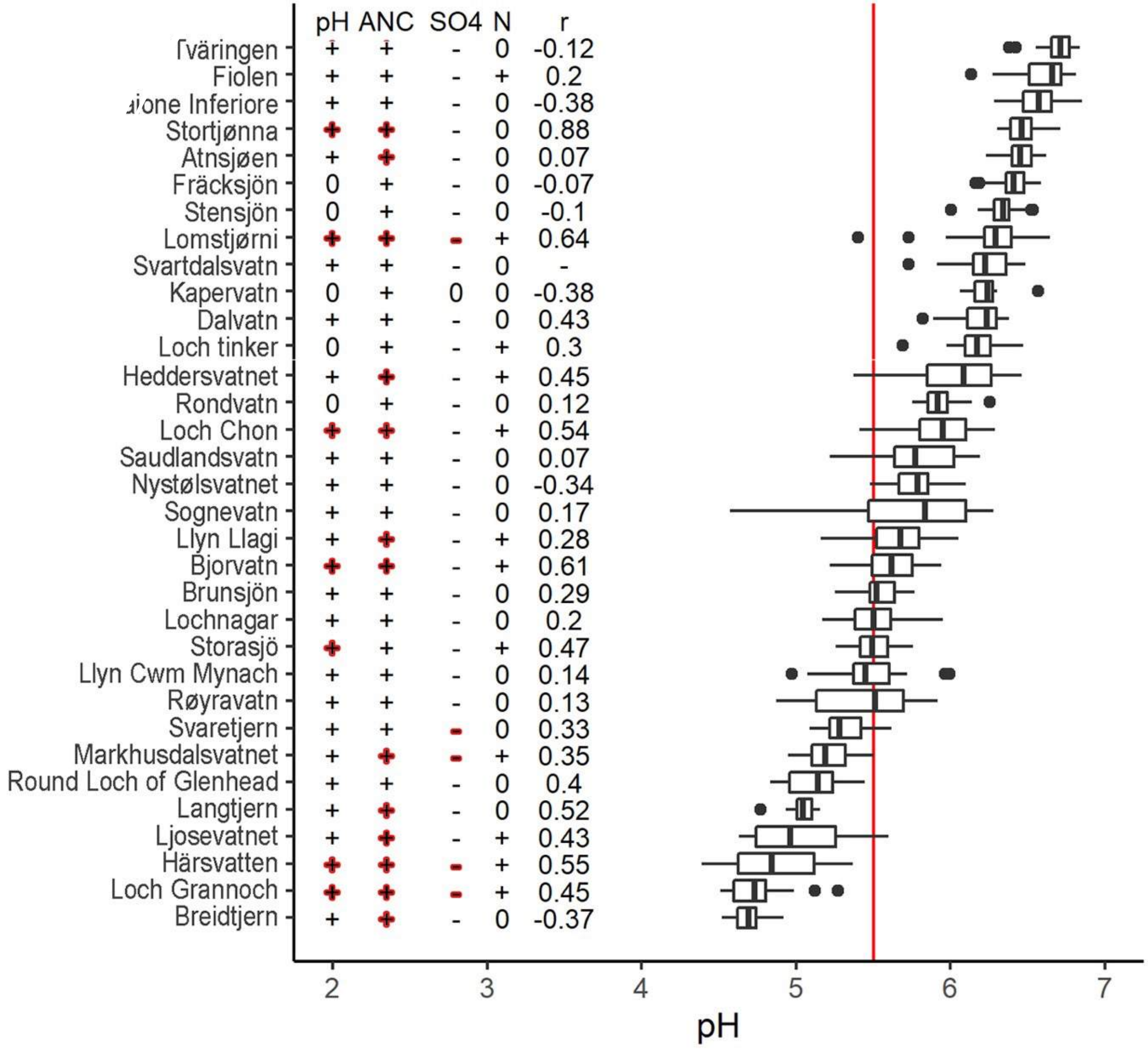
RESULTS


Tväringen
Fiolen
Paione Inferiore
Stortjønna
Atnsjøen
Fräcksjön
Stensjön
Lomstjørni
Svartdalsvatn
Kapervatn
Dalvatn
Loch tinker
Heddersvatnet
Rondvatn
Loch Chon
Saudlandsvatn
Nystølsvatnet
Sognevatn
Llyn Llagi
Bjorvatn
Brunsjön
Lochnagar
Storasjö
Llyn Cwm Mynach
Røyravatn
Svaretjern
Markhusdalsvatnet
Round Loch of Glenhead
Langtjern
Ljosevatnet
Härsvatten
Loch Grannoch
Breidtjern
5
6
7
pH

RESULTS

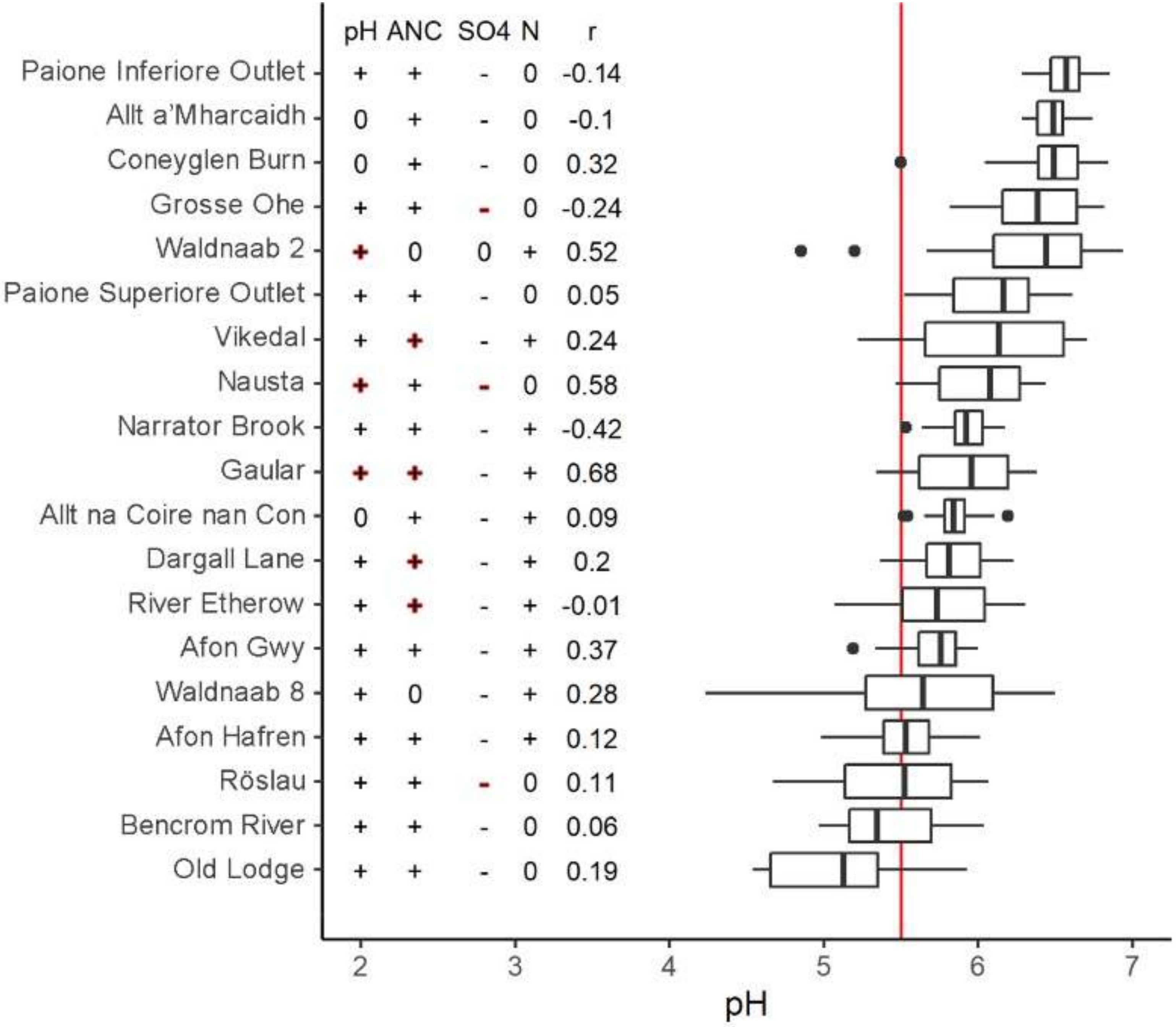
- **36% lakes with increased richness**

- **Temporal correlation to richness**
- ANC: 40% of lakes
- pH: 21% of lakes
- SO_4: 15% of lakes



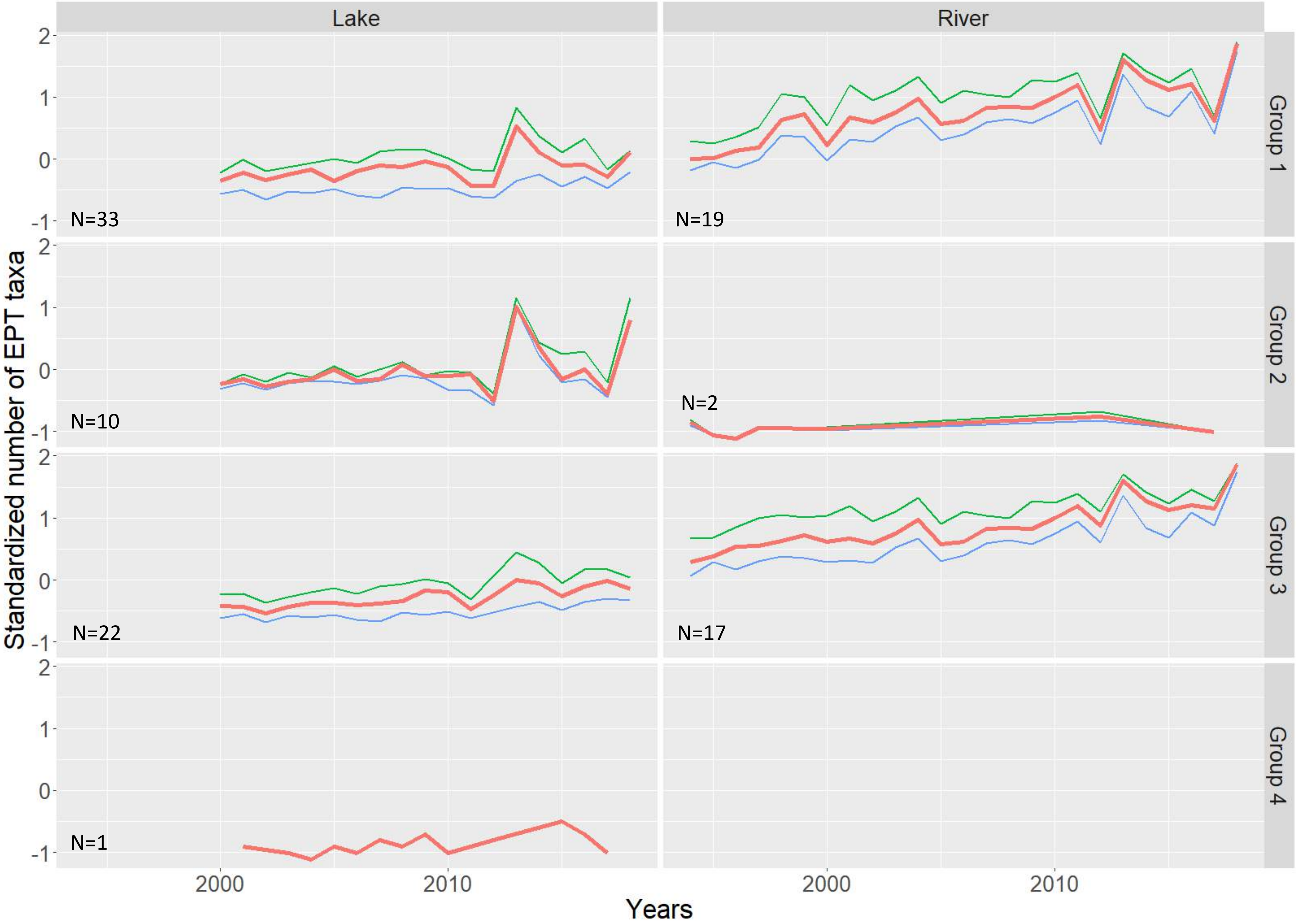
- **53% rivers with increased richness**

- **Temporal correlation to richness**
- ANC: 21% of rivers
- pH: 16 % of rivers
- SO_4: 16% of rivers



	pH	ANC	SO4	N	r
Paione Inferiore Outlet	+	+	-	0	-0.14
Allt a'Mharcaidh	0	+	-	0	-0.1
Coneyglen Burn	0	+	-	0	0.32
Grosse Ohe	+	+	-	0	-0.24
Waldnaab 2	+	0	0	+	0.52
Paione Superiore Outlet	+	+	-	0	0.05
Vikedal	+	+	-	+	0.24
Nausta	+	+	-	0	0.58
Narrator Brook	+	+	-	+	-0.42
Gaular	+	+	-	+	0.68
Allt na Coire nan Con	0	+	-	+	0.09
Dargall Lane	+	+	-	+	0.2
River Etherow	+	+	-	+	-0.01
Afon Gwy	+	+	-	+	0.37
Waldnaab 8	+	0	-	+	0.28
Afon Hafren	+	+	-	+	0.12
Röslau	+	+	-	0	0.11
Bencrom River	+	+	-	0	0.06
Old Lodge	+	+	-	0	0.19

Temporal changes in richness



Temporal changes in the proportion of feeding traits

Lake
River

Predators (decrease/ increase)

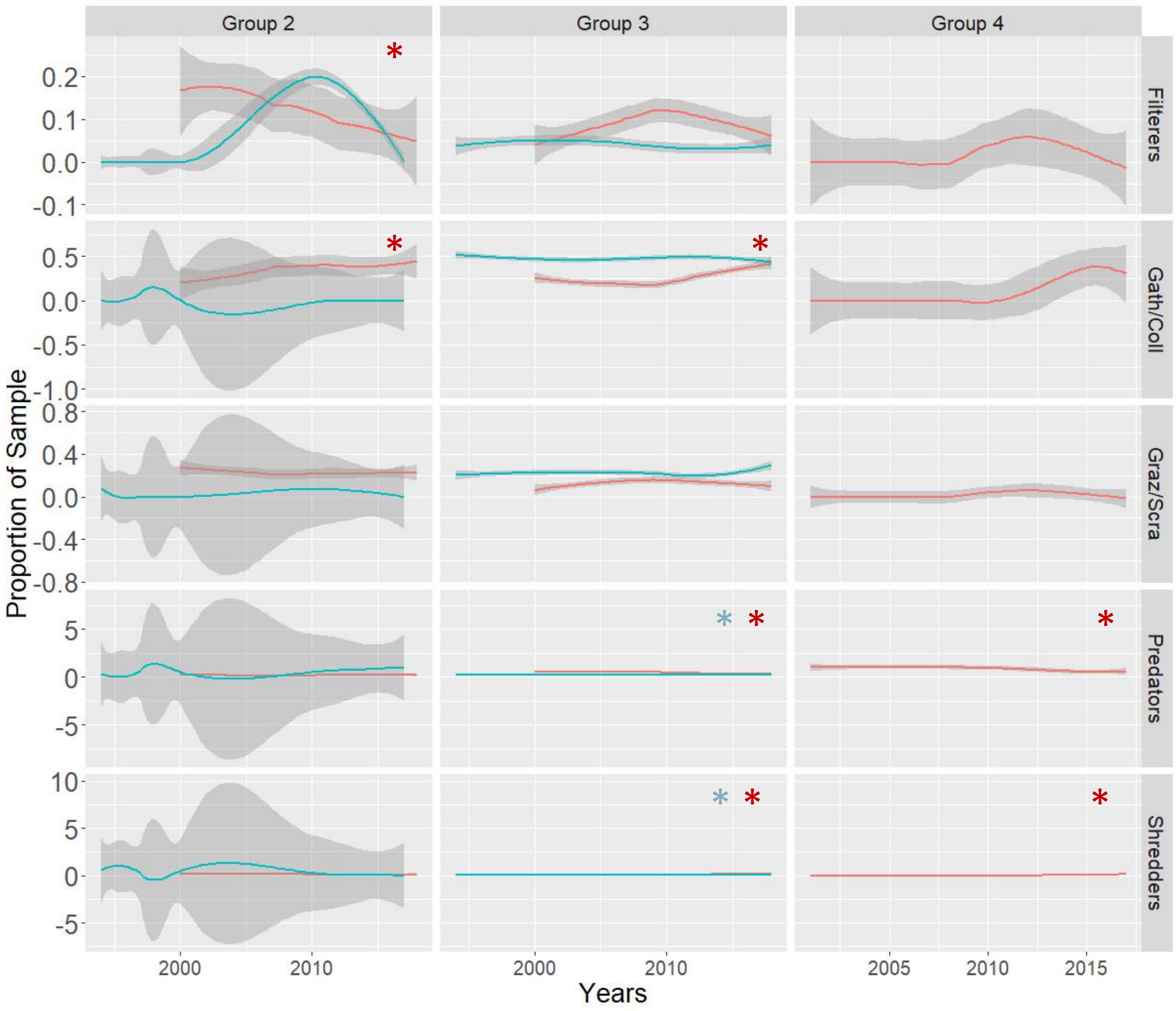
- Caused by more fish predators in lakes?
- Can influence rates of biomass turnover
- Presently lower proportions than what is common: Ecosystems not in equilibrium?

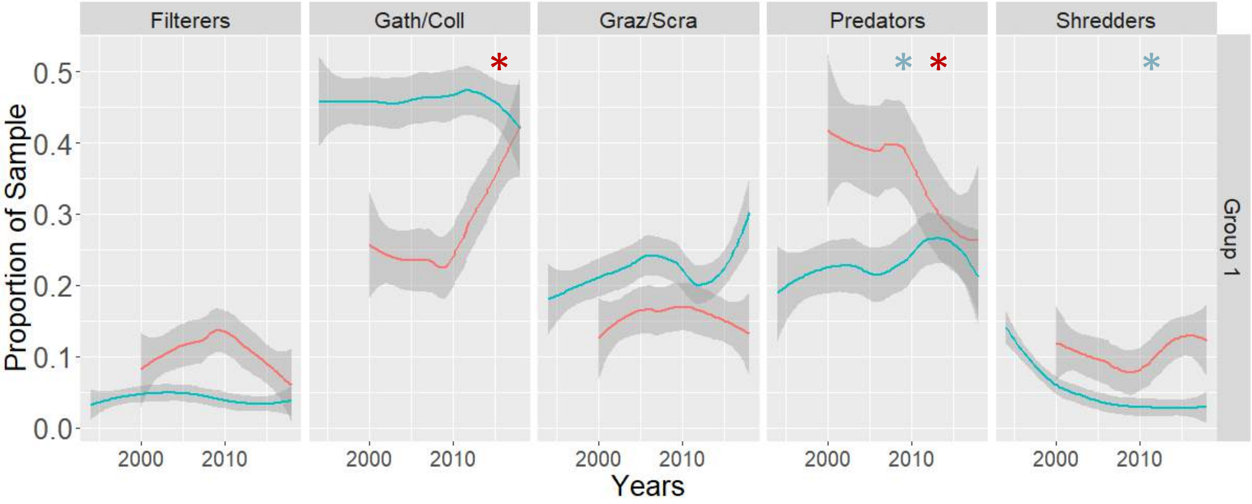
Shredders (decrease/ increase)

- Linked to increasing abundance of macrophytes in lakes?
- A decrease can cause decreased decomposition

Gatherers (increase)

- Suggest increased fine detritus - linked to DOC?





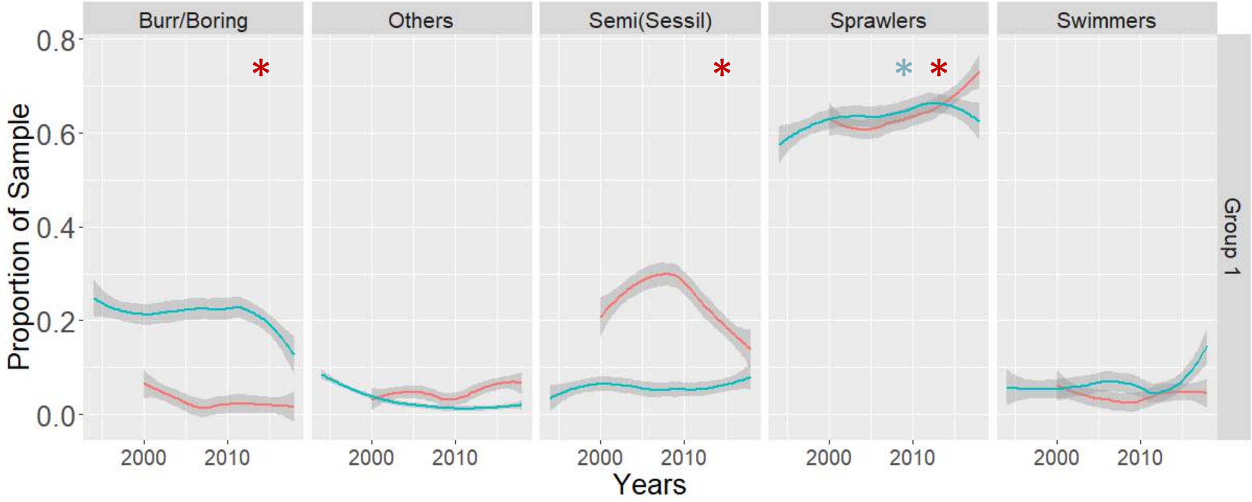
Temporal changes in the proportion of movement traits

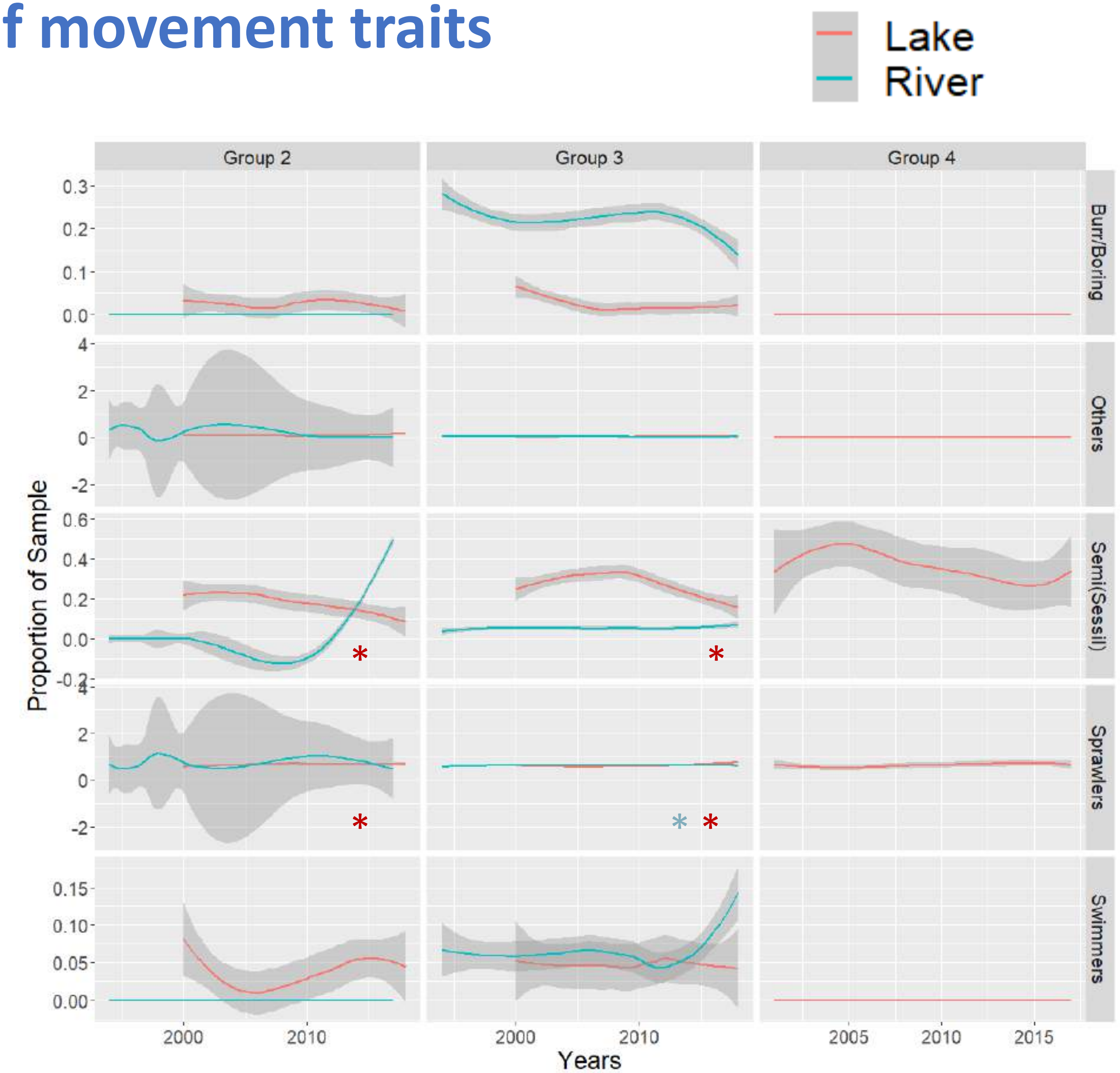
Sprawlers (increase)

- Some species are acid sensitive
- Water browning causing reduced predation pressure by visual predators/ fish?

Semisessil (decrease)

- Linked to a recovery of fish?





Summary

1. Richness has increased in about 45% of the sites
2. The increase in richness is more pronounced in rivers than in lakes
3. Richness over time is more often correlated to ANC than to SO_4 and pH
4. Proportion of functional traits has changed over time, especially in lakes
5. Changes in richness and function more pronounced in acid sensitive sites, but correlation between richness and ANC in only 30% of sites

- **Rapid changes in function and richness: assemblages not in equilibrium with concurrent environmental conditions?**
- **No 1:1 relationship between richness and chemical recovery**

- *What are potential impacts of climate?*
- *Did something happen around 2008-2012?*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HOW AIRBORNE NITROGEN IMPACTED ECOSYSTEM FUNCTION AND BIODIVERSITY AT ZÖBELBODEN, AUSTRIA – A SYNTHESIS

Dirnböck, T., Brielmann, H., Djukic, I., Venier, S., Hartmann, A.,
Humer, F., Kobler, J., Kralik, M., Liu, Y., Mirtl, M., Pröll, G.

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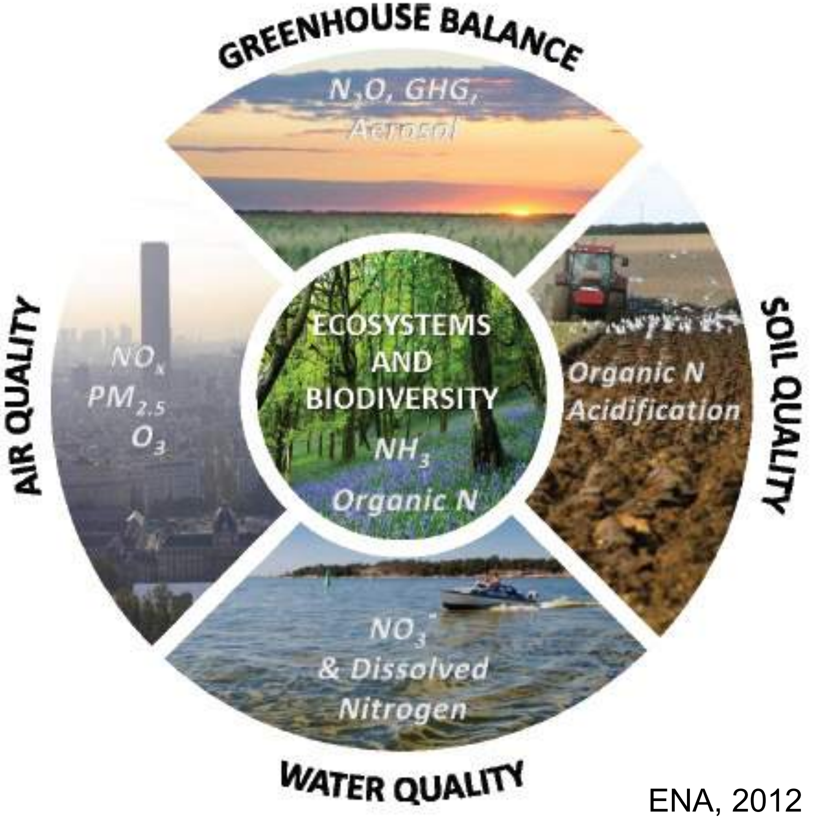
UNIVERSITÄT FREIBURG

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

REACTIVE NITROGEN HARMS THE ENVIRONMENT



ENA, 2012

- **Nitrogen is an essential nutrient** but today emissions from agriculture and fossil fuel burning provide ¾ of the N input into the biosphere (in Europe)
- **Ecosystem effects** include tree nutritional imbalances, NO_3 loss to the groundwater, N_2O emissions, soil acidification, and biodiversity loss

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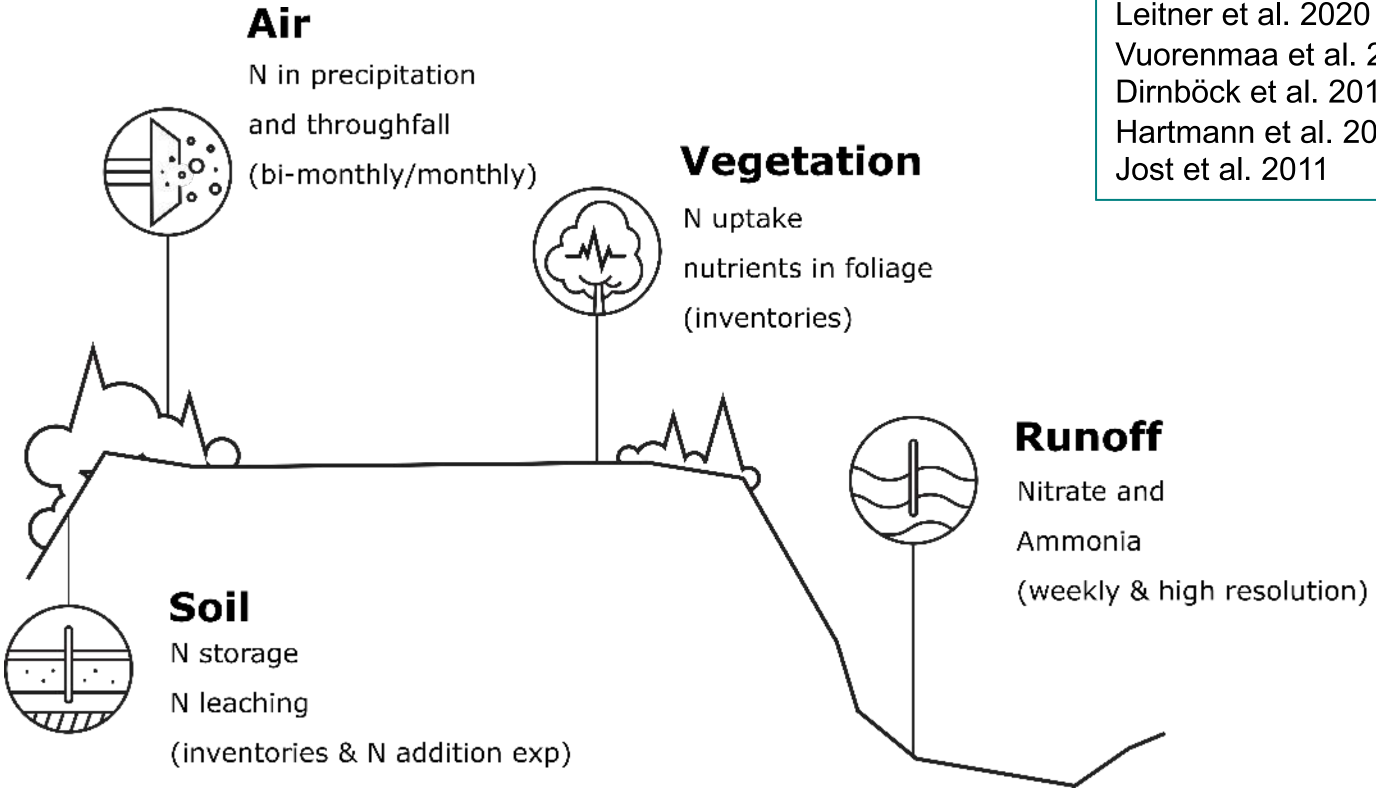
Synthesizing long- and short-term N cycle data and studies

Templer et al. 2022
Hood-Nowotny et al. 2021
Leitner et al. 2020
Vuorenmaa et al. 2017, 2018
Dirnböck et al. 2016, 2017a, 2017b
Hartmann et al. 2011, 2016
Jost et al. 2011



Air
N in precipitation
and throughfall
(bi-monthly/monthly)

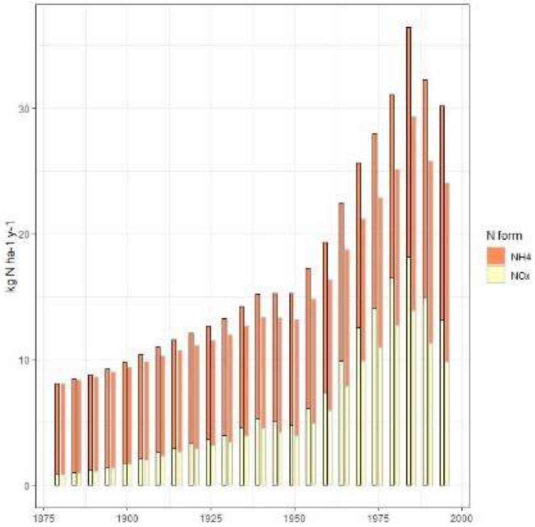
Vegetation
N uptake
nutrients in foliage
(inventories)

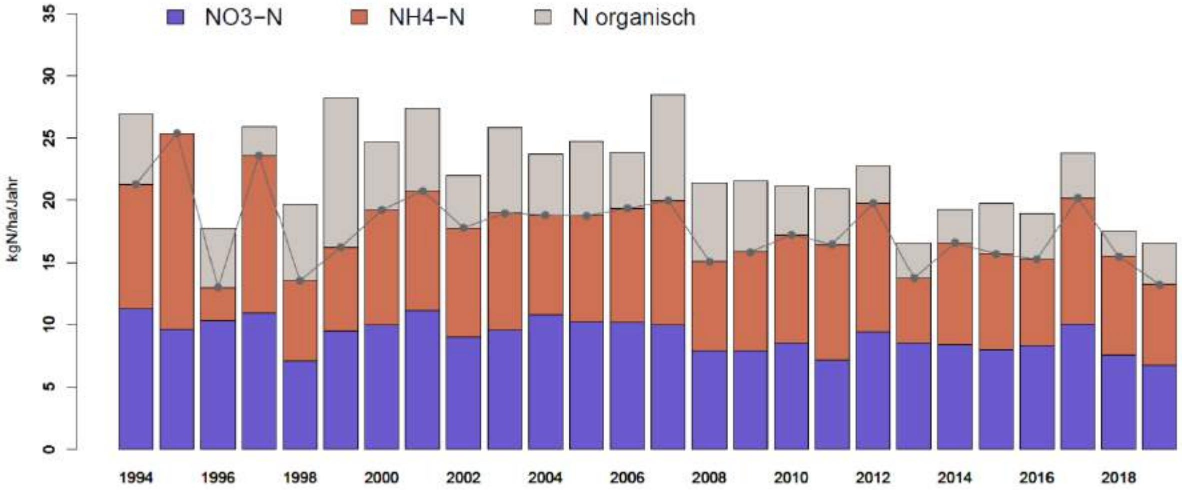
Runoff
Nitrate and
Ammonia
(weekly & high resolution)

Soil
N storage
N leaching
(inventories & N addition exp)

NITROGEN DEPOSITION

- N depostion peaked in the late 1980ies
- Chronic N deposition above or at the Critical Load (10-15 kg/ha/yr) since 1960ies
- N deposition is slowly declining (mostly NOx emission reductions)

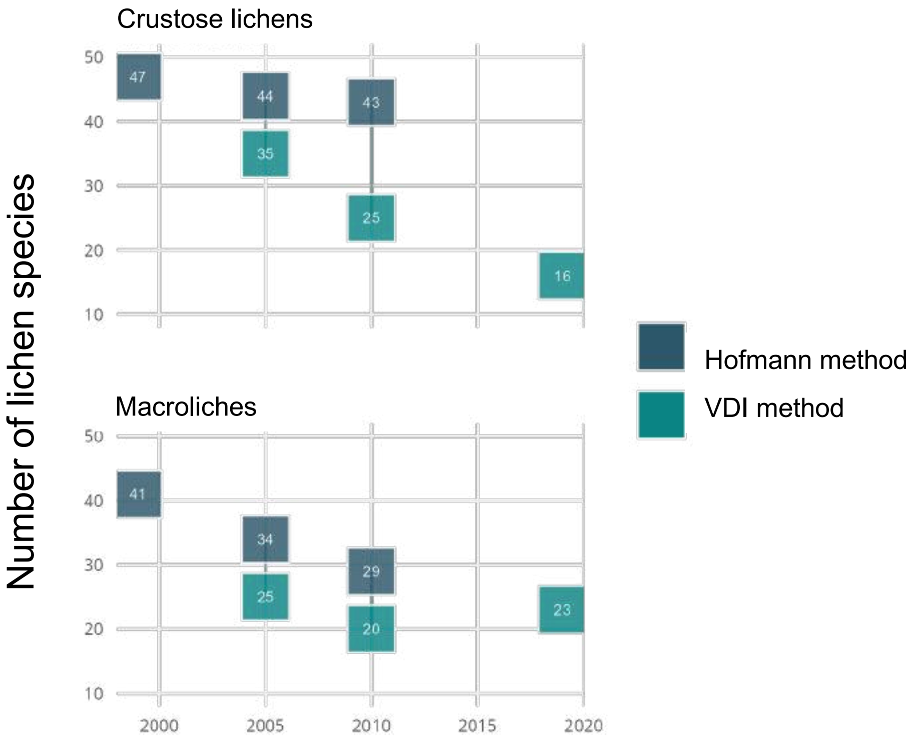


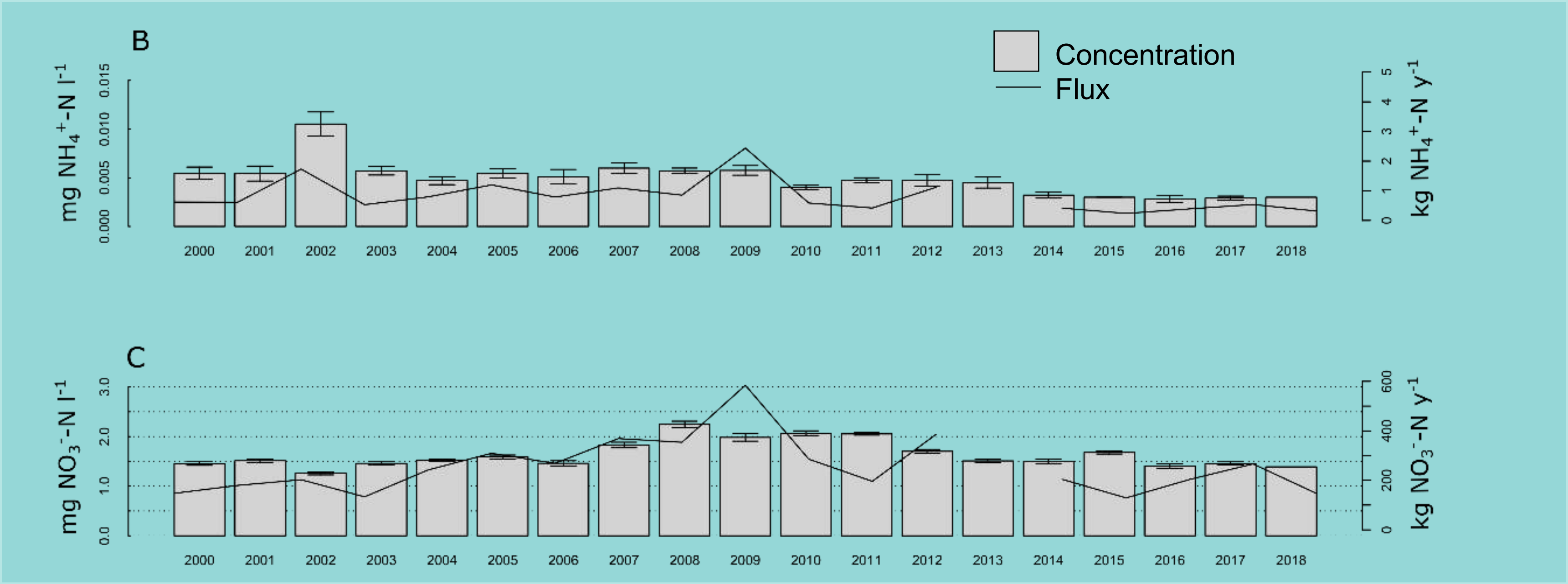


STRONG IMPACT ON LICHEN DIVERSITY

CLEAR SIGNALS IN VASCULAR PLANTS AND MOSSES

© Roman Türk





- **Catchment runoff:**
  - **Small decrease in Ammonia**
  - **Constant Nitrate runoff**
  - **Peak N runoff during forest disturban**

N ADDITION EXPERIMENT (1x1m plots)

- **Decrease in decomposition** and effective **increase in soil C and N storage in the O horizon**
- **“N-Saturation” of the soil is unlikely** (high immobilization potential)
- **N leaching** due to soil chemical changes is also unlikely

Treatment	**O-Horizon**		**A, B Horizons**
	C [mg cm^{-2}]	N [mg cm^{-2}]	No significant difference
+N	112.3 ±73.3	4.9 ±3.2	
Control	60.0 ±65.3	3.0 ±3.3	

Significant ($p<0.001$) increase in C and N stocks in the O-horizon with 5x ambient N deposition

Hood-Novotny et al. (2021) Environ. Res. Commun. 3 (2021) 025001

LONG-TERM TRENDS IN THE SOIL IN THE ENTIRE CATCHMENT

n=64	1992 - 2004	1992 - 2014
N concentration	–	–
C:N	(+)	–
O horizon N stock	+	
0-10 cm N stock	–	

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- **No net accumulation of N in the soil** albeit increasing N stocks in the organic layer
- **Net loss of 19 kg N ha^{-1} yr^{-1}** annually from the soil between 1992 and 2004
- Significant **decrease in the mineral soil C:N ratio** between 1992 and 2014 (-1.6) might indicate an N effect

FOLIAGE NUTRIENTS DO NOT INDICATE N SATURATION

Foliage concentrations/ratios in Norway spruce and European beech at Zöbelboden between 1992 to 2019. Arrows indicate significantly increasing and decreasing concentrations/ratios according to Mellert et al. 2012

g kg^{-1}	Spruce		Beech
	current year needles	one-year needles	
N	🟥 12.0±0.08 ⬇	🟥 11.4±0.08 ⬇	🟩 20.5±0.13
P	🟥 1.1±0.01	🟥 0.8±0.01 ⬇	🟥 0.7±0.01
K	🟥 4.3±0.08	🟥 3.4±0.06	🟩 6.1±0.1
N:P	🟩 11.3±0.11	🟥 13.8±0.14	🟥 29.0±0.41
N:K	🟩 3.1±0.07	🟥 3.5±0.07	🟩 3.5±0.06 ⬇

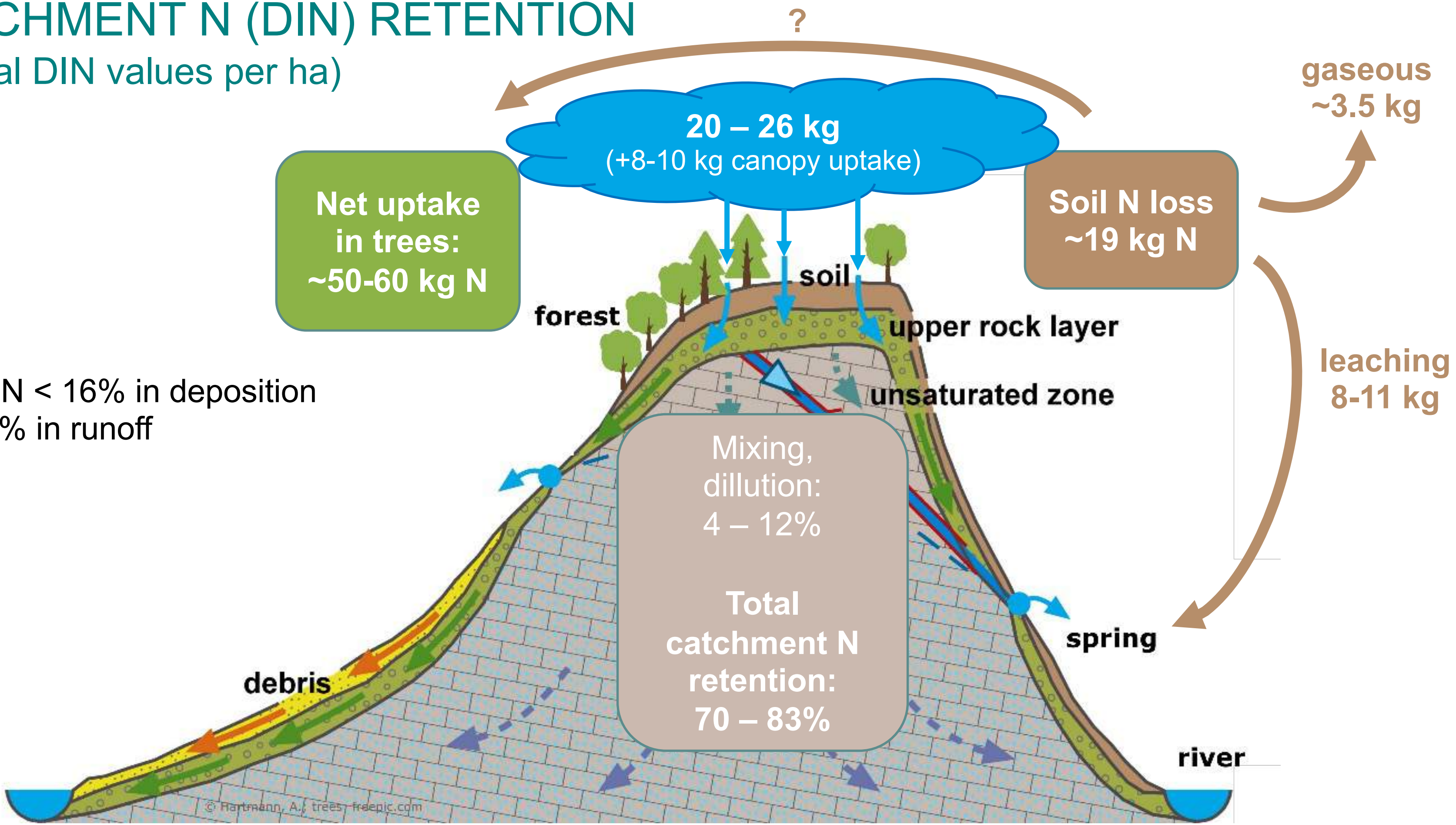
🟥 **deficient**
🟩 **normal**
🟦 **surplus**

⬇ **Significant trend**

- ➢ Increasing N deficiency
- ➢ K and P deficiency did not worsen (much) during the last 27 years
- ➢ Increased growth likely before monitoring started, since 1993 annual N uptake by trees was stable between 50 to 60 kg N/ha (stem only)

CATCHMENT N (DIN) RETENTION

(annual DIN values per ha)



20 – 26 kg
(+8-10 kg canopy uptake)

Net uptake in trees: ~50-60 kg N

Soil N loss ~19 kg N

gaseous ~3.5 kg

leaching 8-11 kg

Mixing, dilution: 4 – 12%

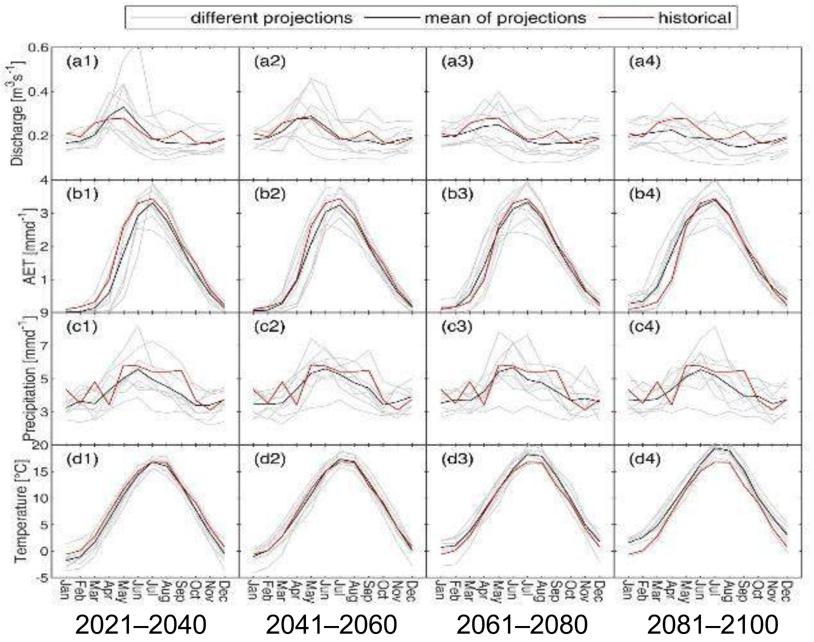
Total catchment N retention: 70 – 83%

DON < 16% in deposition
< 8% in runoff

LIKELY FUTURE DEVELOPMENT

- **Hyopthesis 1.** N runoff will decrease because discharge will decrease (-12% until 2100) with climate change
    - Uncertainty: High-flow events may still increase N moblilization and runoff (unknown)
- **Hypothesis 2.** Increased tree growth due to warming will strengthen N immobilization
    - Uncertainty a: tree nutrition (not likely)
    - Uncertainty b: drought (likely)
- **Hyopthesis 3.** N deposition will decrease
    - Uncertainty: depends upon the success of current policies (likely)
- **Hypothesis 4**. Climatically triggered Spruce bark beetle outbreaks will cause pulses of N runoff
    - Uncertainty: likely

Comparisons between historical and projected mean monthly (a) discharge, (b) actual evapotranspiration, (c) precipitation, and (d) temperature (CORDEX RCP 8.5 climate model ensemble)



Dirnböck et al. 2020. Forests

CONTACT & INFORMATION

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LTER Zöbelboden Information and Data

www.umweltbundesamt.at/umweltthemen/oekosystemmonitoring/zoebelboden

https://deims.org/8eda49e9-1f4e-4f3e-b58e-e0bb25dc32a6

https://www.researchgate.net/project/LTER-Zoebelboden-Austria

Level II
Forstliches Umweltmonitoring

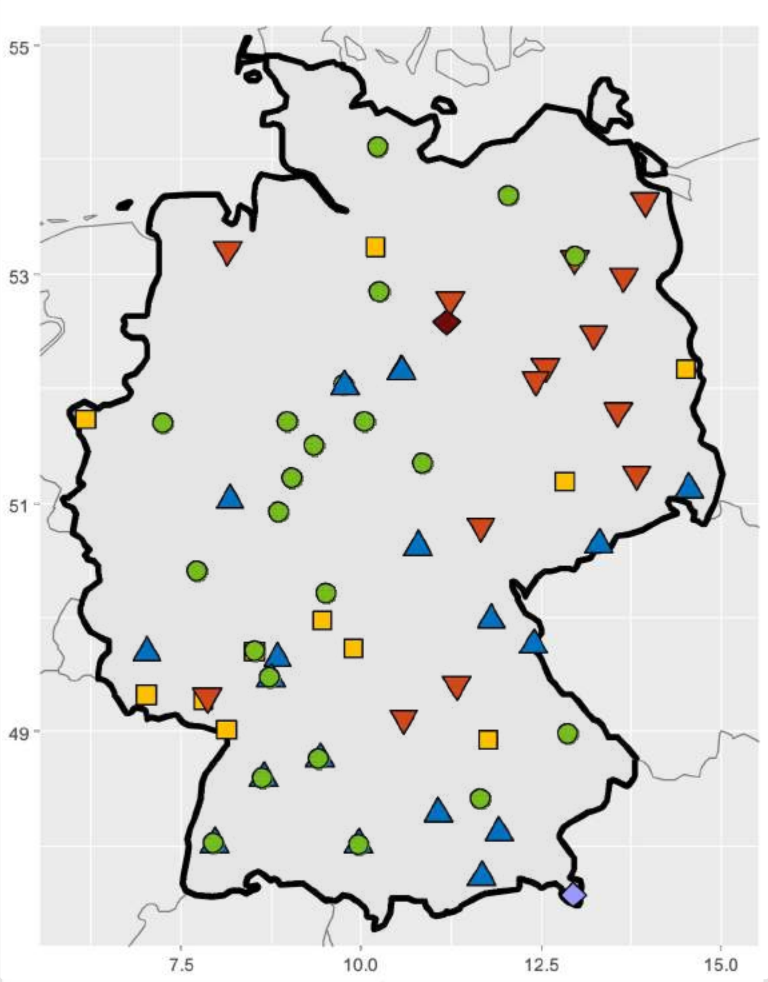
THÜNEN

Nutrient status & biodiversity: results from Level II sites

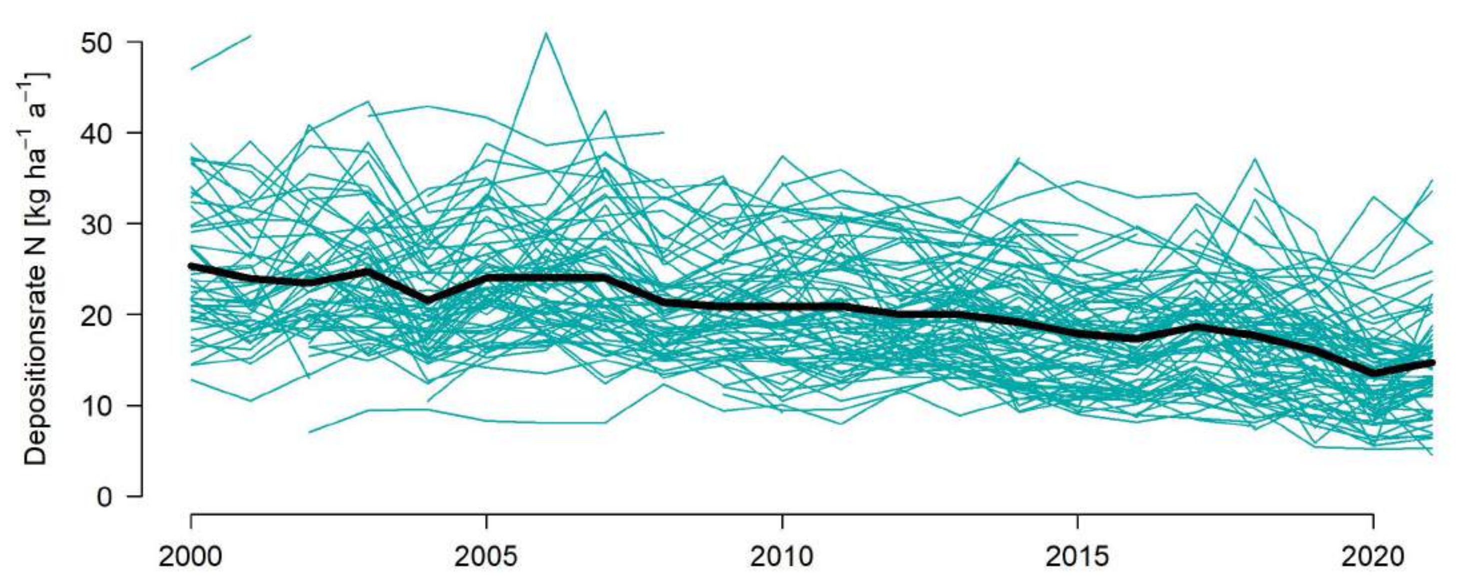
Inken Krüger

10/05/2023
ICP IM Meeting

ICP Forests Level II network in Germany



N deposition rates at Level II plots



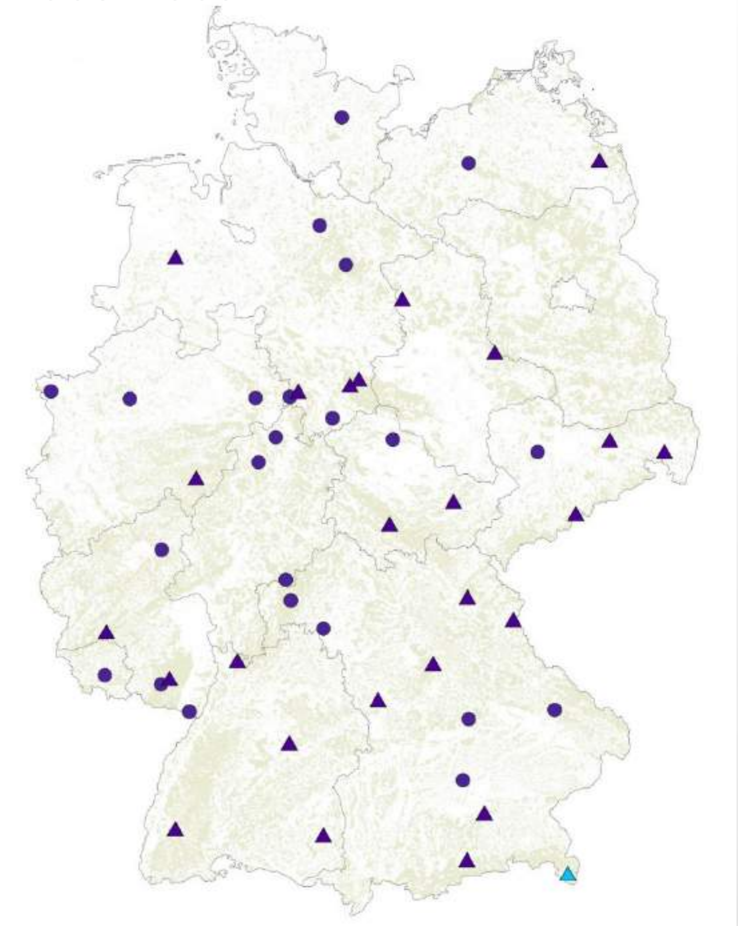
- mean total N deposition 15 – 21 kg N / ha yr
- Up to 33 kg N / ha yr
- N deposition rate decreased by 16 % between 2005-2009 and 2015-2019

Level II
Forstliches Umweltmonitoring

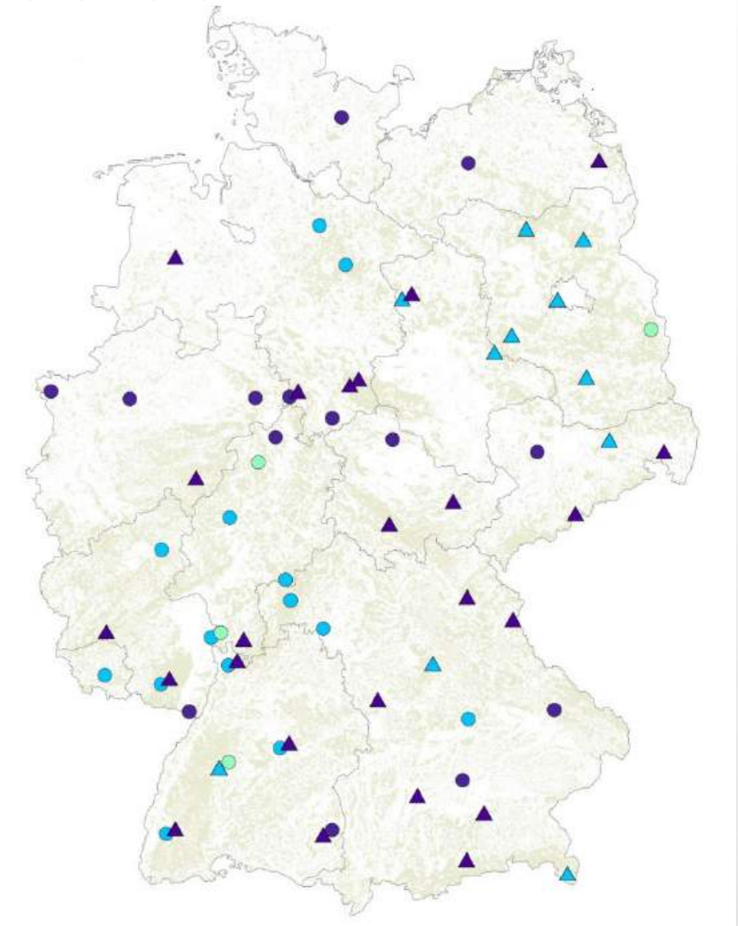
THÜNEN

N deposition – critical limits

2005-2009



2015-2019

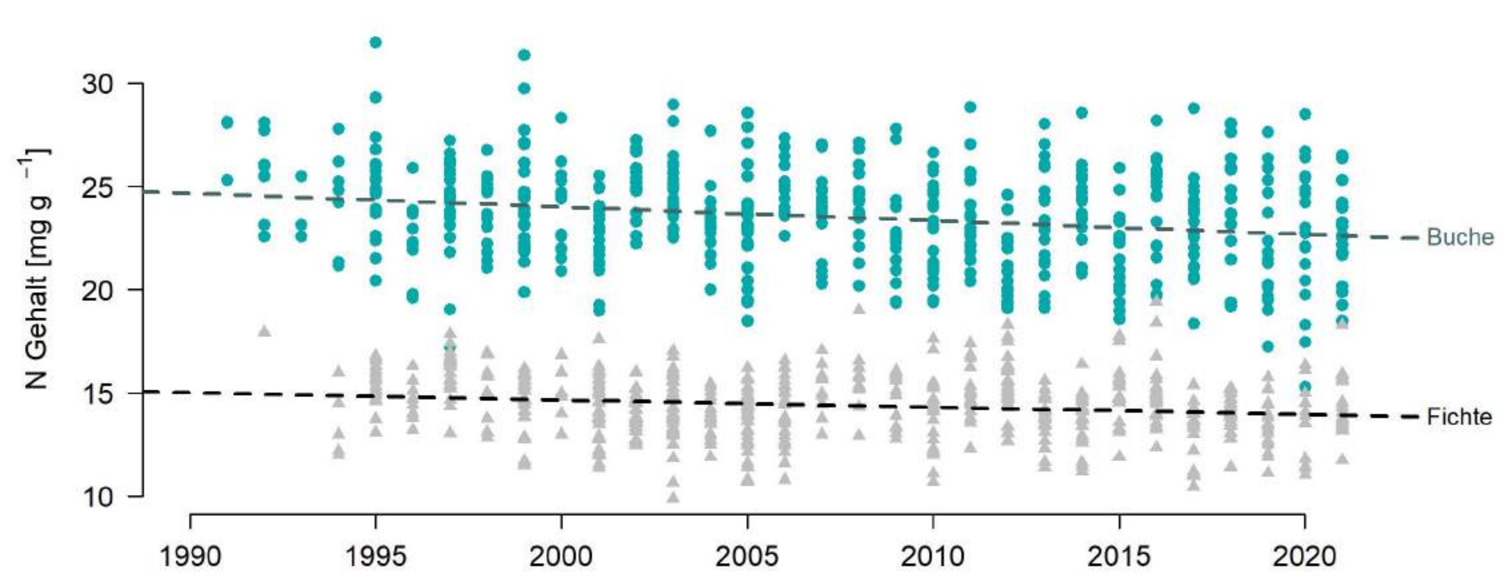


🟩 below CL

🟪 above CL

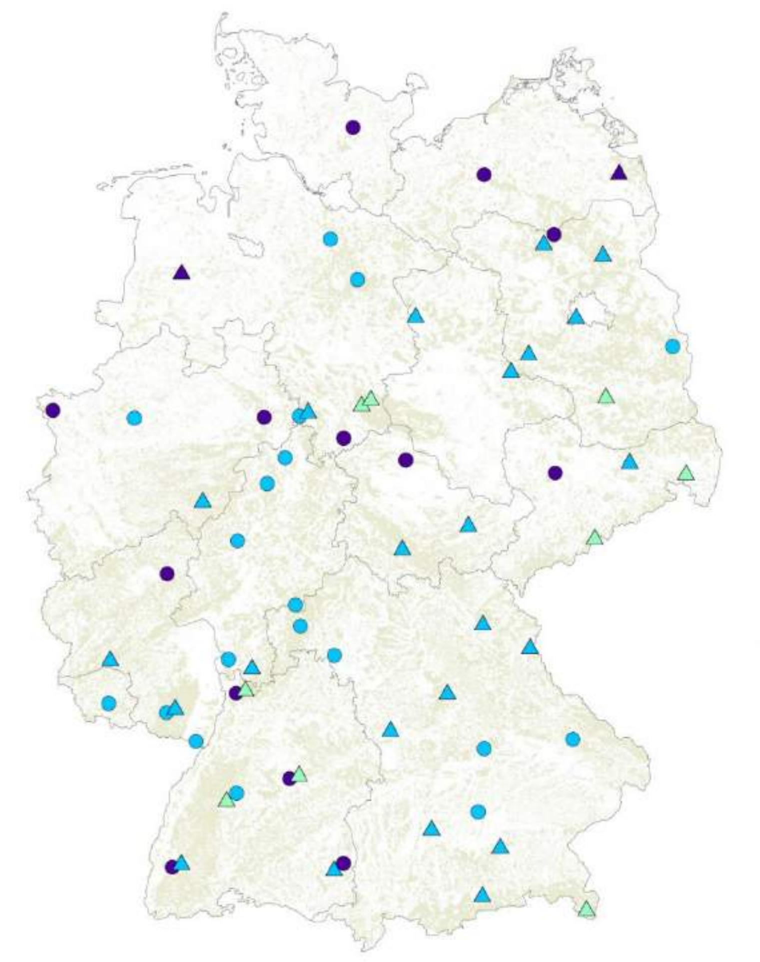
🟦 Between lower and upper CL

Trends in foliar N



- Significant decrease in foliar N for all four main tree species
- Foliar N decreased by 5-6 % between 2005-2009 and 2015-2019

Nutrient status (2016-2020)



% sites where foliar nutrient concentrations are below normal ranges according to *Mellert & Göttlein, 2012*

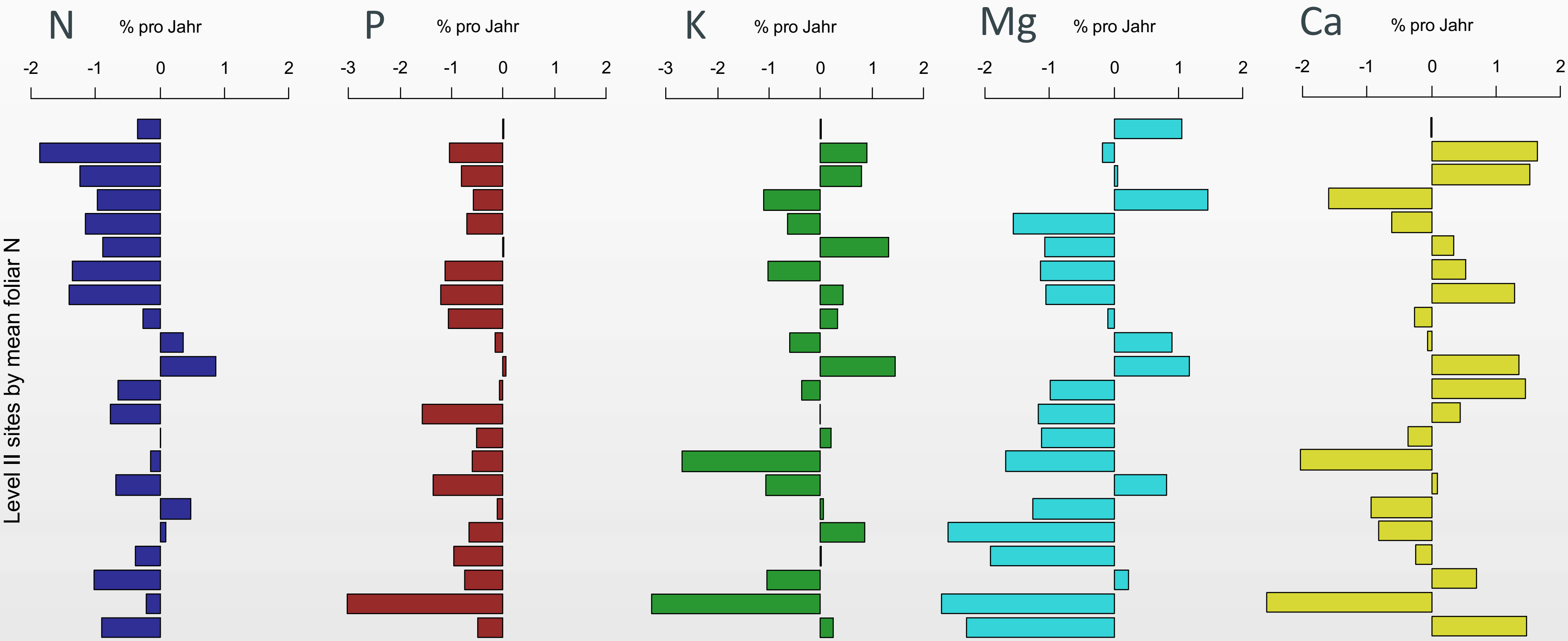
	N	P	K	Ca	Mg
Beech	0	63	27	31	53
Oak	0	50	31	69	12
Spruce	45	62	69	22	17
Pine	17	28	22	63	39

🟩 deficiency

🟦 normal ranges

🟪 surplus

Trends in foliar nutrient concentration (beech)



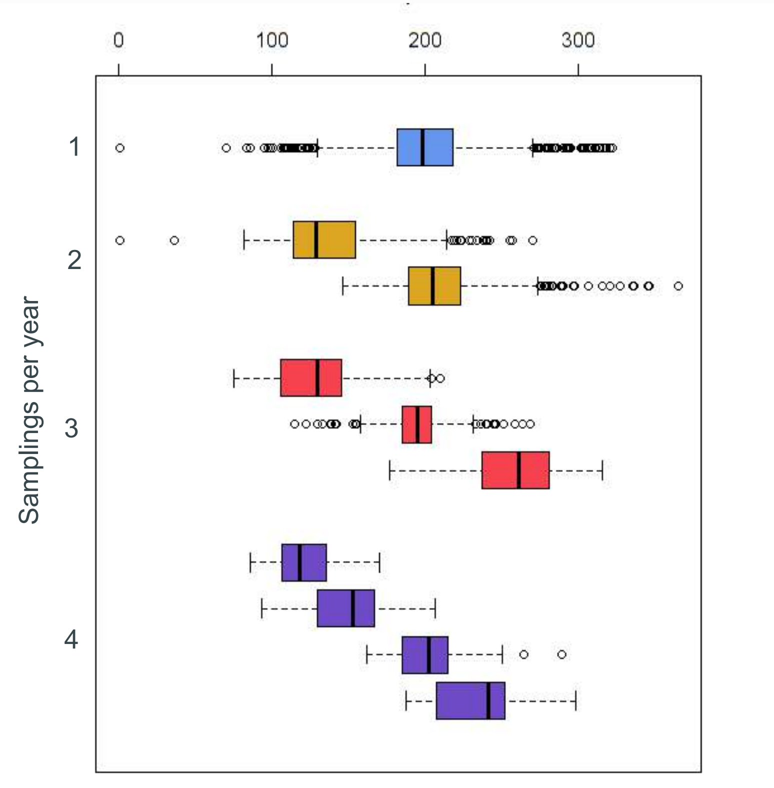
Level II
Forstliches Umweltmonitoring

THÜNEN

Can species traits of the ground vegetation be linked to nutrient supply gradients at the national scale of Germany?

Ground vegetation

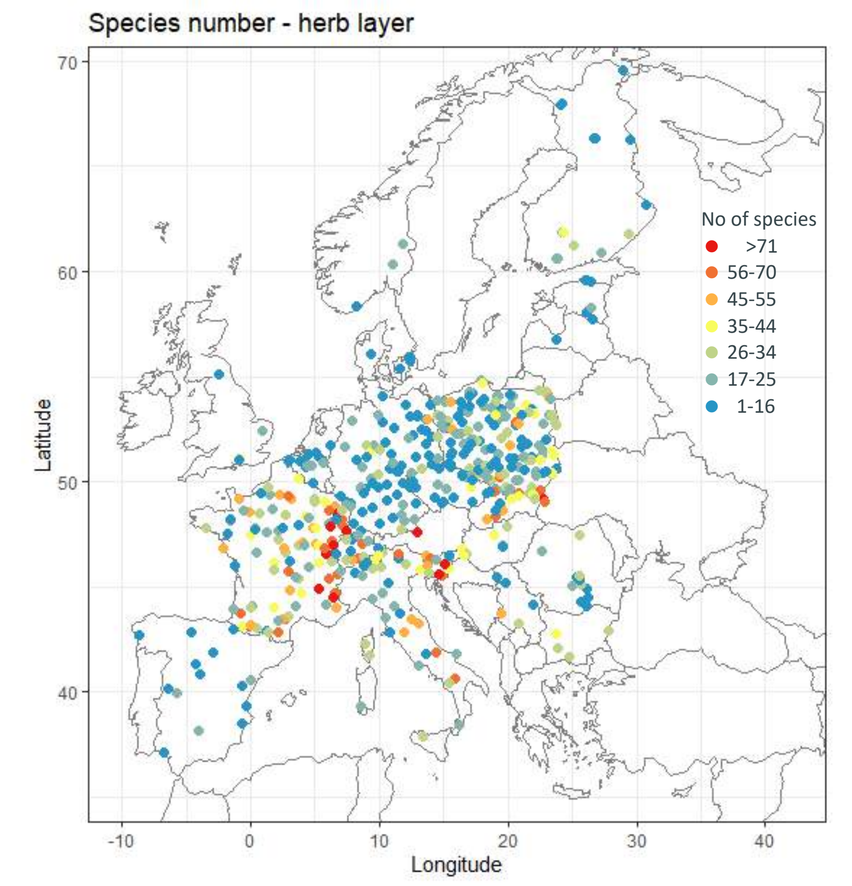
- At least one survey every five years
- Survey should be performed during the maximum biomass (additional spring/autumn samplings depending on vegetation type)

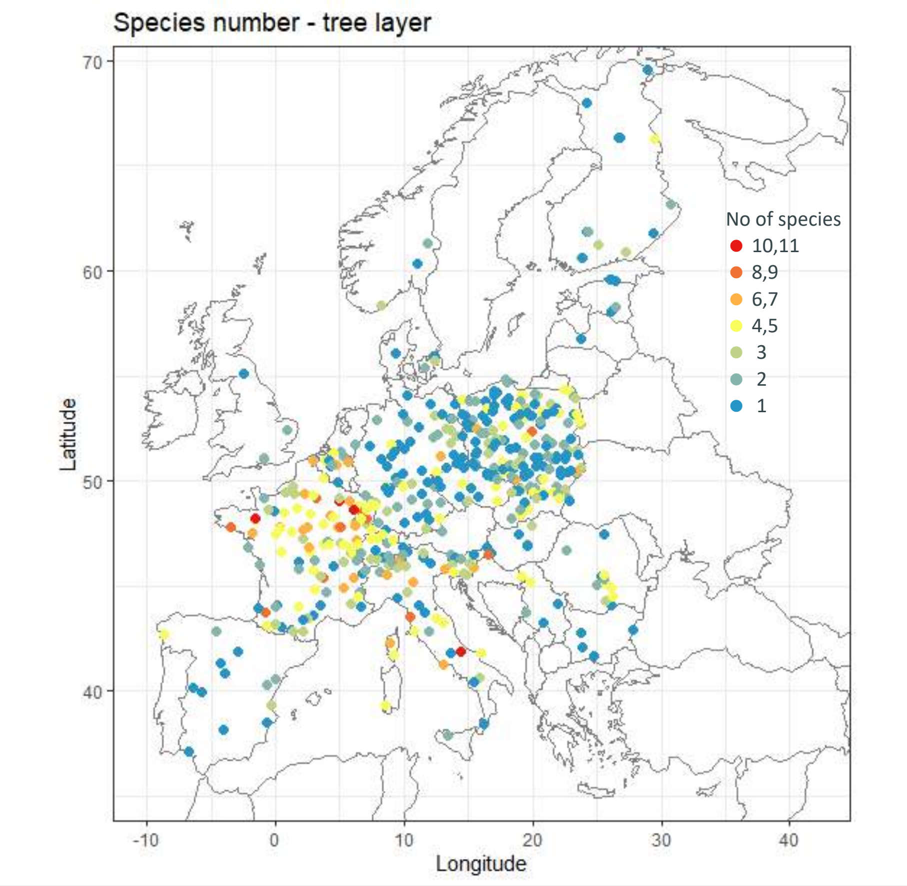


- Total sample area 400 m²
- Fenced and/or unfenced plots

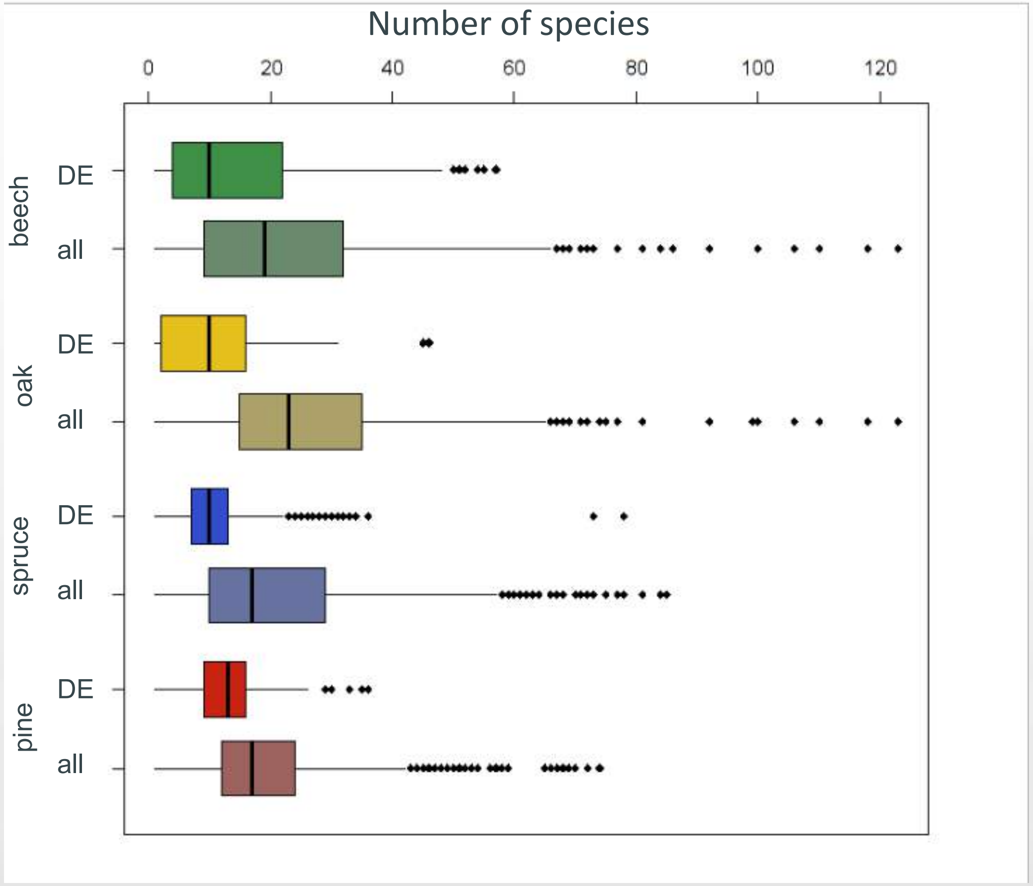
- Moss layer – **herb layer** – shrub layer – tree layer

Species number – current state (>2010)





Species number – herb layer (sample area 400 m²)



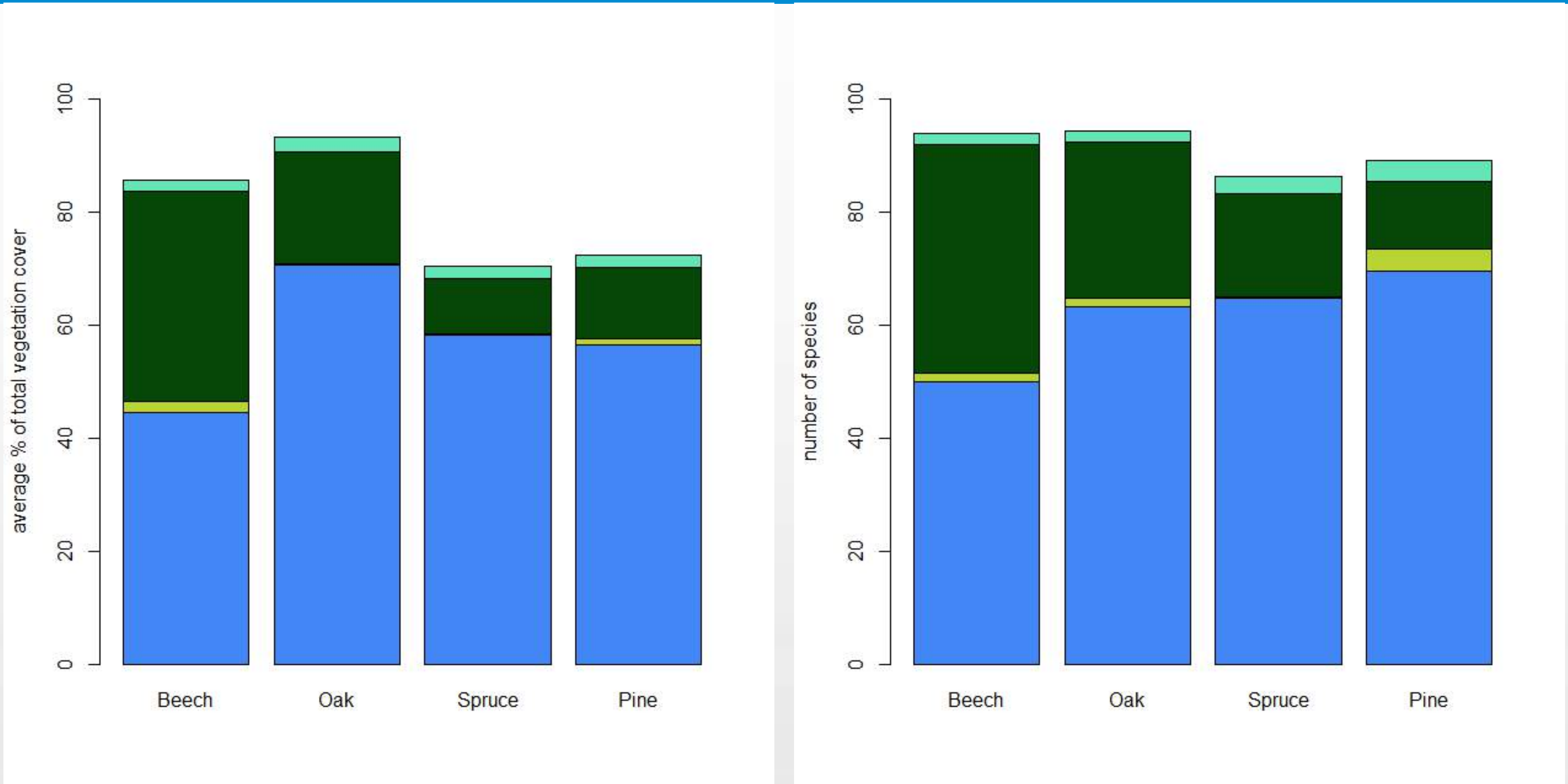
Germany:

- 416 different species in the herb layer
- 1 - 78 species at plot level
- Mean: 13.8 Median: 11

All:

- 2400 different species in the herb layer
- 1 – 123 species at plot level
- Mean: 22.0 Median: 18

Forest species



🟦 In forest and open vegetation

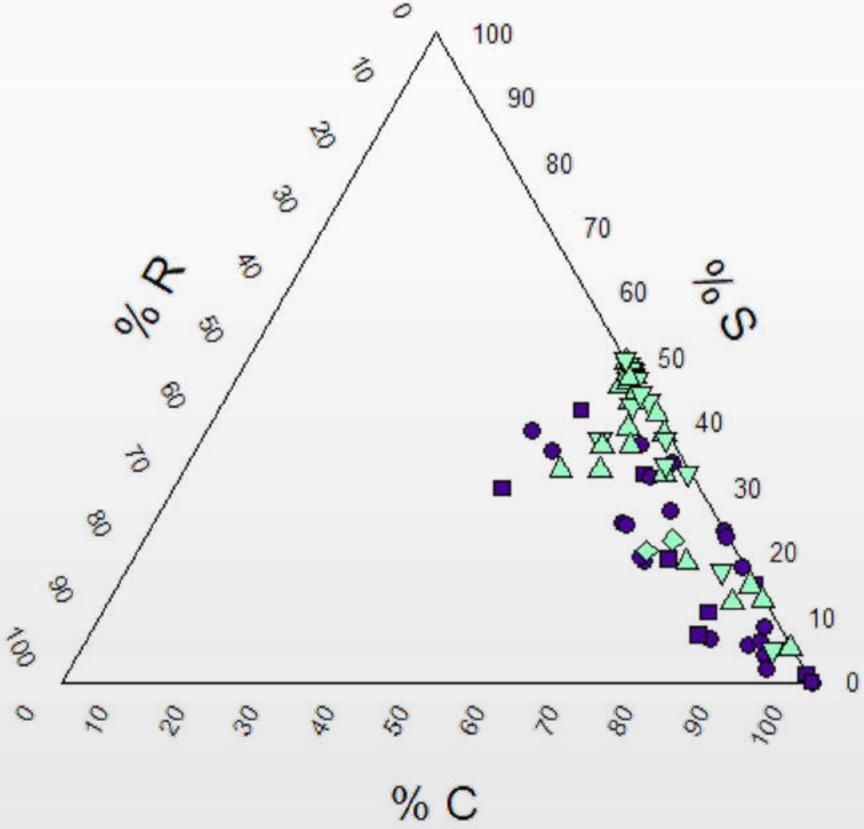
🟩 mainly in the closed forest

🟩 mainly in open vegetation

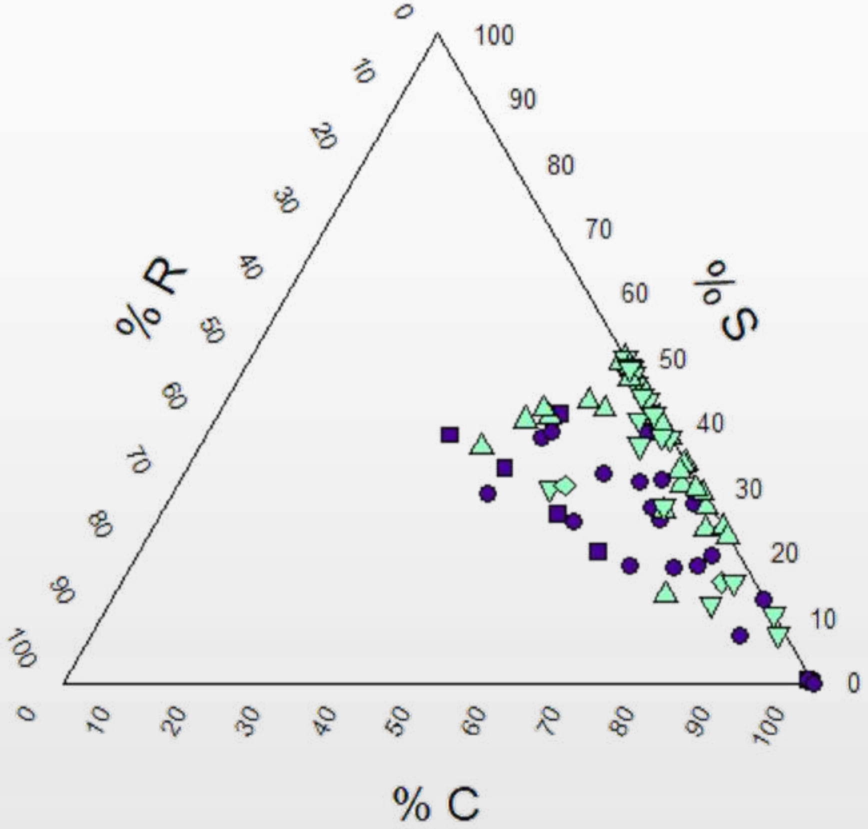
🟩 typical along forest edges and in forest openings

Classification according to: Heinken et al. (2019) European Forest Plant Species List

Ecological strategies



1996-2005

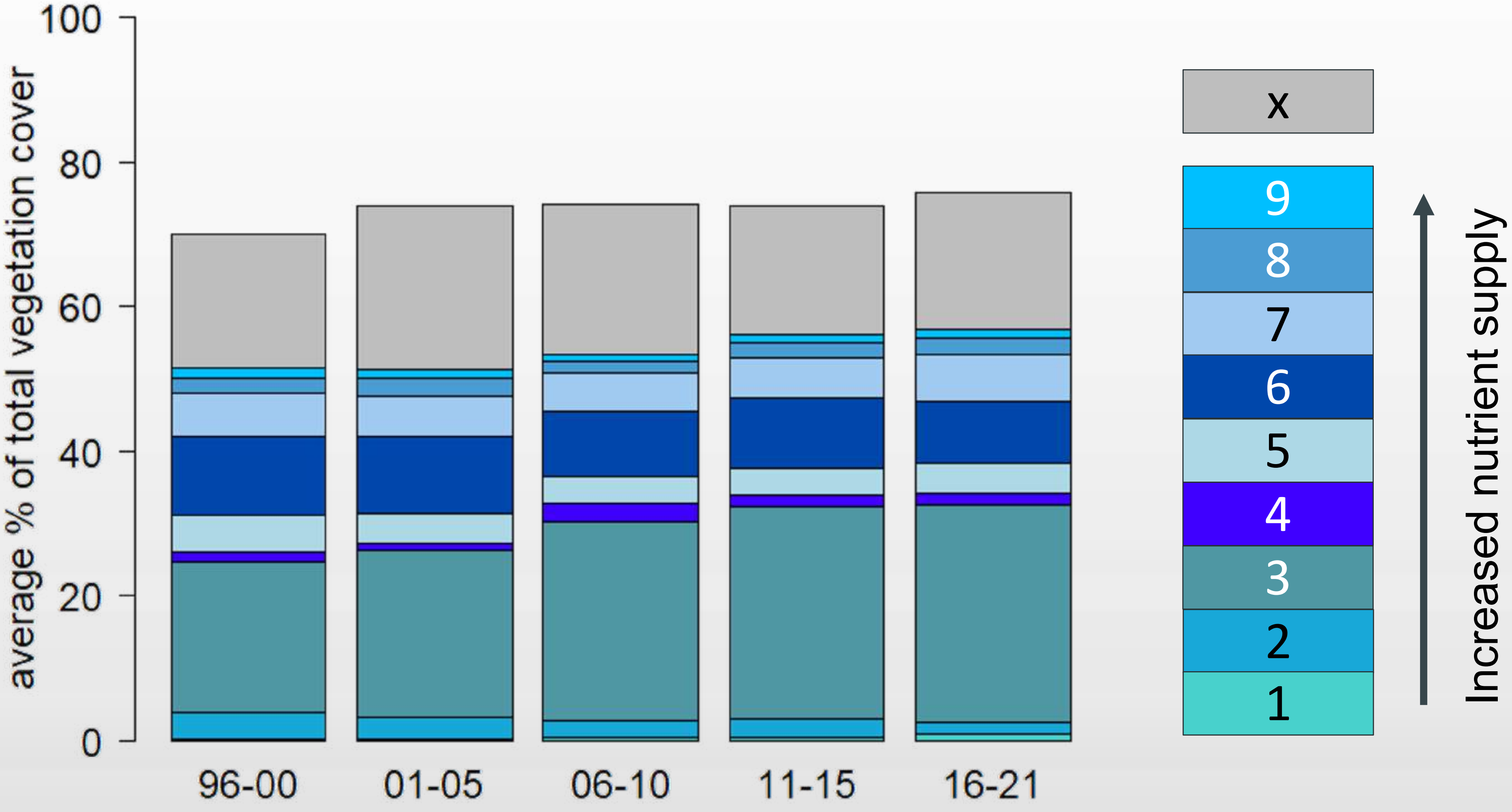


2011-2020

- significant shift from S- to C-strategy over the last 25 years

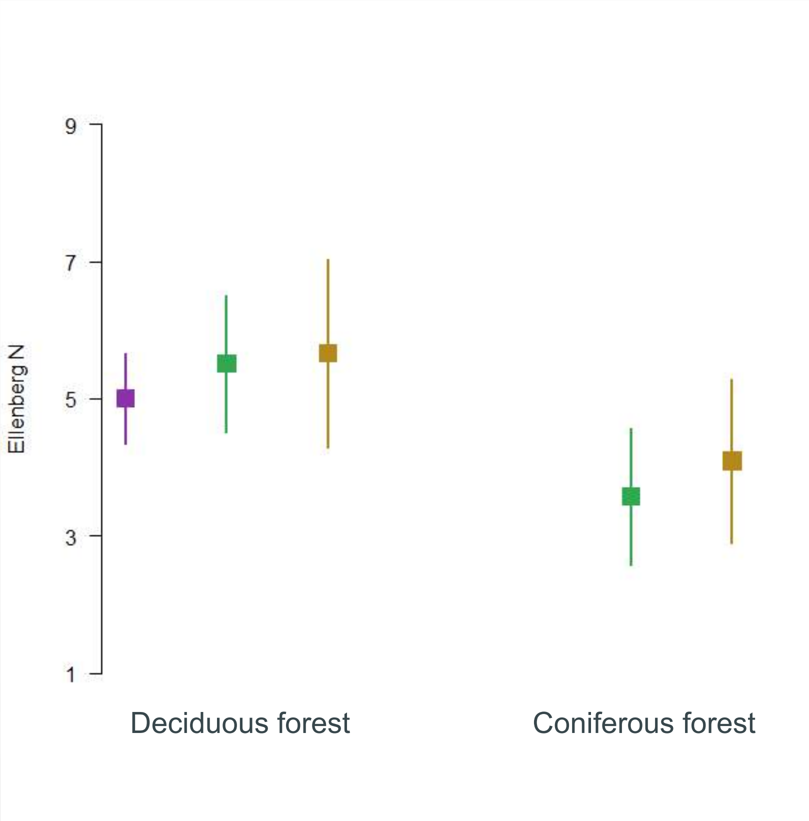
Classification according to: Klotz et al. (2002). Eine Datenbank zu biologisch-ökologischen Merkmalen der Gefäßpflanzen in Deutschland

Ellenberg N value



Classification according to: Ellenberg et al. (2001). Zeigerwerte von Pflanzen in Mitteleuropa

Links between Ellenberg N and N deposition



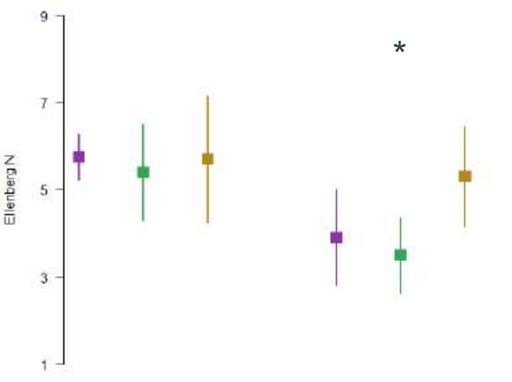
🟪 below CL 🟫 above CL

🟩 Between lower and upper CL

- No significant link between mean Ellenberg N and deposition

Links between Ellenberg N and foliar nutrition

N



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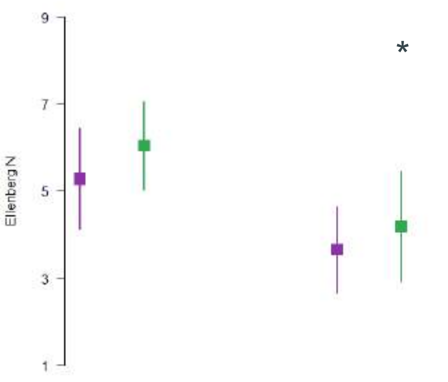
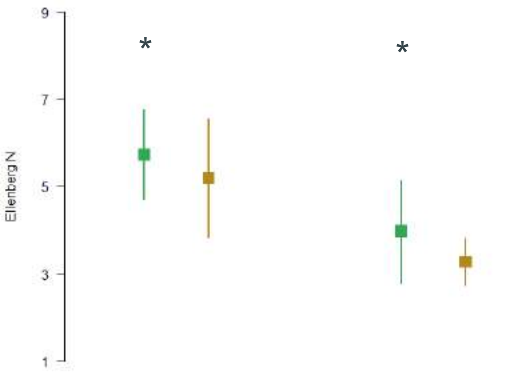
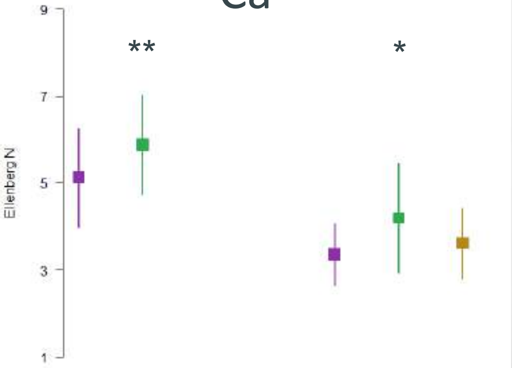


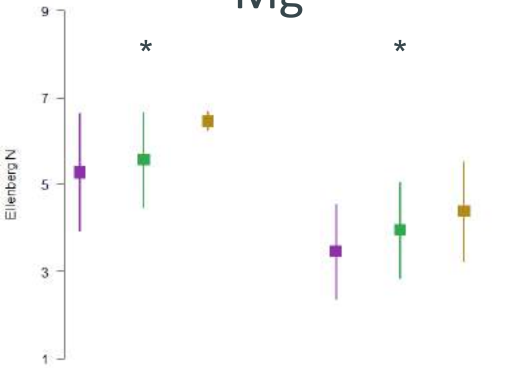
N/P



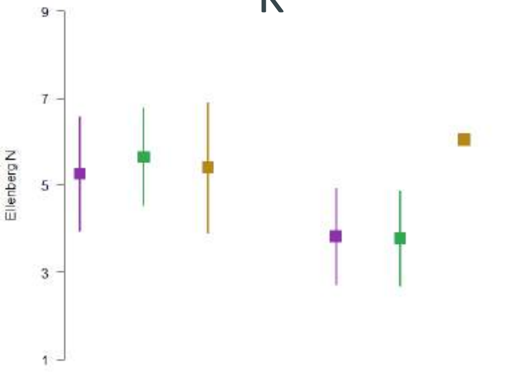
Ca



Mg



K



Summary

- Significant decrease in N deposition and foliar nutritents at Level II plots
- Slight shifts in species traits of the herb layer
- No significant effect of N deposition on species traits of the herb layer
- Some links between foliar nutrition and species traits of the herb layer

Bioacoustic monitoring – AkWamo project

- 3 year pilot study on 4 beech plots and 4 pine plots Level II plots + 2 unmanged forest
- since spring 2023
- Calculation of acoustic diversity indices
- Links to forest condition

Acknowledgements:

All data was collected by the forestry research institutions of the German Federal States as part of the Level II programme.

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Biodiversity monitoring at Zöbelboden; Classical methods meet modern approaches

Ika Djukic, Johannes Kobler, Karl Knaebel, Gisela Pröll, Thomas Dirnböck

2023-05-09

umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

ZÖBELBODEN

Reference site for carbonate mixed beech forests

© M. Mirtl

Flagship-species of national park

Rosalia alpina © E. Weigand

Phyrganophilus ruficollis © E. Weigand

E.g.
1324 beetle species:
- 354 are red-list species (thereof 282 endangered)
- 570 wood living beetles (41 are forest relict species)
- 2 FFH priority species

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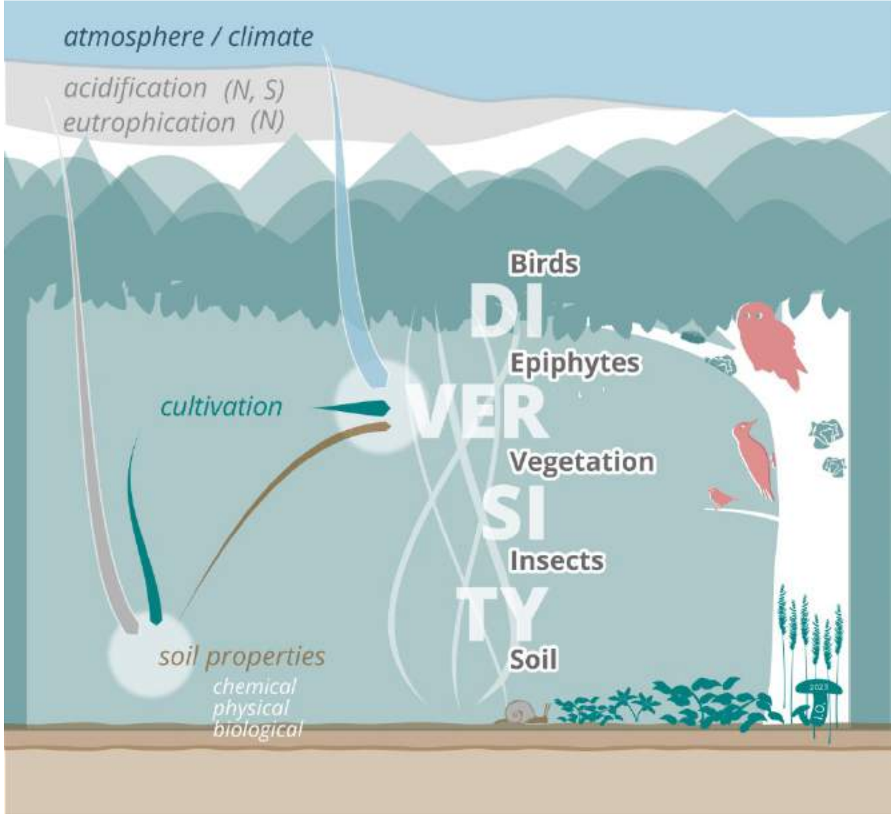
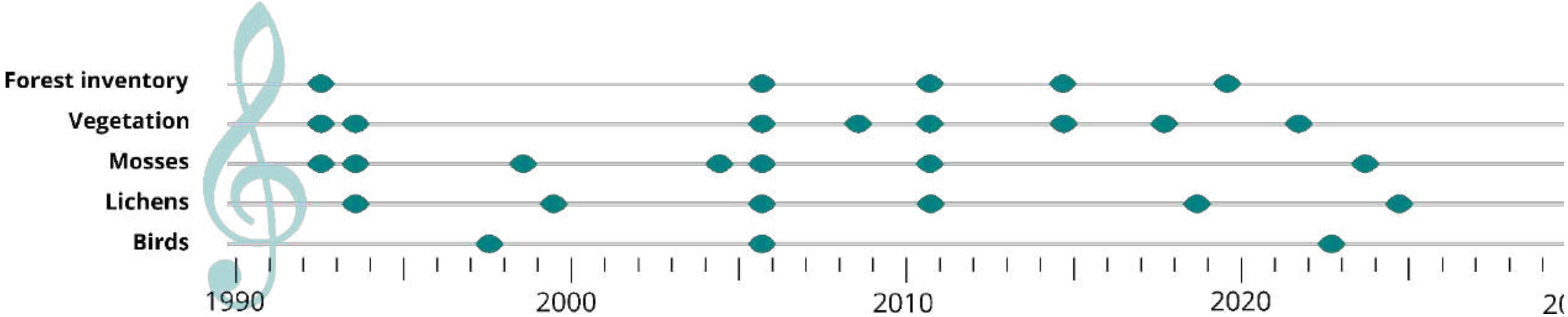
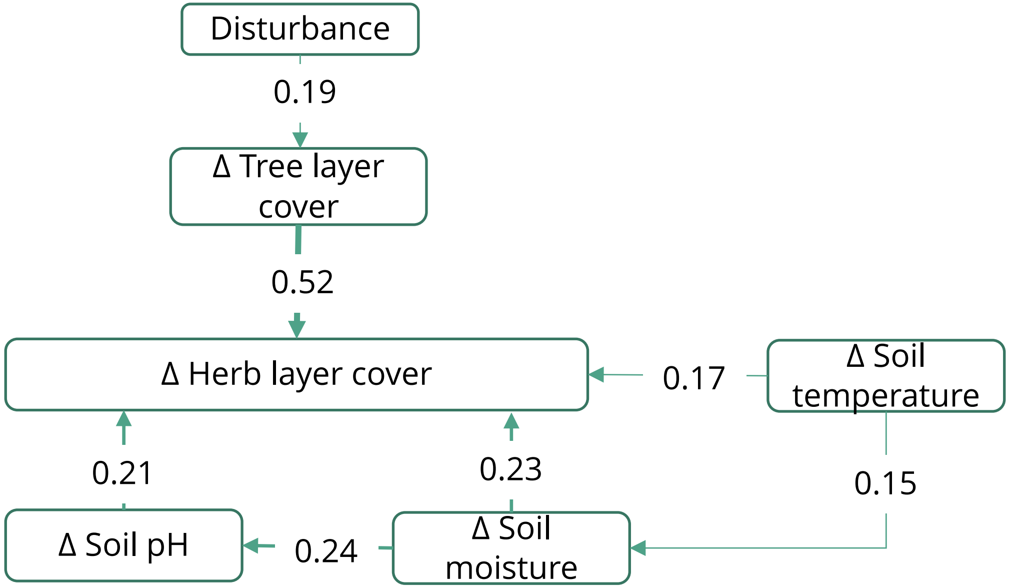
INFLUENCES ON FOREST DIVERSITY



ORCHESTRATED MONITORING



CHANGES IN FOREST UNDERSTORY COMPOSITION



Source: Helm et al., 2017

RED LIST COUNTS

65/12

192/ 2 FFH

114

398/ 1 FFH

- 39 species are classified in the Red Lists as endangered or threatened with extinction
- 15 species are found in the annexes of the European Flora-Fauna-Habitat Directive

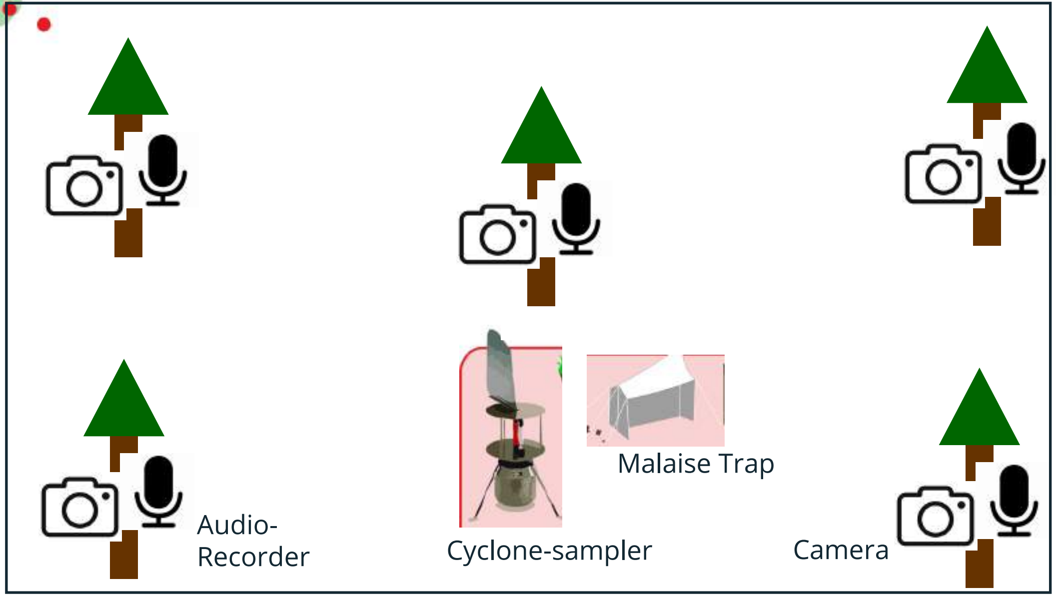
Automated biodiversity monitoring in cooperation with LifePlan

Sampling design

- European Research Grant, Univ. Helsinki in coop. with eLTER
- 200 sites worldwide, 3 in Austria

LIFEPLAN
A PLANETARY INVENTORY OF LIFE

https://www.helsinki.fi/en/projects/lifeplan



Automated biodiversity monitoring in cooperation with LifePlan

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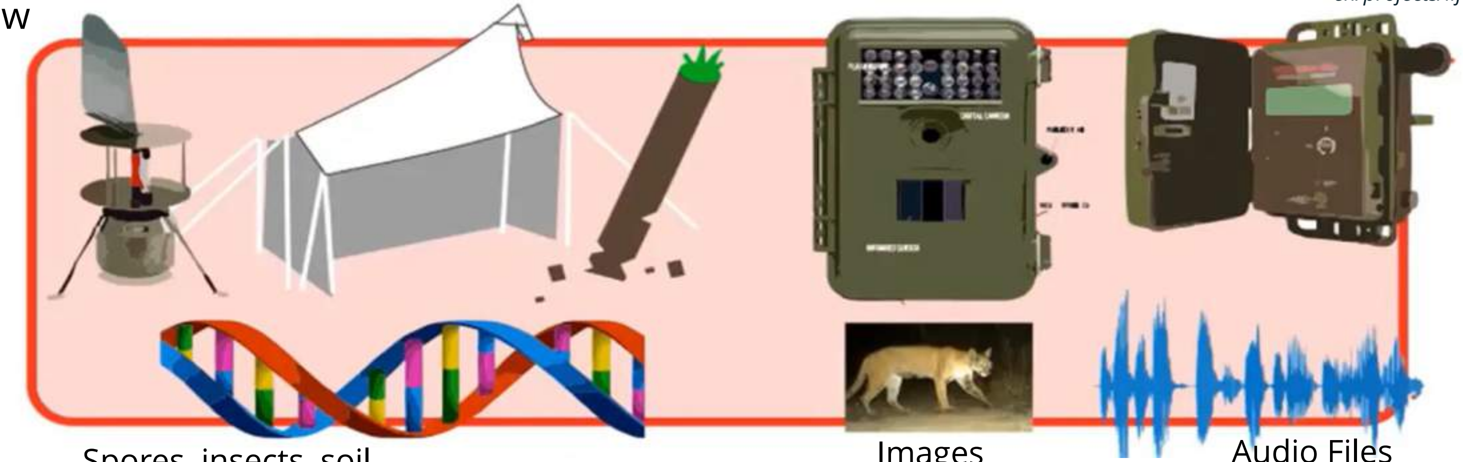
ENVIRONMENT AGENCY AUSTRIA

https://www.helsinki.fi/en/projects/lifeplan

LIFEPLAN
A PLANETARY INVENTORY OF LIFE

Workflow



Spores, insects, soil

- DNA extraction & sequencing
- Sequence library

Images

Image library:
- Experts verification

Audio Files

Sound library:
- Automated species identification
- Verification - Citizen science project „BIRD SOUNDS GLOBAL“

https://bsg.laji.fi/

Species identification

Automated biodiversity monitoring as part of the European eLTER infrastructure from 2025

Filling a
critical gap
for top-class
science at the
continental
scale

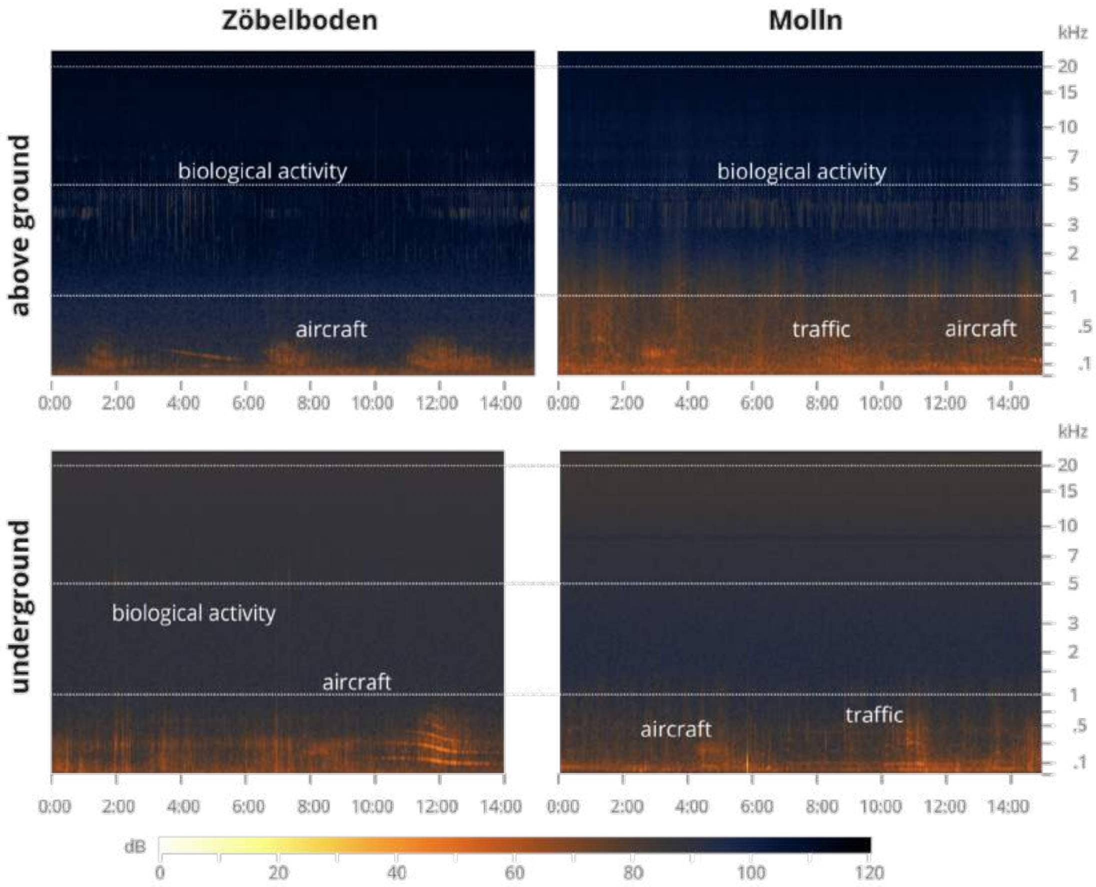
- Continuation of the Lifeplan design in approx. 100-200 locations in Europe with additional data on all essential drivers (climate, soil, air, humans)
- Linking to the Austrian Biodiv-Monitoring and FFH Monitoring

GLOBAL SOIL BIODIVERSITY MONITORING-SOILBON INITIATIVE

- Standardized investigation of soil biodiversity and activities inside and outside protected areas worldwide
- Zöbelboden is one of 1000 sites participating in this program

https://www.globalsoilbiodiversity.org/soilbon

ECO-ACOUSTICS



Dissertation: Erpelding Sam

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ICP IM Meeting 2023
Lunze am See, 2023-05-09