Recovery of benthic algal assemblages from acidification: how long does it take, and is there a link to eutrophication?

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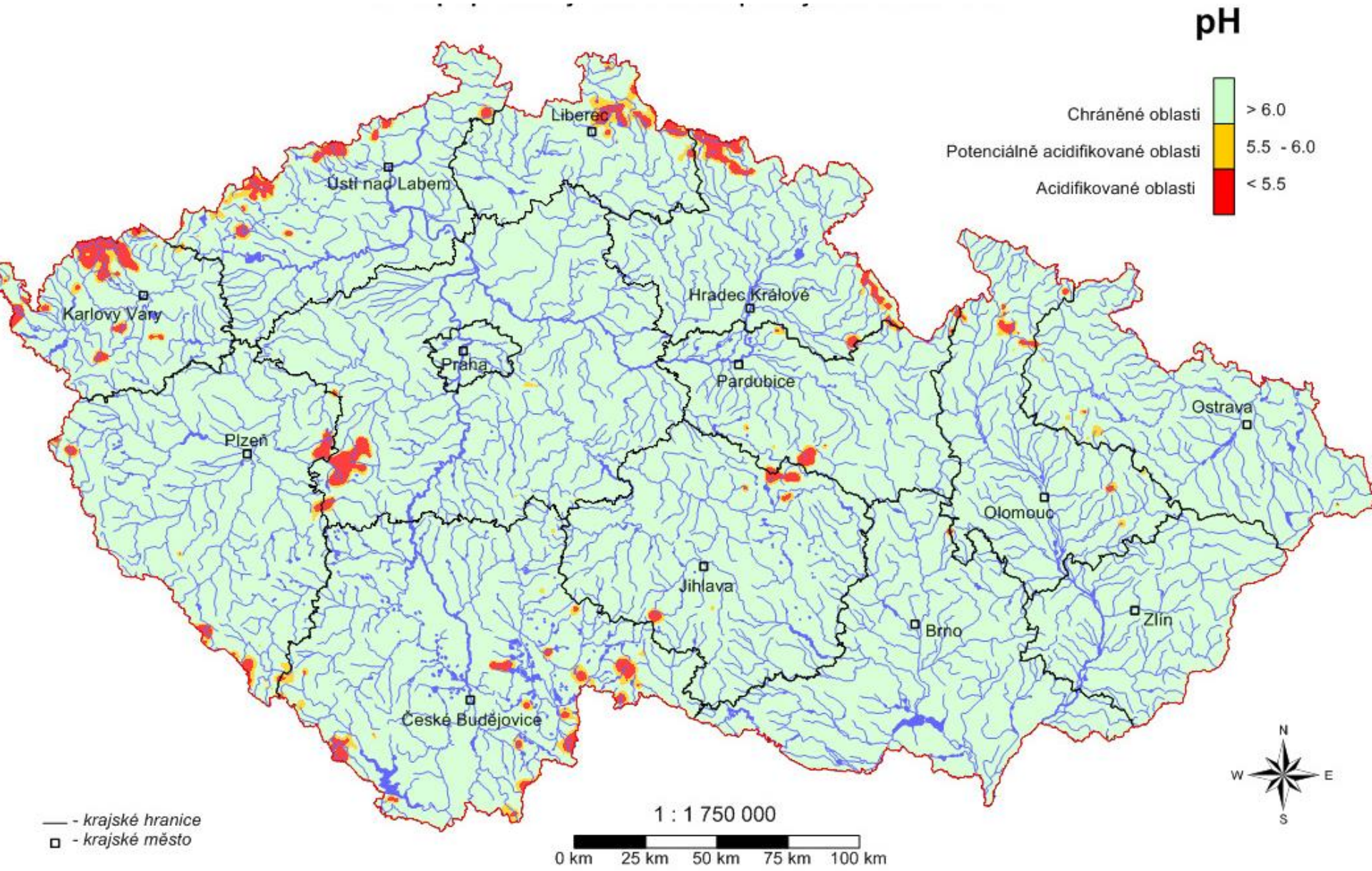
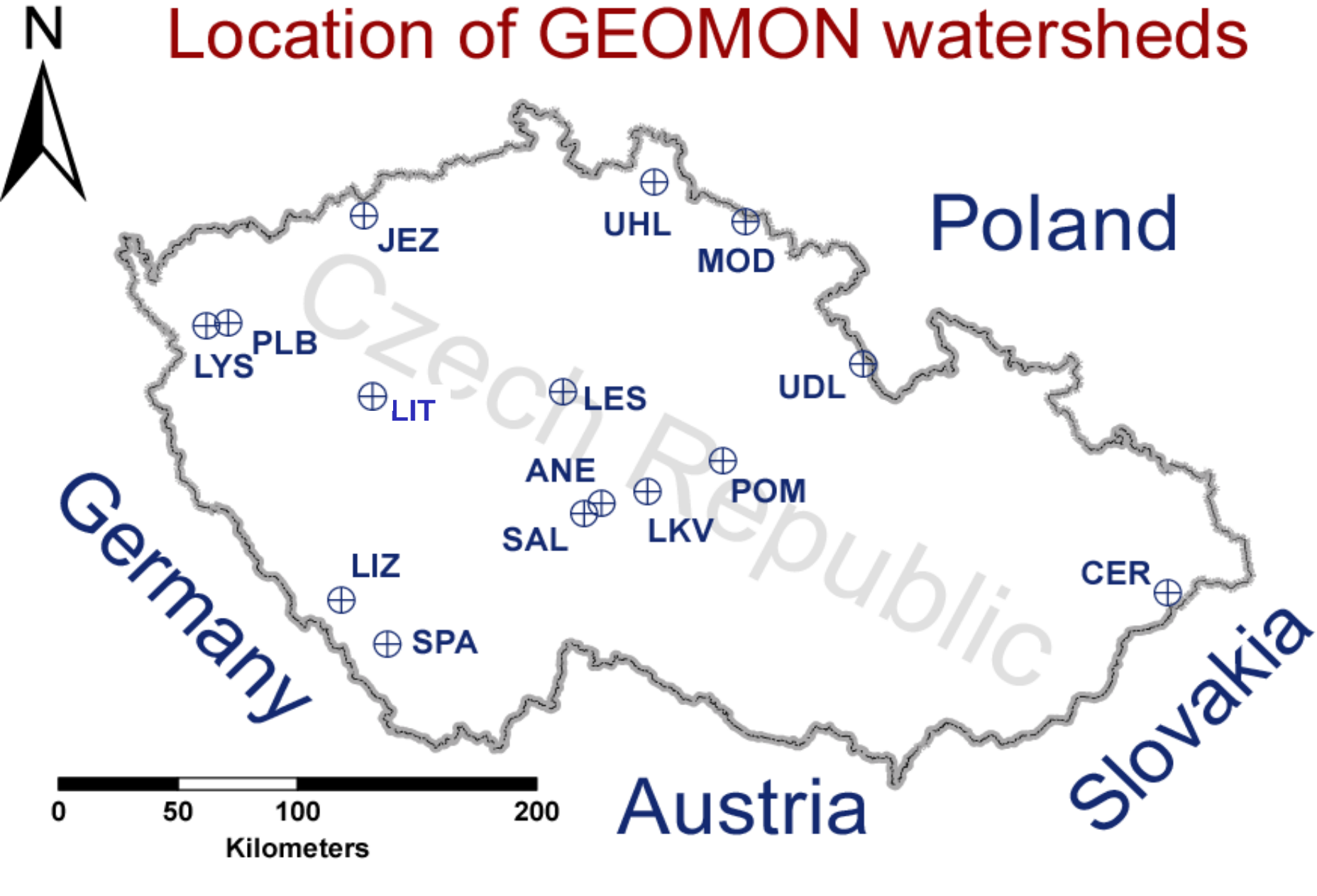
Acidified surface waters in the Czech Republic

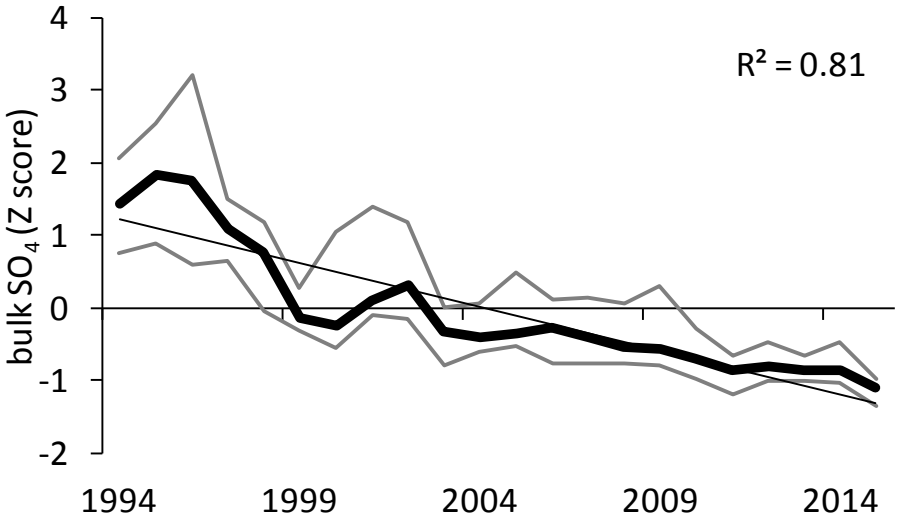



N
Location of GEOMON watersheds
Poland
Germany
Austria
Slovakia
Czech Republic
JEZ
UHL
MOD
PLB
LYS
LIT
LES
UDL
ANE
POM
SAL
LKV
LIZ
CER
SPA
0
50
100
200
Kilometers

GEOMON

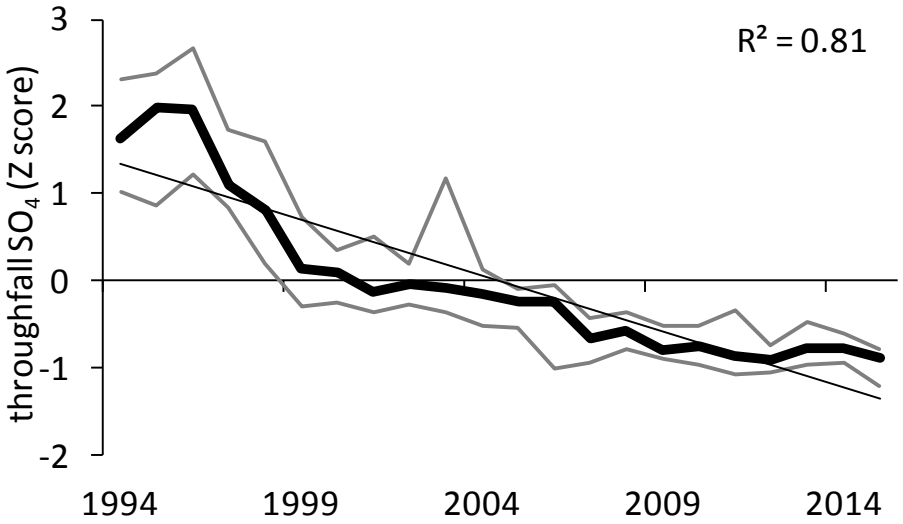
Oulehle et al. (2017) *Biogeochemistry* 132:251–272

S deposition (1994 - 2015)



14 kg S ha^{-1} yr^{-1}

3.7 kg S ha^{-1} yr^{-1}

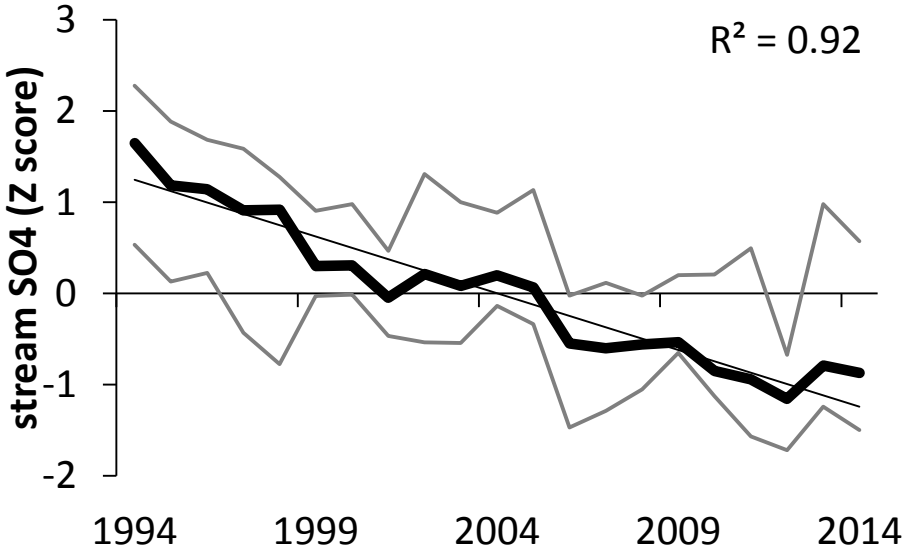


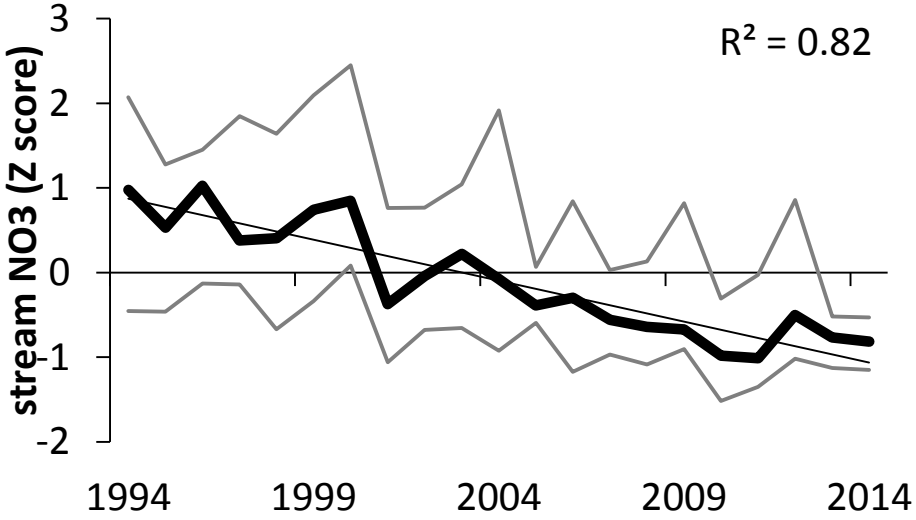
36 kg S ha^{-1} yr^{-1}

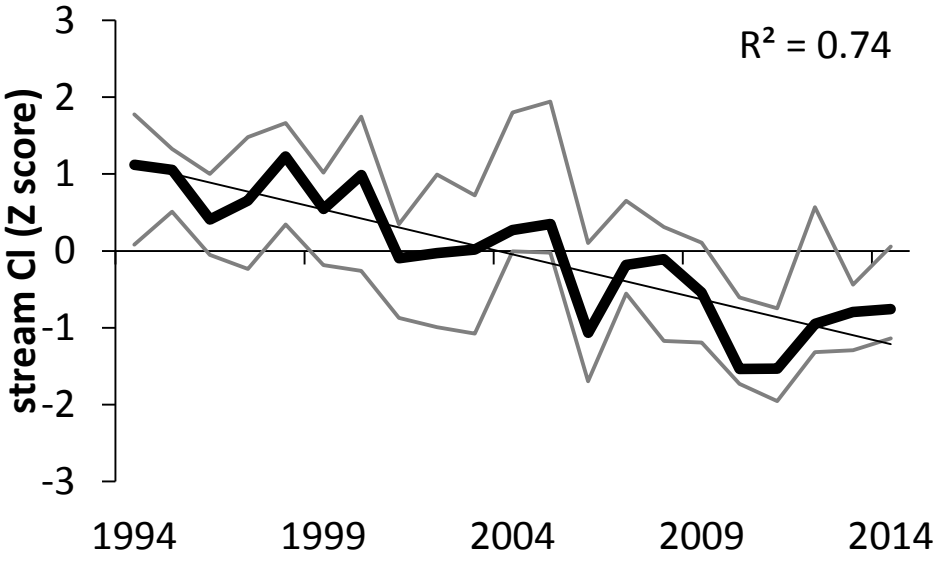
9.7 kg S ha^{-1} yr^{-1}

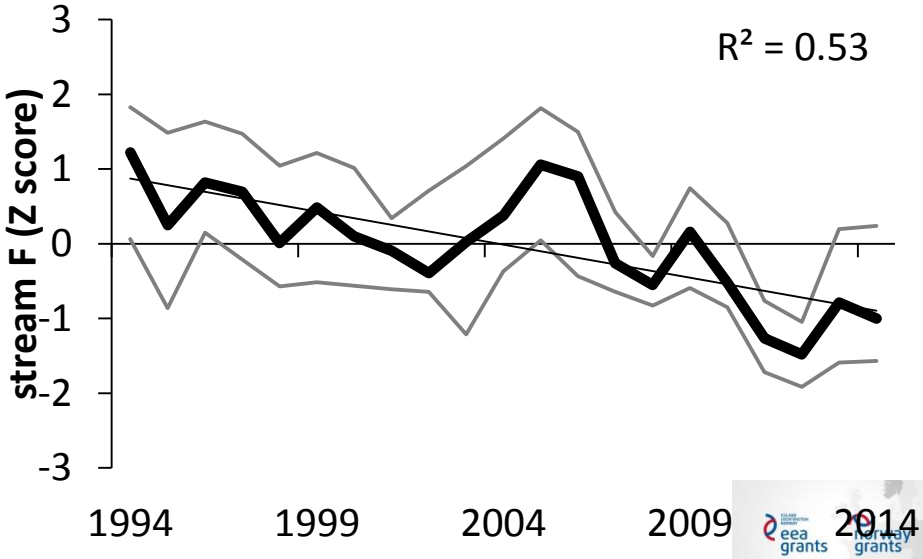
Dry deposition still important

GEOMON Runoff (anions)

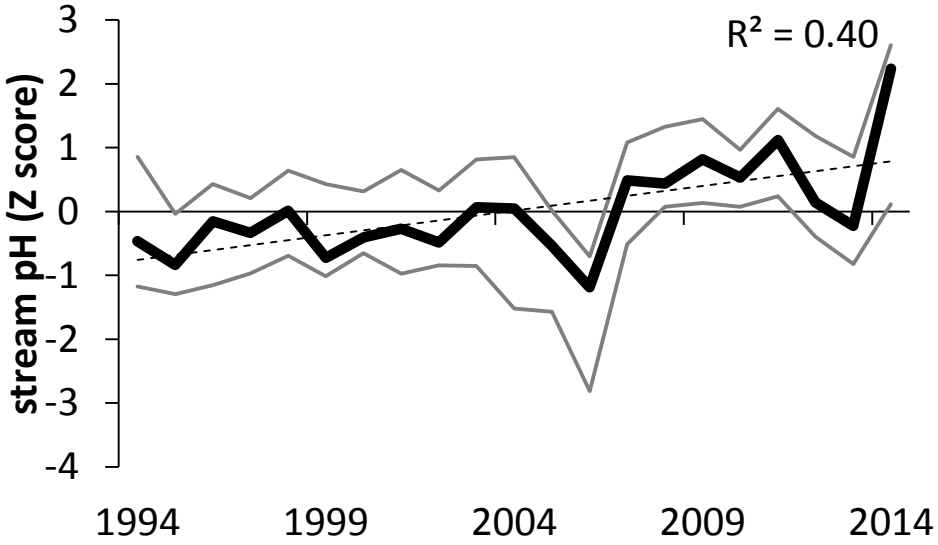


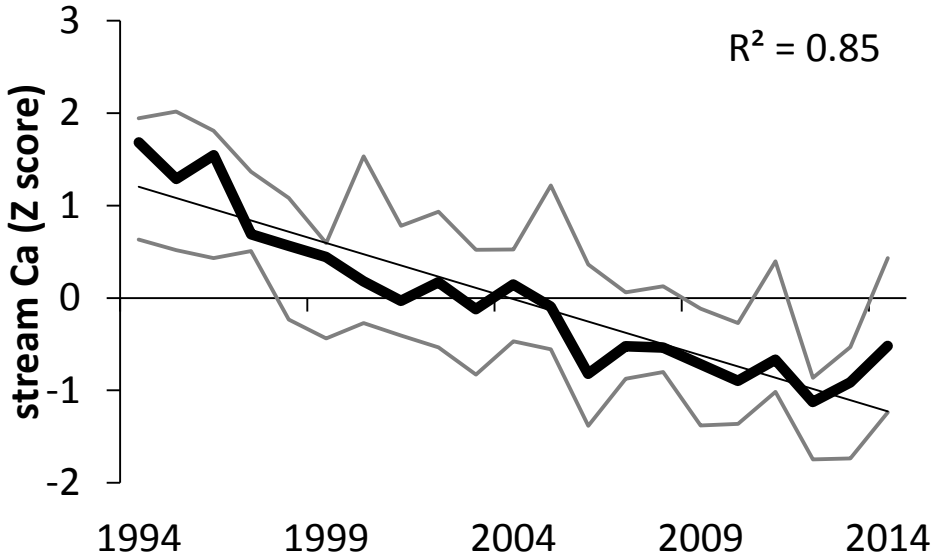


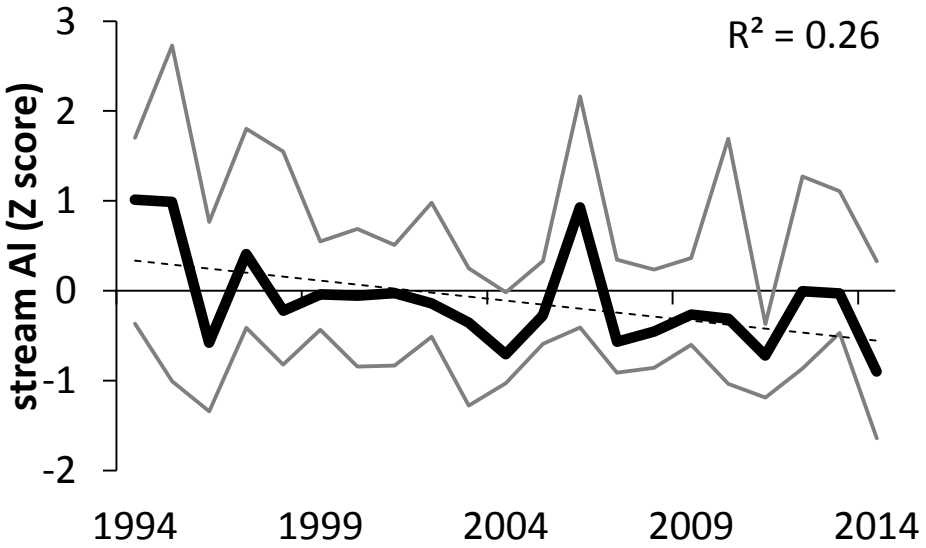


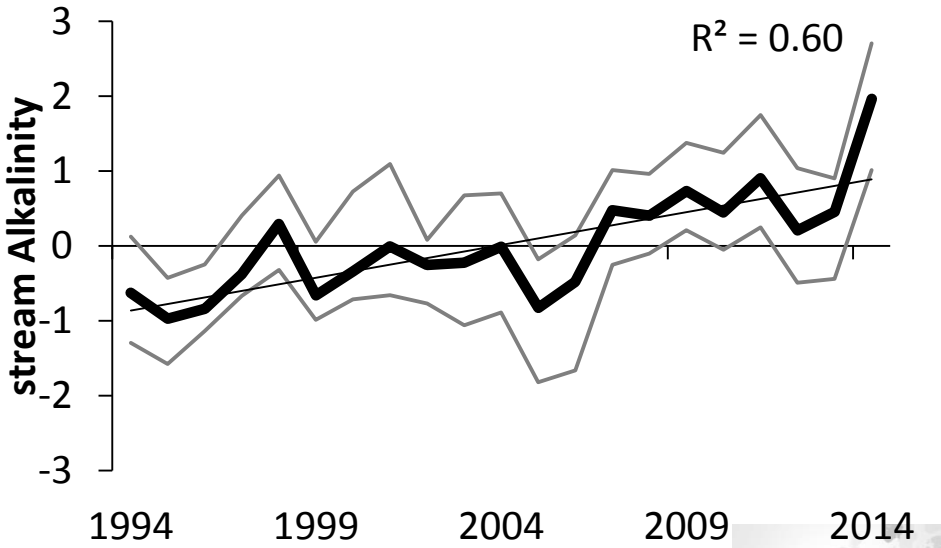


GEOMON Runoff (cations, alk)



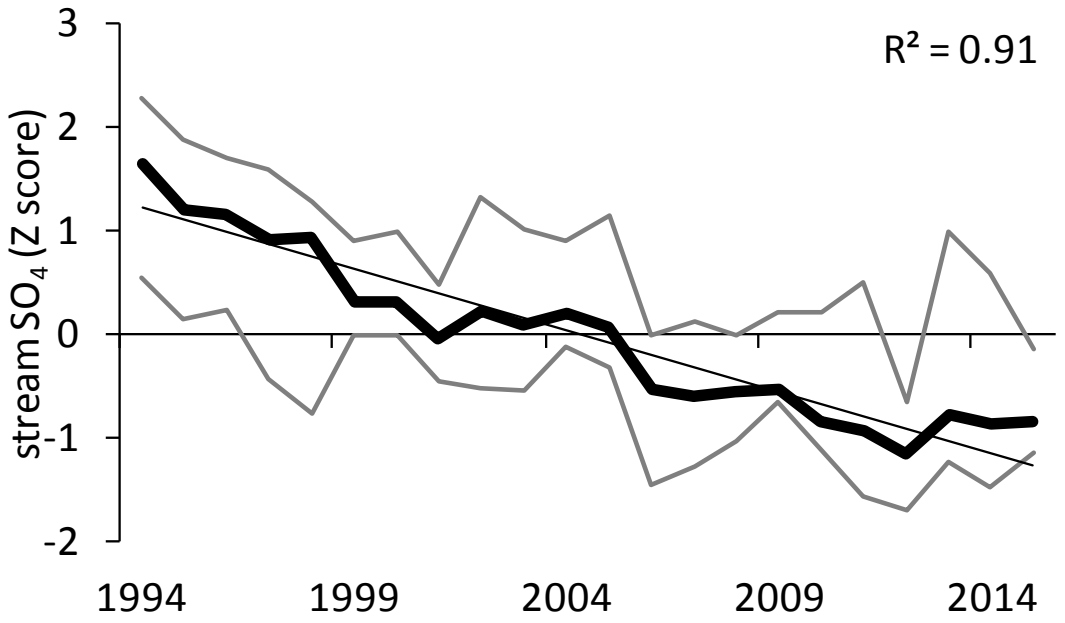


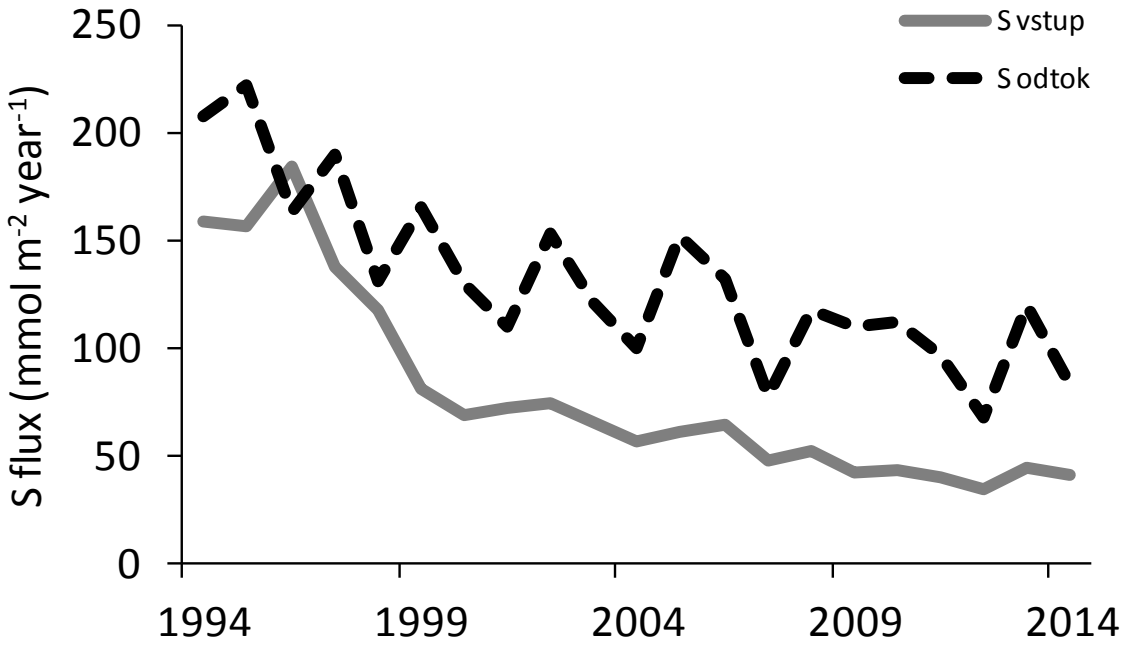




GEOMON

S budget





Susi Schneider

	ANE	CER	JEZ	LES	LIT	LIZ	LKV	LYS	MOD	NAZ	PLB	POM	SAL	UDL	UHL
cyanobacteria															
Calothrix elenkinii											xx				
Calothrix fusca											x				
Chamaesiphon confervicola		x							x						
Chamaesiphon incrustans												x			
Chamaesiphon polonicus			<1					<1							
Chroococcus spp.														x	
Heteroleibleinia spp.		xx				x						x	x		
Hydrococcus cesati											x				
Hydrococcus sp.													<1	<1	
Leptolyngbya spp.	<1		x										x		
Oscillatoria spp.		x							x						
Phormidium autumnale						<1			1						
Phormidium favosum		<1													
Phormidium inundatum															<1
Phormidium spp.												x	x	x	
Pleurocapsa minor										xxx	5				
Pseudanabaena spp.									xx					x	
Pseudanabaena starmachii															x
Scytonema spp.												<1			
unidentified coccoid cyanobacteria	xxx														
green algae															
Actinotaenium cruciferum									x					x	
Closterium spp.		x		x			xx								x
Cosmarium spp.									xx						
Gongrosira spp.		2	<1		<1										
Hormidium flaccidum										5	10	x			
Hormidium rivulare					xx				<1						
Microspora palustris var minor			x		10			15							x
Microspora tumidula										x					
Microthamnion strictissimum					x			x							
Mougeotia a (6 -12u)					xx			xx						x	
Mougeotia d/e (27-36u)							x								
Oedogonium b (13-18u)		<1													
Oedogonium c (23-28u)										x			x		
Oedogonium d (29-32u)		xx													
Oedogonium e (35-43u)			x												
Spirogyra a (20-42u,1K,L)							<1								
Staurastrum spp.		x												x	x
Stigeoclonium spp.	x							15						x	
unidentified coccoid green algae					<1			<1							
Ulothrix tenerrima				xx											
Ulothrix zonata		x													
Zygogonium sp3 (16-20u)															x
chrysophytes															
Epipyxis spp.					x										
red algae															
Audouinella chalybaea		<1													
Audouinella pygmaea						x	x		x						x
Batrachospermum confusum															1
Batrachospermum spp.	xx														
unidentified red algae				x						x		x	x	x	
xanthophytes															
Vaucheria spp.			<1				<1								
AIP	n.d.	7.13	*6.5*	n.d.	*5.8*	*7.2*	*7*	*5.7*	6.75	*7.1*	*7*	*7.3*	*7.1*	n.d.	*5.5*
PIT	7.76	14.3	15.5	*20*	5.15	22.4	23	5.2	13.1	6.87	5.49	11.1	8.3	3.95	15.3
algal taxon richness	4	11	6	3	7	3	5	6	8	5	5	6	6	9	8
taxon richness cyanobacteria	2	4	2	0	0	2	0	1	4	1	4	4	4	4	2
taxon richness green algae	1	6	3	2	6	0	3	5	3	3	1	1	1	4	4

Oedogonium e (35-43u)			x												
Spirogyra a (20-42u,1K,L)							<1								
Staurastrum spp.		x												x	x
Stigeoclonium spp.	x							15						x	
unidentified coccoid green algae					<1			<1							
Ulothrix tenerrima				xx											
Ulothrix zonata		x													
Zygogonium sp3 (16-20u)															x
chrysophytes															
Epipyxis spp.					x										
red algae															
Audouinella chalybaea		<1													
Audouinella pygmaea						x	x		x						x
Batrachospermum confusum															1
Batrachospermum spp.	xx														
unidentified red algae				x						x		x	x	x	
xanthophytes															
Vaucheria spp.			<1				<1								
AIP	n.d.	7.13	*6.5*	n.d.	*5.8*	*7.2*	*7*	*5.7*	6.75	*7.1*	*7*	*7.3*	*7.1*	n.d.	*5.5*
PIT	7.76	14.3	15.5	*20*	5.15	22.4	23	5.2	13.1	6.87	5.49	11.1	8.3	3.95	15.3
algal taxon richness	4	11	6	3	7	3	5	6	8	5	5	6	6	9	8
taxon richness cyanobacteria	2	4	2	0	0	2	0	1	4	1	4	4	4	4	2
taxon richness green algae	1	6	3	2	6	0	3	5	3	3	1	1	1	4	4

AIP – Acidification Index Periphyton 5,2 (UHL) – 7,3 (POM)

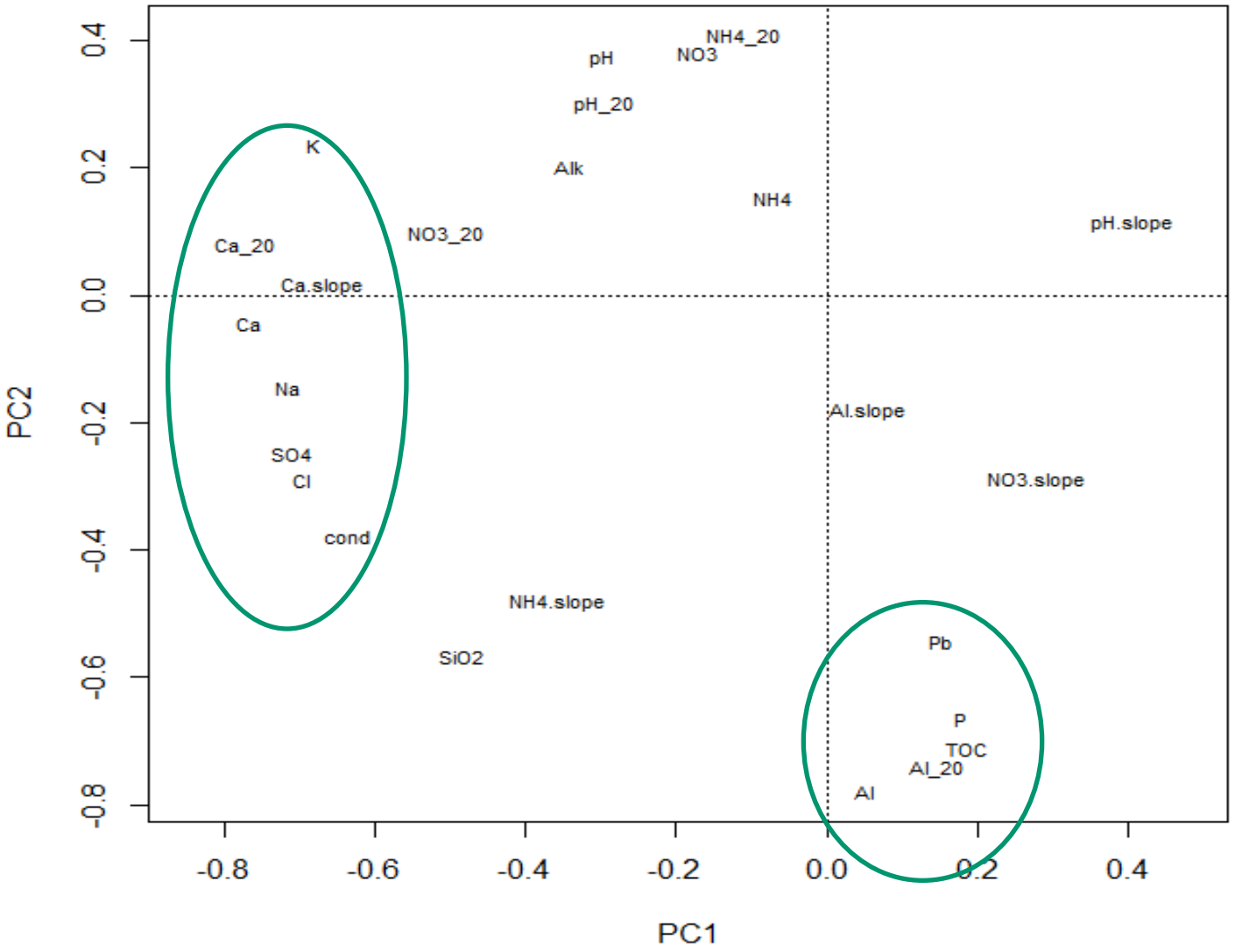
PIT – Periphyton Index of Trophic Status 3,95 (UDL) – 23,0 (LKV)

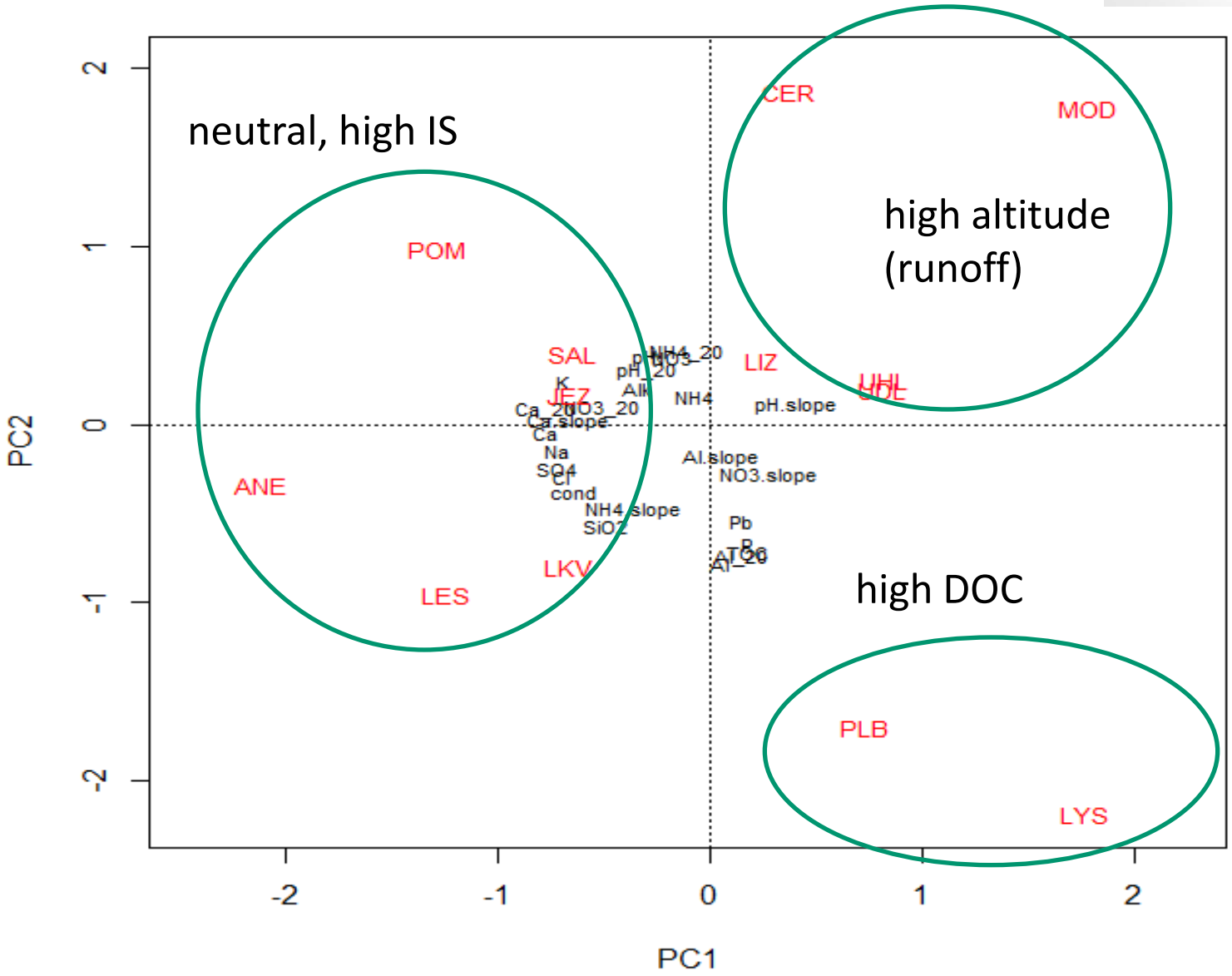
		PC1	PC2	PC3
	Eigenvalue	7,64	5,88	4,86
	Proportion Explained	0,31	0,24	0,19
	Cumulative Proportion	0,31	0,54	0,74
2015	pH	-0,30	0,37	-0,66
	Na	-0,71	-0,14	0,30
	K	-0,68	0,24	0,11
	NH4	-0,07	0,15	-0,16
	Ca	-0,77	-0,04	0,22
	Cl	-0,69	-0,29	0,02
	NO3	-0,17	0,38	-0,50
	SO4	-0,71	-0,25	0,19
	SiO2	-0,48	-0,57	-0,26
	Al	0,05	-0,78	-0,01
	Alk	-0,34	0,20	-0,70
	cond	-0,64	-0,38	-0,18
	DOC	0,19	-0,71	-0,23
	Pb	0,15	-0,54	-0,48
	P	0,18	-0,67	-0,13
1995-2014	pH_20	-0,29	0,30	-0,66
	pH.slope	0,40	0,11	0,08
	NH4_20	-0,11	0,41	-0,36
	NH4.slope	-0,36	-0,48	-0,35
	Ca_20	-0,77	0,08	0,28
	Ca.slope	-0,67	0,02	0,37
	NO3_20	-0,50	0,10	-0,31
	NO3.slope	0,28	-0,29	-0,27
	Al_20	0,15	-0,74	0,10
	Al.slope	0,06	-0,18	-0,70

Main component analysis – streamwater chemistry

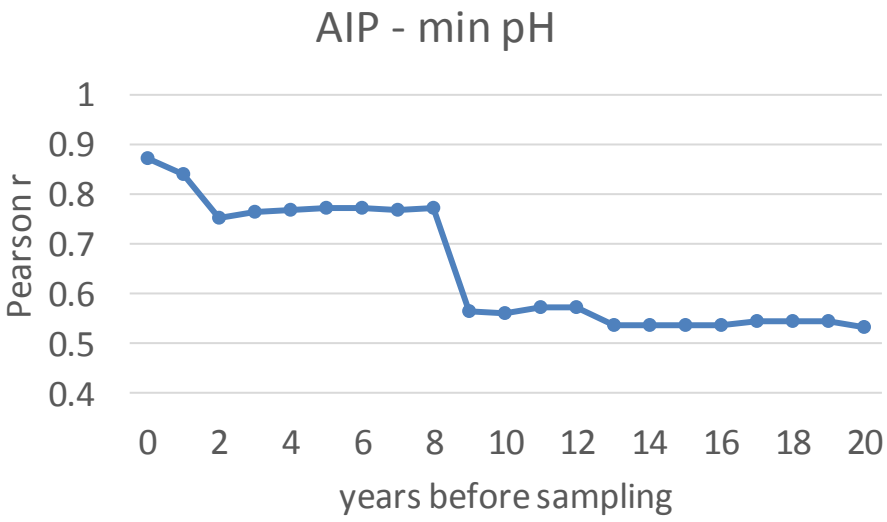
PC1 – ionic strenght
PC2 – DOC
PC3 – acidity

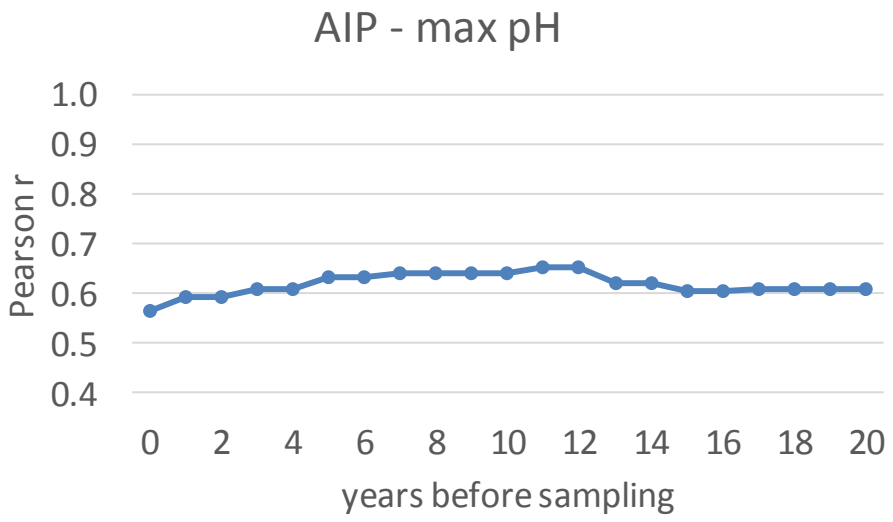
All together -74% of variability

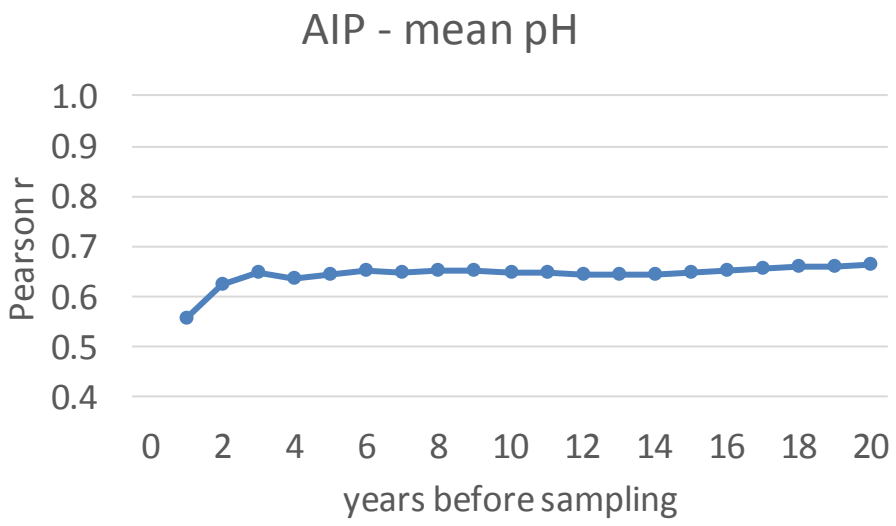

NH4_20
NO3
pH
pH_20
K
Alk
NH4
pH.slope
NO3_20
Ca_20
Ca.slope
Ca
Na
Al.slope
SO4
Cl
NO3.slope
cond
NH4.slope
SiO2
Pb
P
TOC
Al_20
Al
PC2
PC1
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4

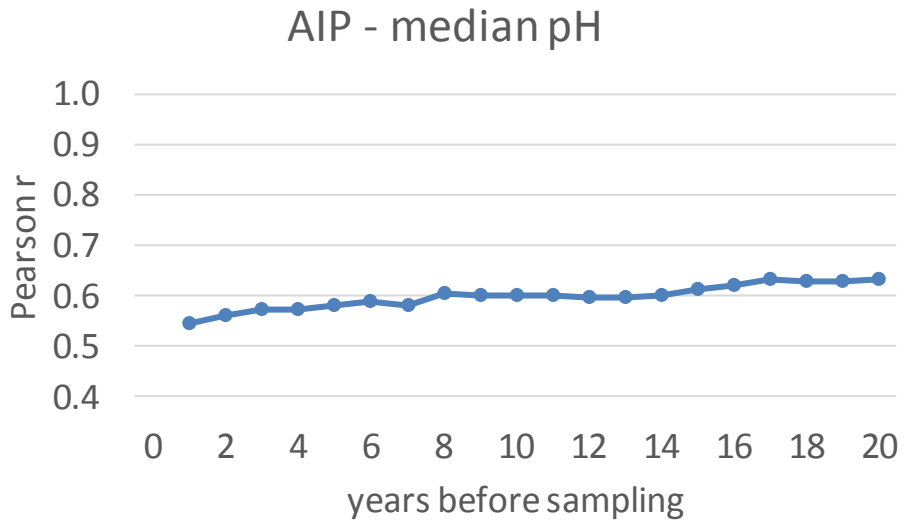

neutral, high IS
high altitude
(runoff)
high DOC
CER
MOD
POM
SAL
LIZ
JEZ
UHL
ANE
LES
LKV
PLB
LYS
NH4_20
pH_20
K
Alk
NH4
pH.slope
Ca_20
NO3_20
Ca.slope
Ca
Na
SO4
Cl
cond
NH4.slope
SiO2
Al.slope
NO3.slope
Pb
Al_20
PC1
PC2
-2
-1
0
1
2

Correlation coefficients (Pearson r) between AIP (acidification index periphyton) of algal assemblages and pH, calculated for the time intervals before the algal sampling



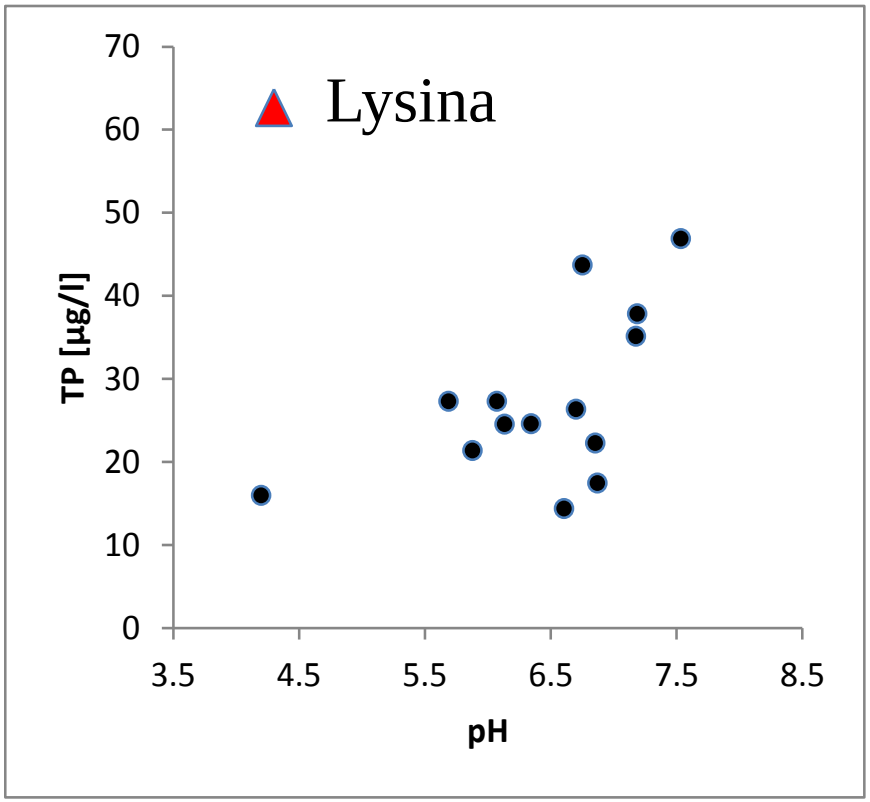


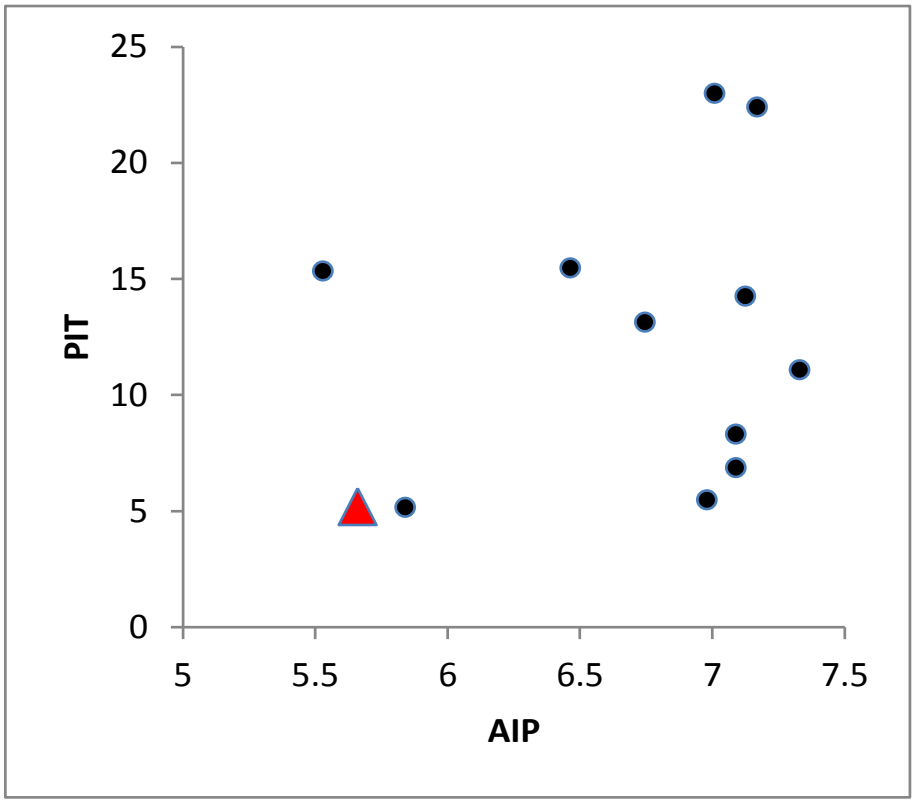




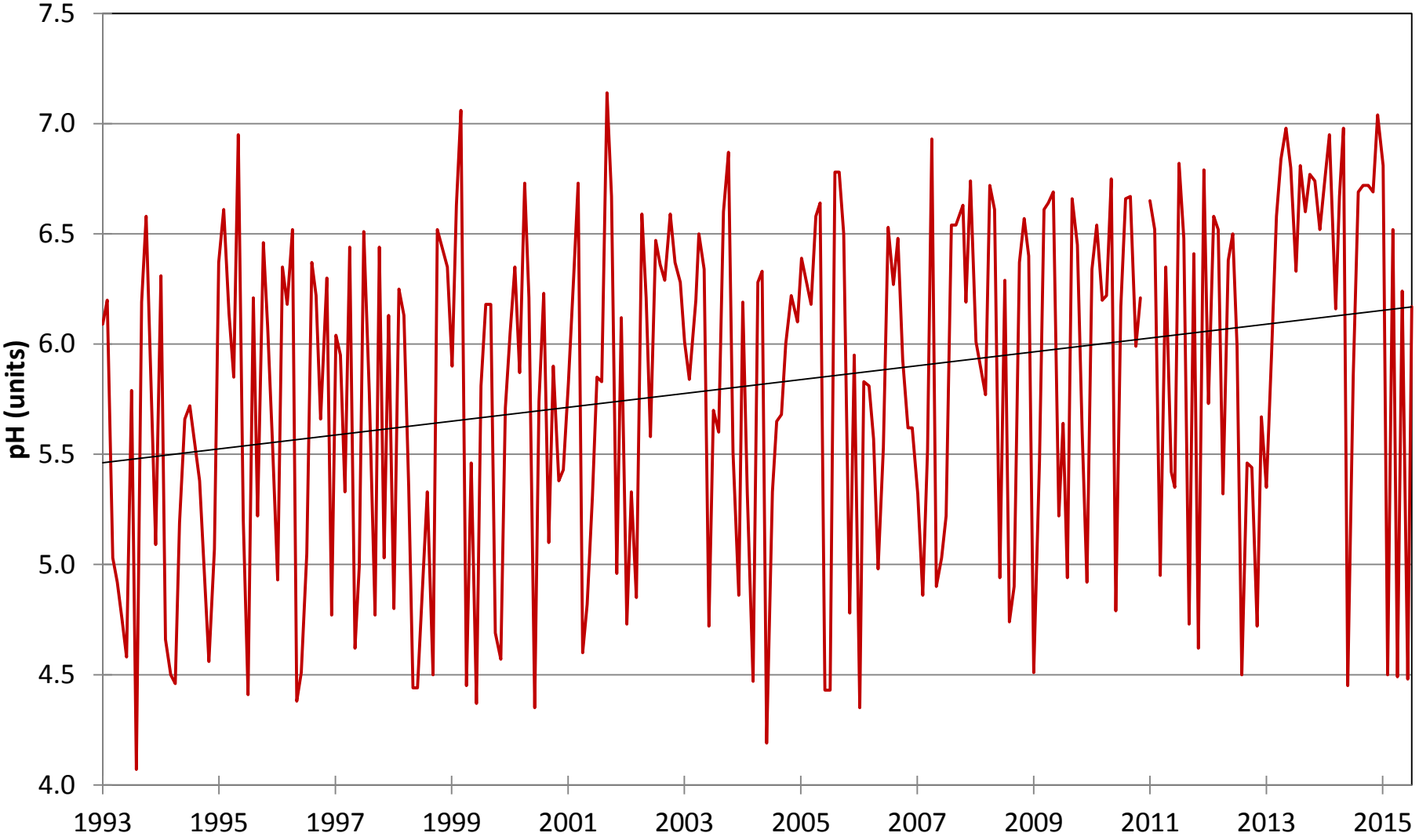
		AIP	PIT	taxon richness cyano-bacteria	taxon richness green algae	total algal taxon richness
catchment characteristics	catchment area	-0,03	0,39	0,05	0,25	0,37
	mean elevation	-0,18	0,04	0,37	0,27	0,46
	min_elevation	-0,31	-0,17	0,35	0,25	0,42
	max_elevation	-0,08	0,17	0,35	0,25	0,46
	Avg Temp	0,28	0,05	-0,41	-0,30	-0,50
	forested area	0,03	0,20	0,10	0,31	0,40
	longitude (X_WGS)	0,28	0,20	0,45	0,24	**0,64**
	latitude (Y_WGS)	-0,50	-0,16	0,11	0,25	0,32
2015	pH	**0,75**	0,13	**0,66**	**-0,66**	-0,08
	Na	0,36	0,39	-0,29	**-0,52**	**-0,57**
	K	0,48	0,11	0,07	-0,35	-0,18
	NH4	-0,50	0,13	-0,05	0,15	0,19
	Ca	0,50	0,40	-0,25	-0,44	-0,45
	Cl	0,40	-0,05	-0,32	-0,48	**-0,66**
	NO3	0,35	-0,08	**0,64**	-0,44	0,06
	SO4	0,22	0,29	**-0,52**	-0,25	-0,51
	SiO2	0,33	0,02	-0,15	**-0,72**	**-0,77**
	Al	**-0,65**	-0,45	**-0,59**	0,22	-0,32
	Alk	**0,66**	0,16	**0,56**	**-0,67**	-0,17
	cond	0,43	0,09	-0,26	-0,51	**-0,62**
	DOC	-0,33	**-0,55**	-0,24	0,04	-0,28
	Pb	-0,47	-0,43	0,04	-0,09	-0,16
	P	-0,14	-0,43	-0,08	-0,14	-0,31
1995-2014	pH_20	**0,79**	-0,06	**0,61**	-0,55	-0,06
	pH.slope	-0,34	0,11	-0,02	0,34	0,28
	NH4_20	0,28	-0,14	**0,61**	-0,18	0,32
	NH4.slope	0,24	-0,19	-0,19	**-0,61**	**-0,66**
	Ca_20	0,37	0,37	-0,41	-0,26	-0,35
	Ca.slope	0,05	0,02	-0,40	-0,10	-0,28
	NO3_20	0,29	-0,29	0,25	-0,42	-0,19
	NO3.slope	0,15	0,12	-0,02	-0,08	-0,16
	Al_20	**-0,63**	-0,35	-0,54	0,04	-0,40
	Al.slope	0,38	-0,20	0,40	-0,41	-0,15
PCA	PC1	-0,56	-0,15	0,25	0,51	0,49
	PC2	0,39	0,30	**0,57**	0,11	**0,56**
	PC3	-0,39	0,33	**-0,62**	0,51	0,08

Stream chemistry, PIT (nutrient) and AIP (acidification) indices





Uhlířská (ICP Waters) - lowest AIP



Conclusions

- acidification more important that eutrophication
- episodes more important than long-term averages
- expected results, but not much documented

Schneider et al. (in review, Hydrobiologia)