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pH controls phenol oxidase and DOC leaching from global peatland

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DOC increases & Peatlands

- Increases in DOC (Dissolved Organic Carbon) concentrations in rivers and lakes have been noted in Europe, North America, Eastern Asia
- Mechanisms
  - Global climate change
    - Warming
    - Drought and flushing
    - Elevated CO_2
  - Land use change
  - Recovery from acidification

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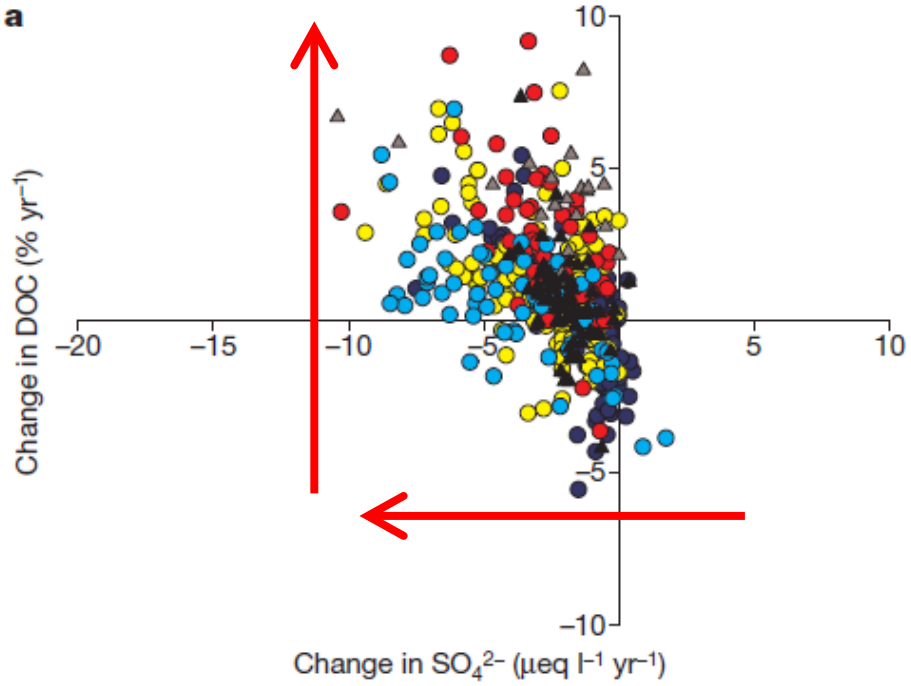
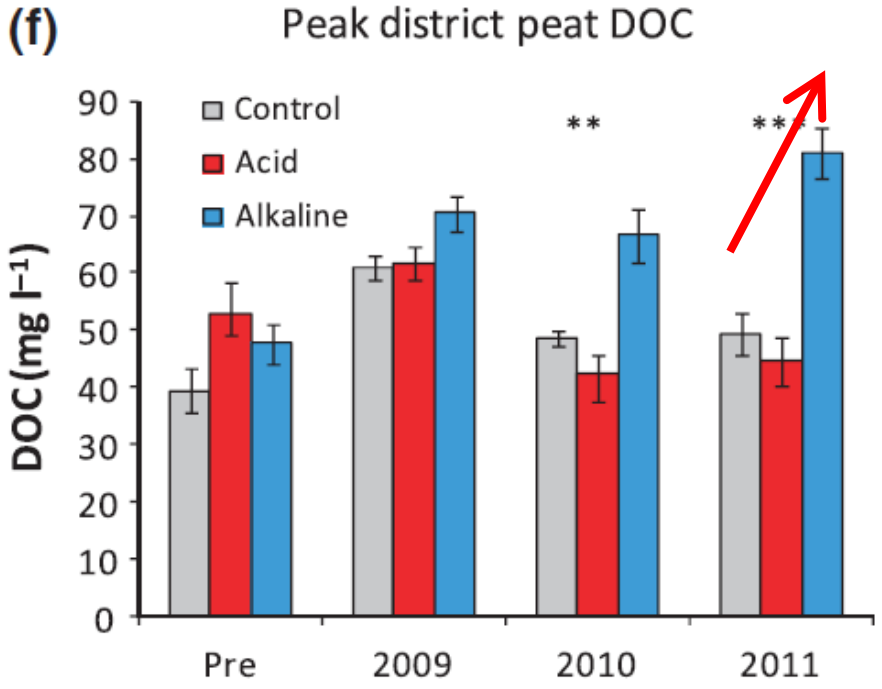
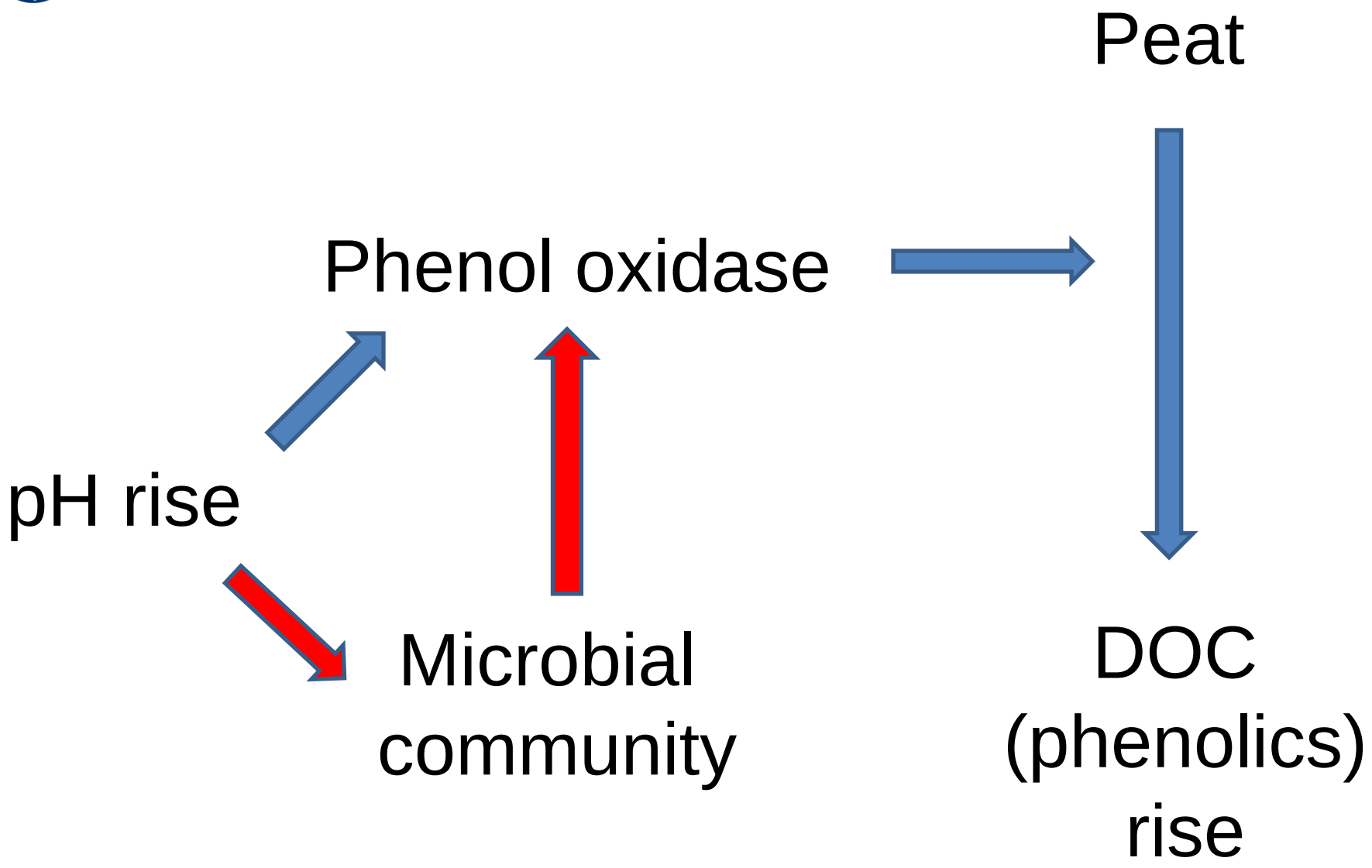
Acidification recovery

- Monteith *et al.* (2007)
- Evans *et al.* (2012)





All chemical reactions


Peat
Phenol oxidase
pH rise
Microbial community
DOC (phenolics) rise

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Methods

- Field monitoring
  - 7 peatlands in Korea, UK, Japan, Indonesia
- Manipulation experiments
  - 2 peatlands in UK (long-term)
  - 1 in Korea (short-term)
- Enzyme addition & knock-out
- Measurements
  - Phenol oxidase, hydrolases
  - NGS, real time qPCR

Field Survey

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Site description

	Yong	Odae	Mujechi	Tadewara	Kalimantan	Migneint	Peaknaze
Location	38°21′ N 128°13′ E	37°80′ N 128°54′ E	35°26′ N 129°8′ E	32°39′ N 131°29′ E	1°88′ S 113°53′ E	52°96′ N 3°82′ W	53°47′ N 1°92′ W
MAT (°C)	14.4	7.4	10.5	8.0	27.5	8.6	8.0
ppt (mm)	1,176	2,100	1,155	2,700	2,765	2,200	1,000
OM (%)	51.0 ± 25.9	62.5 ± 14.6	41.0 ± 19.5	91.4 ± 1.6	88.2 ± 2.8	96.8 ± 1.4	92.0 ± 2.6
pH	5.41 ± 0.23	5.94 ± 0.25	4.97 ± 0.47	5.17 ± 0.14	4.45 ± 0.09	4.32 ± 0.13	3.95 ± 0.15
DOC (mg L^{-1})	8.30 ± 4.06	5.98 ± 4.51	6.78 ± 4.18	2.30 ± 0.21	39.79 ± 1.00	26.36 ± 9.59	53.20 ± 3.76
Phenolics (mg L^{-1})	1.84 ± 1.54	2.14 ± 0.97	0.82 ± 1.26	2.10 ± 0.12	5.19 ± 1.74	5.31 ± 2.32	8.04 ± 3.99

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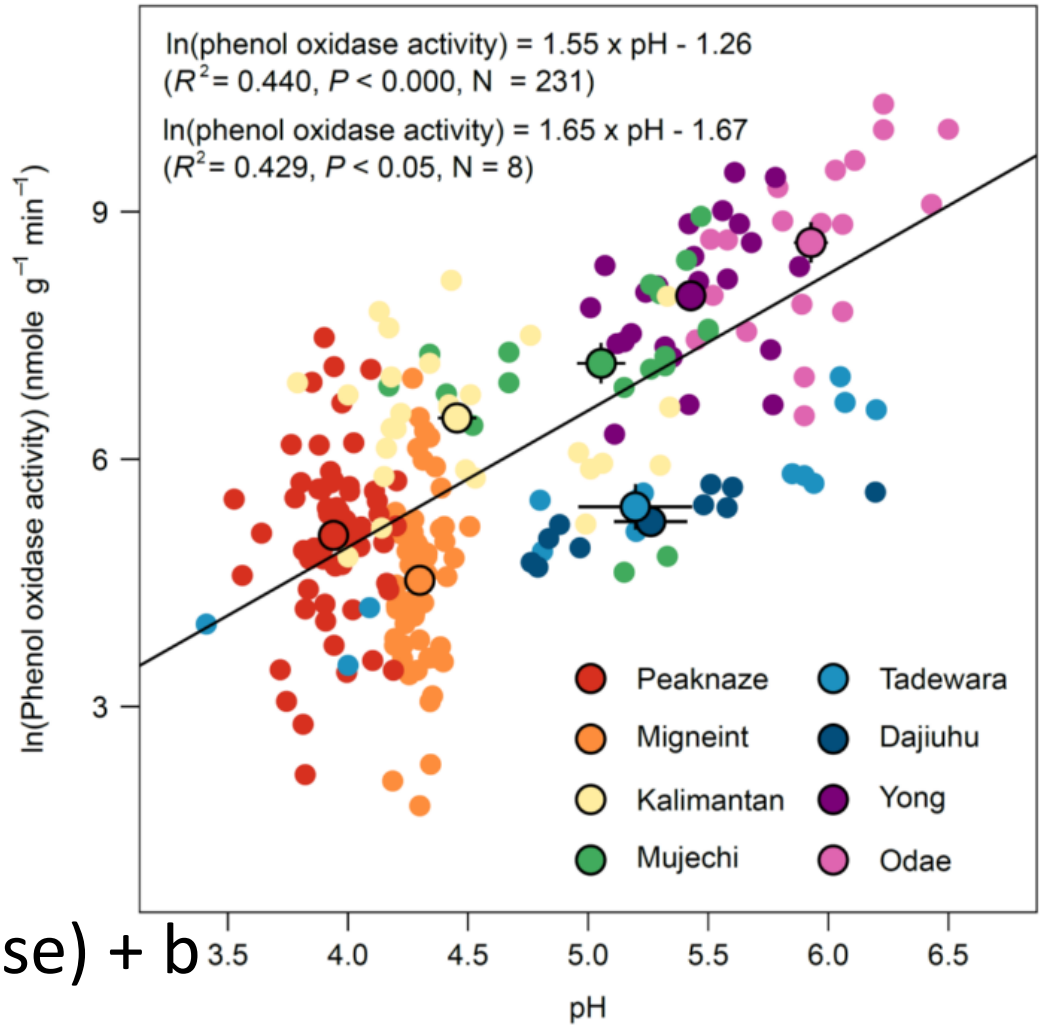
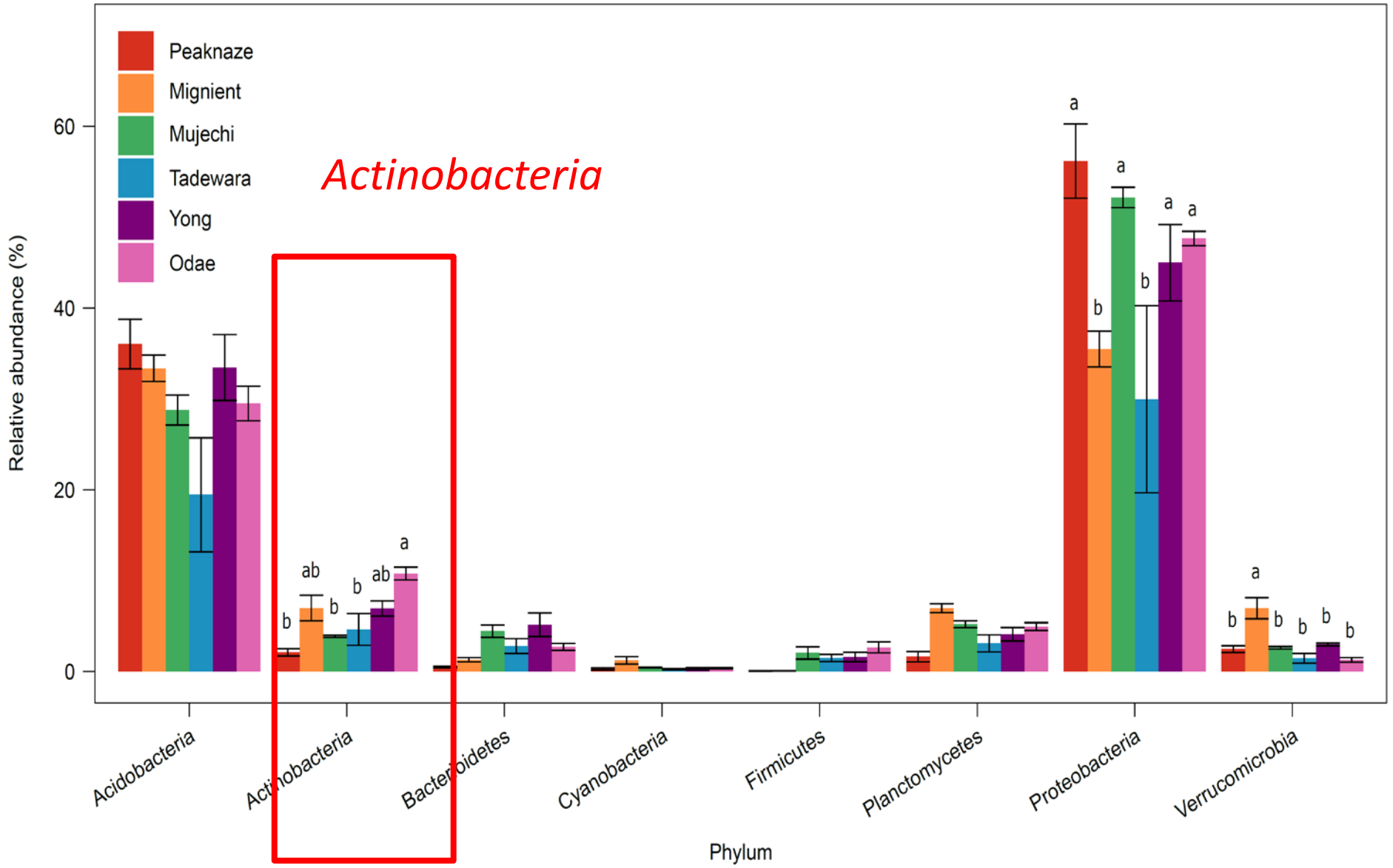
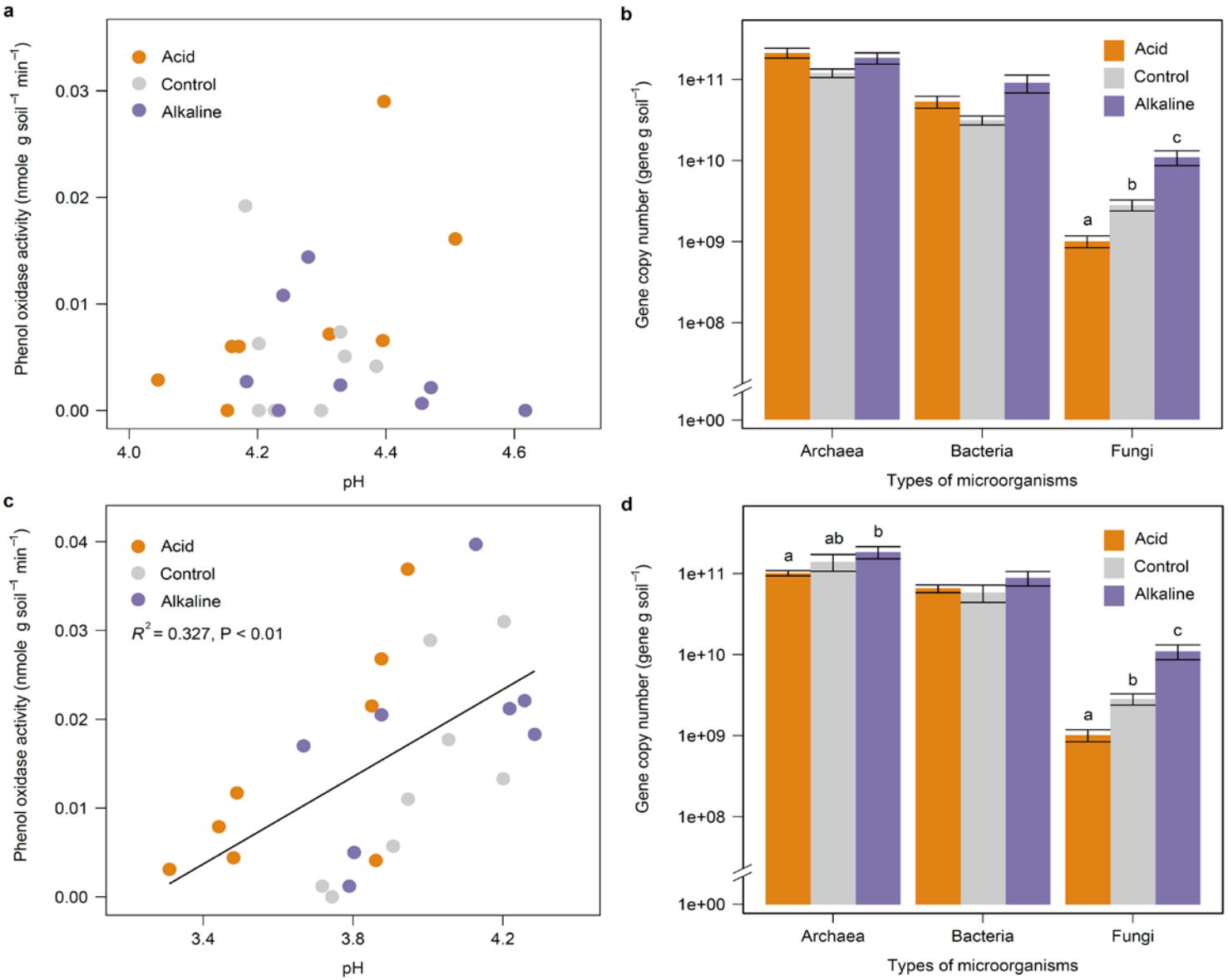


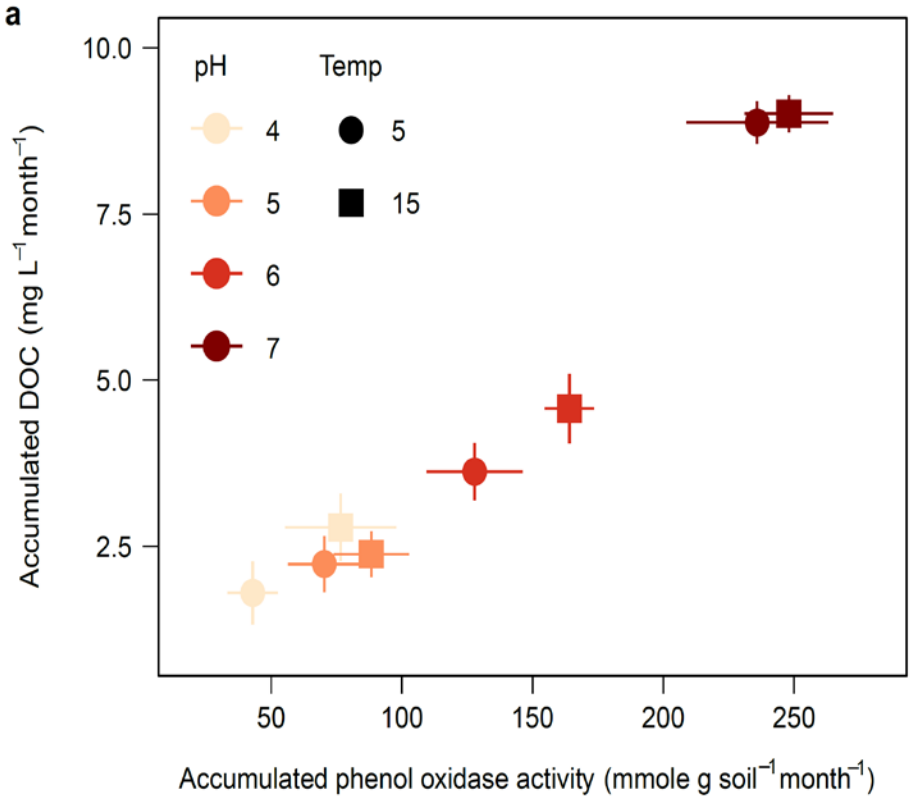
Phenolics = a·(phenol oxidase) + b

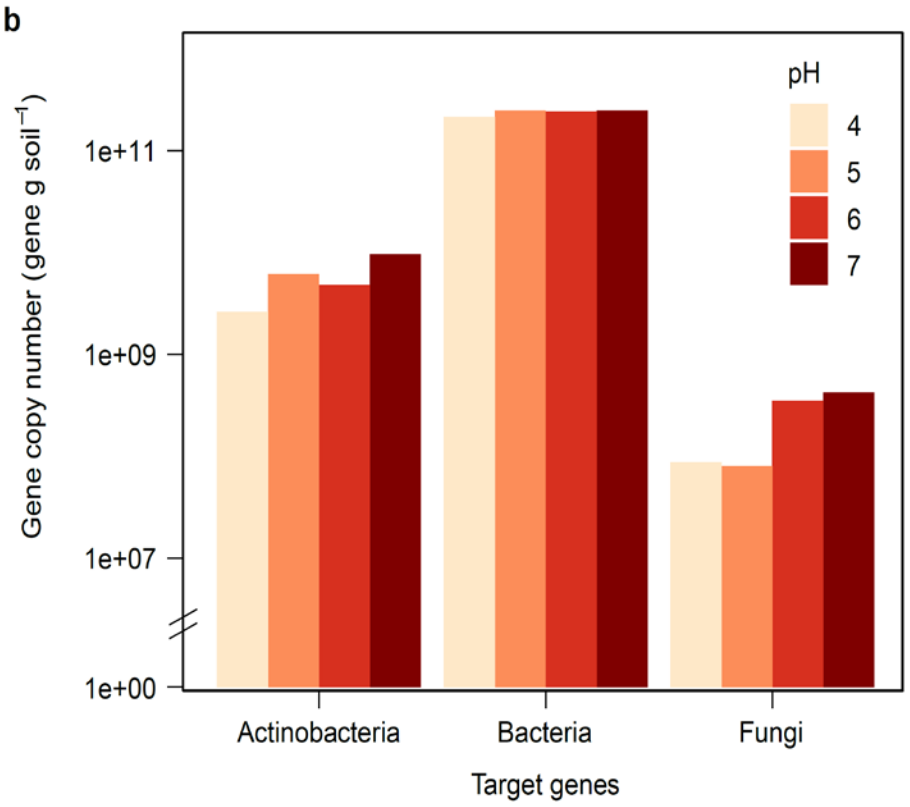
	Odae	Yong	Mujechi	Tadewara	Kalimantan	Migneint	Peaknaze
R^2	0.206	0.129	0.149	0.339	0.142	0.096	0.064
a	2.691	1.887	0.233	0.231	0.027	0.091	0.100
P value	0.023	0.092	0.084	0.023	0.040	0.007	0.028
N	24	22	20	15	30	76	76


Peaknaze
Mignient
Mujechi
Tadewara
Yong
Odae
Actinobacteria
Relative abundance (%)
0
20
40
60
Acidobacteria
Actinobacteria
Bacteroidetes
Cyanobacteria
Firmicutes
Planctomycetes
Proteobacteria
Verrucomicrobia
Phylum

pH manipulation experiments

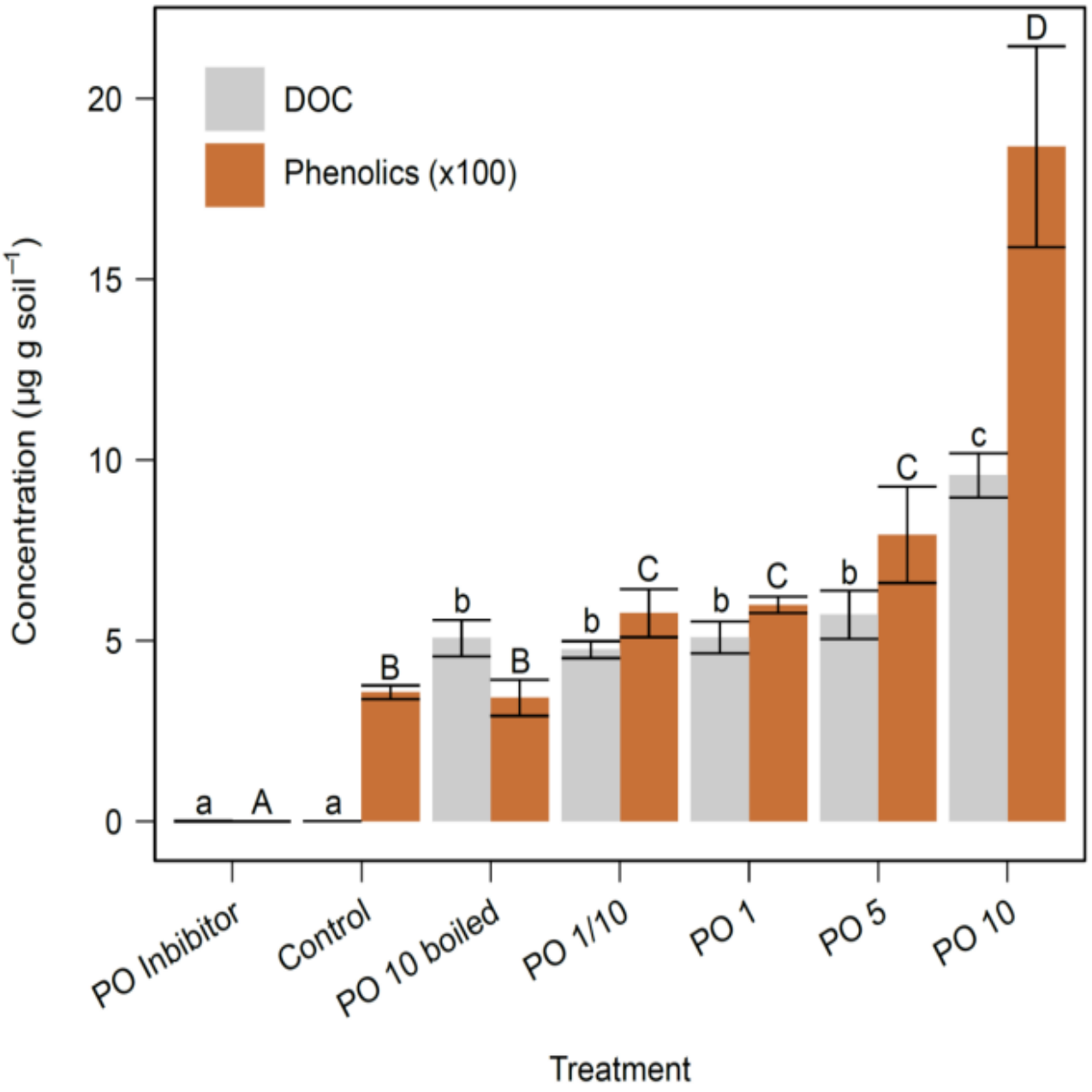

a
Phenol oxidase activity (nmole g soil^{-1} min^{-1})
0.00
0.01
0.02
0.03
4.0
4.2
4.4
4.6
pH
Acid
Control
Alkaline
b
Gene copy number (gene g soil^{-1})
1e+00
1e+08
1e+09
1e+10
1e+11
a
b
c
Archaea
Bacteria
Fungi
Types of microorganisms
Acid
Control
Alkaline
c
Phenol oxidase activity (nmole g soil^{-1} min^{-1})
0.00
0.01
0.02
0.03
0.04
3.4
3.8
4.2
pH
Acid
Control
Alkaline
R^2 = 0.327, P < 0.01
d
Gene copy number (gene g soil^{-1})
1e+00
1e+08
1e+09
1e+10
1e+11
a
ab
b
a
b
c
Archaea
Bacteria
Fungi
Types of microorganisms
Acid
Control
Alkaline


a
pH
Temp
4
5
6
7
5
15
10.0
7.5
5.0
2.5
50
100
150
200
250
Accumulated DOC (mg L^{-1} month^{-1})
Accumulated phenol oxidase activity (mmole g soil^{-1} month^{-1})


b
pH
4
5
6
7
1e+11
1e+09
1e+07
1e+00
Gene copy number (gene g soil^{-1})
Actinobacteria
Bacteria
Fungi
Target genes

Enzyme addition/knock-out

- Enzyme: Purified phenol oxidase from almond
- Inhibitor: Sodium diethyldithiocarbamate
- Incubations: 8 hours at 15°C
- Design
  - Inhibitor, water only, boiled-enzyme, 3 levels of enzymes


DOC
Phenolics (x100)
Concentration (µg g soil^{-1})
0
5
10
15
20
a
A
a
B
b
B
b
C
b
C
b
C
c
D
PO Inbibitor
Control
PO 10 boiled
PO 1/10
PO 1
PO 5
PO 10
Treatment

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Conclusions

- Higher pH is associated with higher phenol oxidase, DOC/phenolic leaching in the field observation and manipulation experiments
- This is accompanied by greater abundances of fungi and *Actinobacteria* in the long-term
- Changes in acid deposition will continue to affect DOC leaching from peatland

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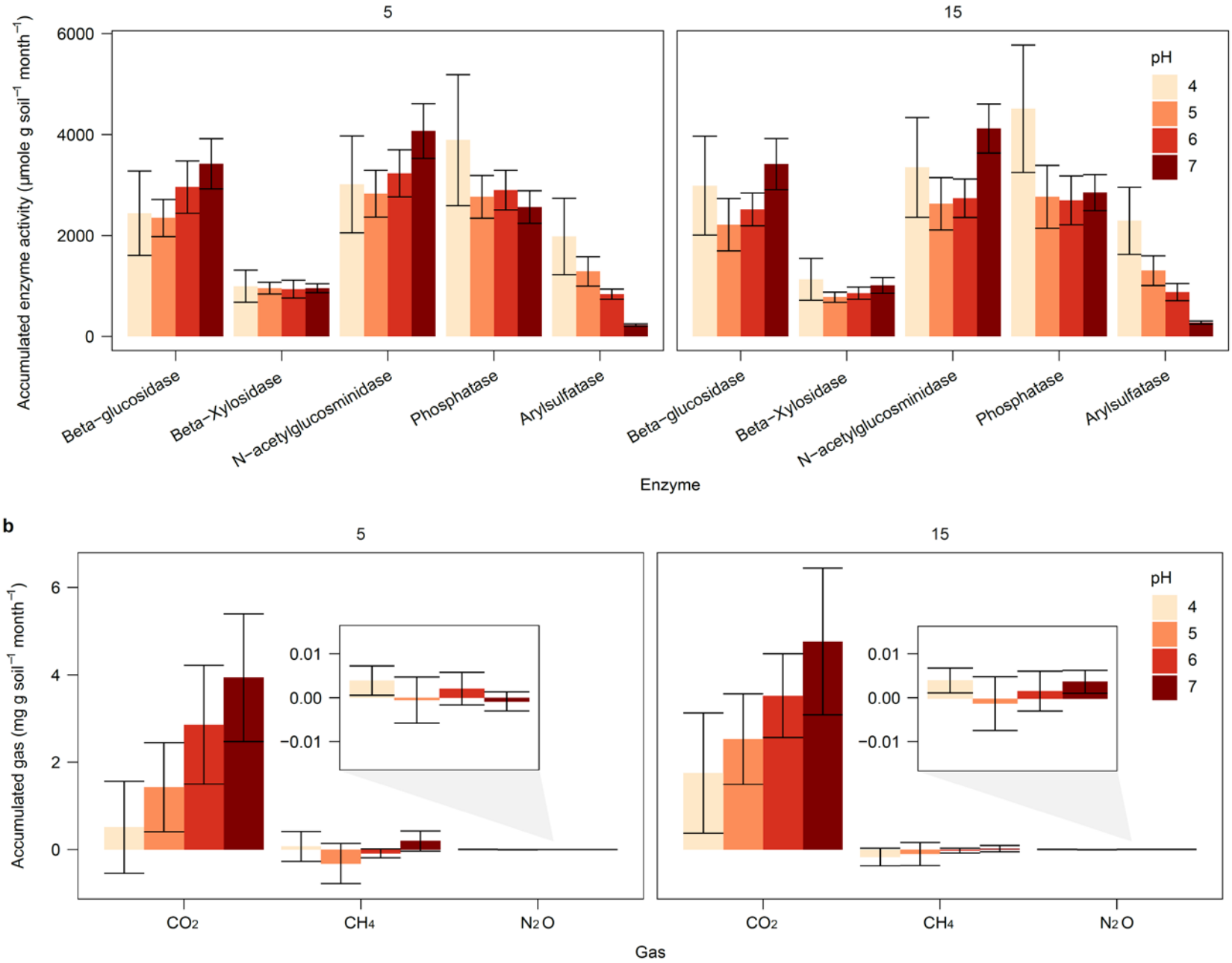
5
15
Accumulated enzyme activity (μmole g soil^{-1} month^{-1})
6000
4000
2000
0
pH
4
5
6
7
Beta−glucosidase
Beta−Xylosidase
N−acetylglucosminidase
Phosphatase
Arylsulfatase
Enzyme
b
Accumulated gas (mg g soil^{-1} month^{-1})
6
4
2
0
0.01
0.00
−0.01
CO_2
CH_4
N_2O
Gas