Below-ground N responses to warming in cold ecosystems: a meta-analysis

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University, of Iceland

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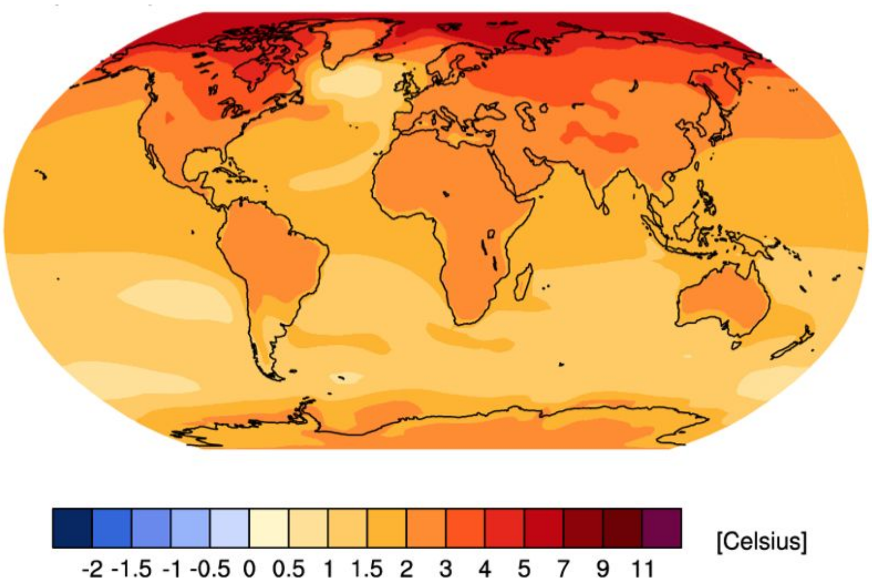
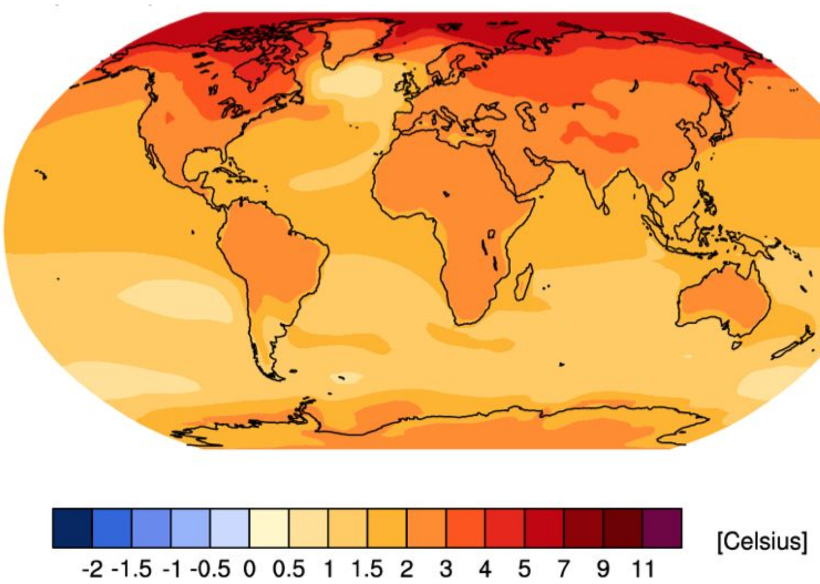
University, of Iceland

Warming in high latitudes: above global average



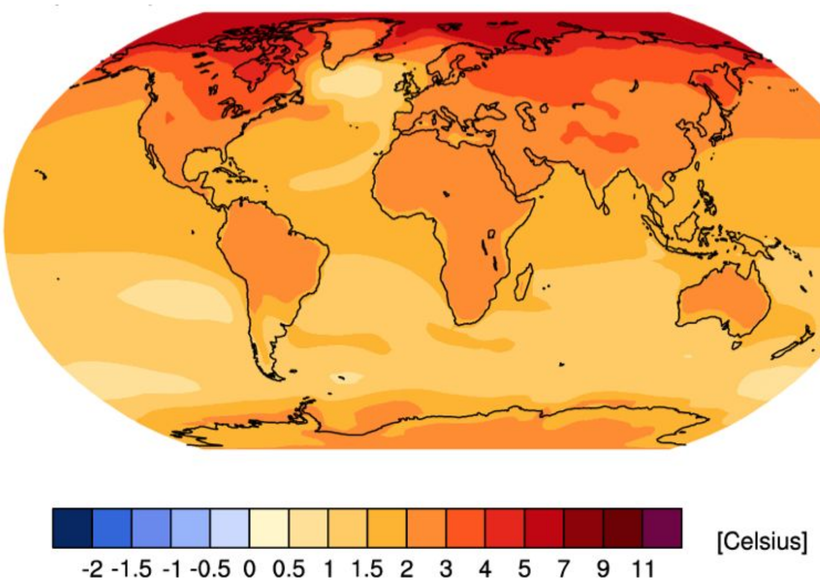
Mean annual temperature 2080-2100 minus 1980-2000 (RCP 4.5; IPCC, 2013)

Consequences?

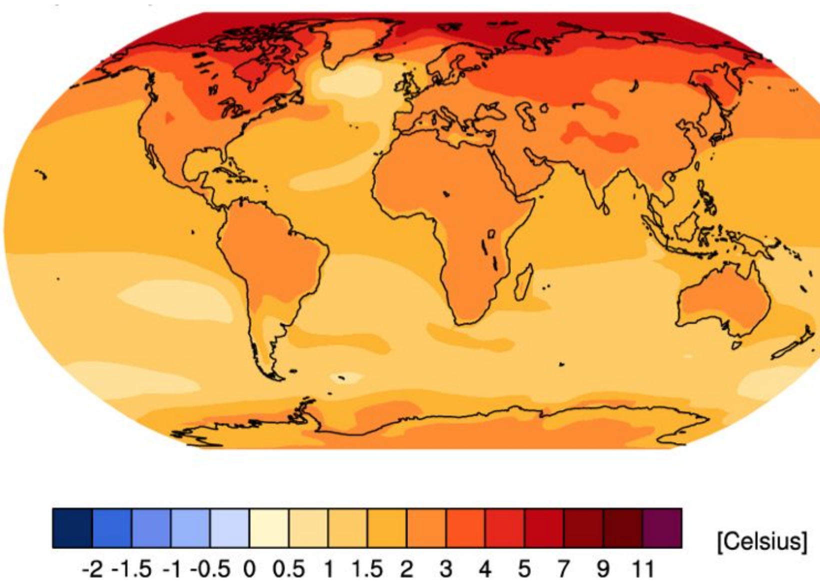


Most meta-analyses focused on above-ground processes and C cycling...
for good reasons!

Responses of below-ground N to warming?

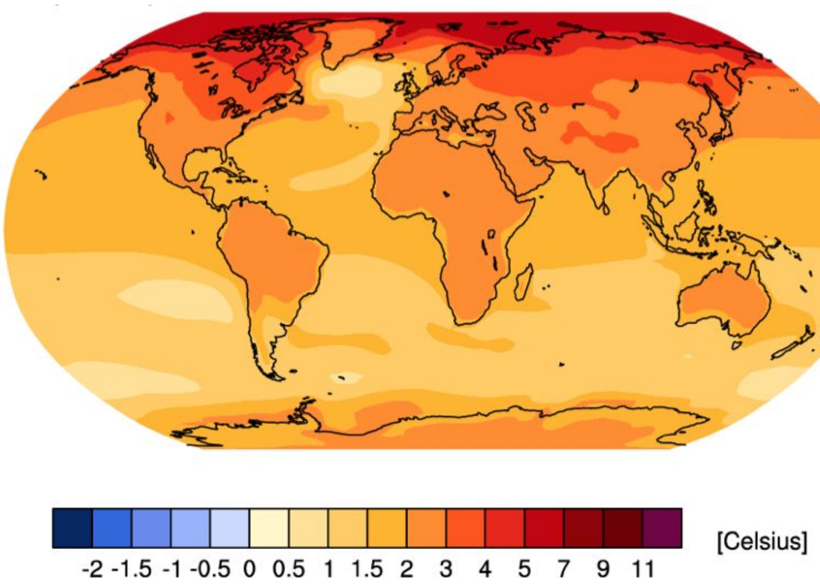


Responses of below-ground N to warming?



Net accumulation, depletion or no change?

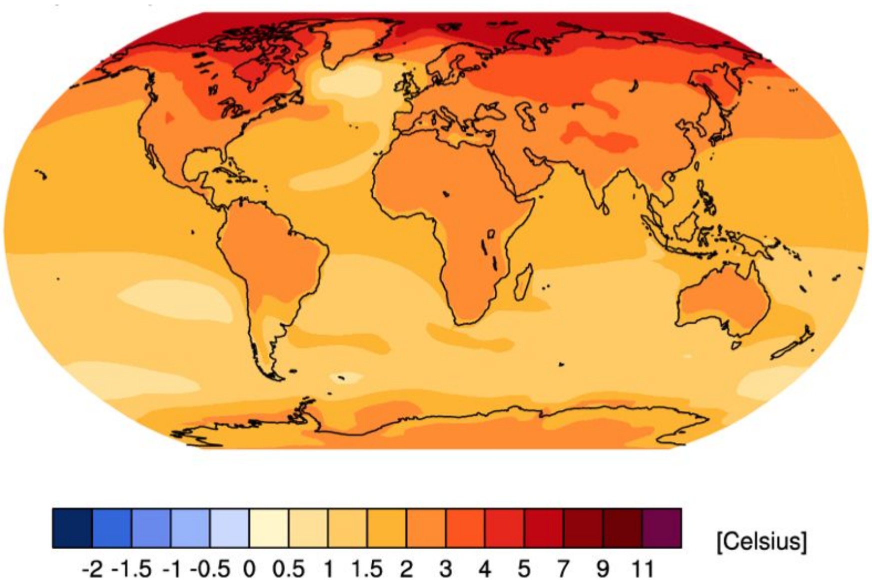
Responses of below-ground N to warming?



Net accumulation, depletion or no change?

Changes in the relative abundance of different N forms (NH_4^+ & NO_3^-)?

Responses of below-ground N to warming?



Net accumulation, depletion or no change?

Changes in the relative abundance of different N forms (NH_4^+ & NO_3^-)?

If there are global responses of below-ground N to warming, consequences for life? who is winning and who is losing?

Hypothesis

Warming in “cold ecosystems”

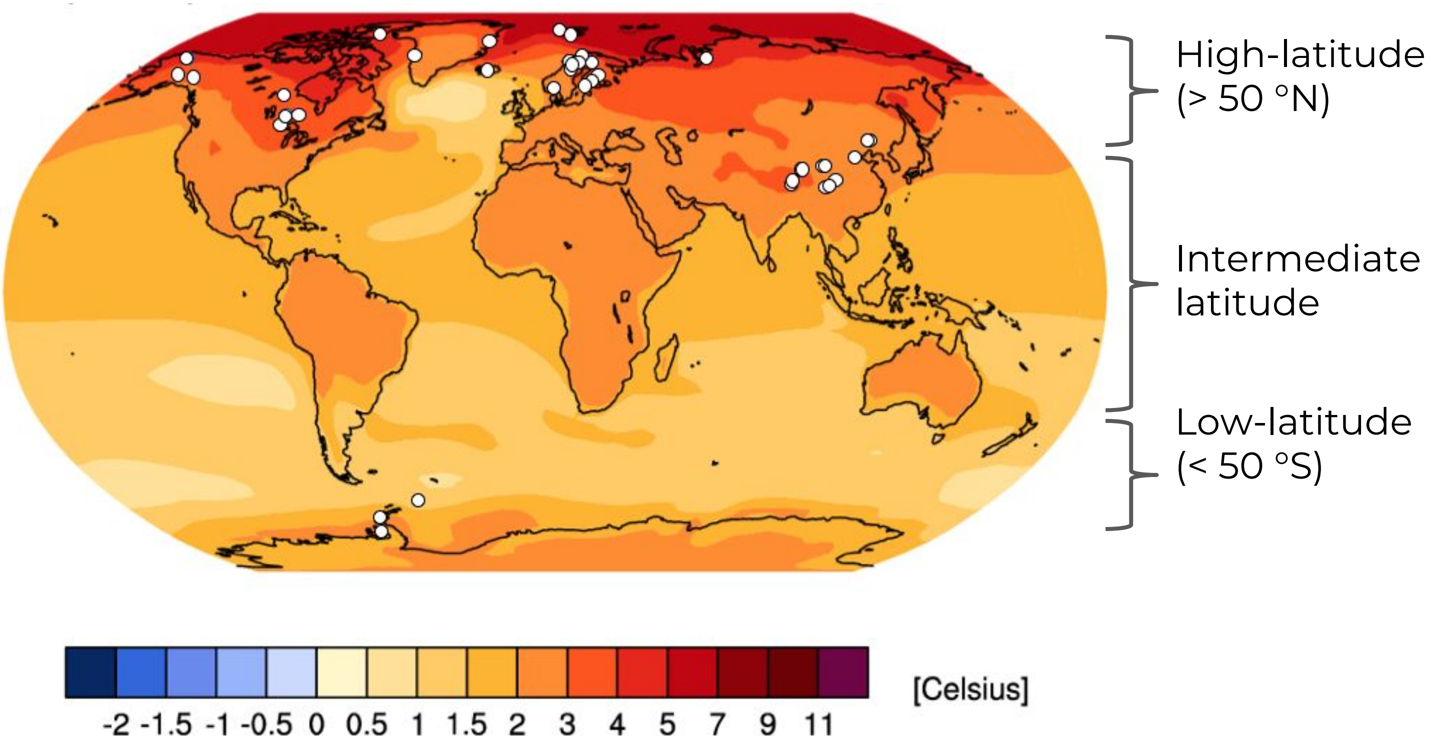
↳ Accelerate fluxes of N below-ground

↳ More N available for living organisms

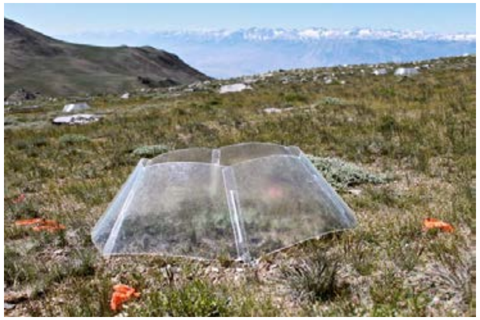
↳ Increase below-ground biomass (winners and losers)

A meta-analysis of field warming experiments in cold ecosystems

(mean annual temperature ≤ 5 °C)

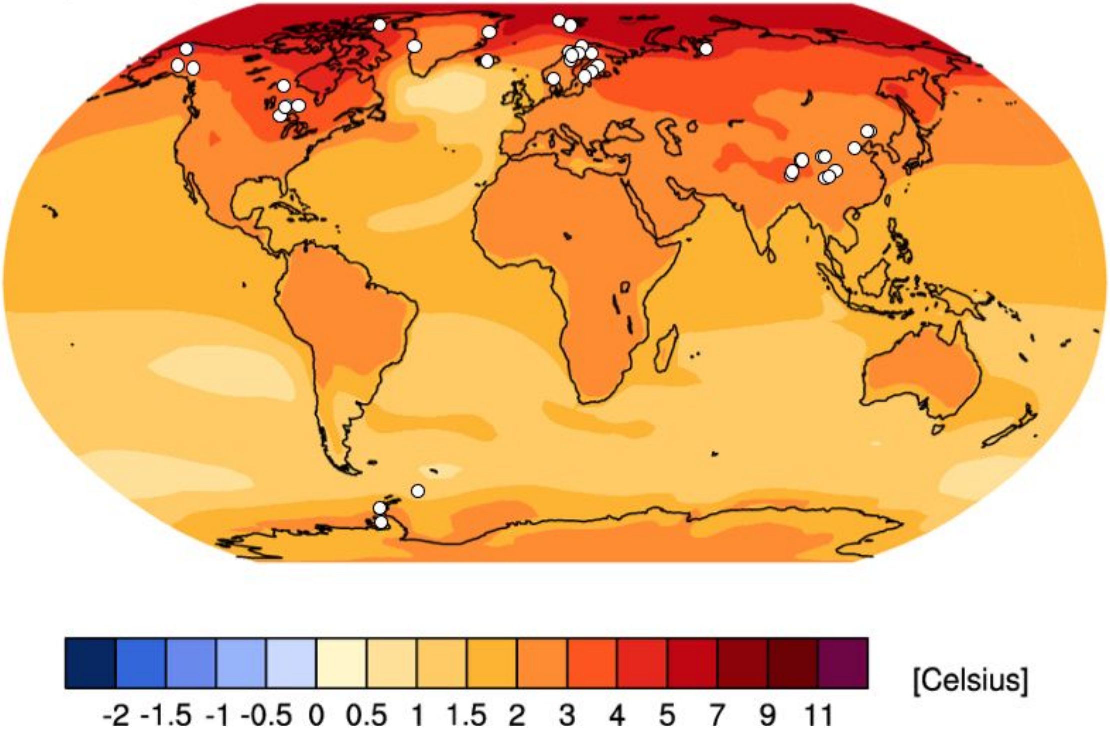


Methods for experimental warming



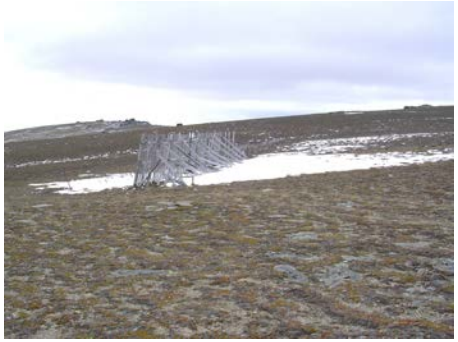
Open Top Chamber (OTC)

Heating cables



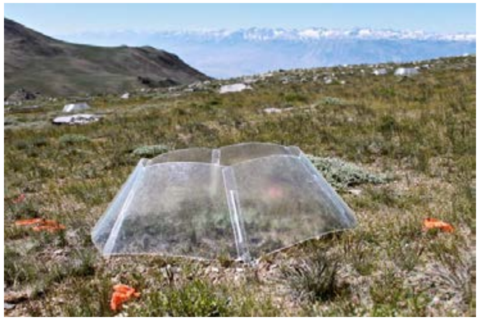
Infrared heaters

Snow fences



Total number of studies:

76



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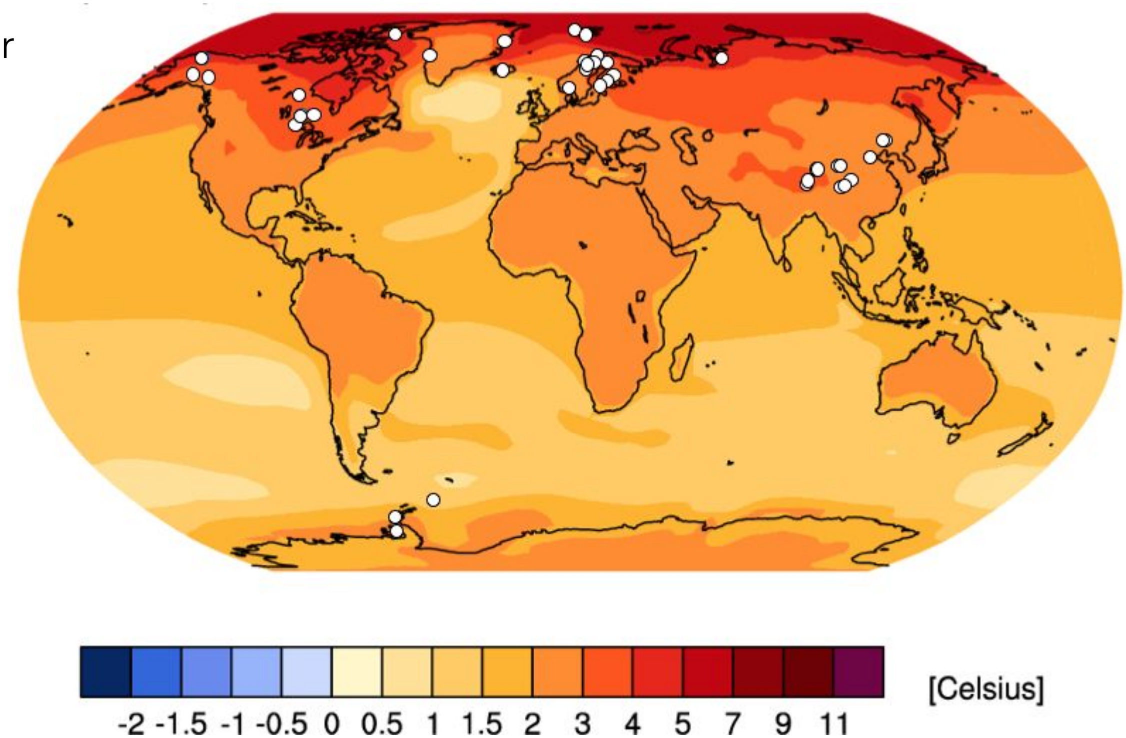

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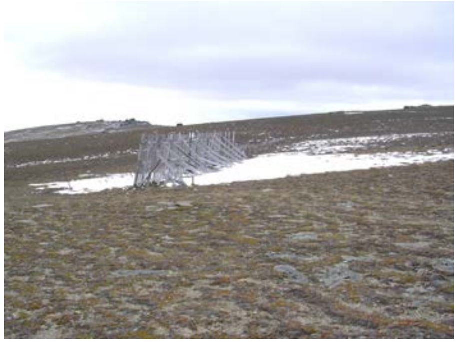
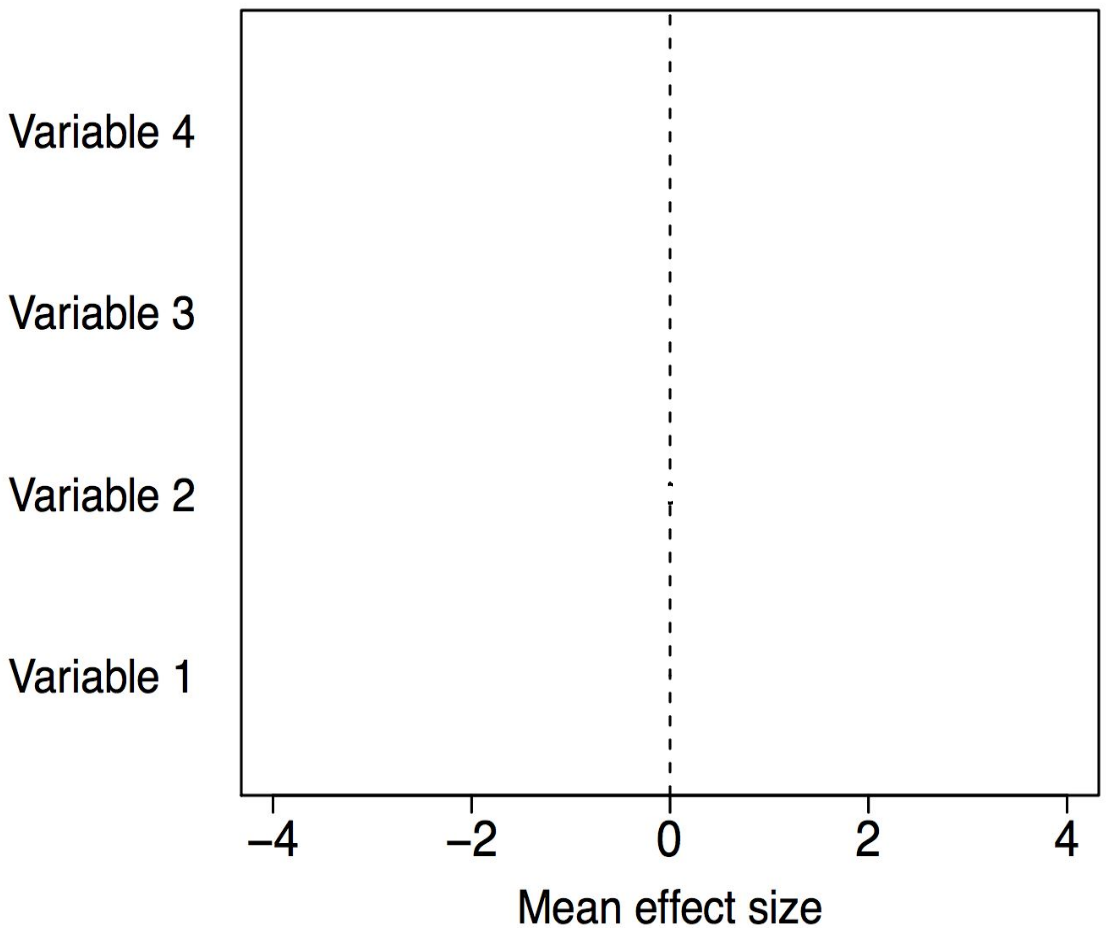


Interpretation of results from meta-analysis



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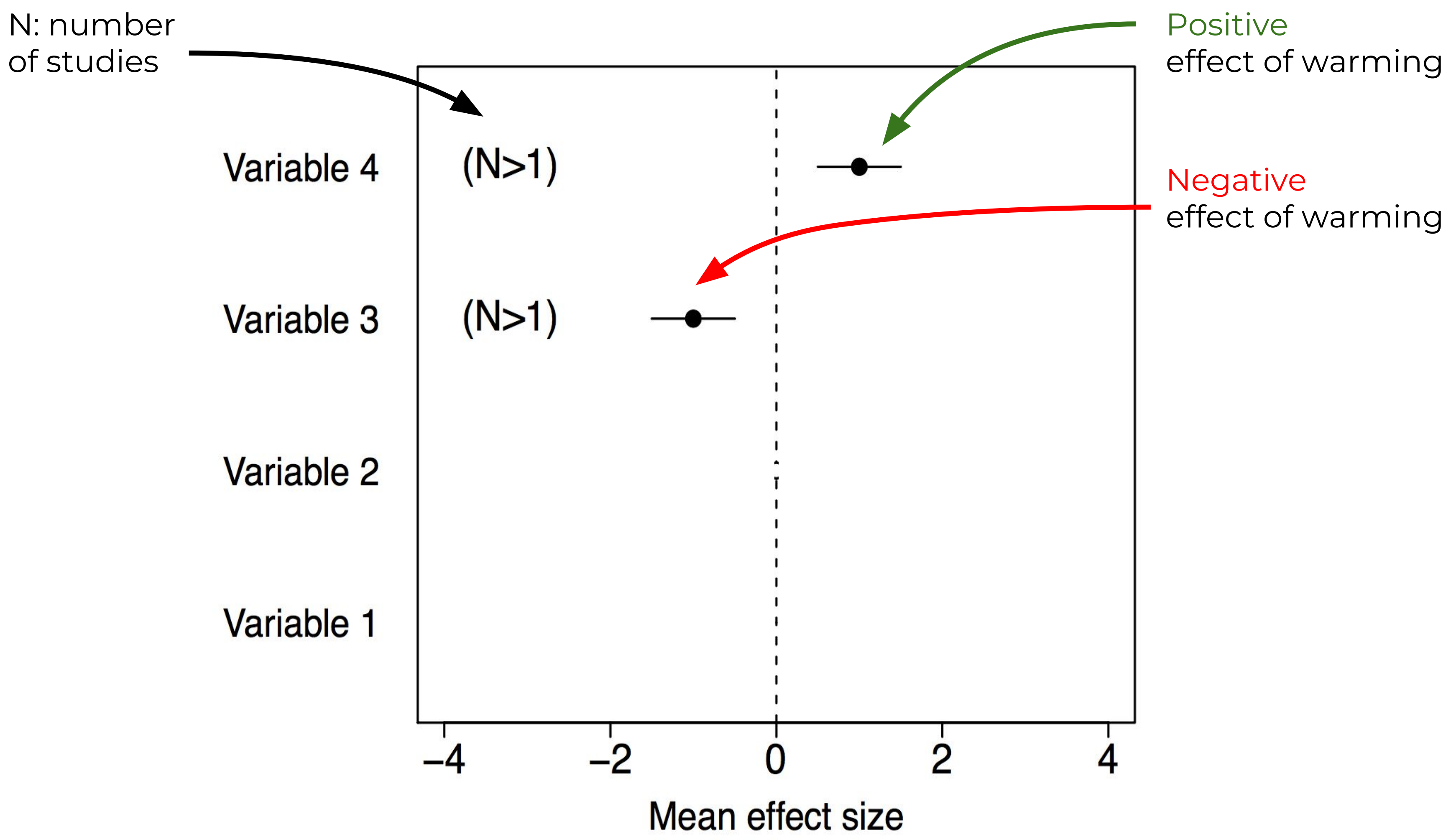

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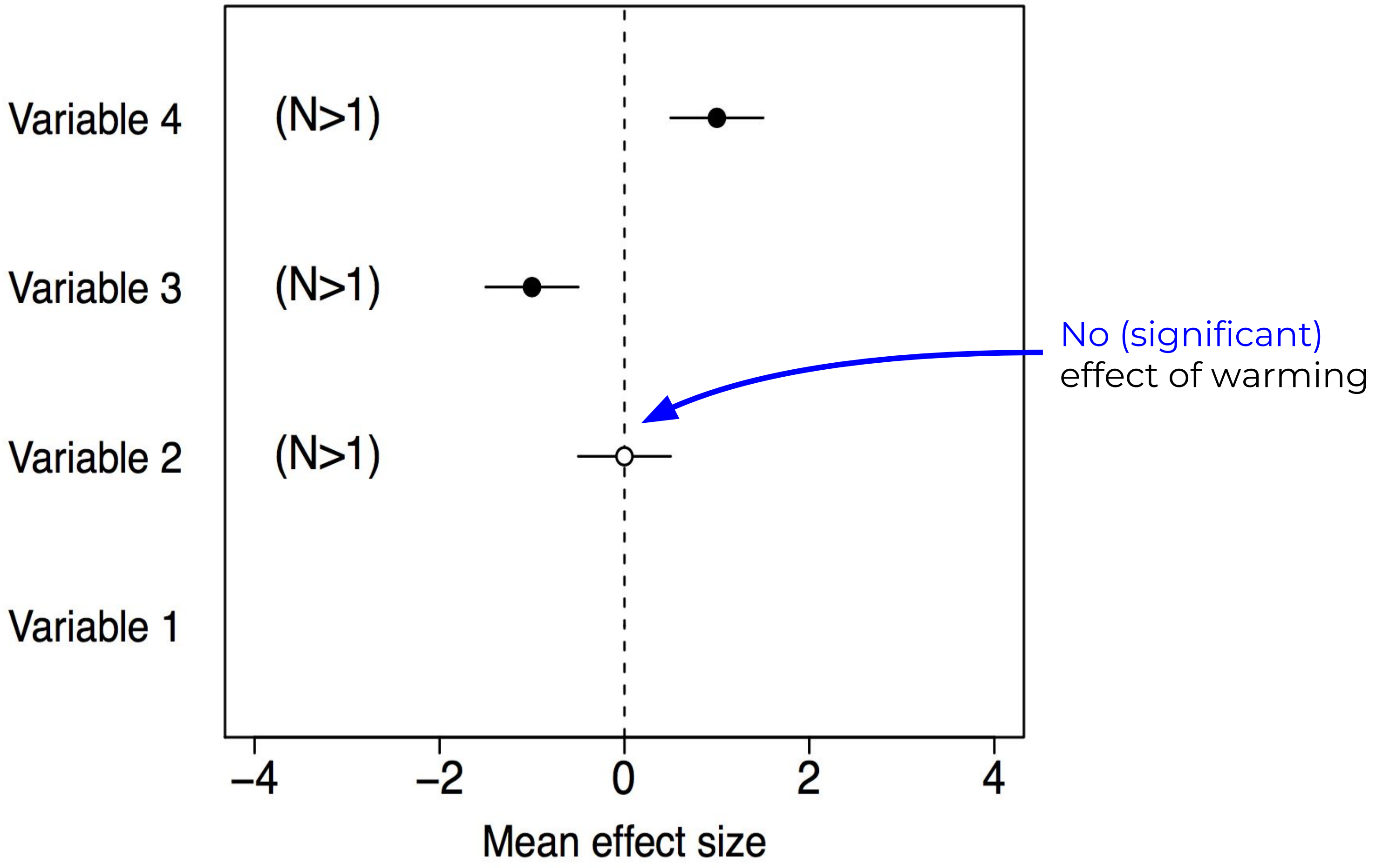

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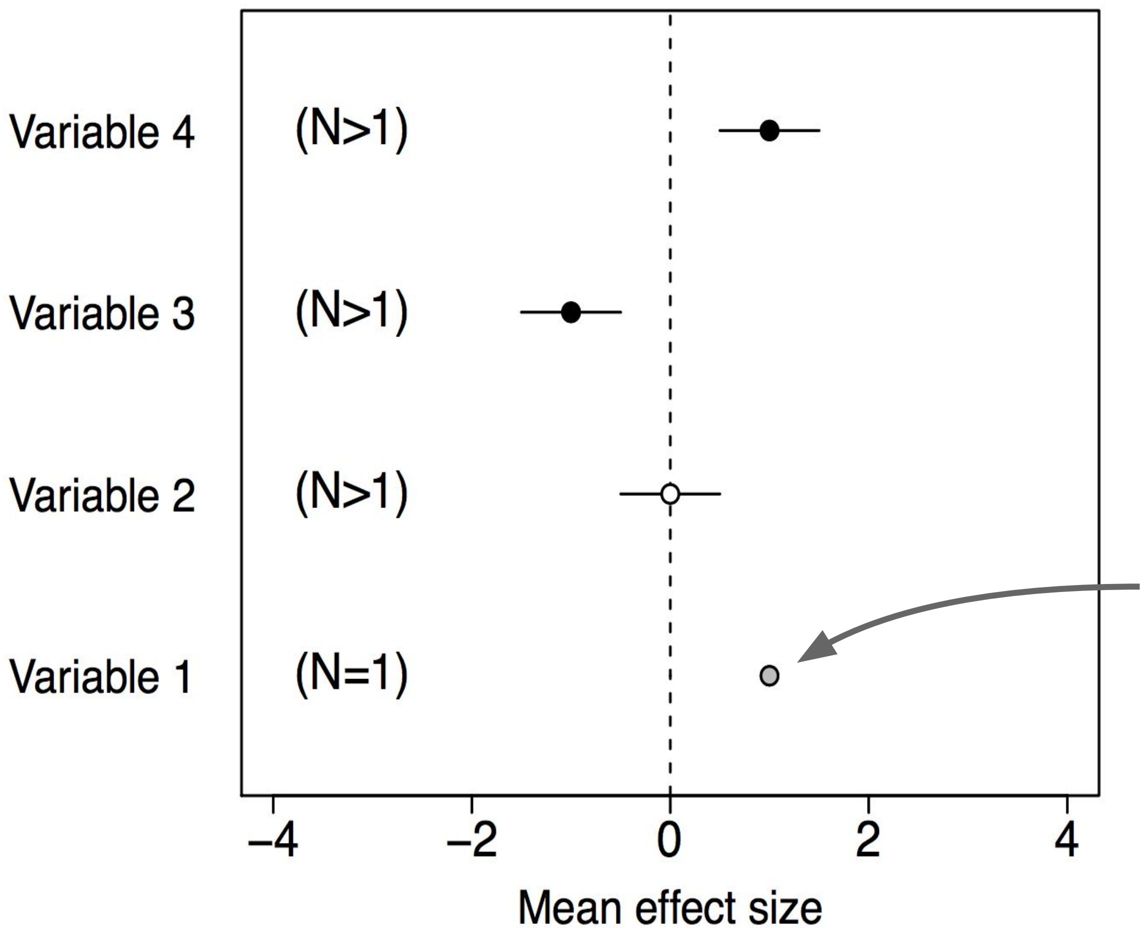
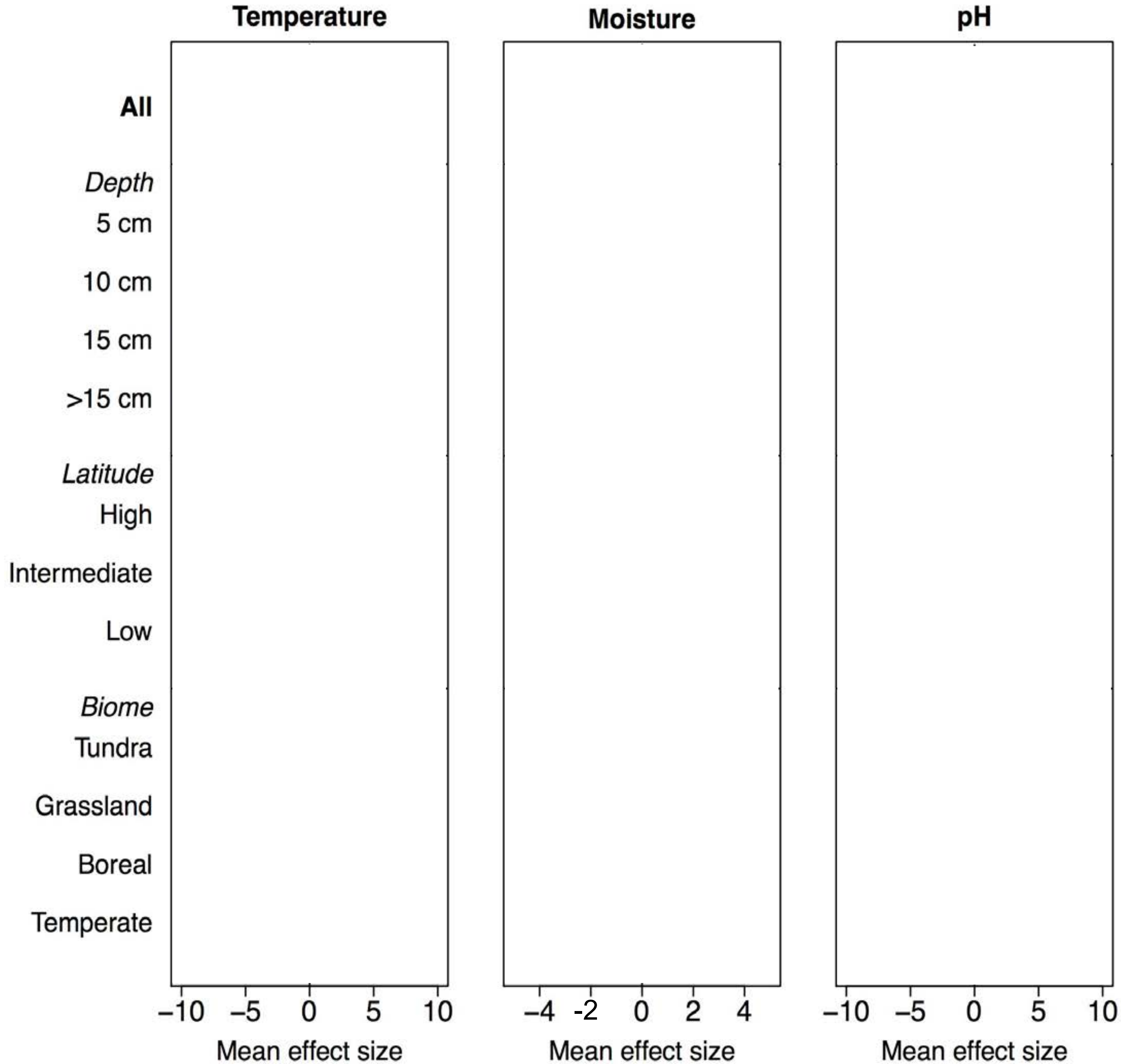


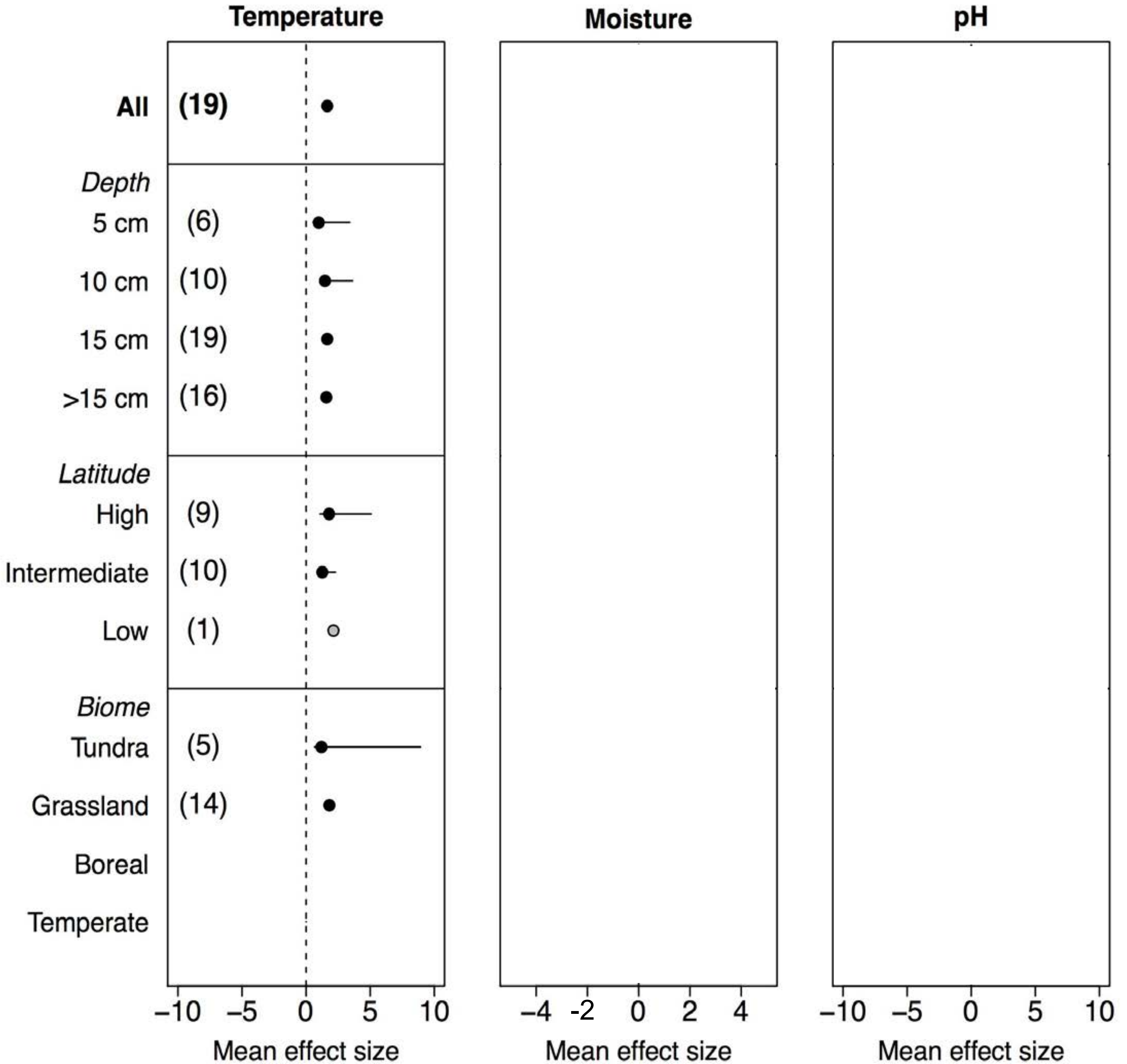
Only one study (no confidence intervals)

Meta-analysis

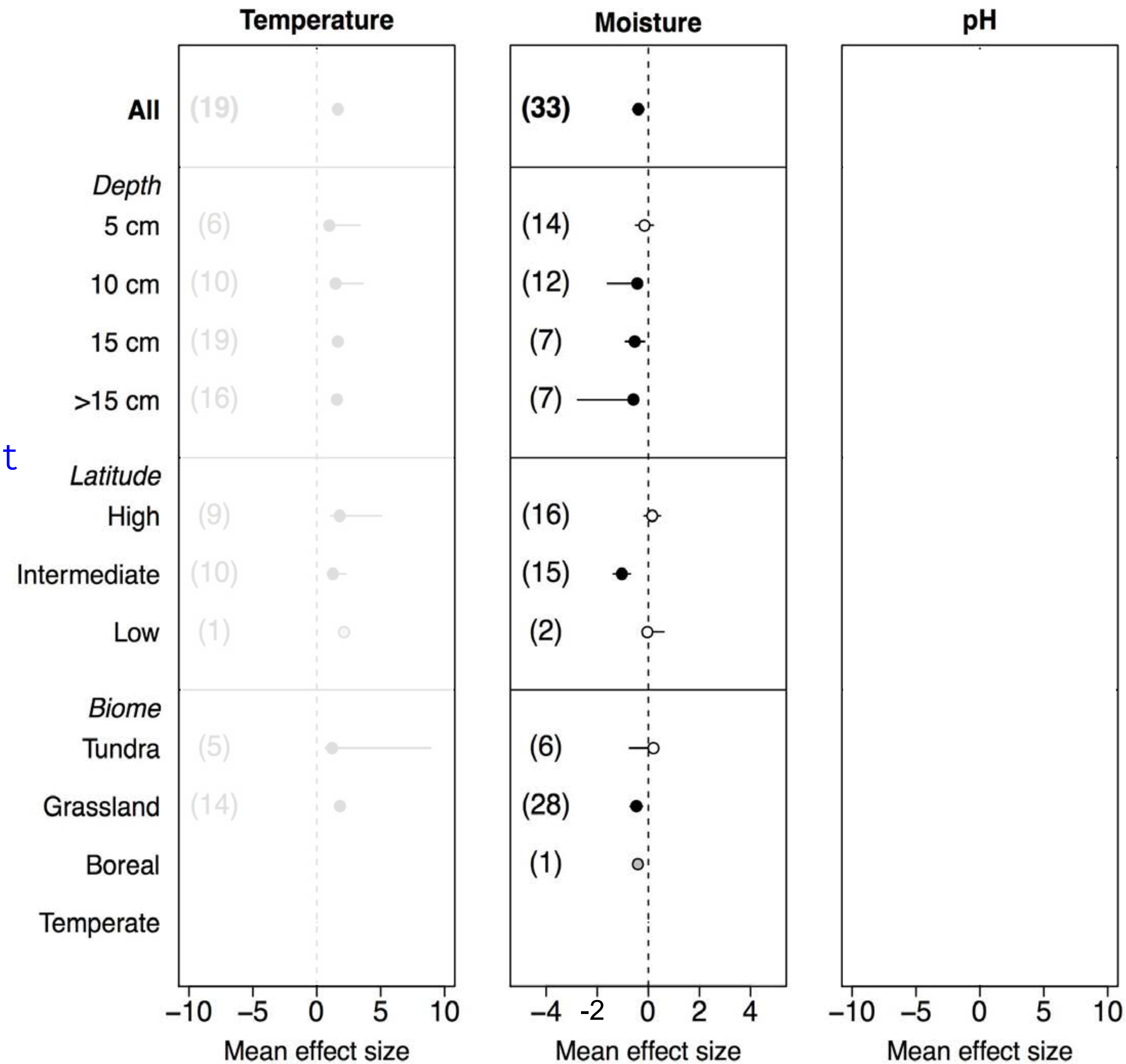
Results


Temperature
Moisture
pH
All
Depth
5 cm
10 cm
15 cm
>15 cm
Latitude
High
Intermediate
Low
Biome
Tundra
Grassland
Boreal
Temperate
–10 –5 0 5 10
–4 -2 0 2 4
–10 –5 0 5 10
Mean effect size
Mean effect size
Mean effect size

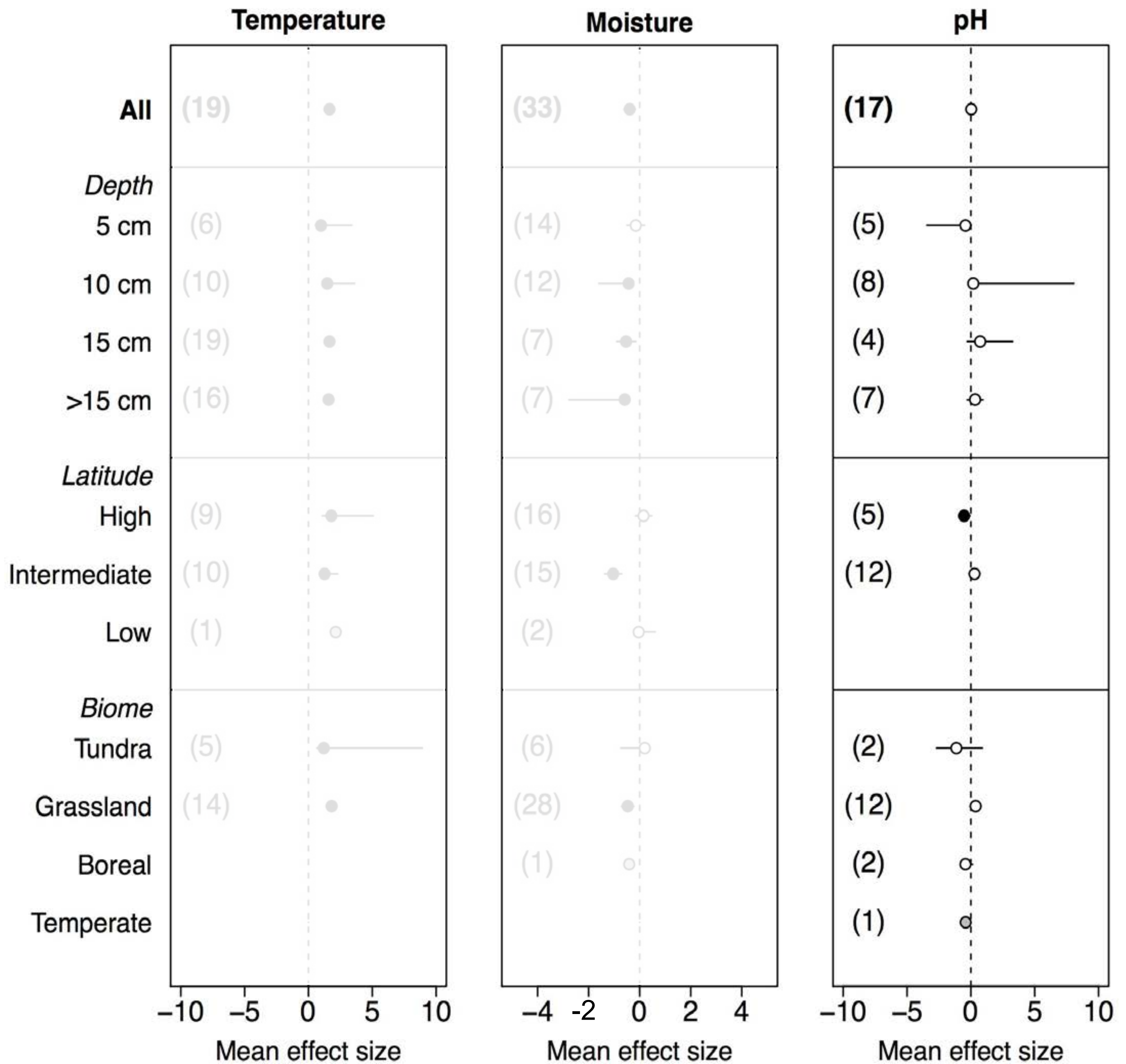
Field experiments are effective at **increasing soil temperature** across soil layers, latitudes and biomes

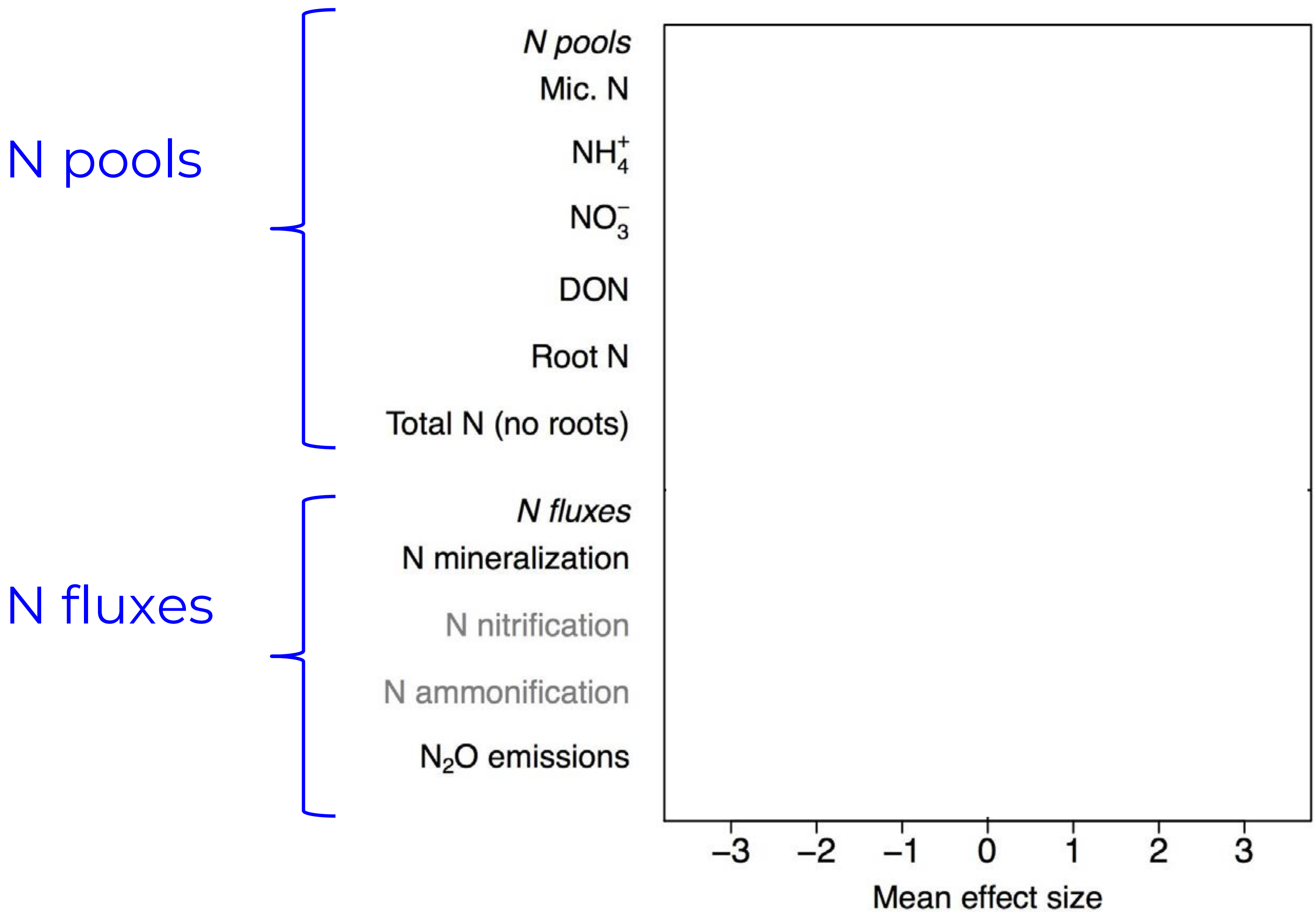


Experimental warming **decreases moisture** content under the soil surface, at intermediate latitudes and in grasslands

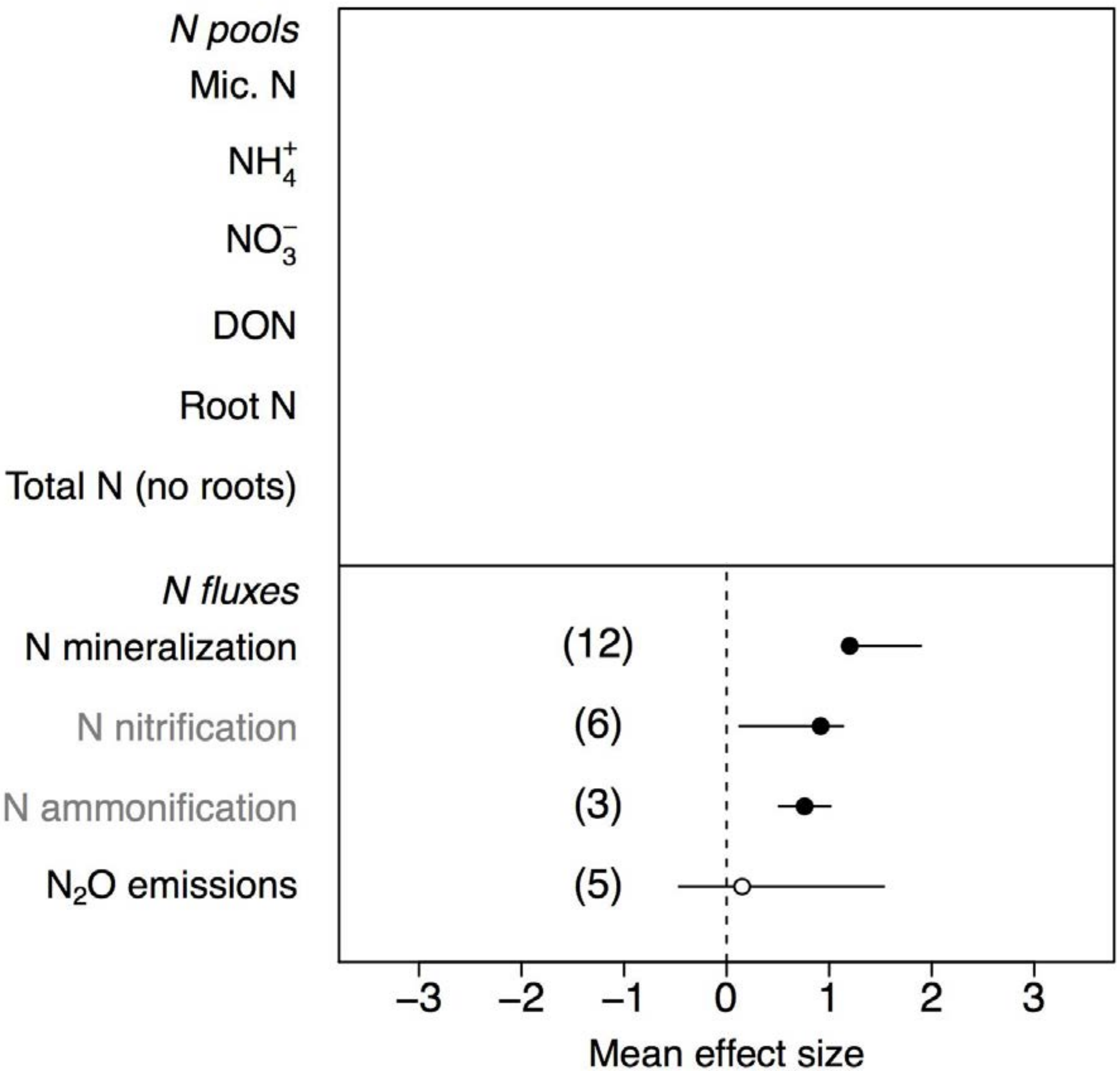


Overall, soil pH is **largely unresponsive** to warming, but it *could* decrease with warming in high-latitudes




N pools
N fluxes
N pools
Mic. N
NH_4^+
NO_3^-
DON
Root N
Total N (no roots)
N fluxes
N mineralization
N nitrification
N ammonification
N_2O emissions
–3
–2
–1
0
1
2
3
Mean effect size

Experimental warming consistently **increases N mineralization rates** but not N_2O emissions (an indicator of denitrification)



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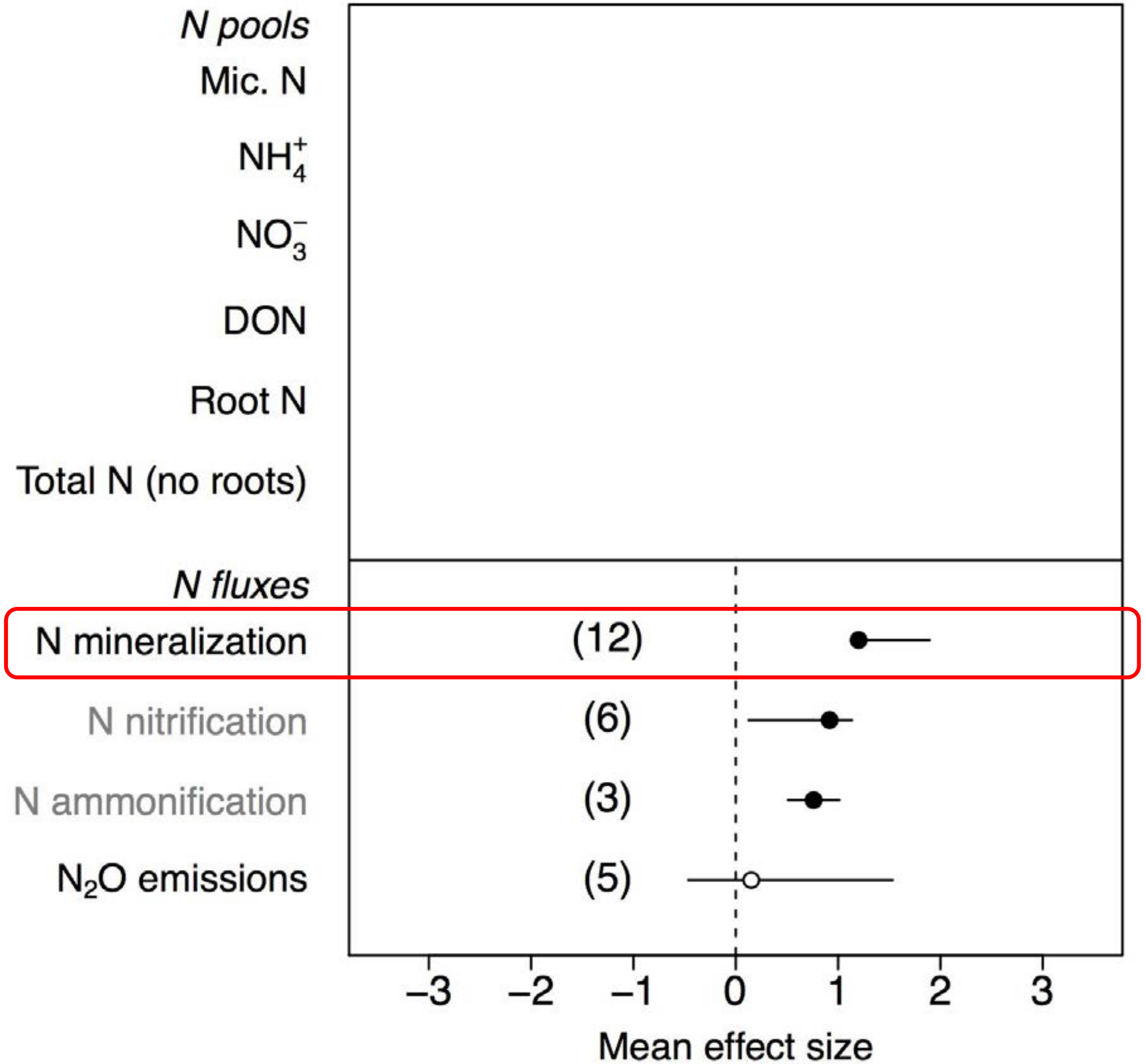
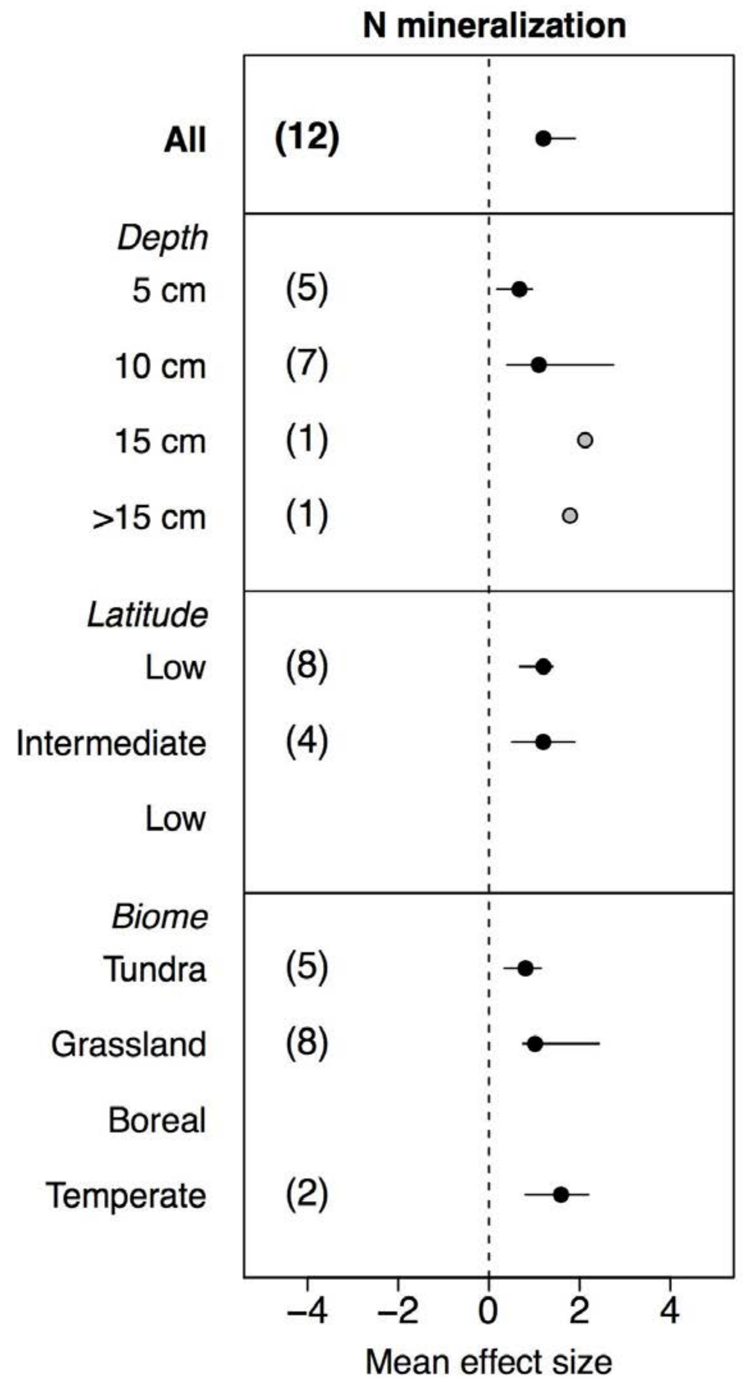
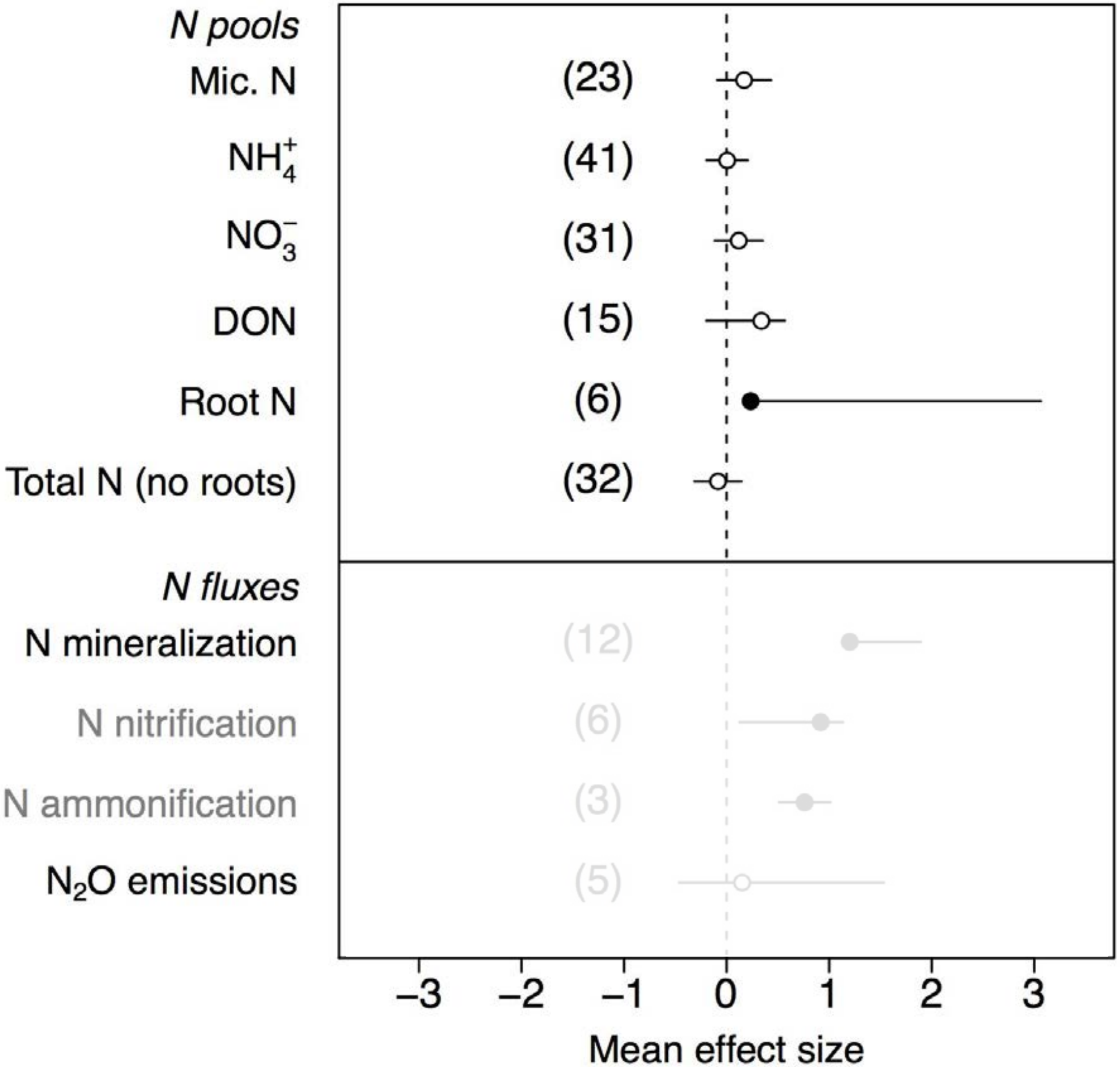


Increases in N mineralization rates with warming are consistent across soil layers, latitudes and biomes



With the exception of root N, below-ground **N pools are largely unresponsive** to warming

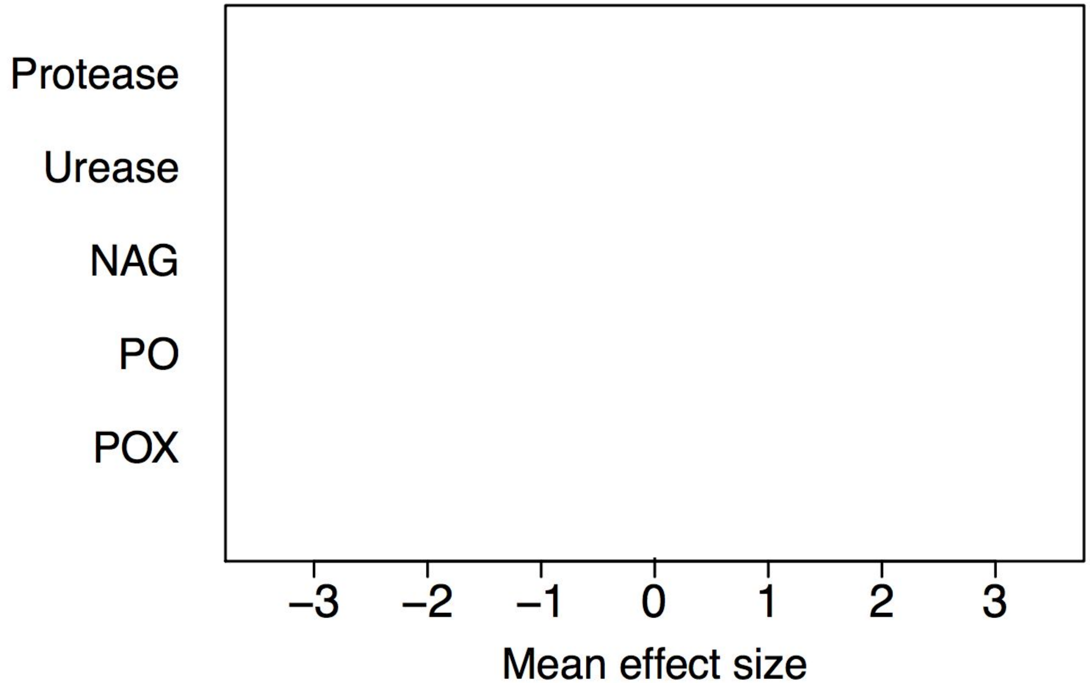


Effects of warming on the activity of N-relevant enzymes

Release N from proteins

Release N from urea

Release N from
recalcitrant sources



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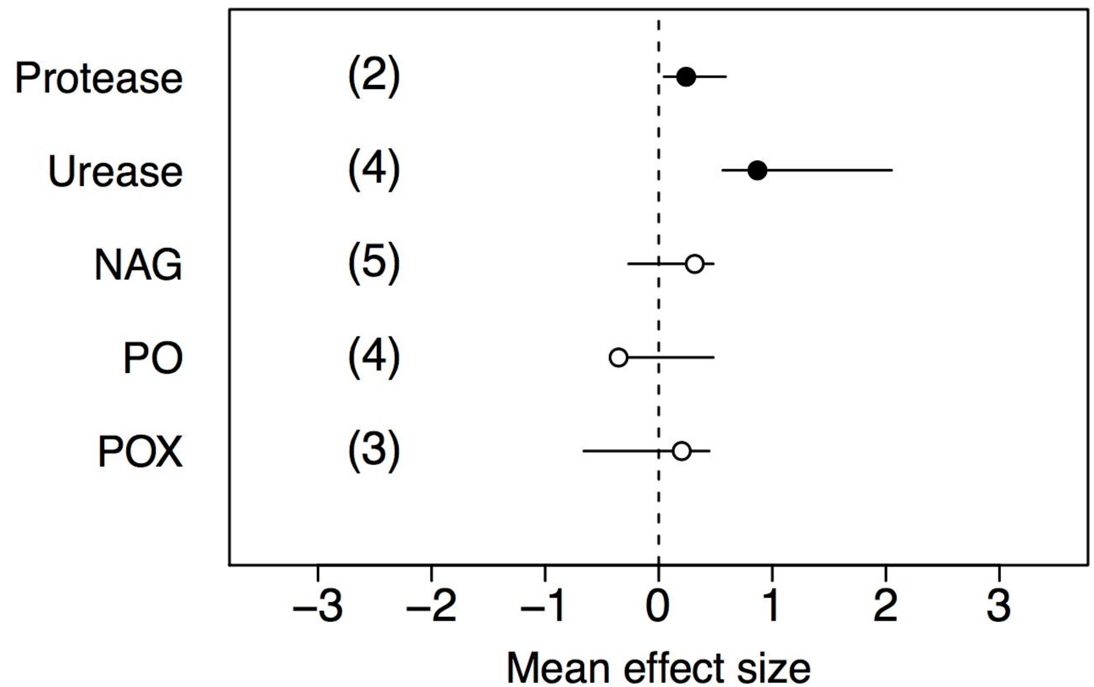


Effects of warming on the abundance of N-relevant genes

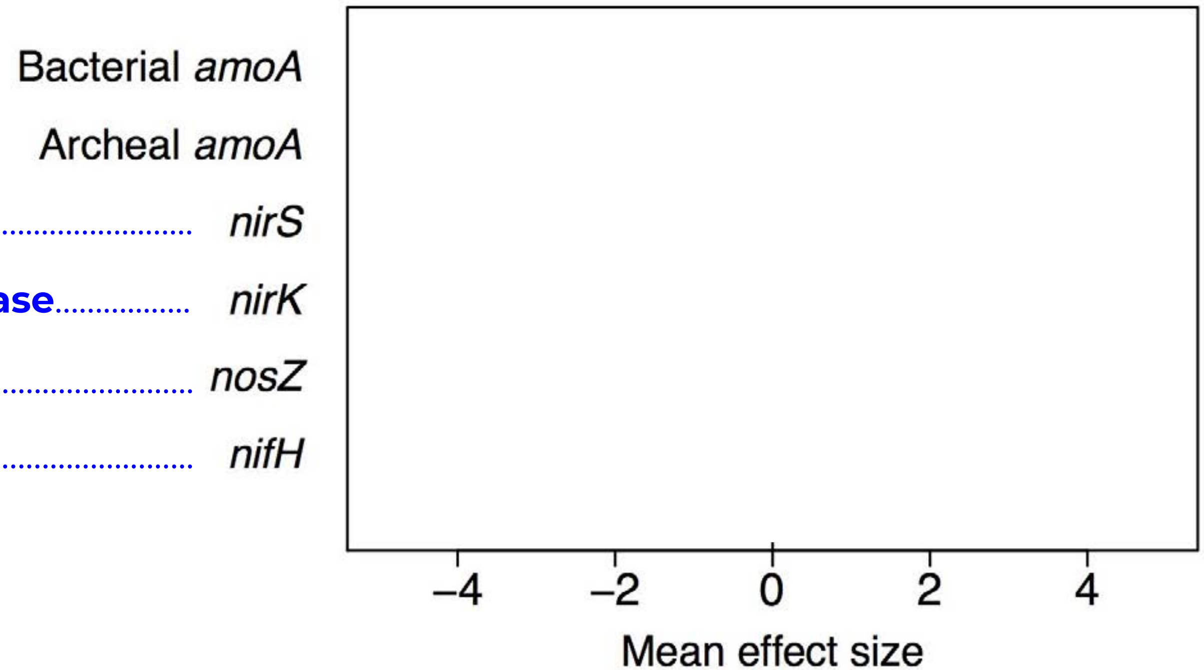
Ammonia **monooxygenase**

Cytochrome cd1 nitrite **reductase**........................

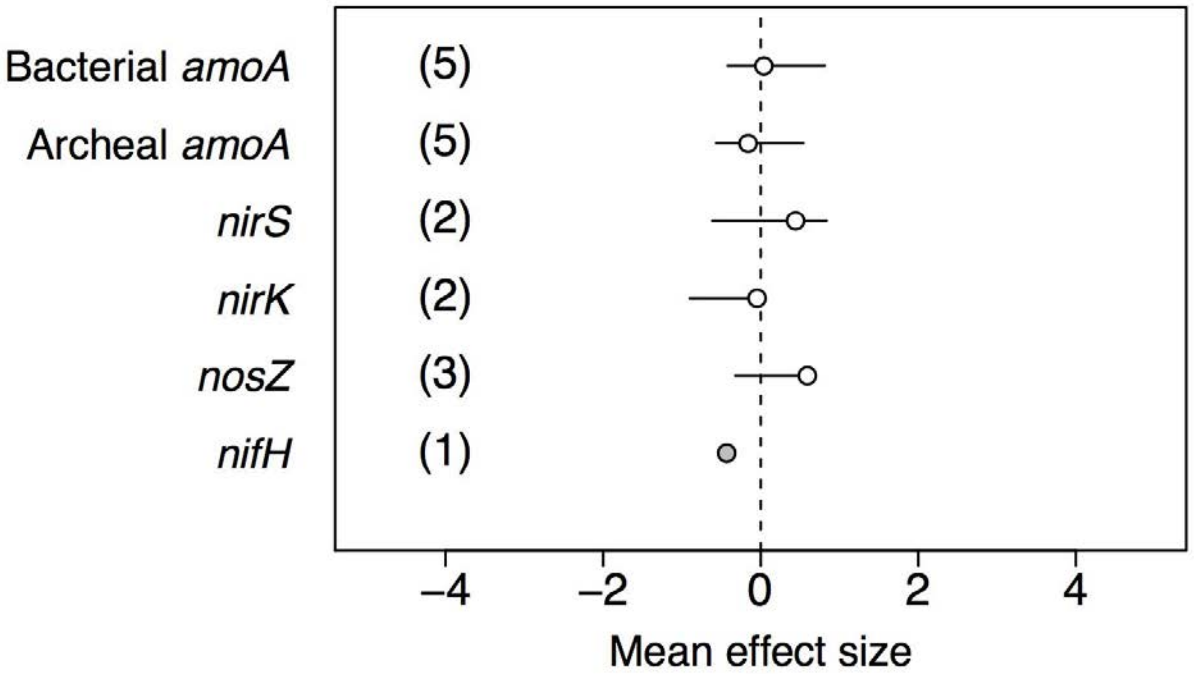
Copper-containing nitrite **reductase**.................

Nitrous oxide **reductase**..

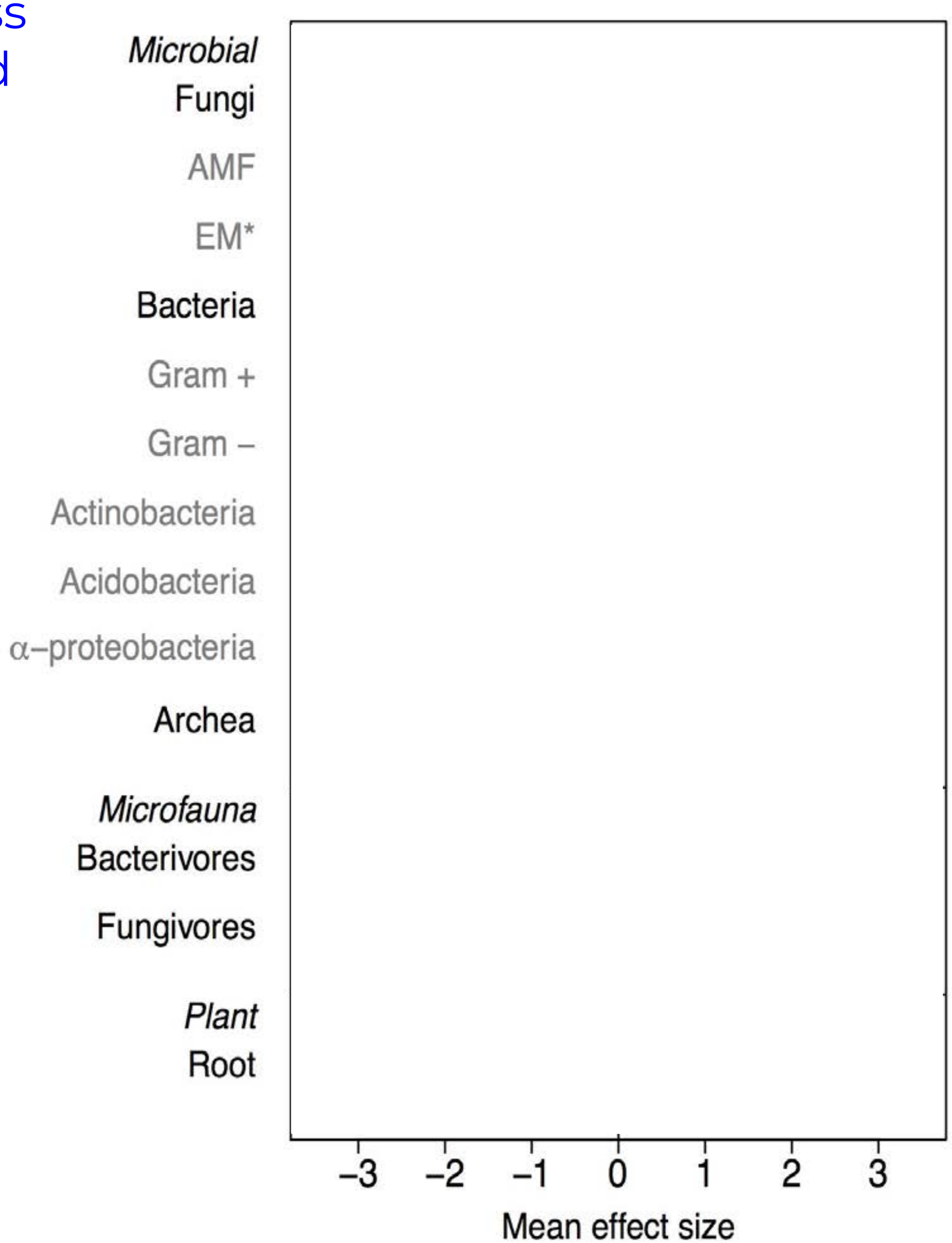
Nitrogenase iron protein...



Warming in cold ecosystems **does not affect** the **abundance** of (these) **N-relevant genes** below-ground



Living biomass below-ground



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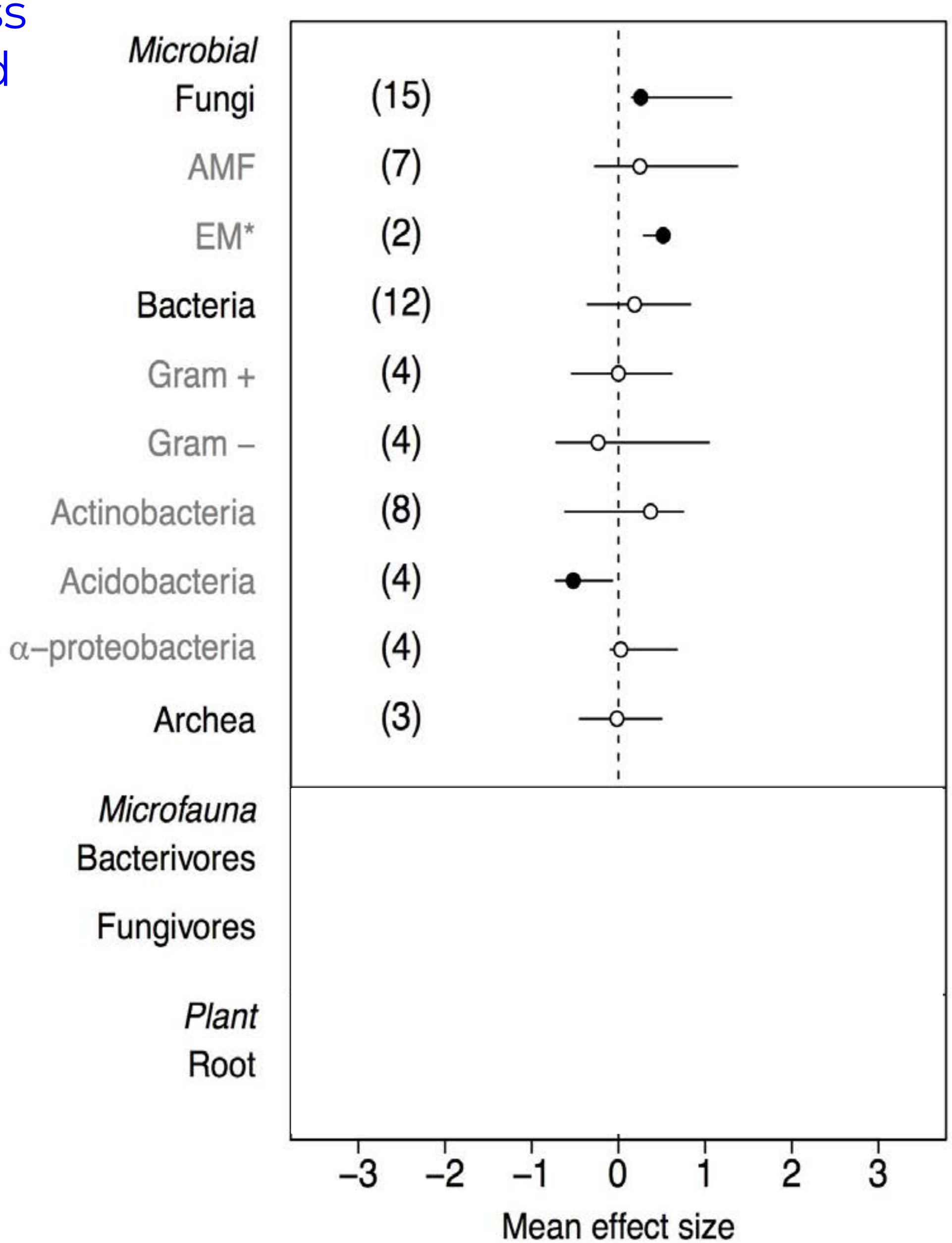

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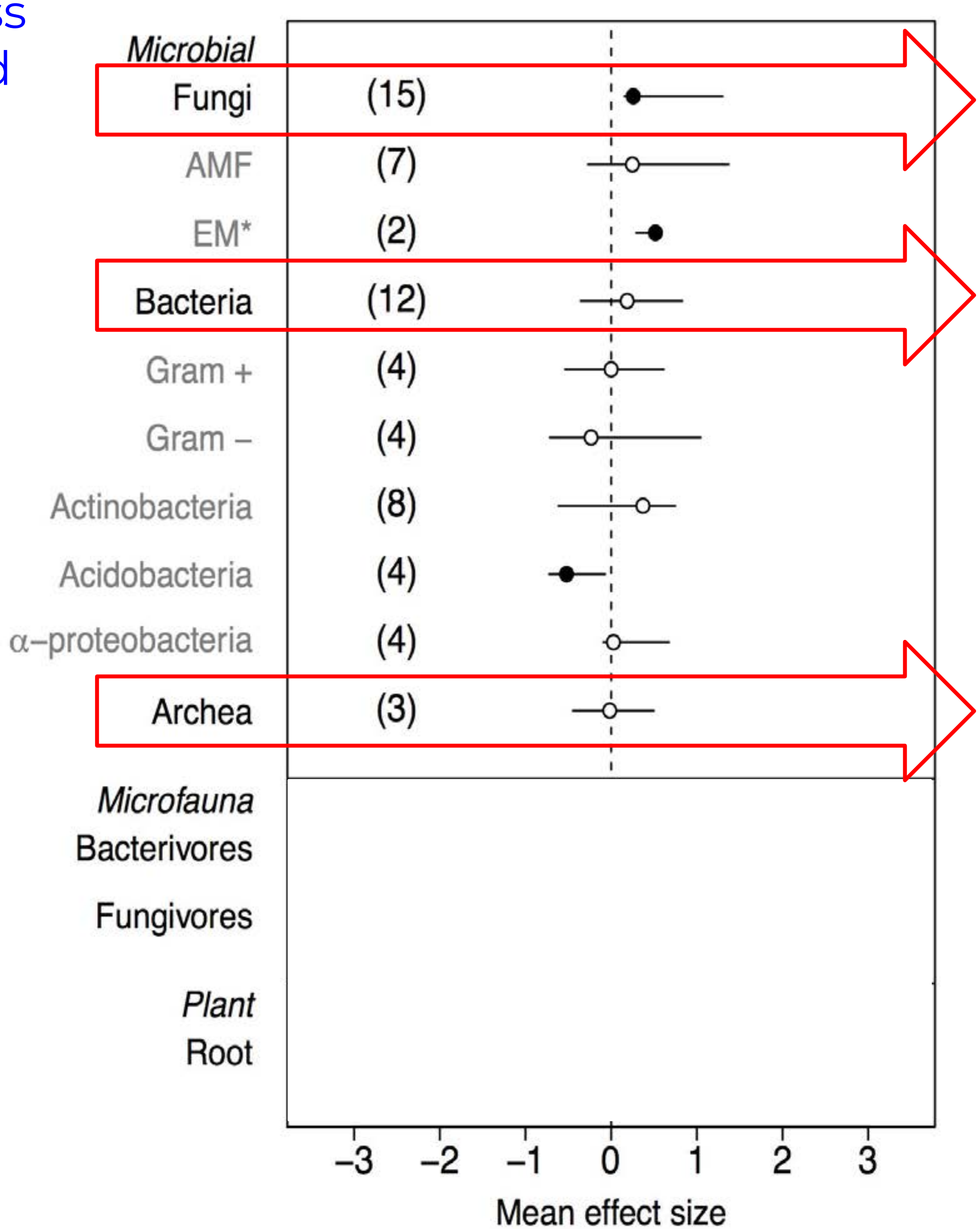
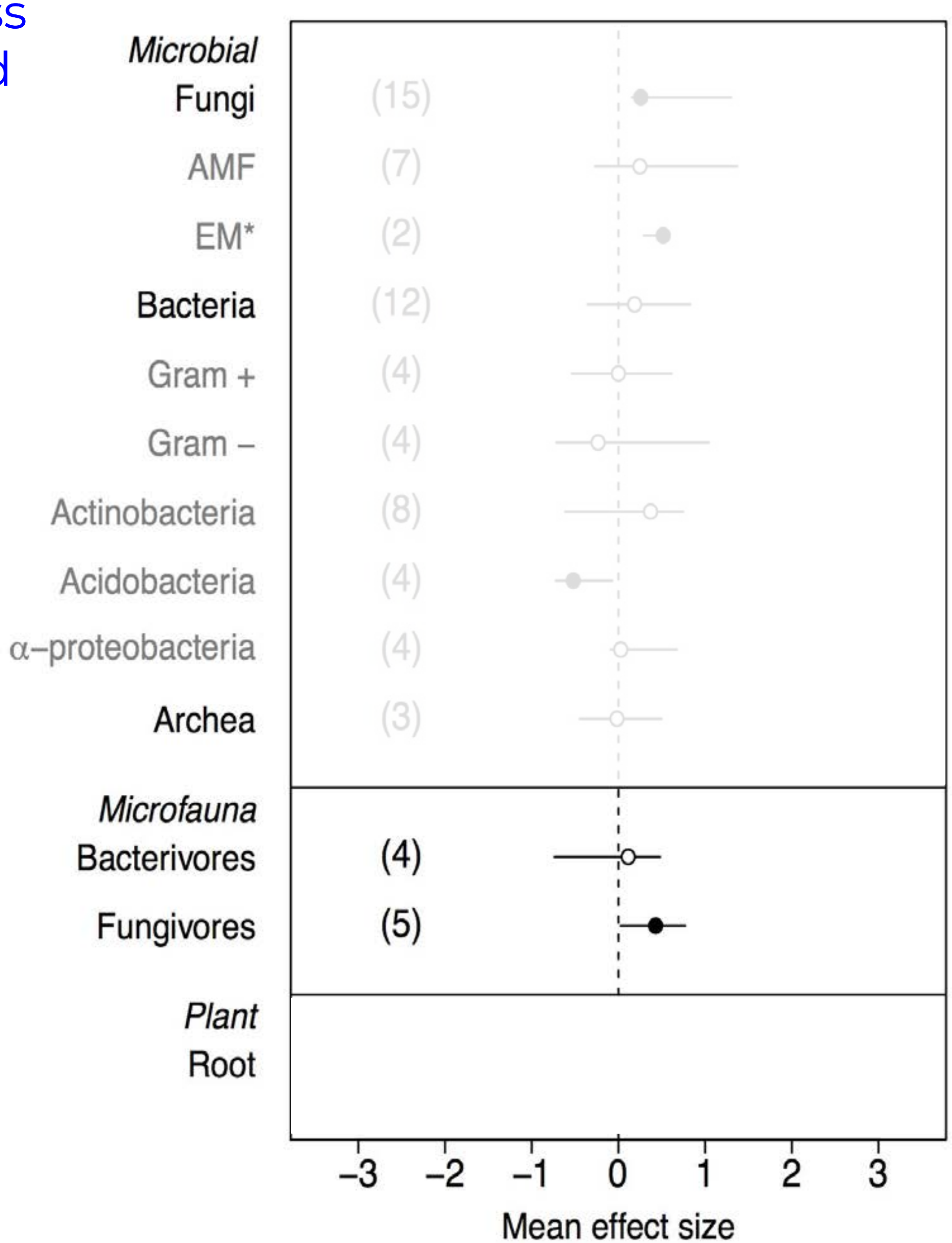


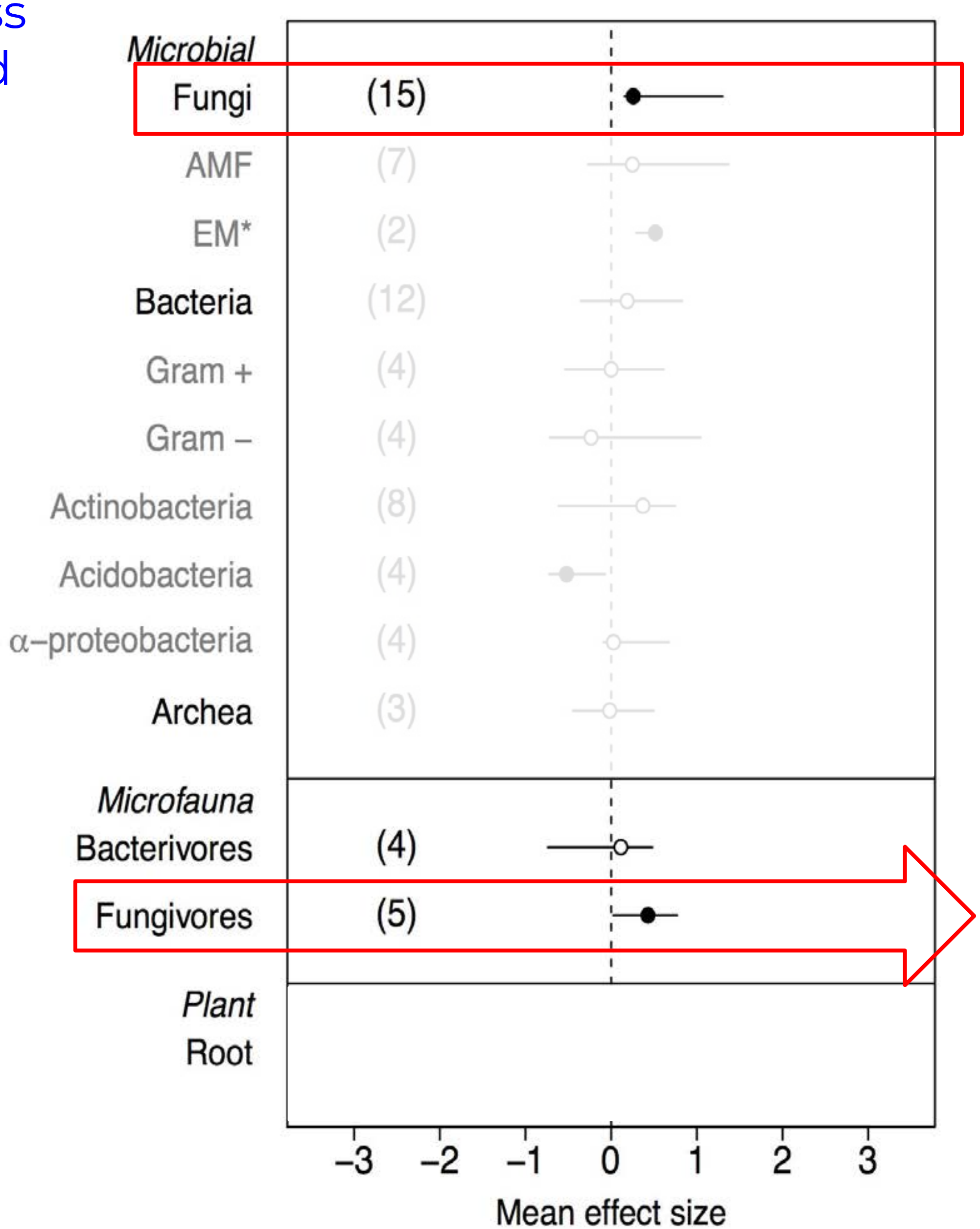
Overall, experimental **warming** in cold ecosystems...

increases fungal but not bacterial and archeal biomass/abundance

Living biomass below-ground

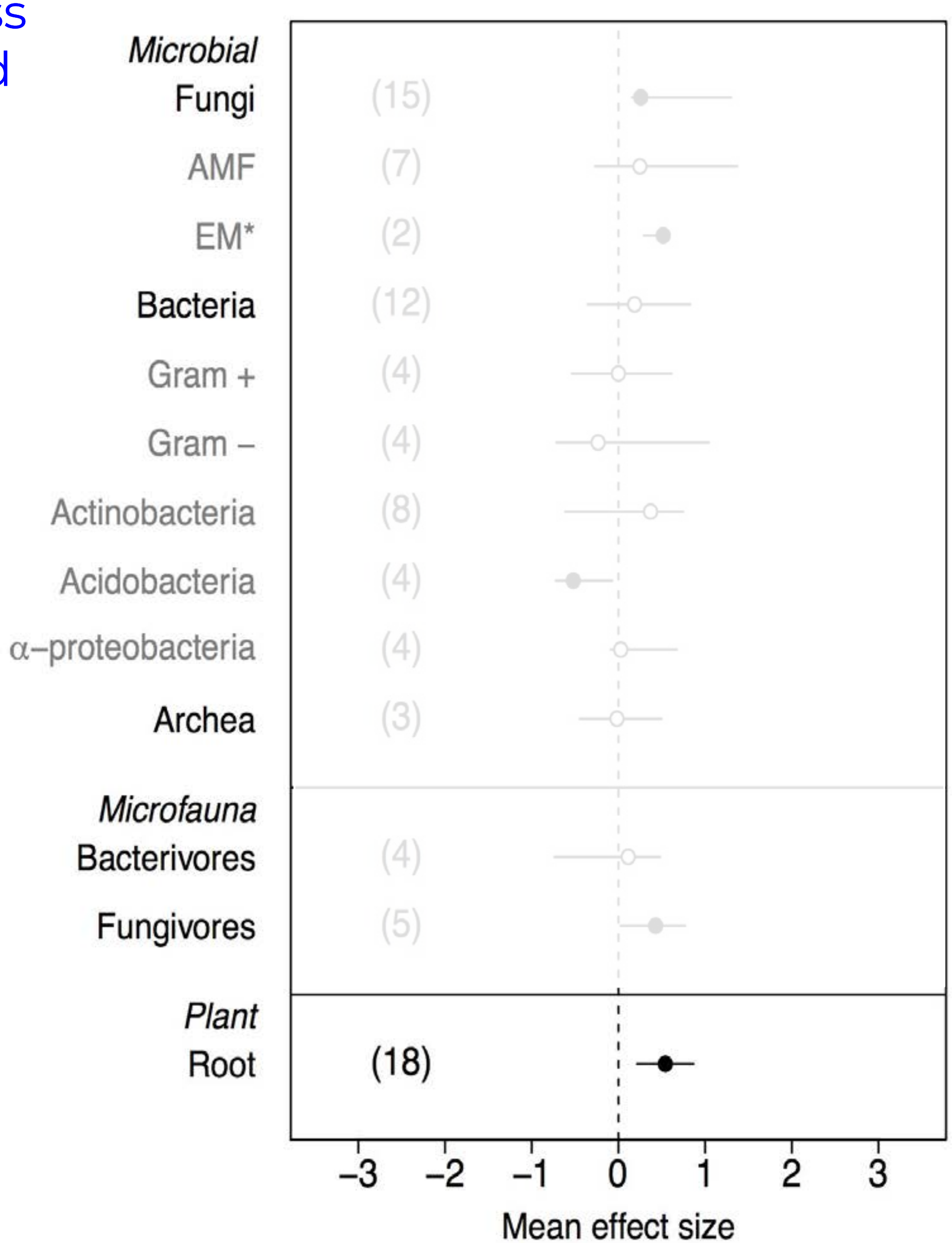


Living biomass below-ground



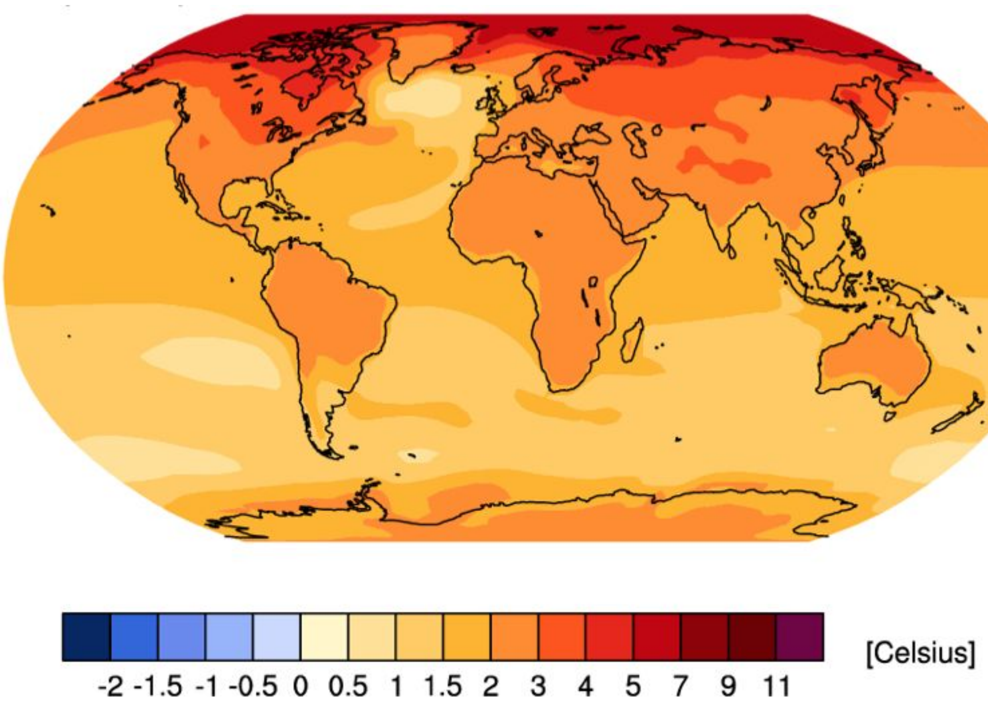
Increases in fungivores are consistent with increases in fungal biomass/abundance

Living biomass below-ground



Overall, warming in cold ecosystems **increases root biomass**

Responses of below-ground N to warming?



Conclusions

Warming in cold ecosystems...

- Accelerates N mineralization below-ground but...

- This does not lead to accumulation of inorganic N in soil

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- Increases activity of enzymes that are important for N cycling
  e.g. protease and urease

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Warming in cold ecosystems...

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  e.g. protease and urease
- Does not affect the abundance of N-relevant genes
  (at least those from this analysis)

Thanks

Alejandro Salazar
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- Increases activity of enzymes that are important for N cycling
  e.g. protease and urease
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  (at least those from this analysis)

JIC

Conclusions

Warming in cold ecosystems...

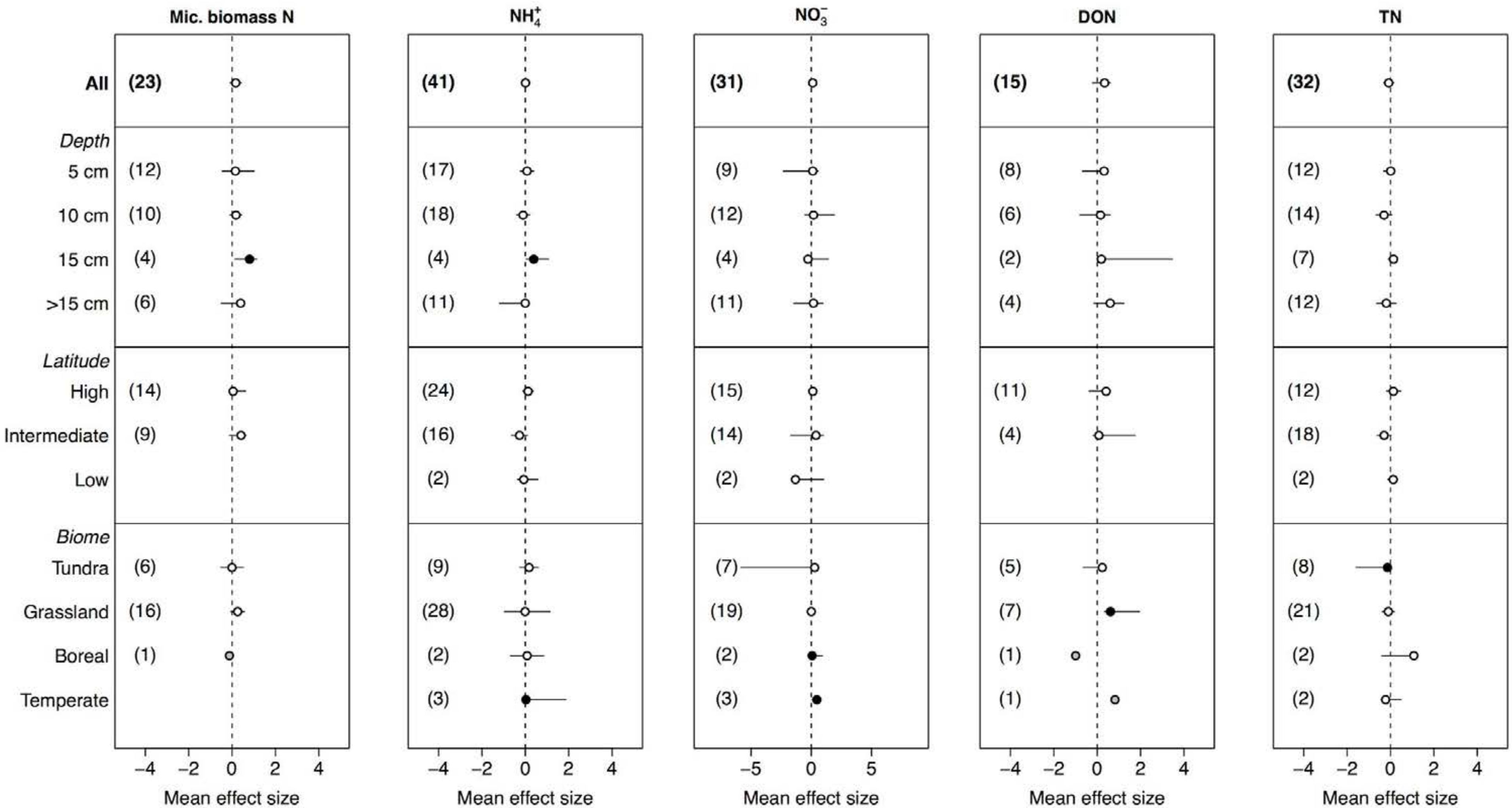
- Accelerates N mineralization below-ground

but has minimum effects of N pools

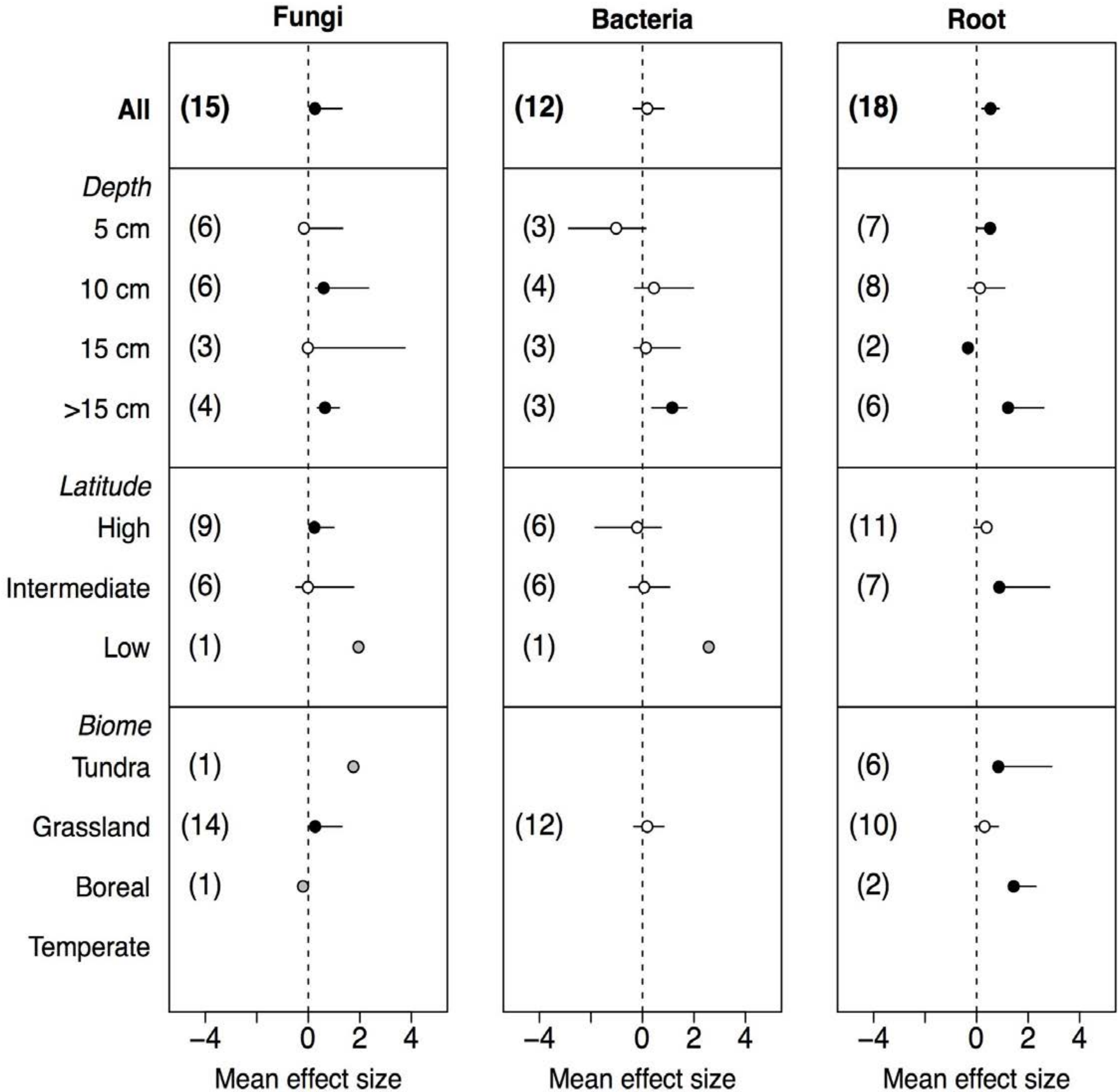
- Plant roots and fungi quickly take up the extra N and grow (favoring fungivores)

- Increases activity of (some) N-relevant enzymes

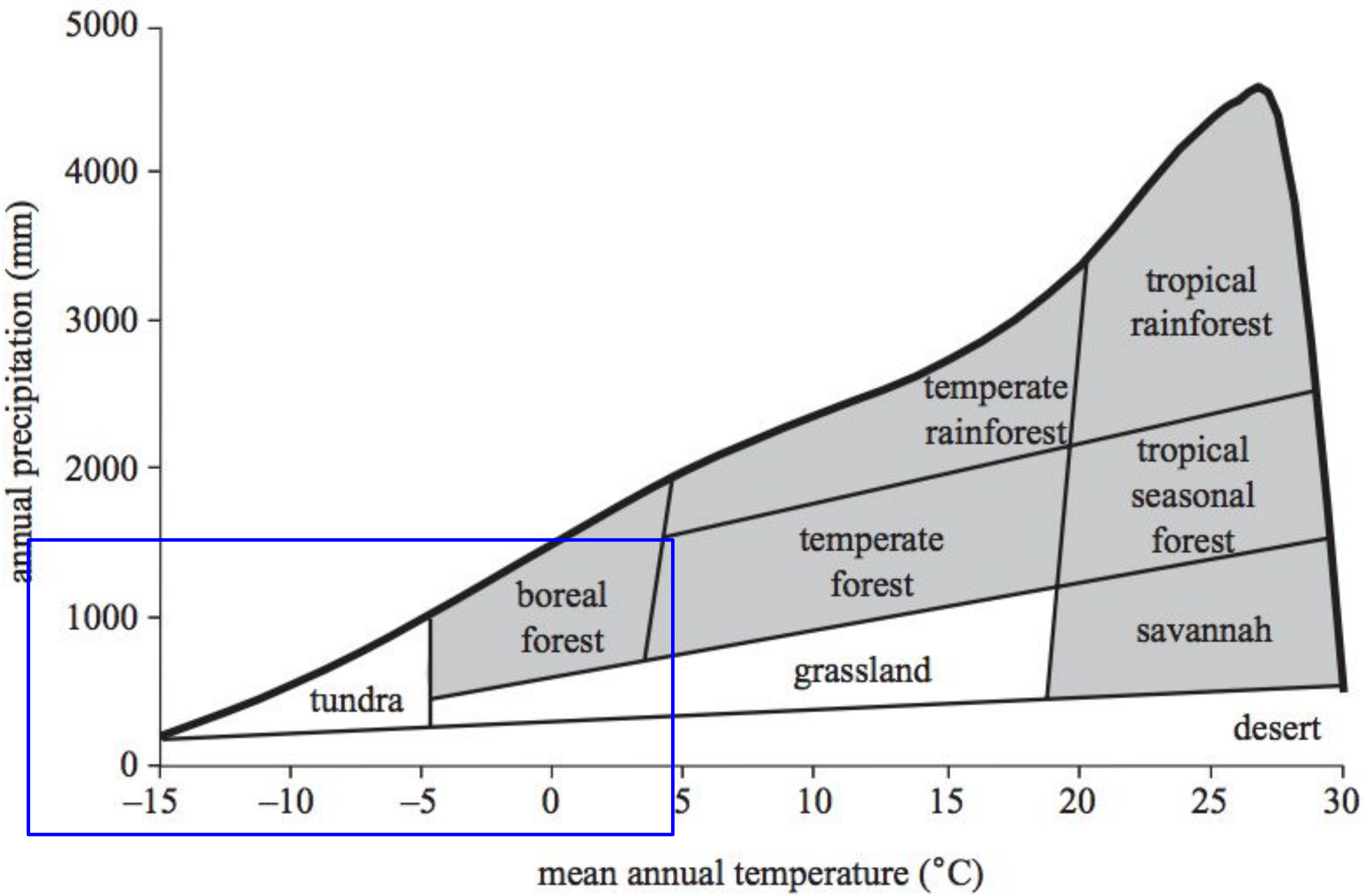
- Does not affect the abundance of N-relevant genes



Mic. biomass N
NH$_4^+$
NO$_3^-$
DON
TN
All
Depth
5 cm
10 cm
15 cm
>15 cm
Latitude
High
Intermediate
Low
Biome
Tundra
Grassland
Boreal
Temperate
(23) (12) (10) (4) (6) (14) (9) (6) (16) (1)
(41) (17) (18) (4) (11) (24) (16) (2) (9) (28) (2) (3)
(31) (9) (12) (4) (11) (15) (14) (2) (7) (19) (2) (3)
(15) (8) (6) (2) (4) (11) (4) (5) (7) (1) (1)
(32) (12) (14) (7) (12) (12) (18) (2) (8) (21) (2) (2)
Mean effect size



Fungi
Bacteria
Root
All
(15)
(12)
(18)
Depth
5 cm
10 cm
15 cm
>15 cm
(6)
(6)
(3)
(4)
(3)
(4)
(3)
(3)
(7)
(8)
(2)
(6)
Latitude
High
Intermediate
Low
(9)
(6)
(1)
(6)
(6)
(1)
(11)
(7)
Biome
Tundra
Grassland
Boreal
Temperate
(1)
(14)
(1)
(12)
(6)
(10)
(2)
−4
0
2
4
Mean effect size



Woodward, et al., (2004). Global climate and the distribution of plant biomes. Philosophical Transactions of the Royal Society B: Biological Sciences

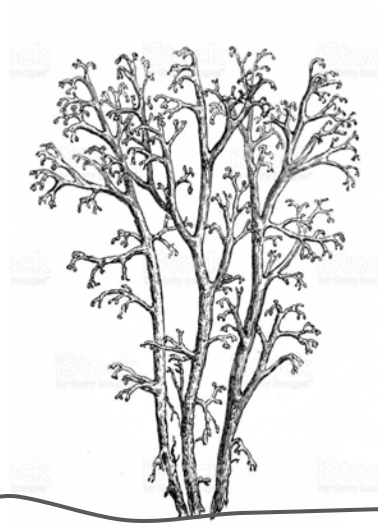
REVIEW

doi:10.1038/nature25753

Meta-analysis and the science of research synthesis

Gurevitch, J. et al, (2018). *Nature*.

Previous meta-analyses



Plant biomass
(low tundra; Rustard et al., 2001)

Plant productivity
(low tundra; Rustard et al., 2001)

Plant C
(Lu et al., 2013)

Plant N
(Bai et al., 2013)

Vegetative growth
(Arft et al., 1999)