



Effects of Winter Climate Change on the Northern Hardwood Forest

Pamela Templer

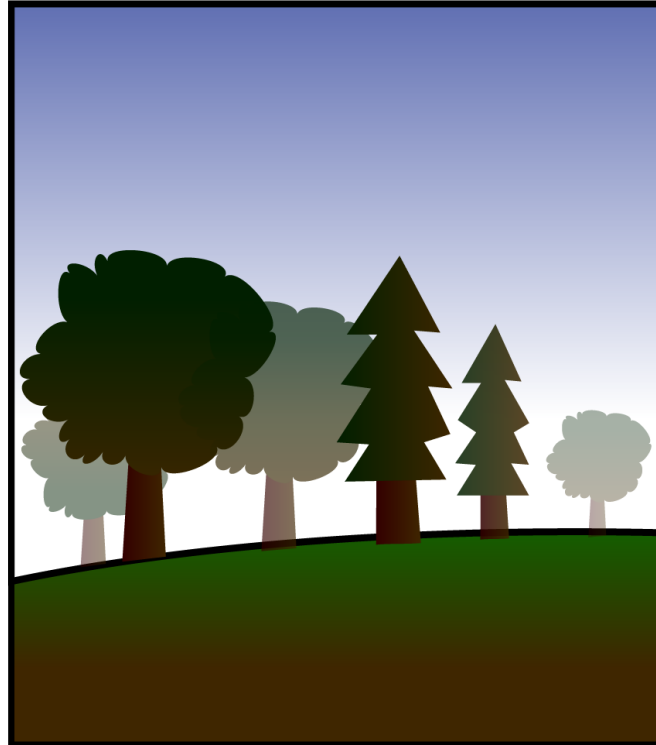
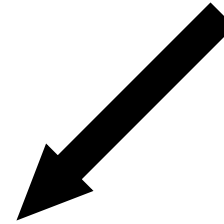
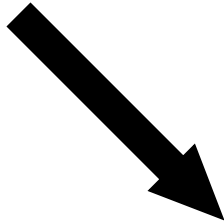
Boston University

ptempler@bu.edu

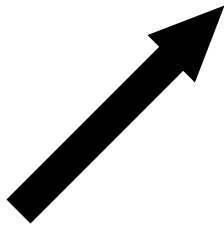


Climate Change

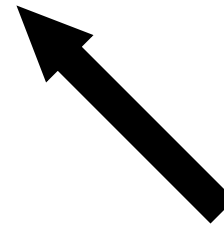
Atmospheric Deposition



Land-Use Change
Urbanization

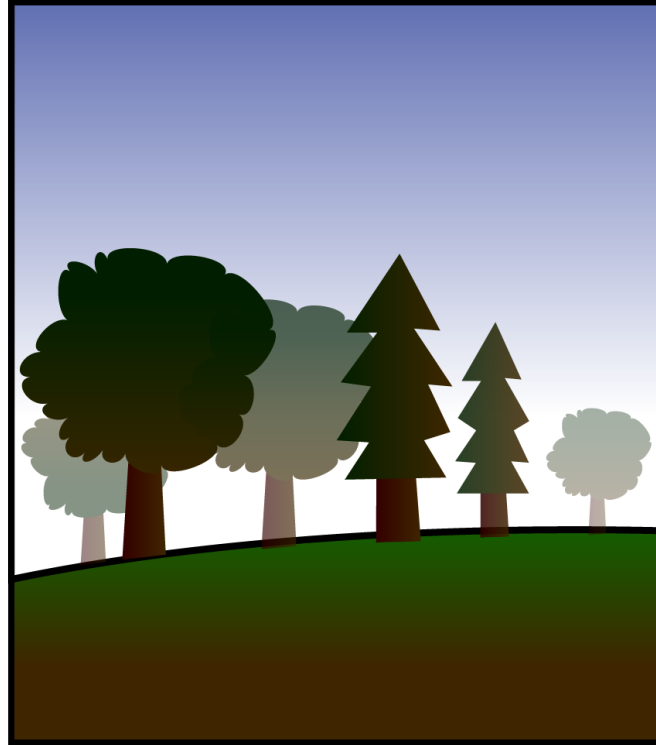


Introduced Pests



Climate Change

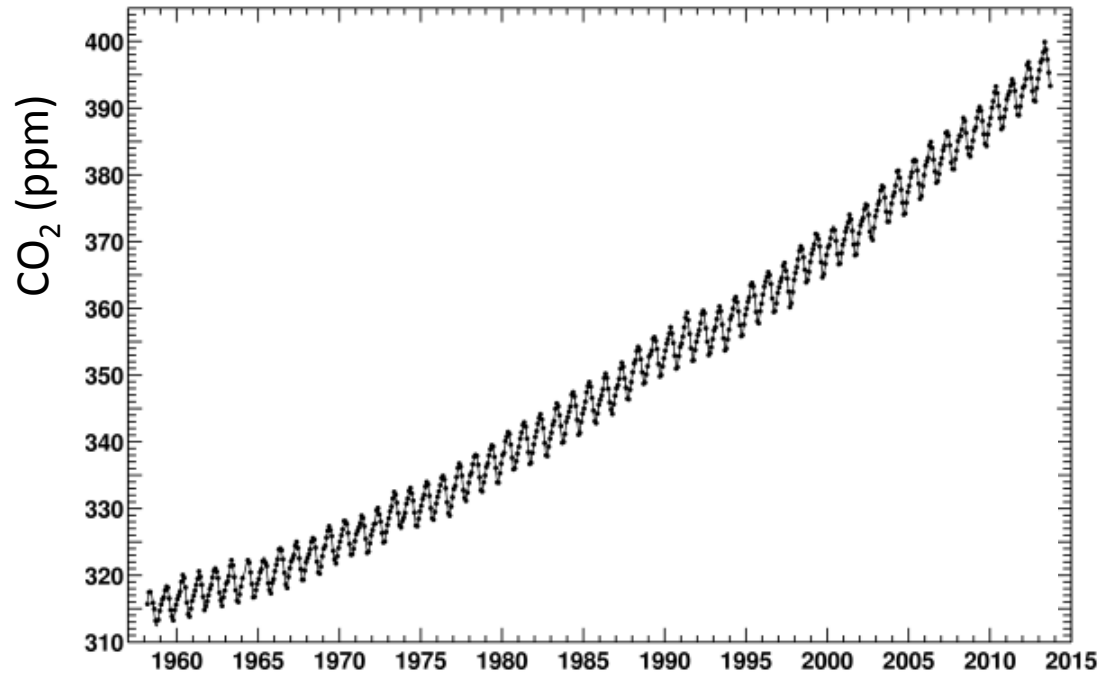
Atmospheric Deposition



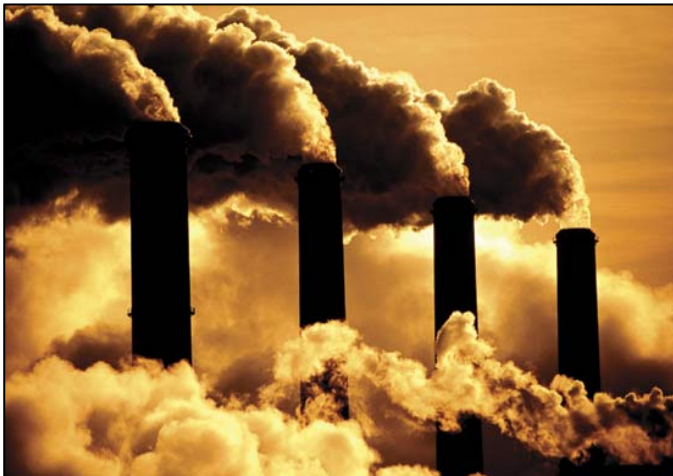
Land-Use Change
Urbanization

Introduced Pests

Atmospheric CO₂ at Mauna Loa Observatory



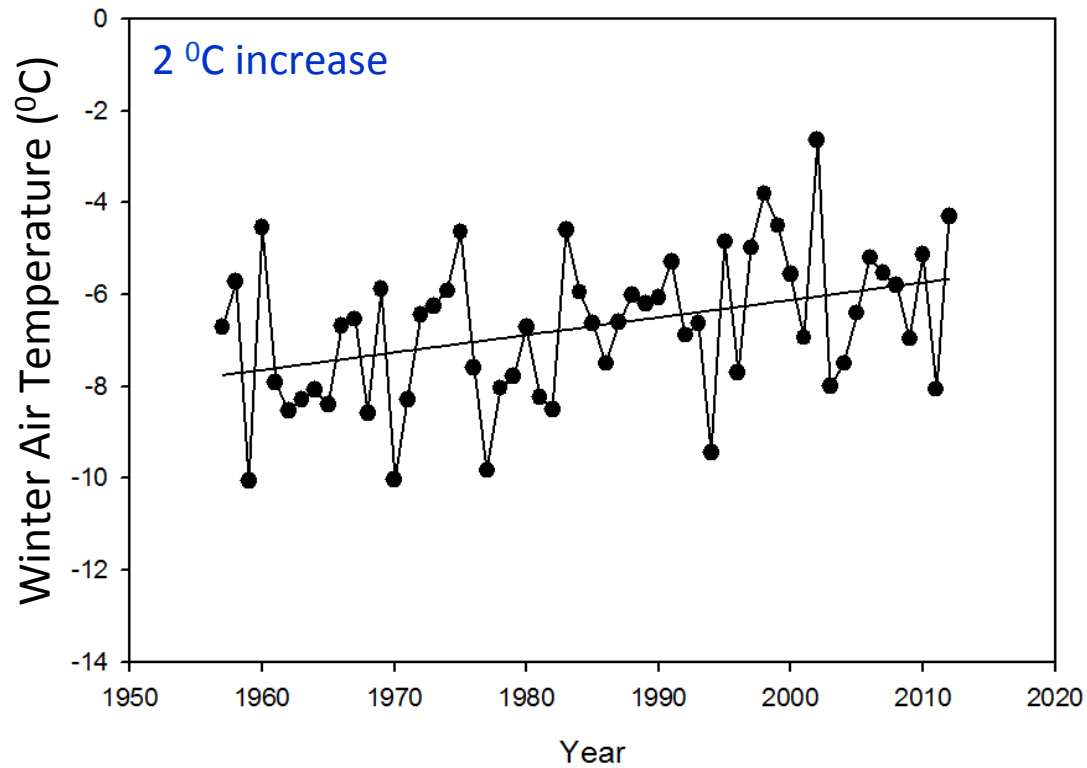
Scripps Institution of Oceanography



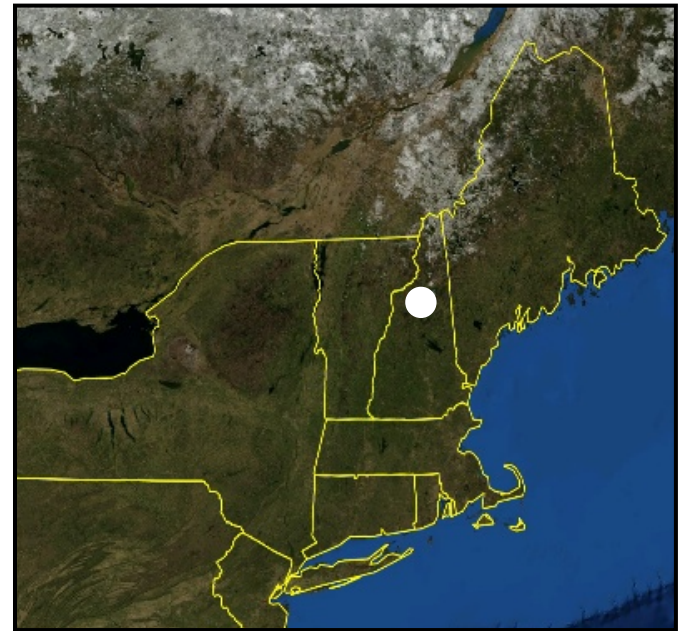
britannica.com



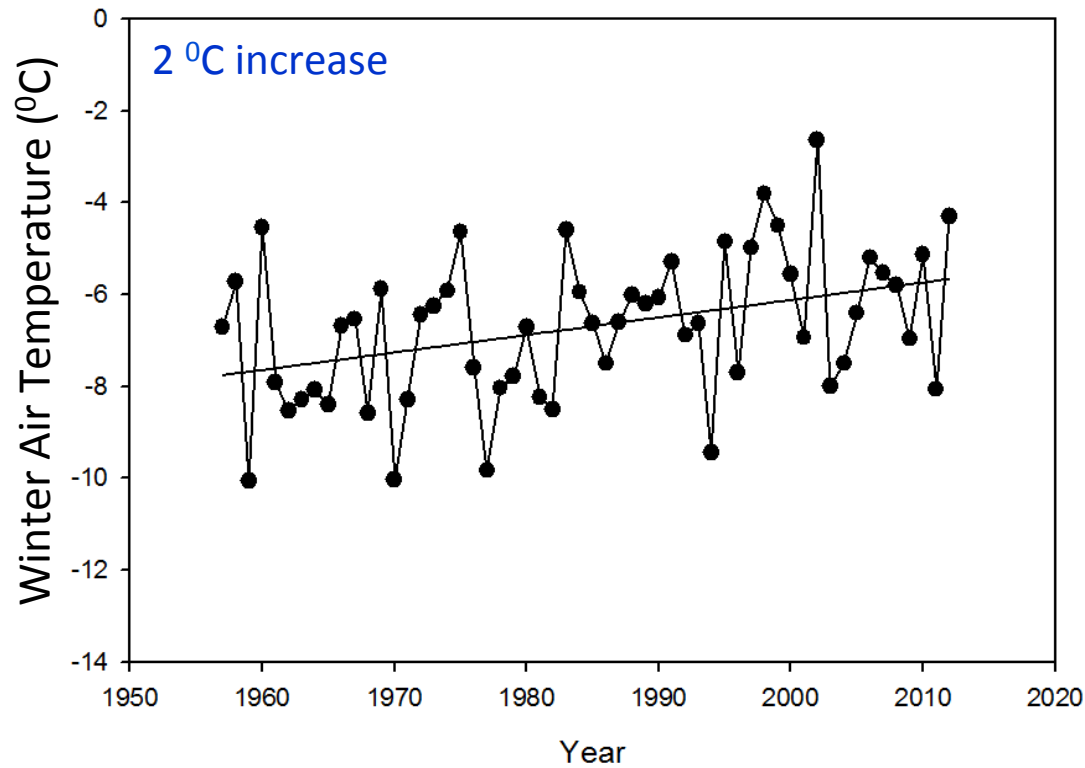
byjus.com



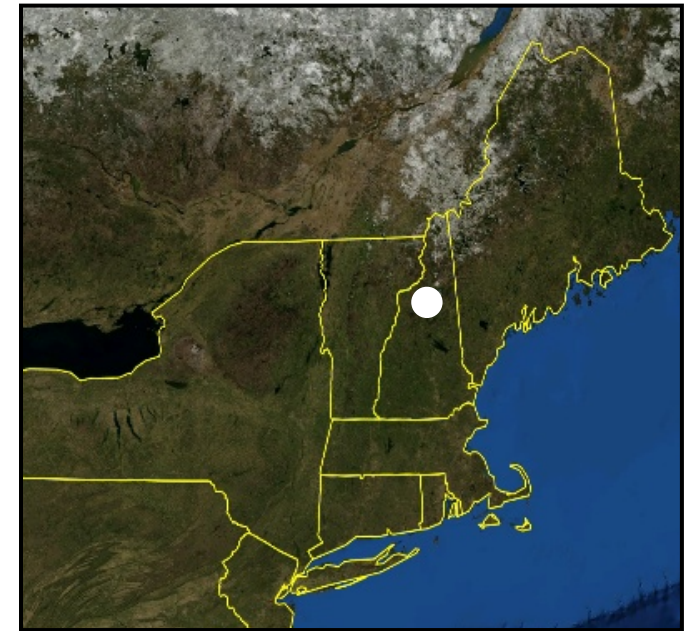
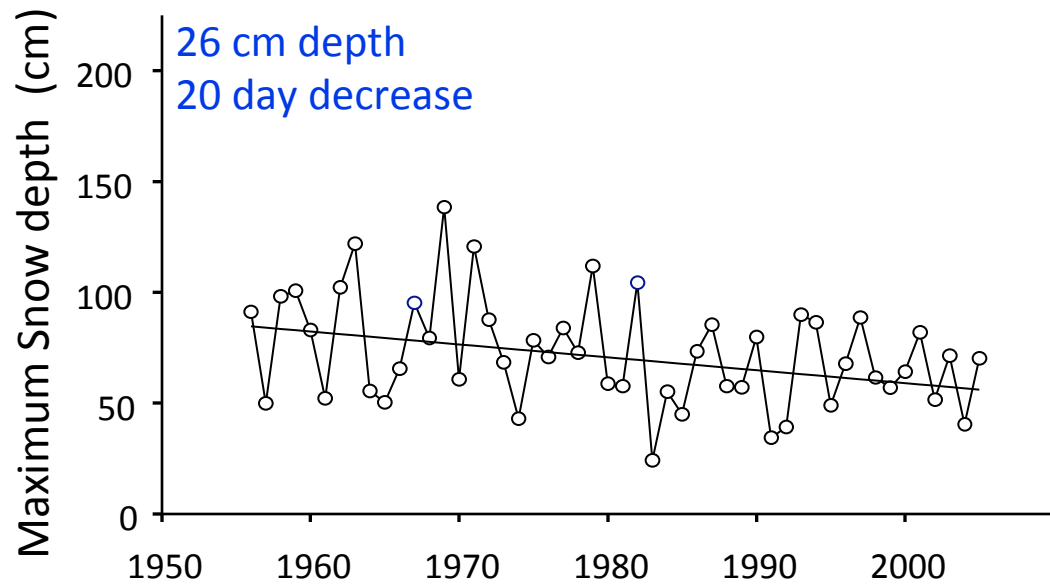
Winter Air
Temperature
s Rising and
Snowpack
Shrinking



Hubbard Brook



Winter Air
Temperature
s Rising and
Snowpack
Shrinking



Hubbard Brook

The End of Snow?

By PORTER FOX FEB. 7, 2014



Slopes were closed last month at Fichtelberg mountain in Oberwiesenthal, Germany.
Jan Woitas/European Pressphoto Agency

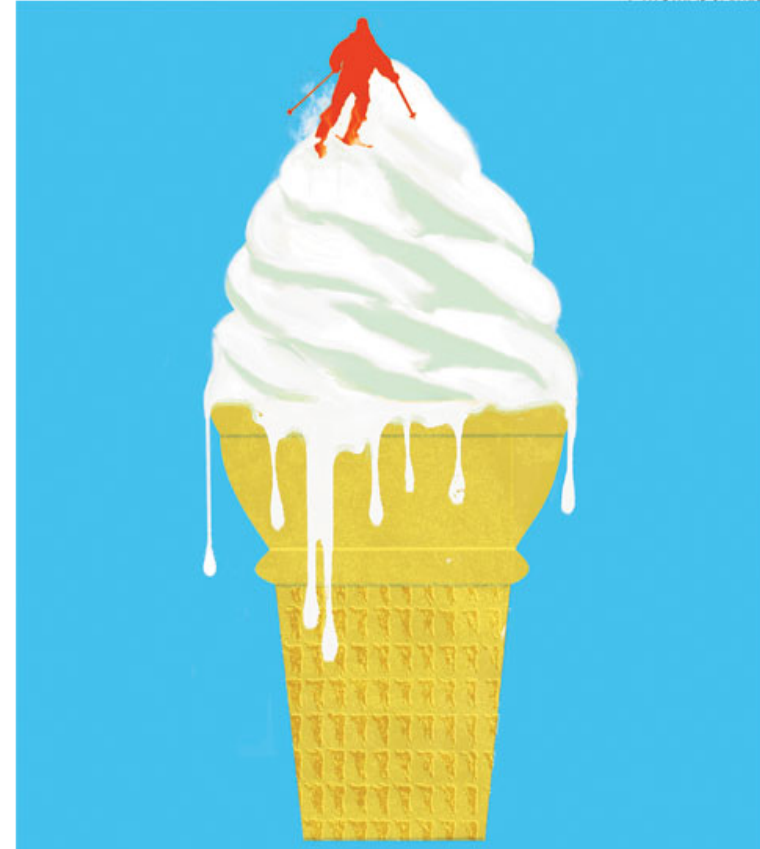
THE PHOENIX

Help, the mountains are melting!

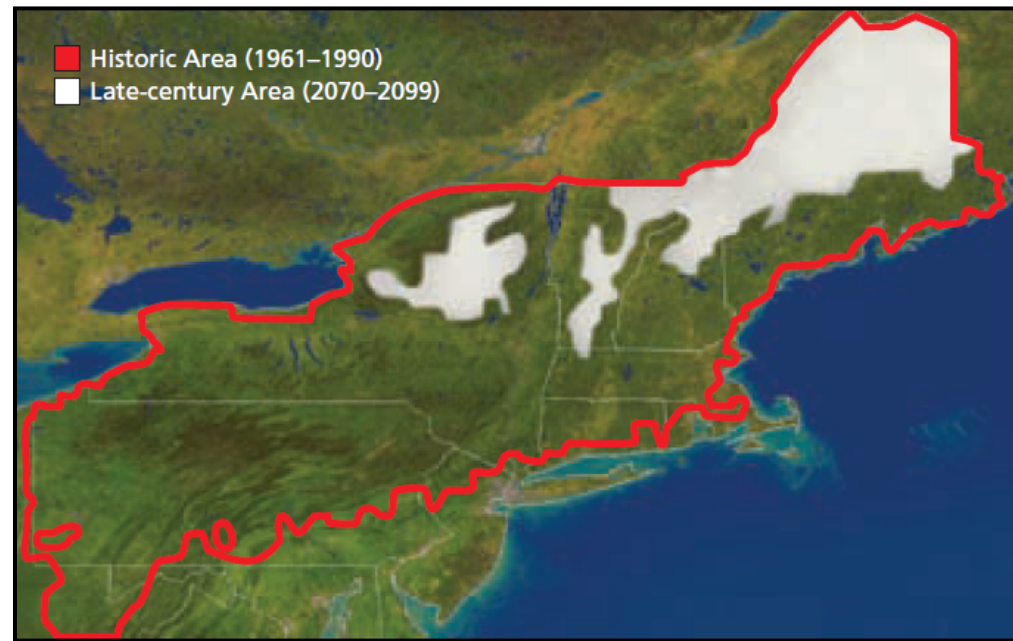
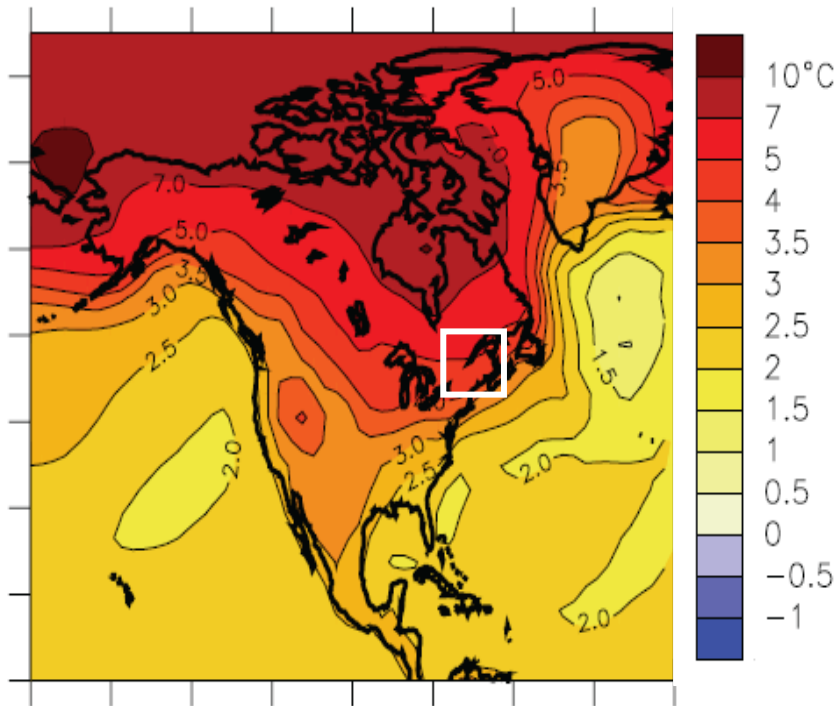
The case of the disappearing ski slopes

By NOAH SCHAFFER | November 7, 2012 [Like](#) 26

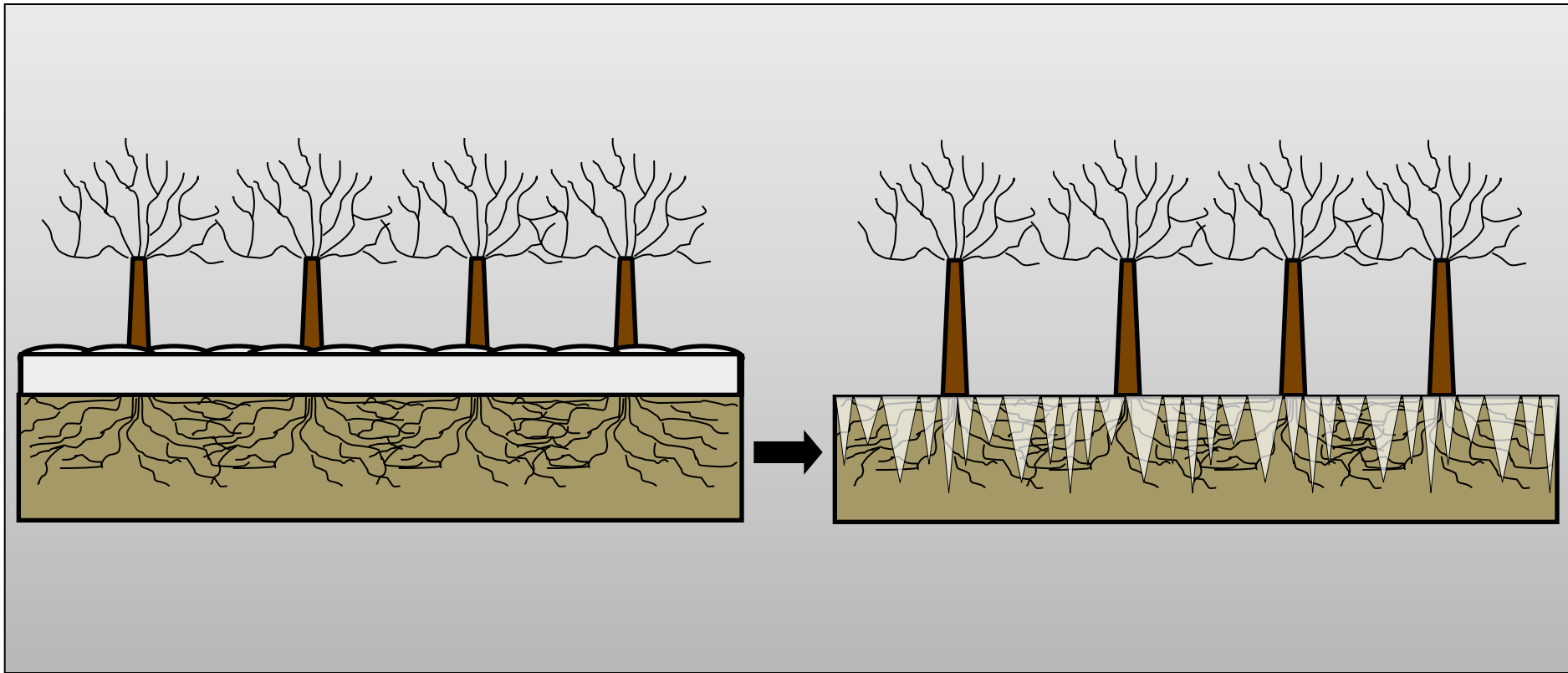
© THOMAS JAMES



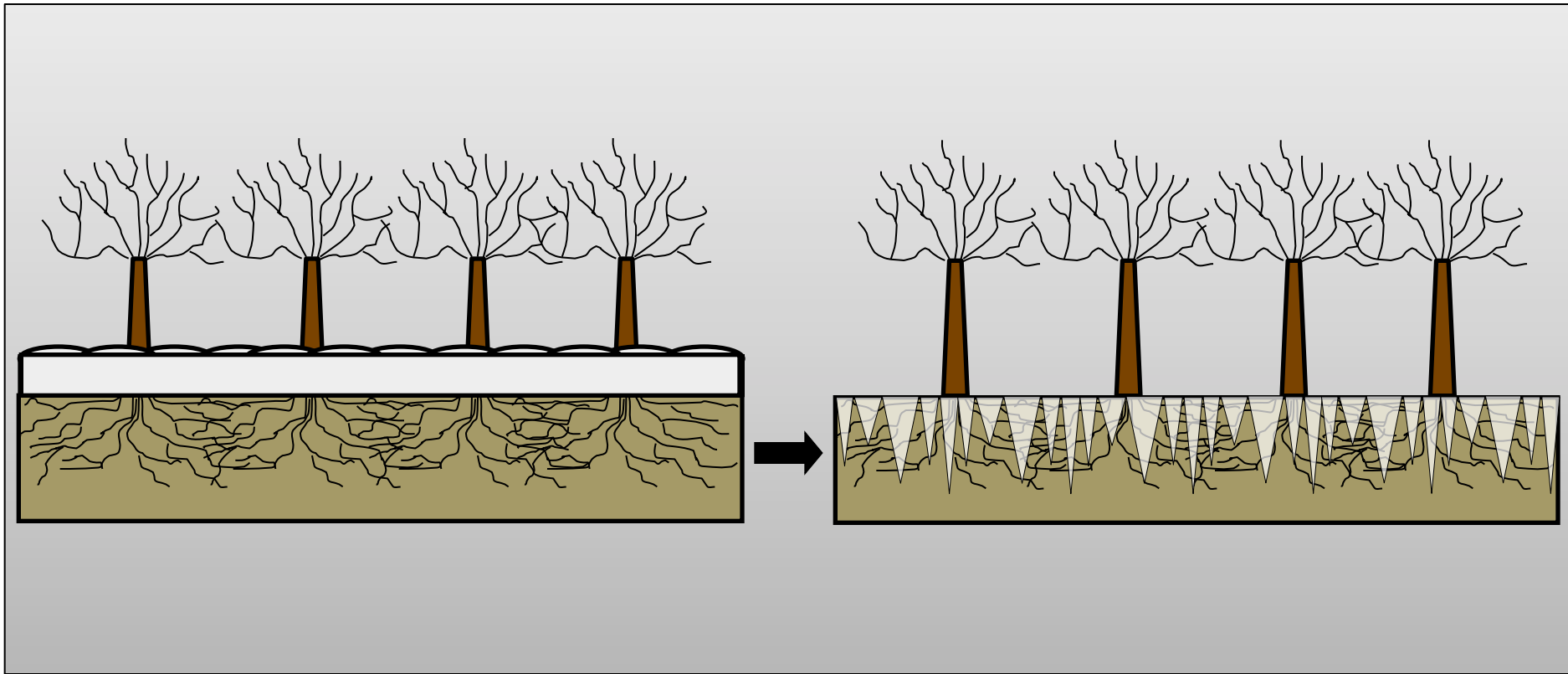
Increased Winter Temperatures and Reduced Snowpack Extent Over Next 100 Years in Northeastern United States



Reduced Snowpack Leads to Soil Freezing



Reduced Snowpack Leads to Soil Freezing



Why Care about Soil Freezing?



Could damage biota in forests:

Plant Roots

Microbes

Arthropods



Water & Air Quality

Snow-Removal Experiments at Hubbard Brook and Harvard Forest



Sugar maple - American beech



Red maple - Red oak

Snow-Removal Experiments at Hubbard Brook and Harvard Forest



n = 4 reference and 4 treatment plots at Hubbard Brook

n = 3 reference and 3 treatment plots at Harvard Forest

Hypotheses

Reduced snowpack and increased soil frost:

- damage roots and reduce nutrient uptake by trees
- decrease ecosystem carbon storage
- decrease arthropod and microbial biomass



Snow and Soil Frost Depth Measurements



Snow Depth



Frost tubes with
methylene blue dye

Snow and Soil Frost Depth Measurements

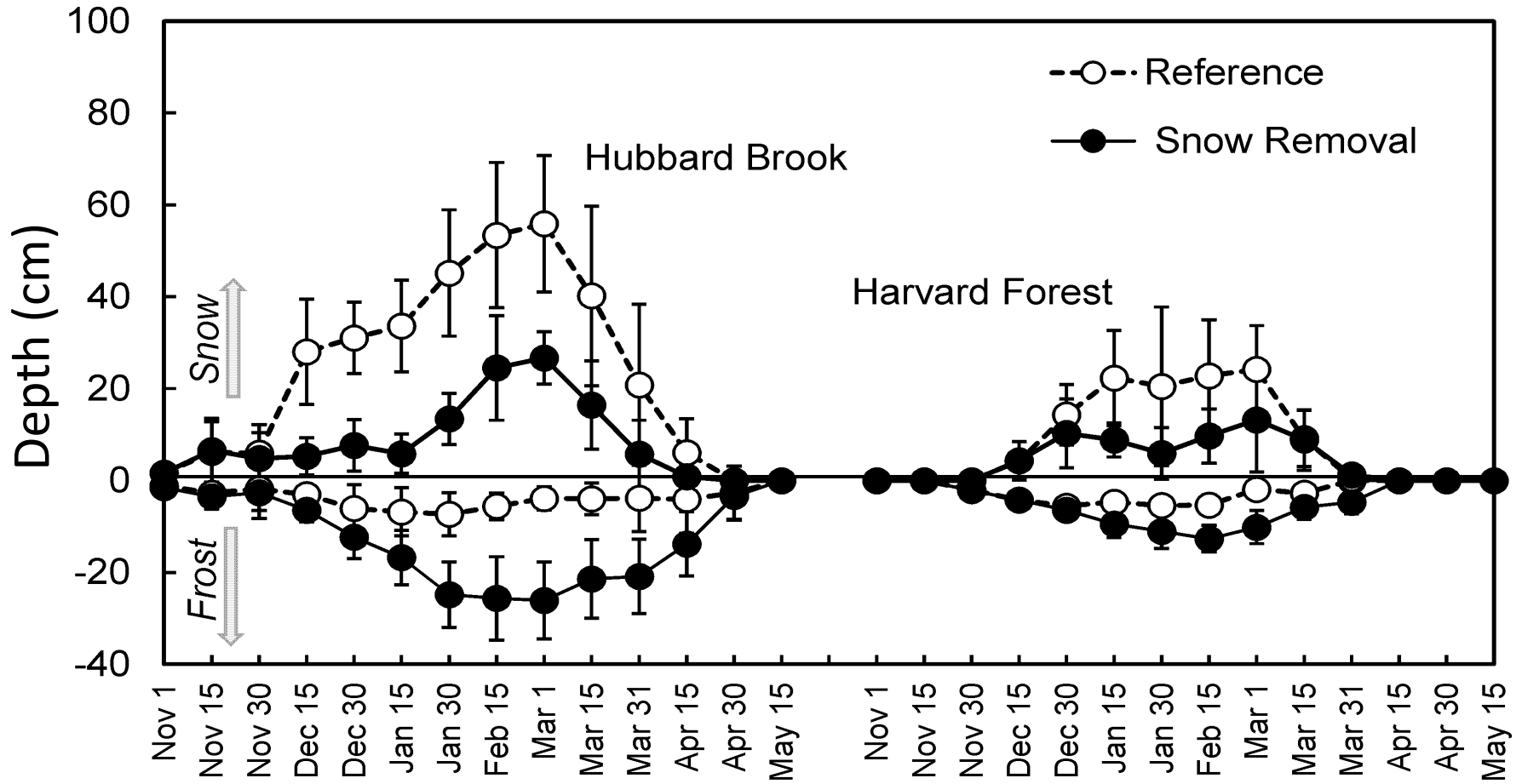


Snow Depth

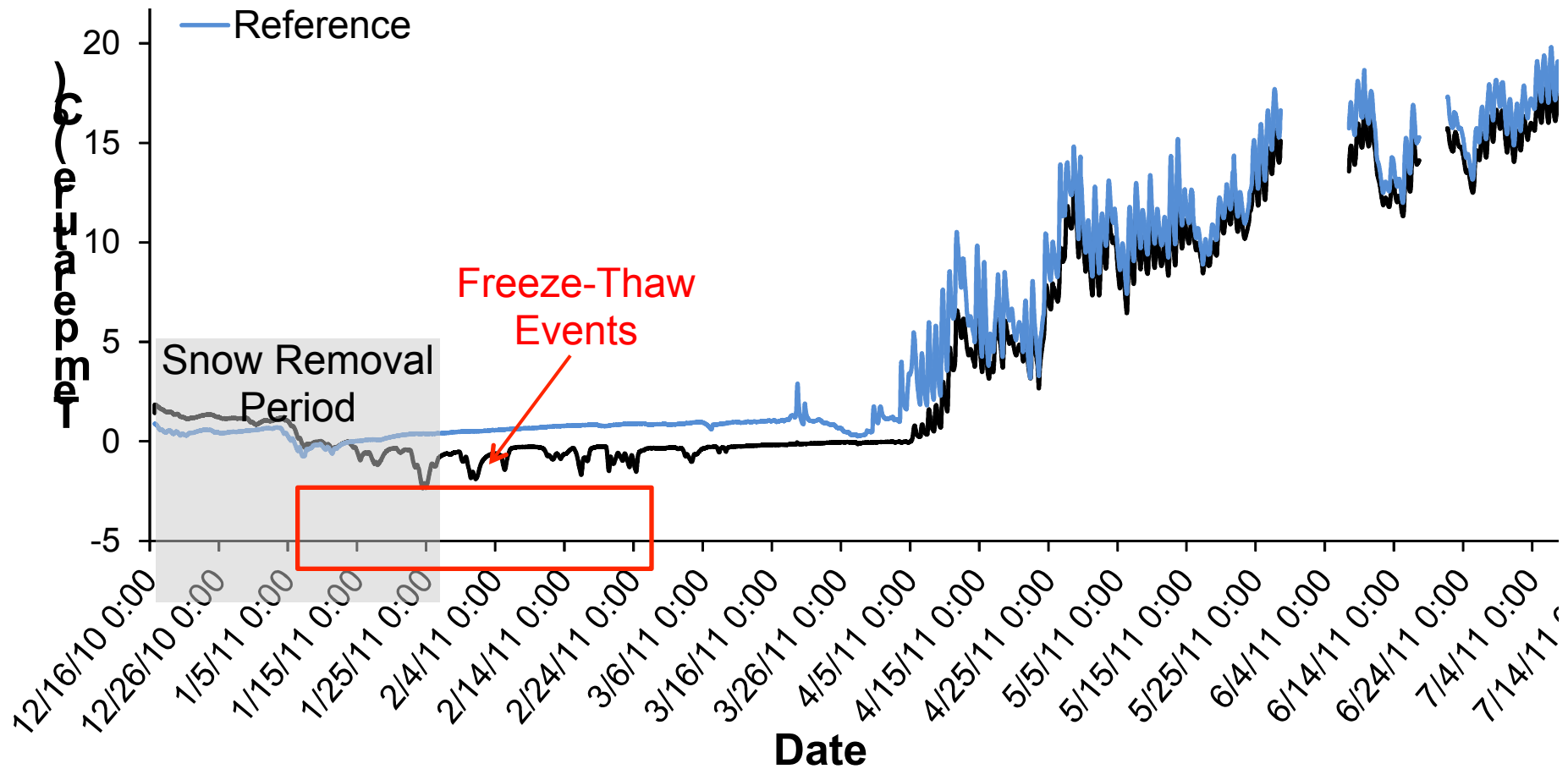


Frost tubes with
methylene blue dye

Smaller Snowpack Increases Soil Frost Depth



Snow Removal Increases Frequency of Soil Freeze-Thaw Events



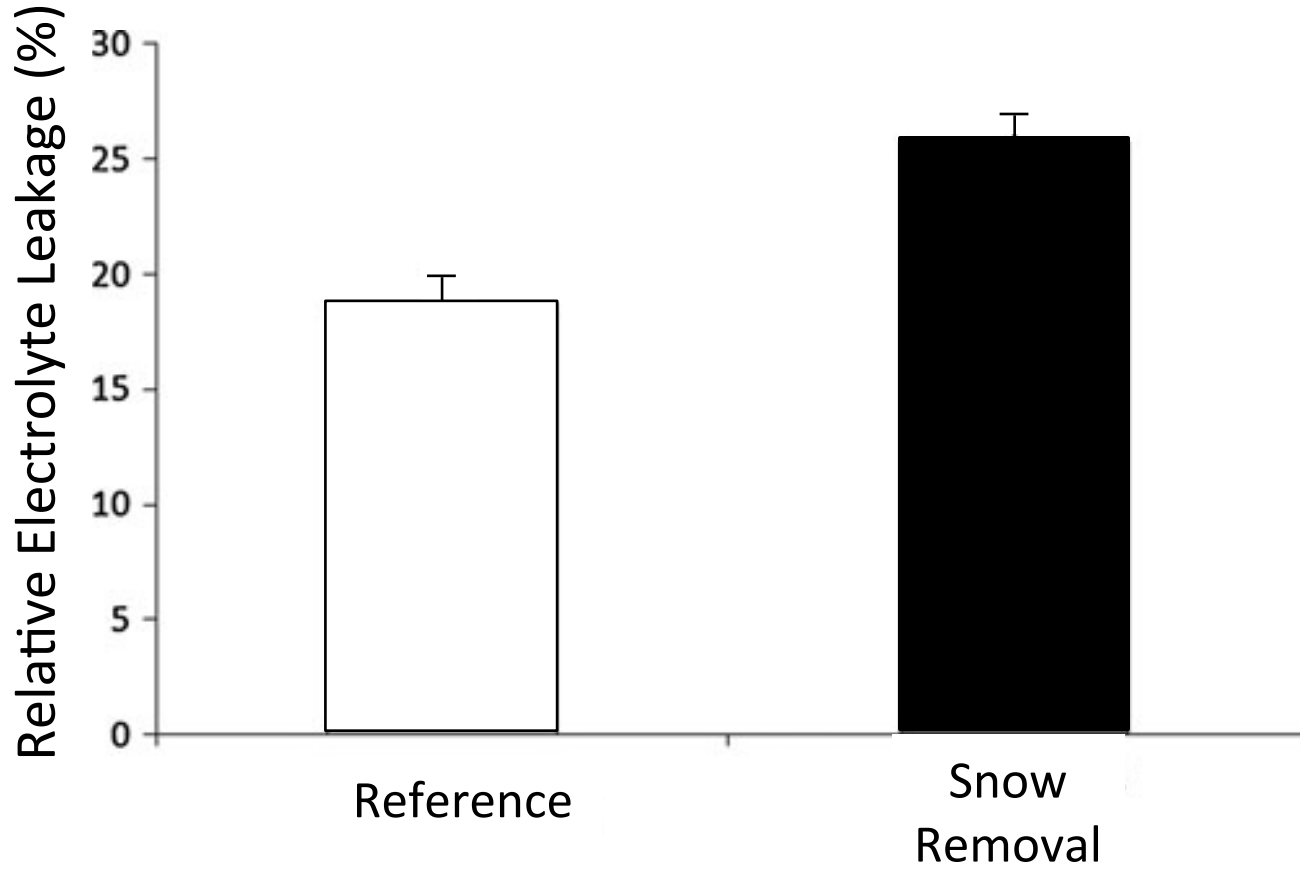
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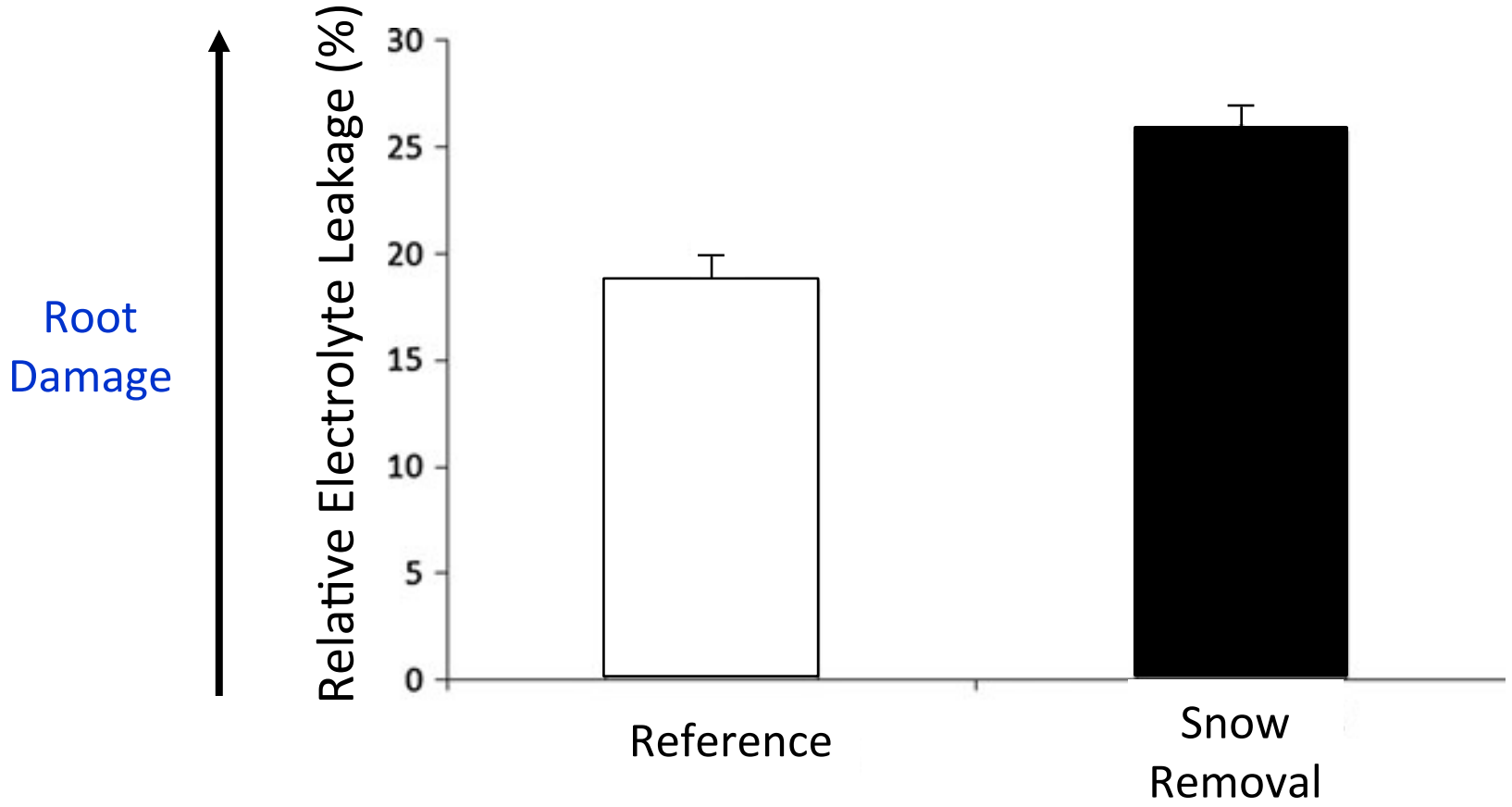
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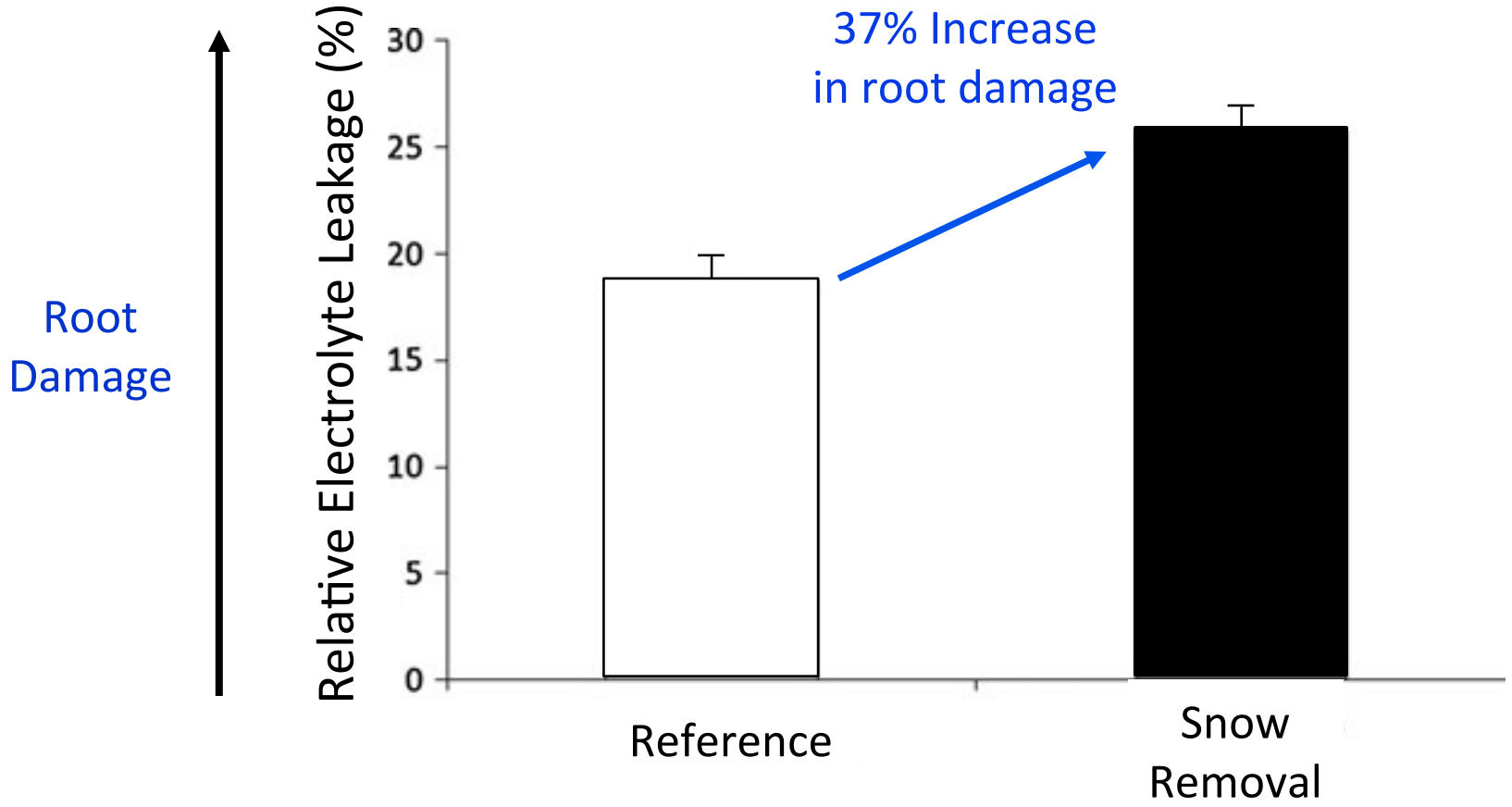
Soil Frost Induces Root Injury of Sugar Maple Trees



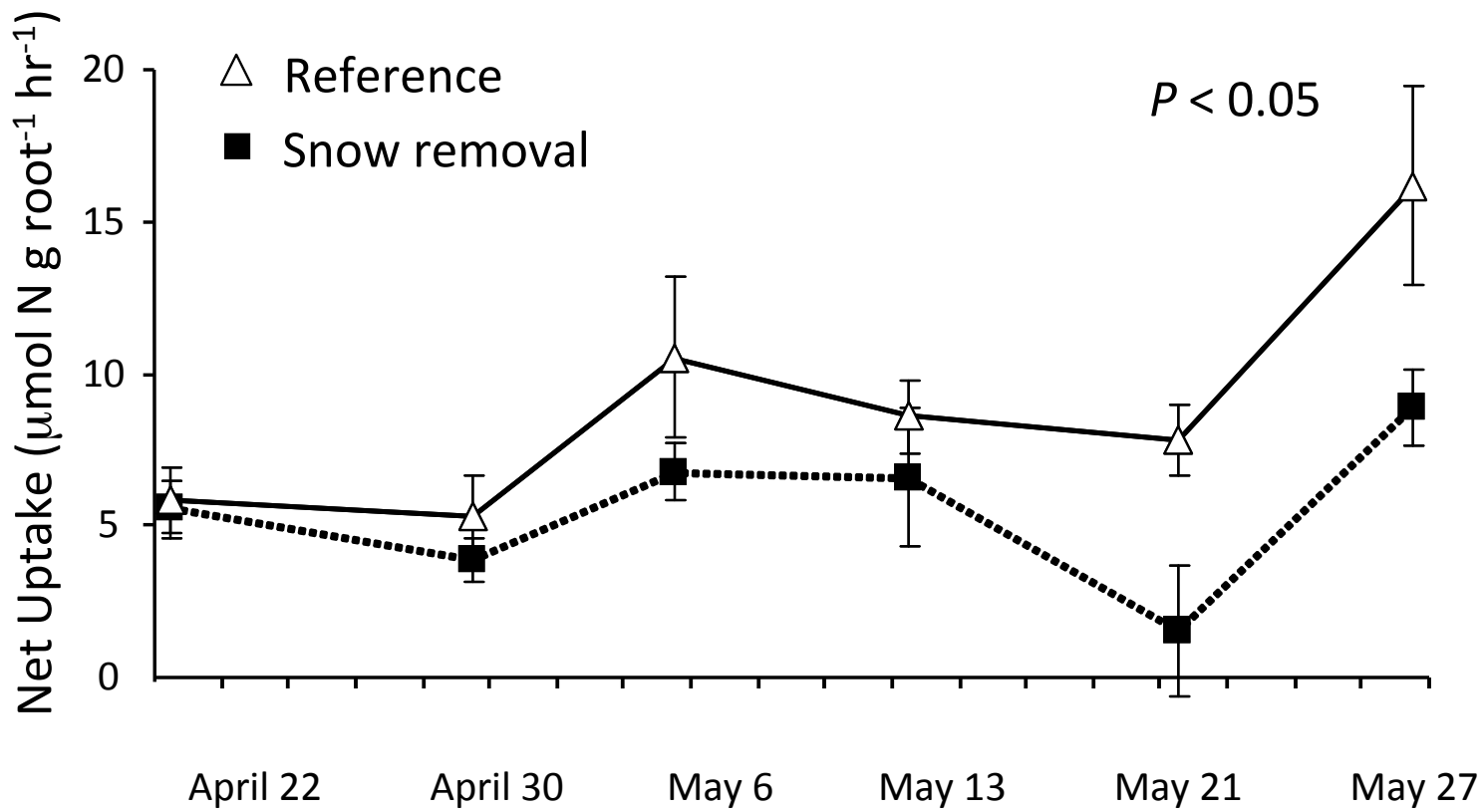
Soil Frost Induces Root Injury of Sugar Maple Trees



Soil Frost Induces Root Injury of Sugar Maple Trees

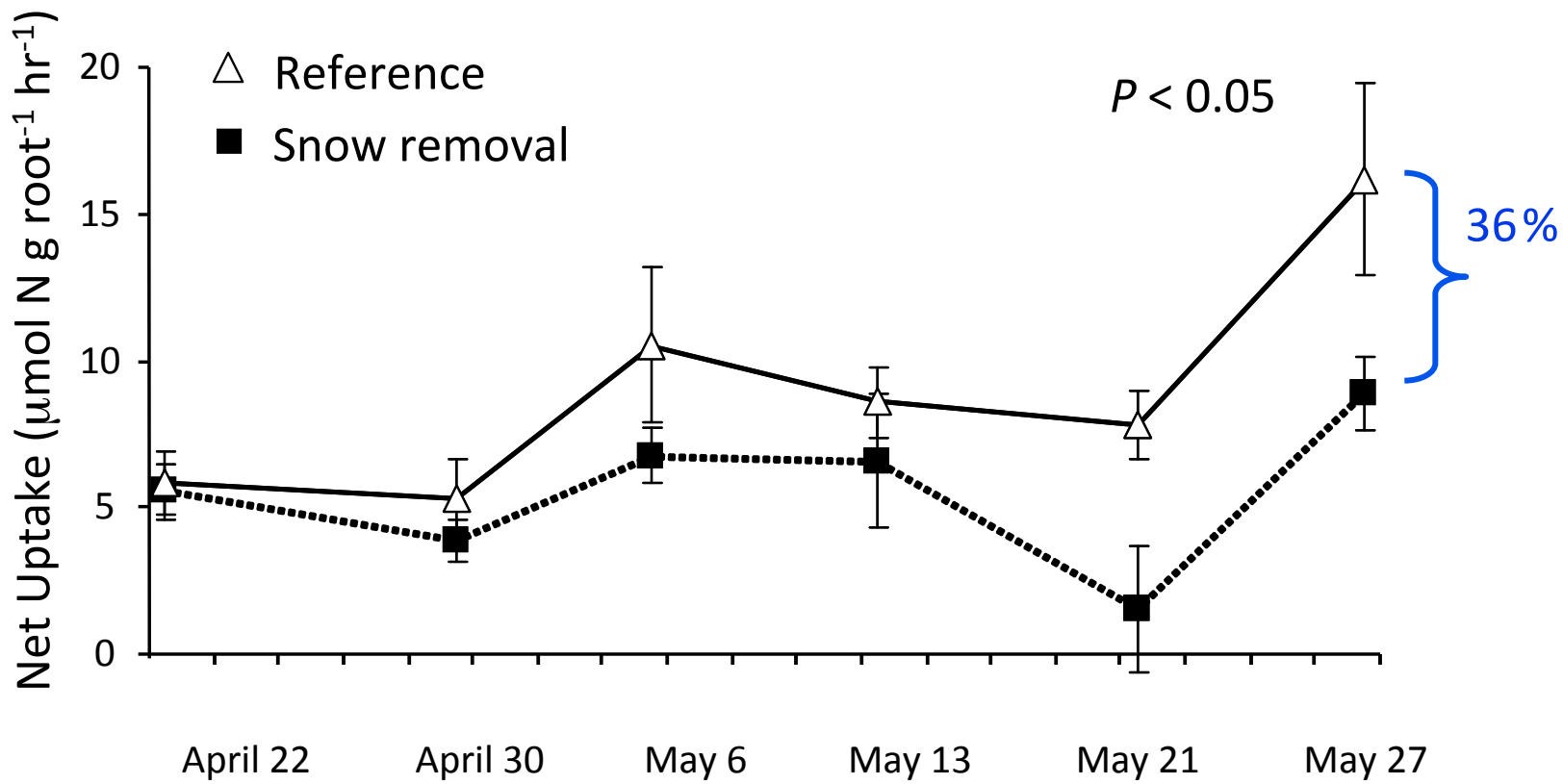


Soil Frost Reduces Nitrogen Uptake by Sugar Maple Trees



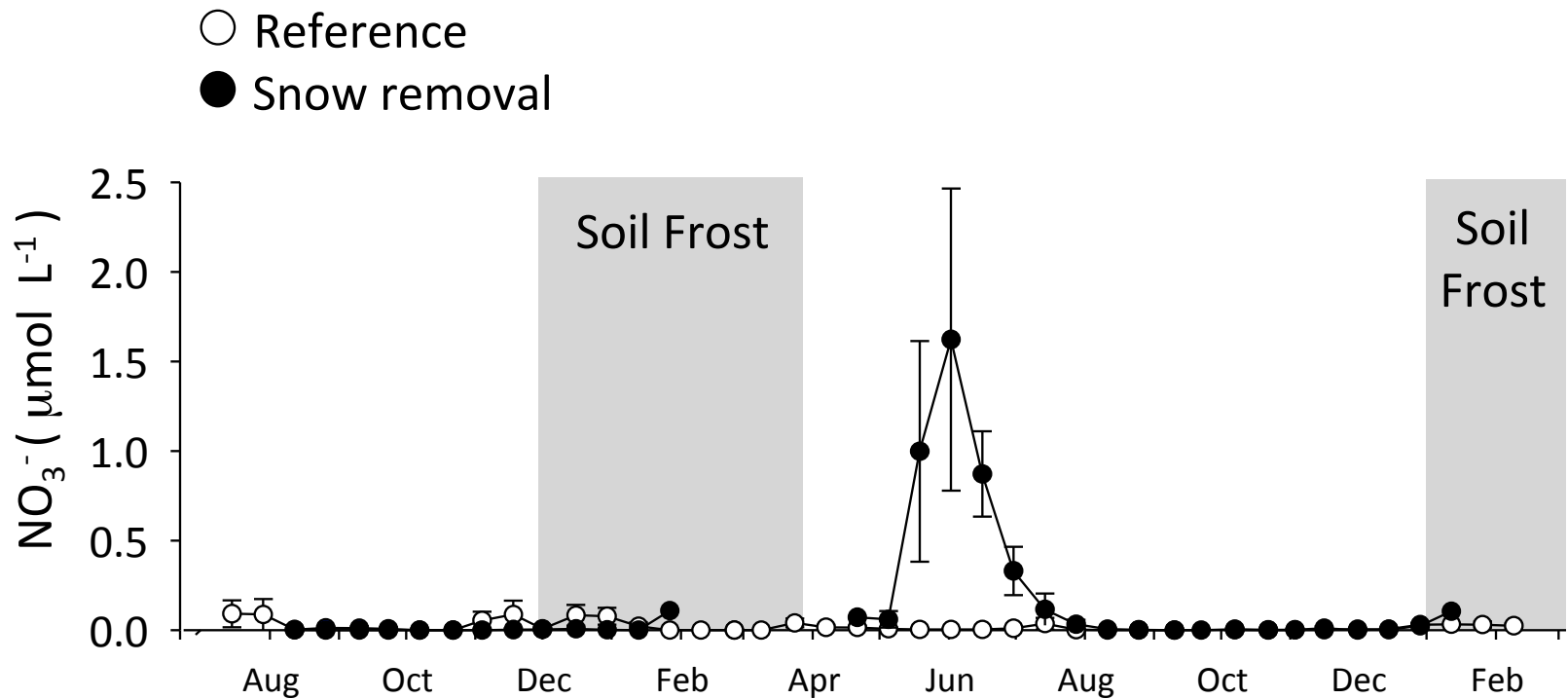
Socci and Templer (2011); Campbell et al. (2014)

Soil Frost Reduces Nitrogen Uptake by Sugar Maple Trees

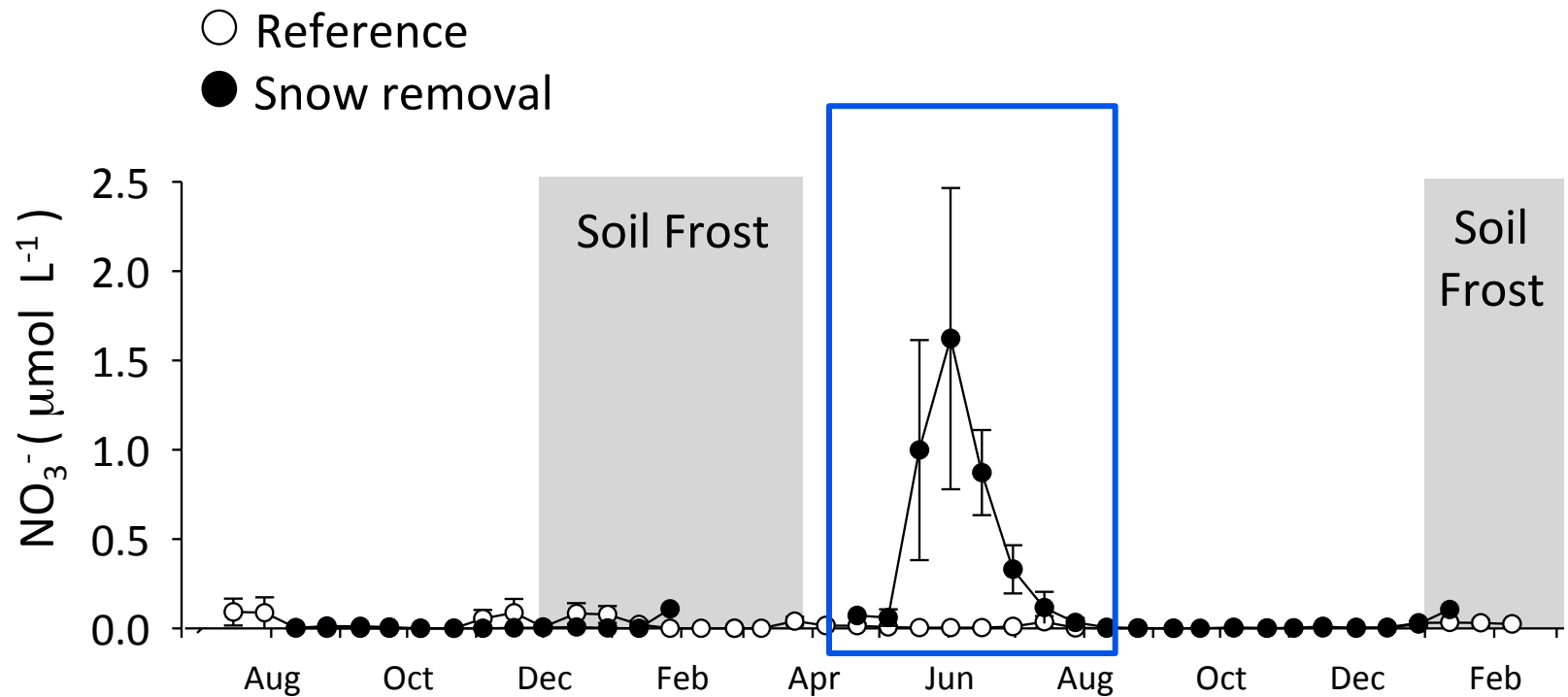


Socci and Templer (2011); Campbell et al. (2014)

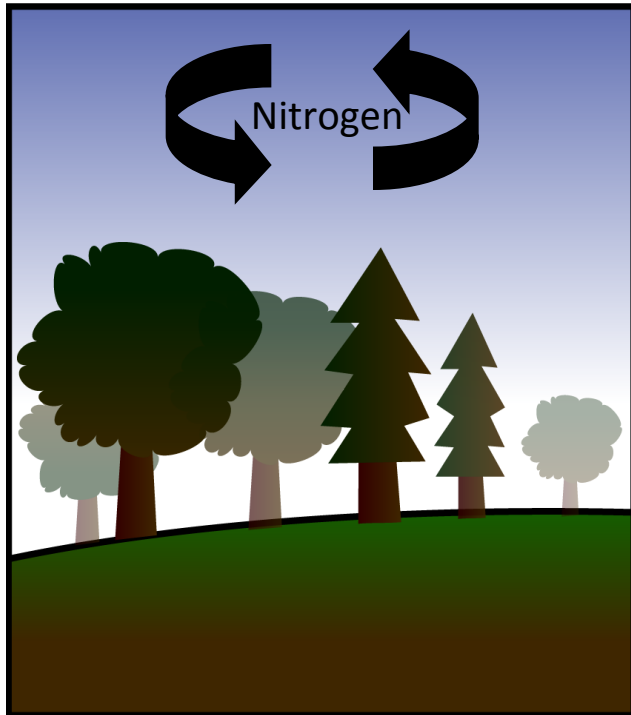
Soil Frost Induces Elevated NO_3^- in Leachate



Soil Frost Induces Elevated NO_3^- in Leachate



Why Care about Nitrogen Leaching?

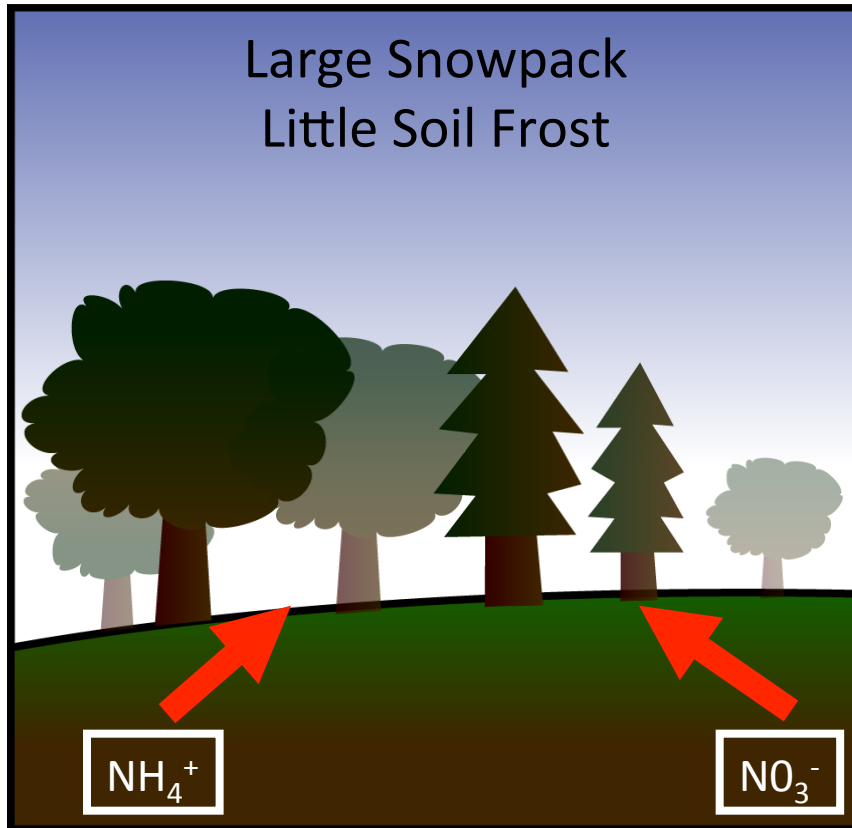


NO_3^- Leaching

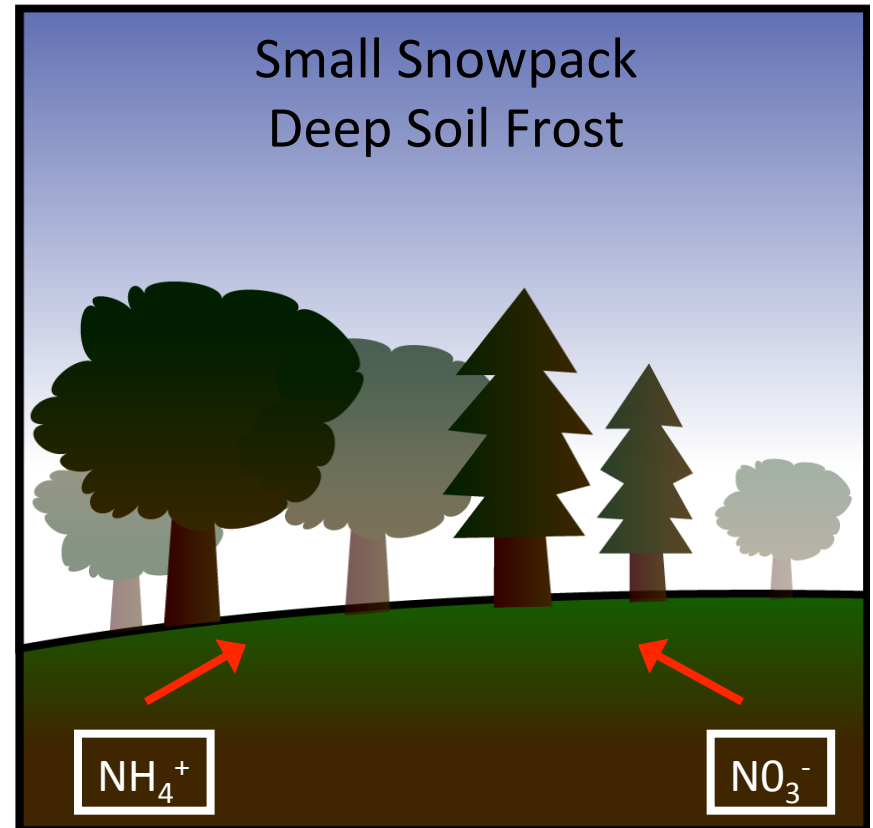
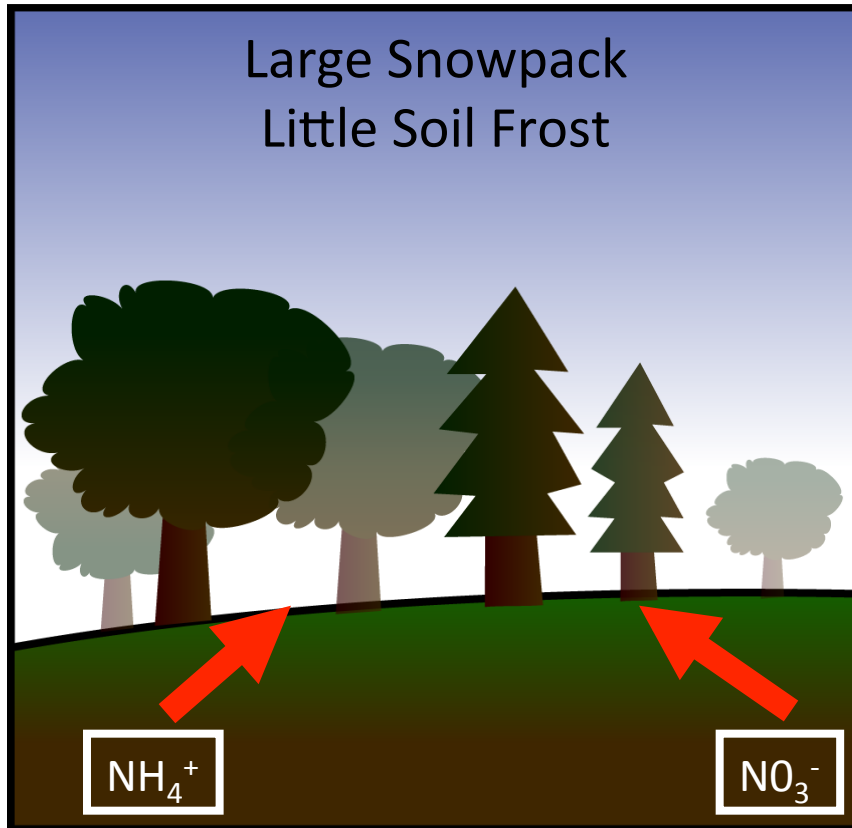


- Release of N_2O
- Reduced forest productivity
- Acidification of stream water
- Eutrophication (algal blooms)
- Human health effects

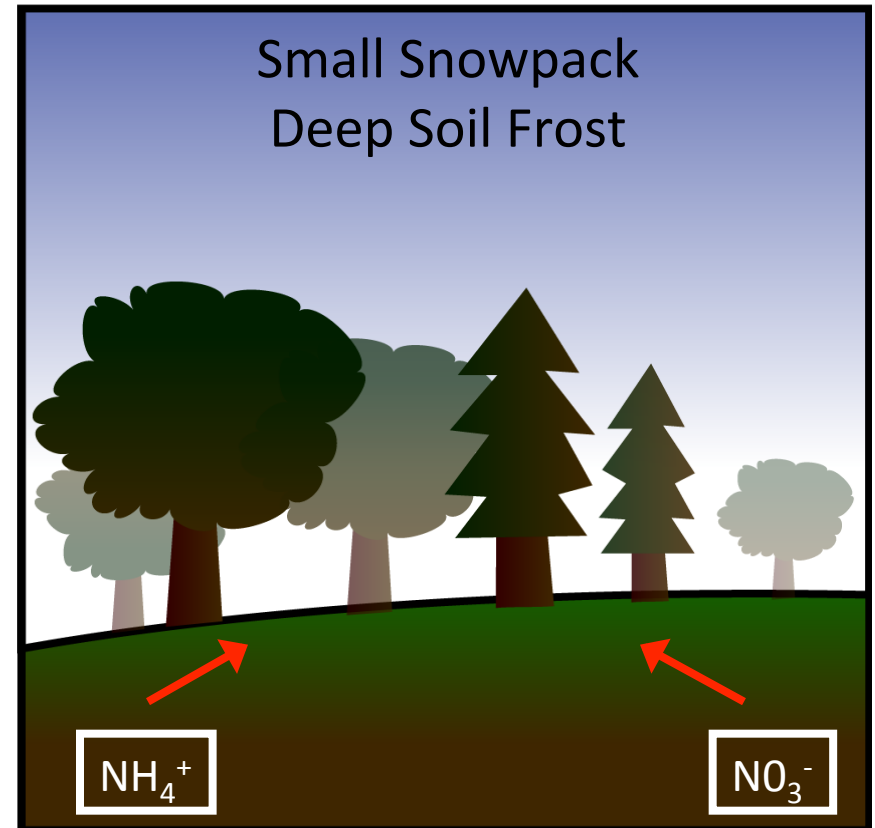
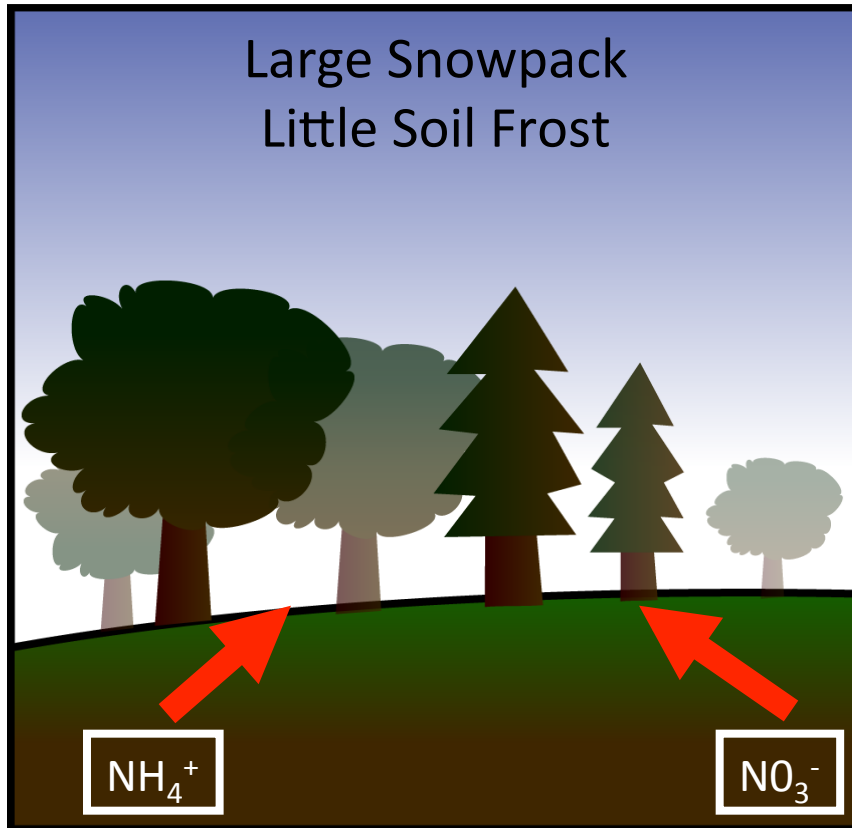
Why does soil freezing lead to N leaching?



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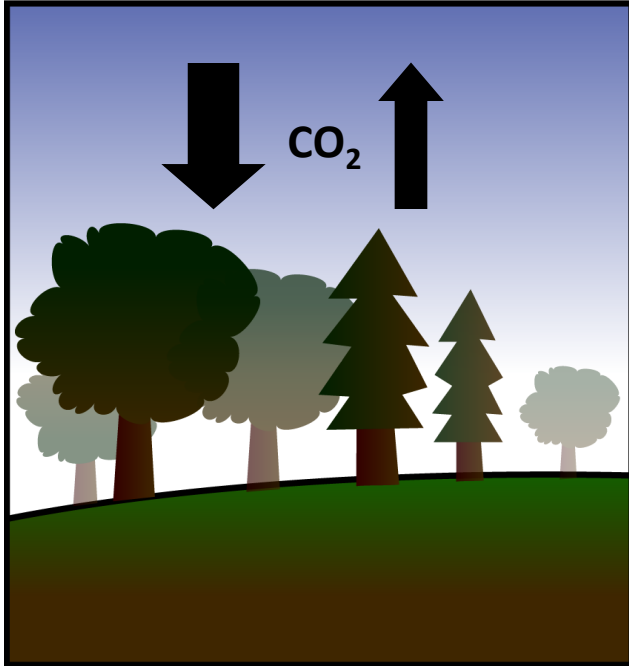
Hypotheses

Reduced snow pack and increased soil frost:

- damage roots and reduce nutrient uptake by trees
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- decrease arthropod and microbial biomass

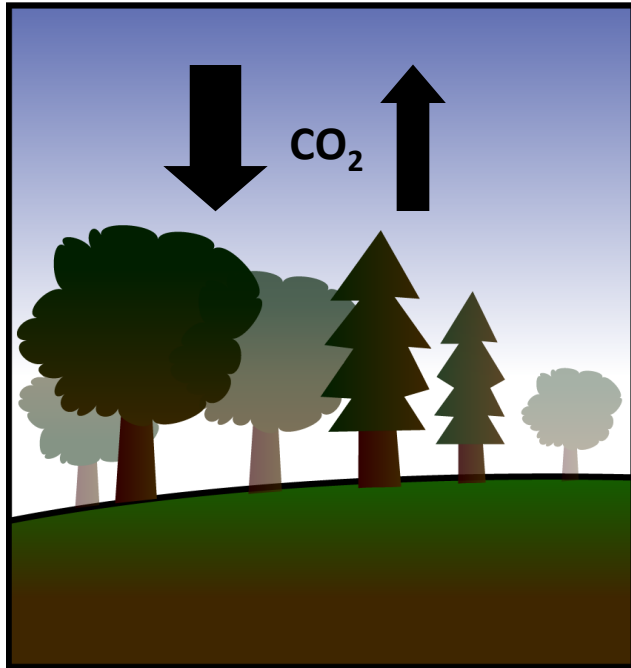


Does soil freezing reduce C sequestration?

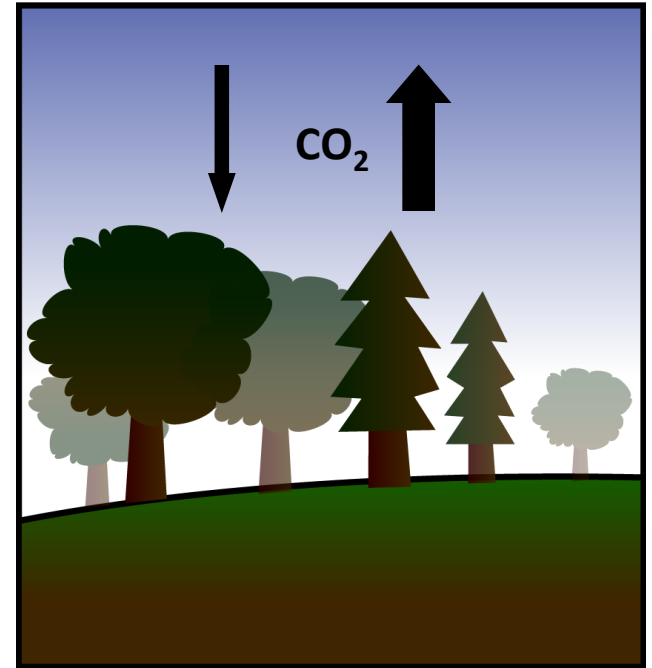


Large Snowpack
Little Soil Frost

Does soil freezing reduce C sequestration?

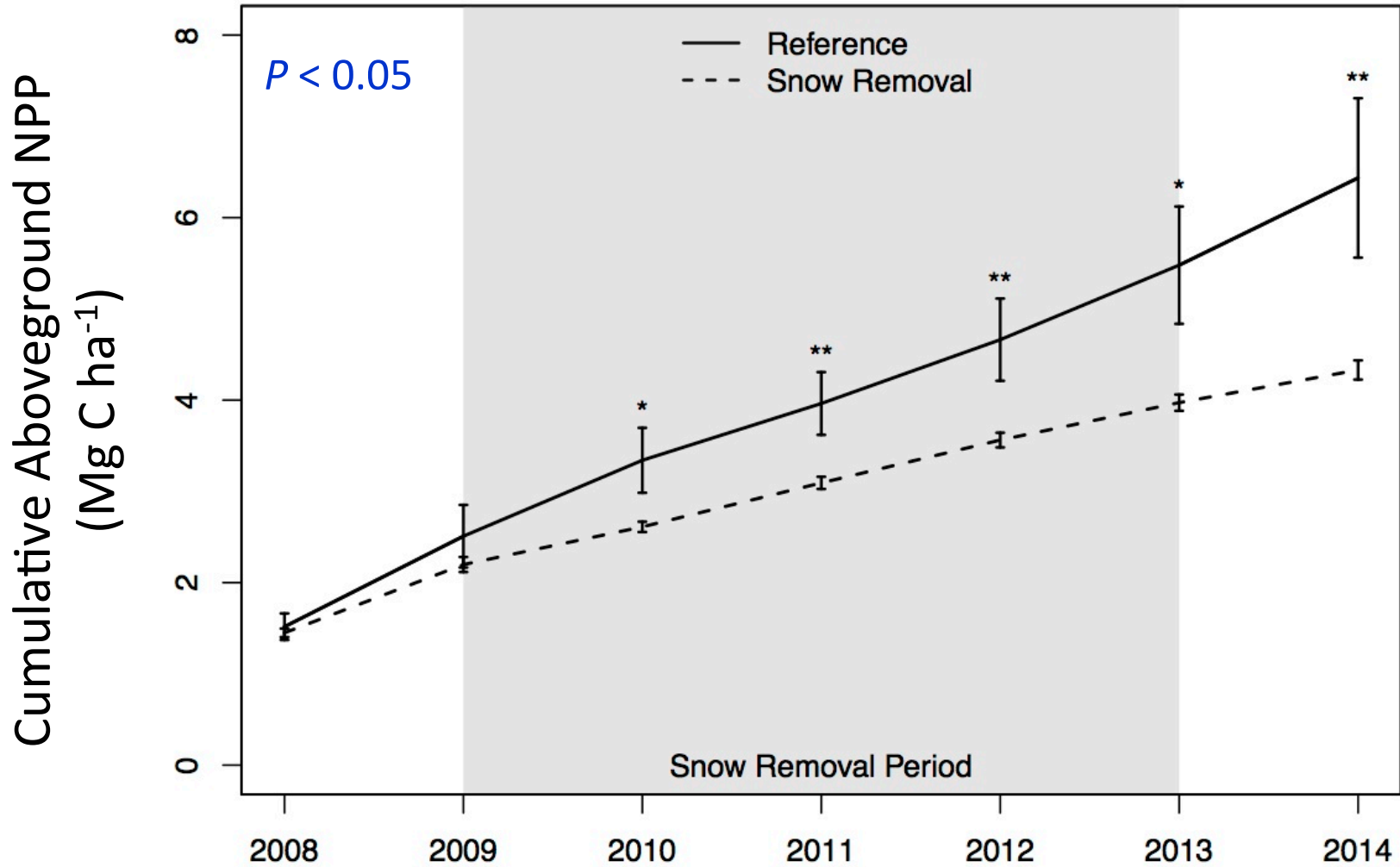


Large Snowpack
Little Soil Frost



Small Snowpack
Deep Soil Frost

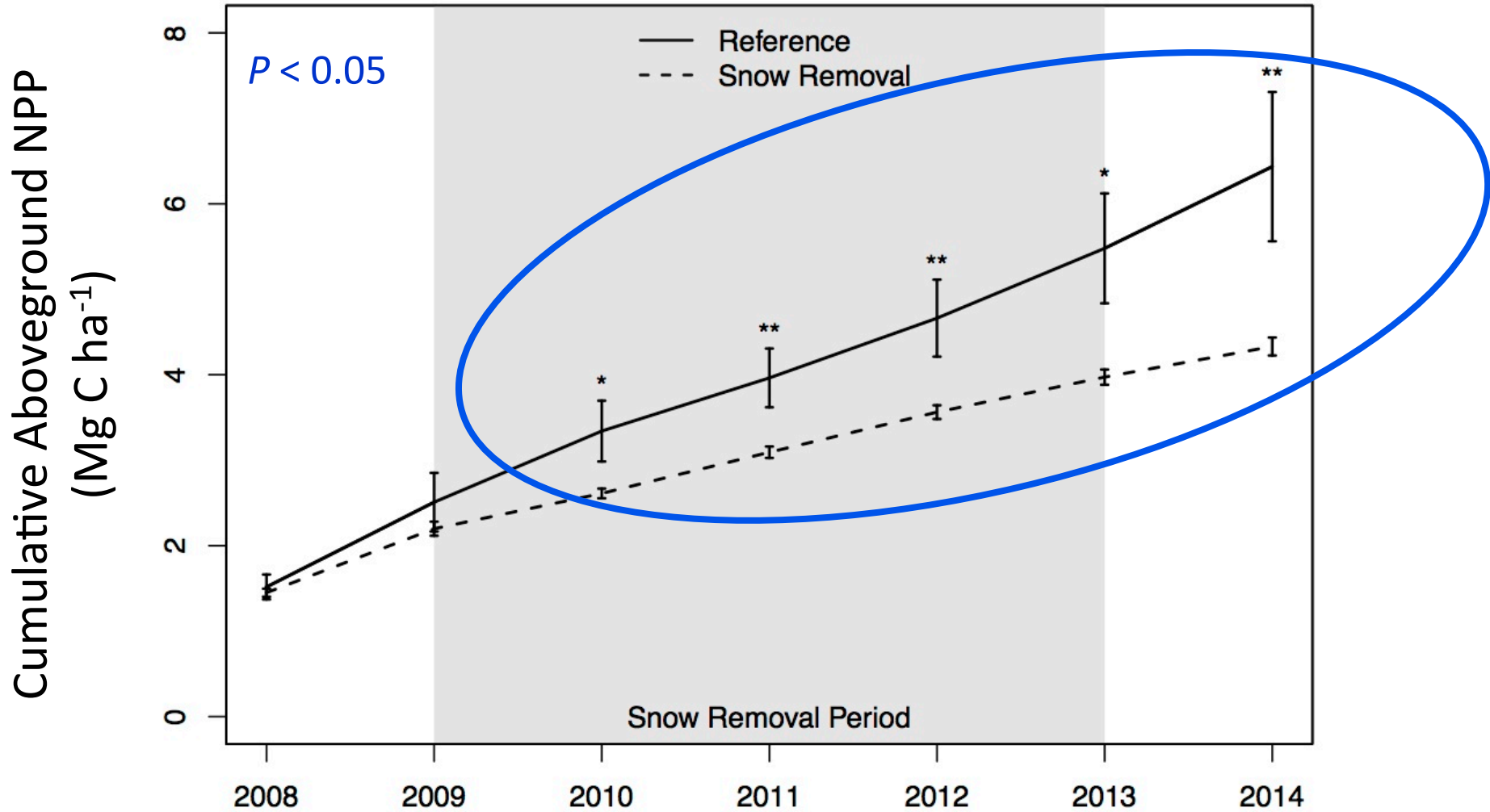
Soil Frost Reduces C Uptake of Maple Forests



Jessica Susser (UROP) & Andy Reinmann (PhD)



Soil Frost Reduces C Uptake of Maple Forests



Jessica Susser (UROP) & Andy Reinmann (PhD)



Soil Frost Increases Carbon Loss from Maple Forests

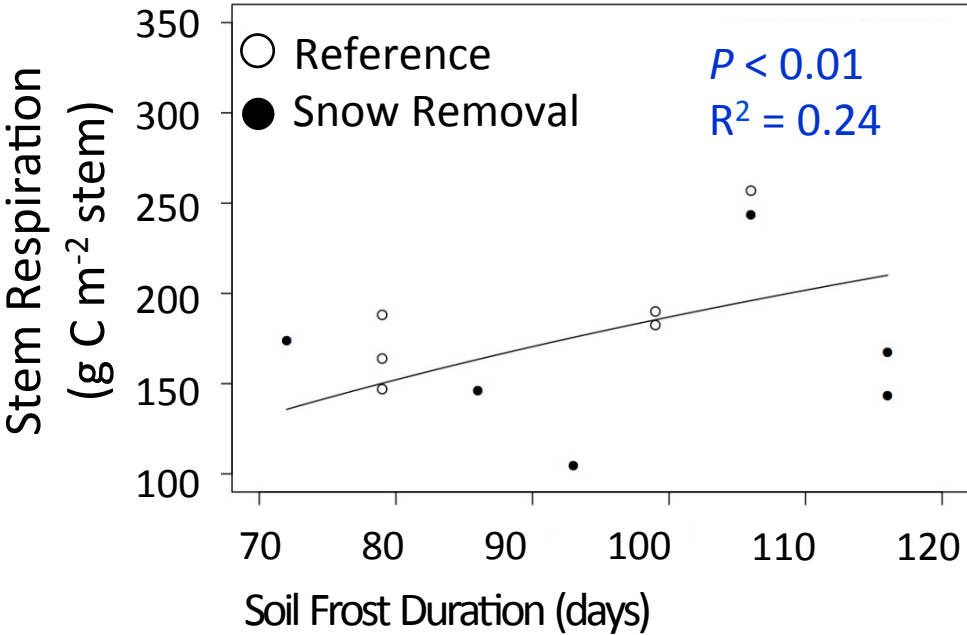


Photo Credit: BU Today

Soil Frost Increases Carbon Loss from Maple Forests

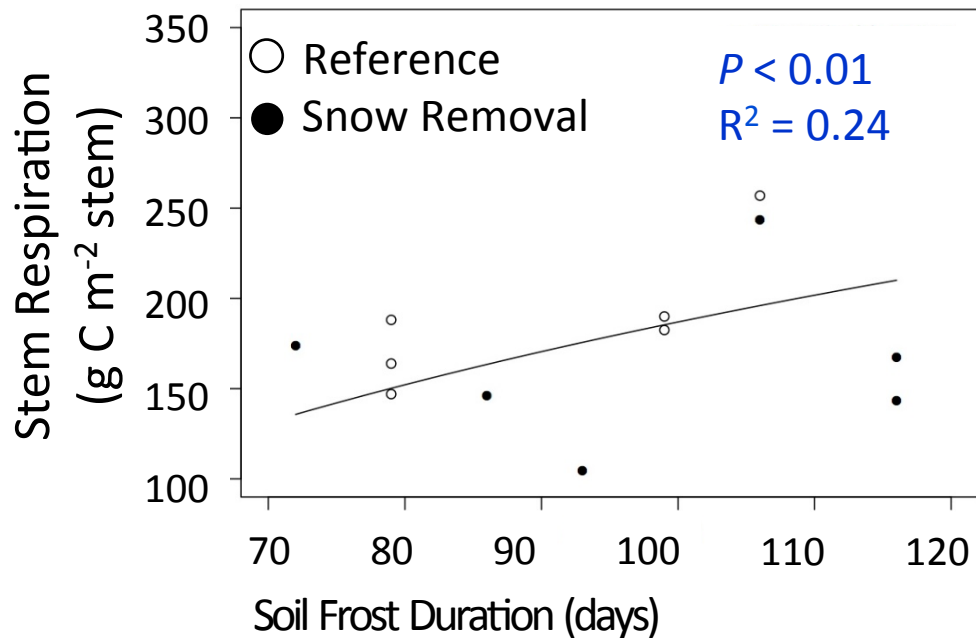
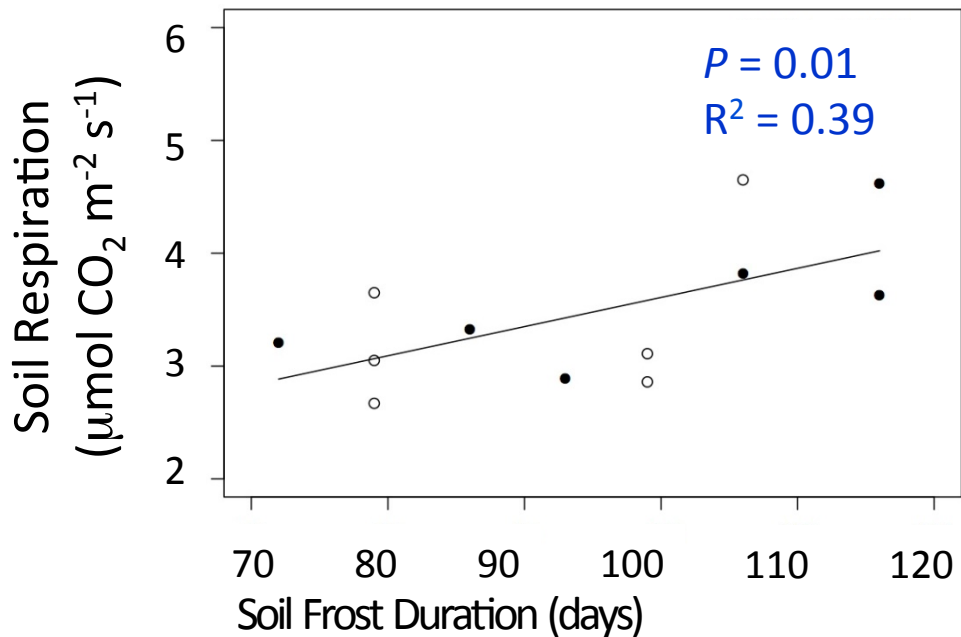
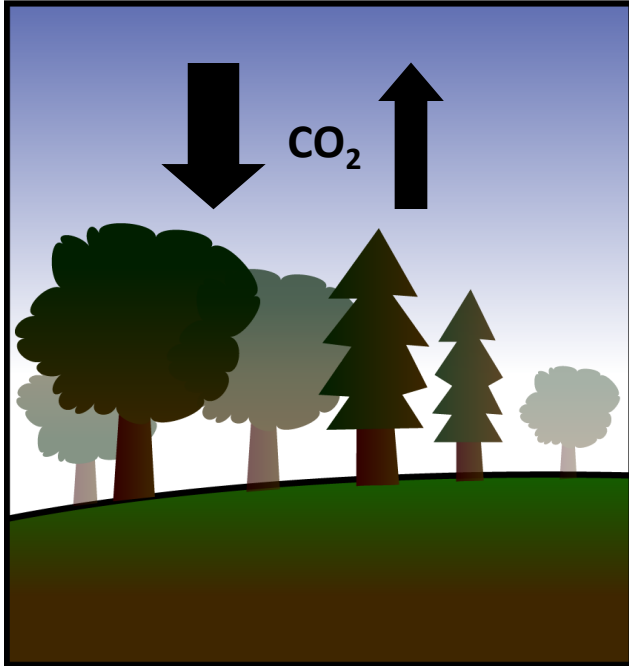


Photo Credit: BU Today



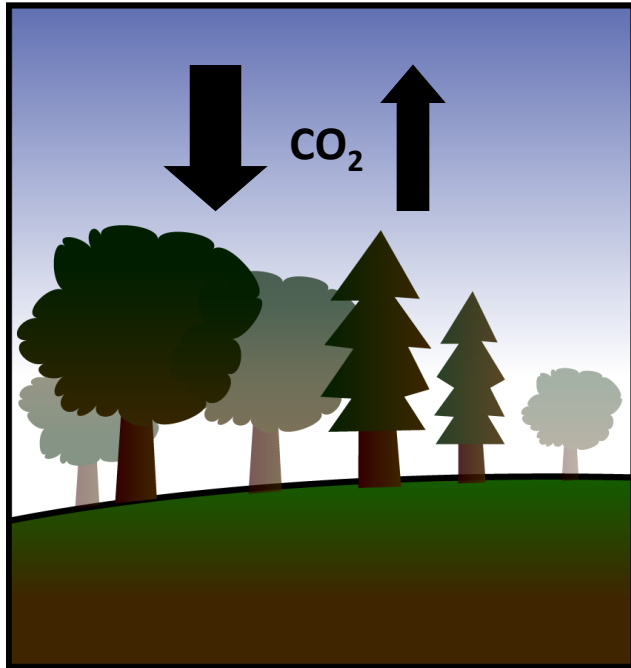
Reinmann & Templer (2016) *Ecosystems*

Does soil freezing reduce C sequestration?

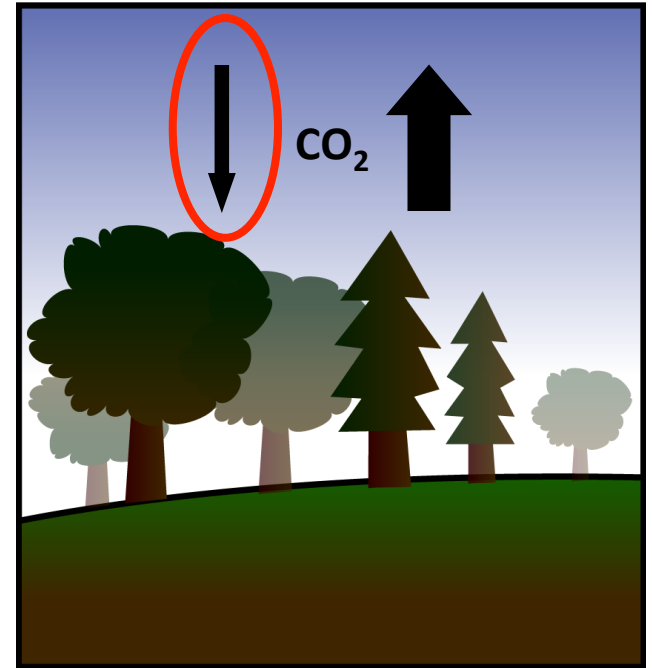


Large Snowpack
Little soil frost

Does soil freezing reduce C sequestration?

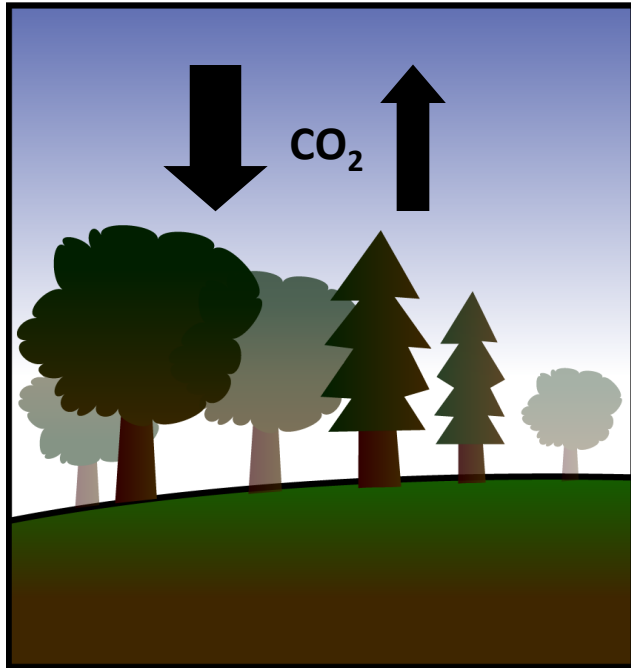


Large Snowpack
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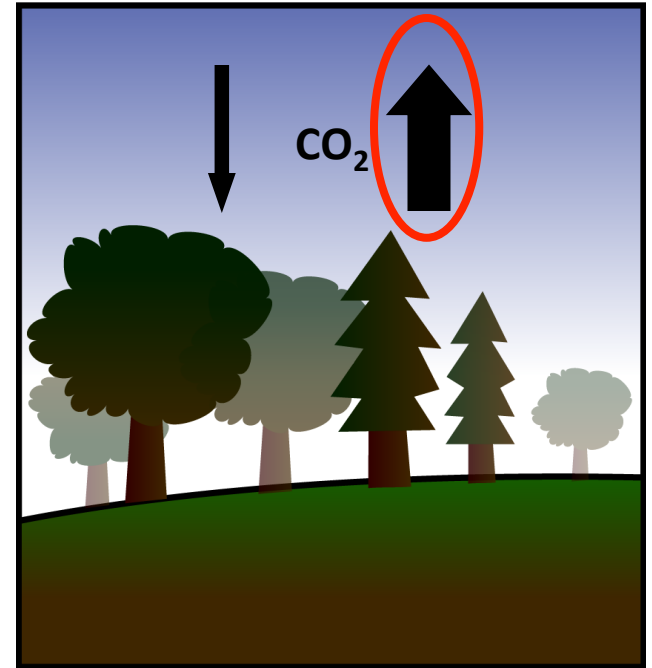


Small Snowpack
Deep soil frost

Does soil freezing reduce C sequestration?

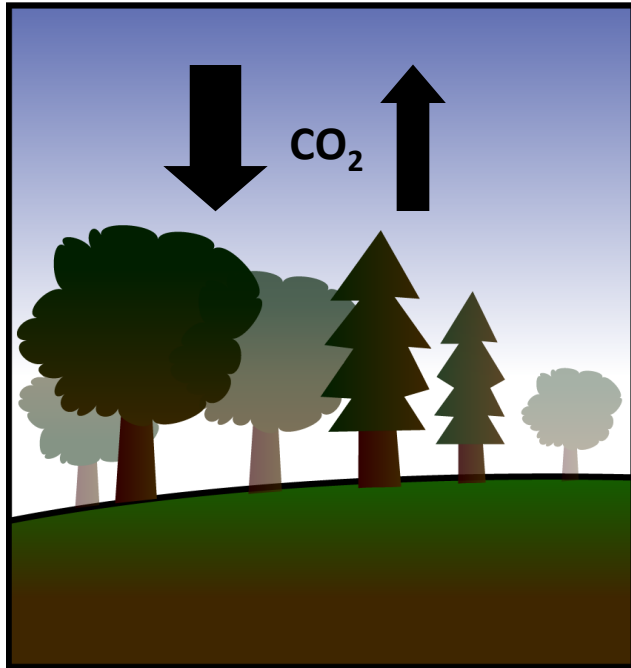


Large Snowpack
Little soil frost



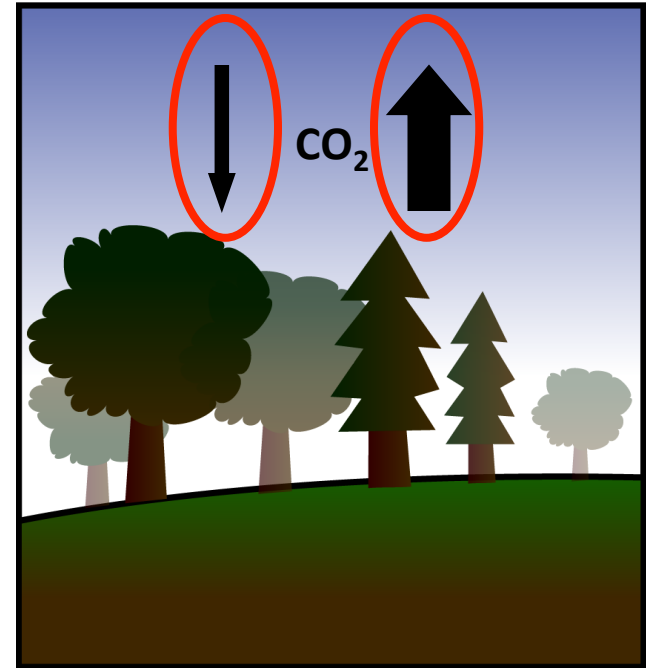
Small Snowpack
Deep soil frost

Does soil freezing reduce C sequestration?

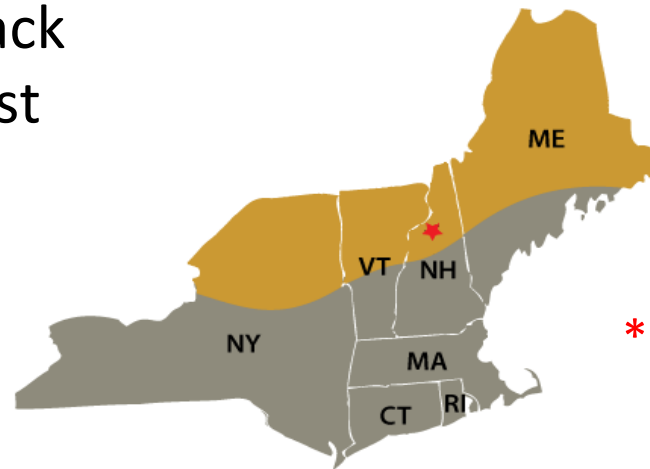


Large Snowpack
Little soil frost

15% reduction
C storage across
northern forest



Small Snowpack
Deep soil frost



* Hubbard Brook

Hypotheses

Reduced snow pack and increased soil frost:

- damage roots and reduce nutrient uptake by trees
- decrease ecosystem carbon storage
- decrease arthropod and microbial biomass



Soil Arthropods

- Alter soil microbial communities
- Enhance rates of decomposition
- Increase rates of plant nutrient uptake and growth



Sampling Soil Arthropods

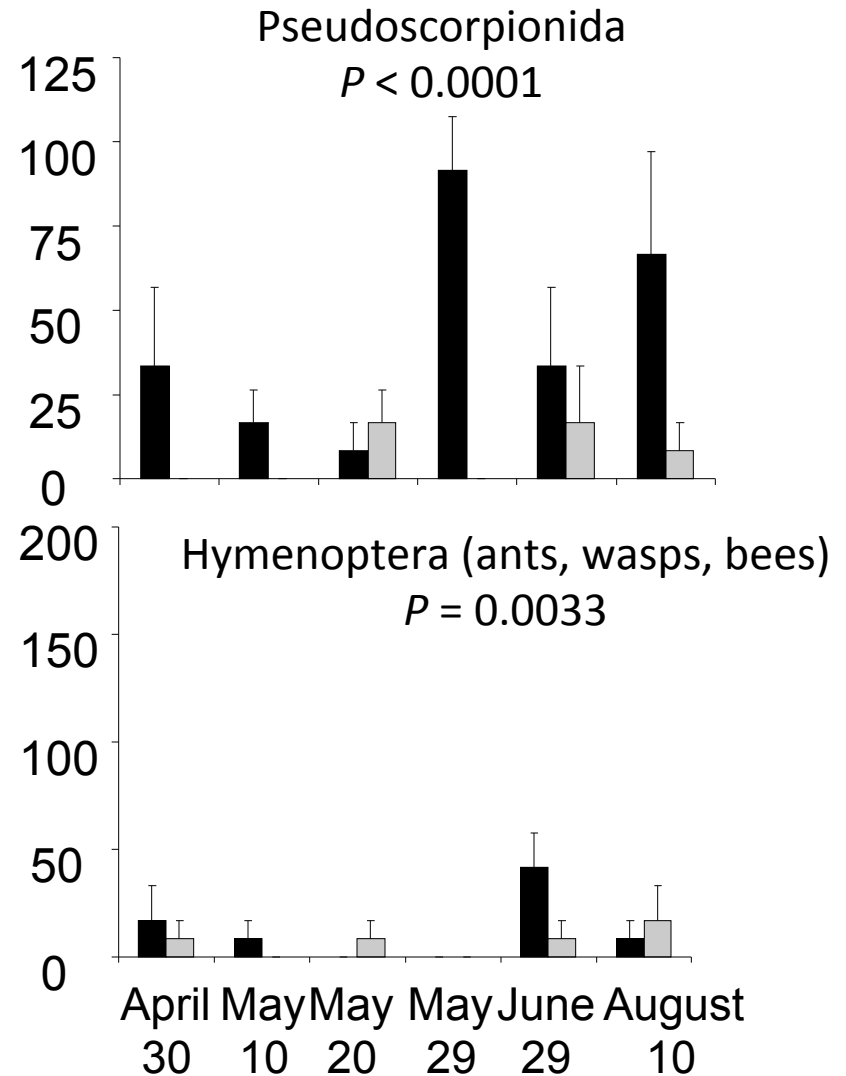
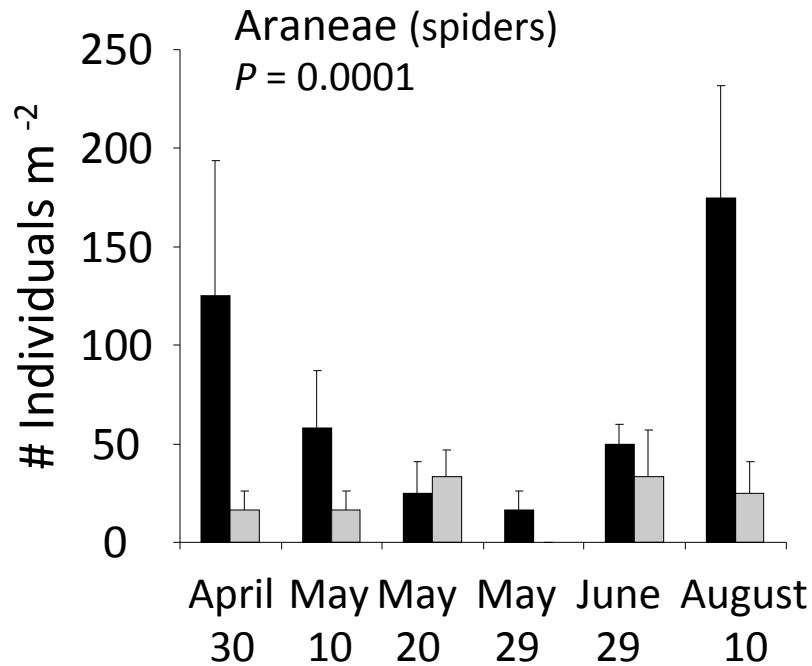
- Surface leaf litter and Oe soil horizon throughout 2009 and 2010 growing seasons
- n=3 samples per plot per date
- Tullgren funnels to sample arthropods



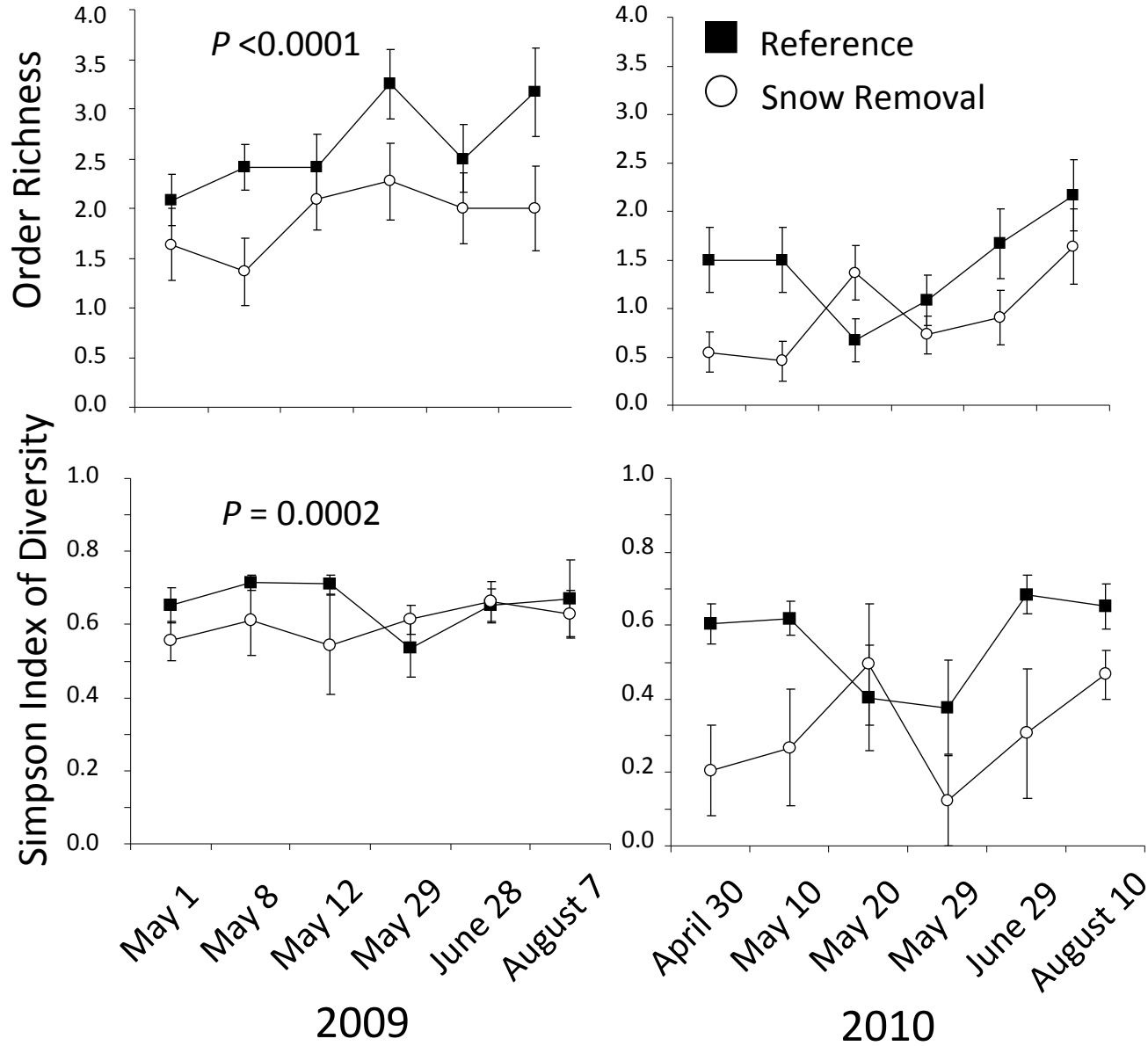
Andrew Schiller

Soil Frost Reduces Arthropod Abundance

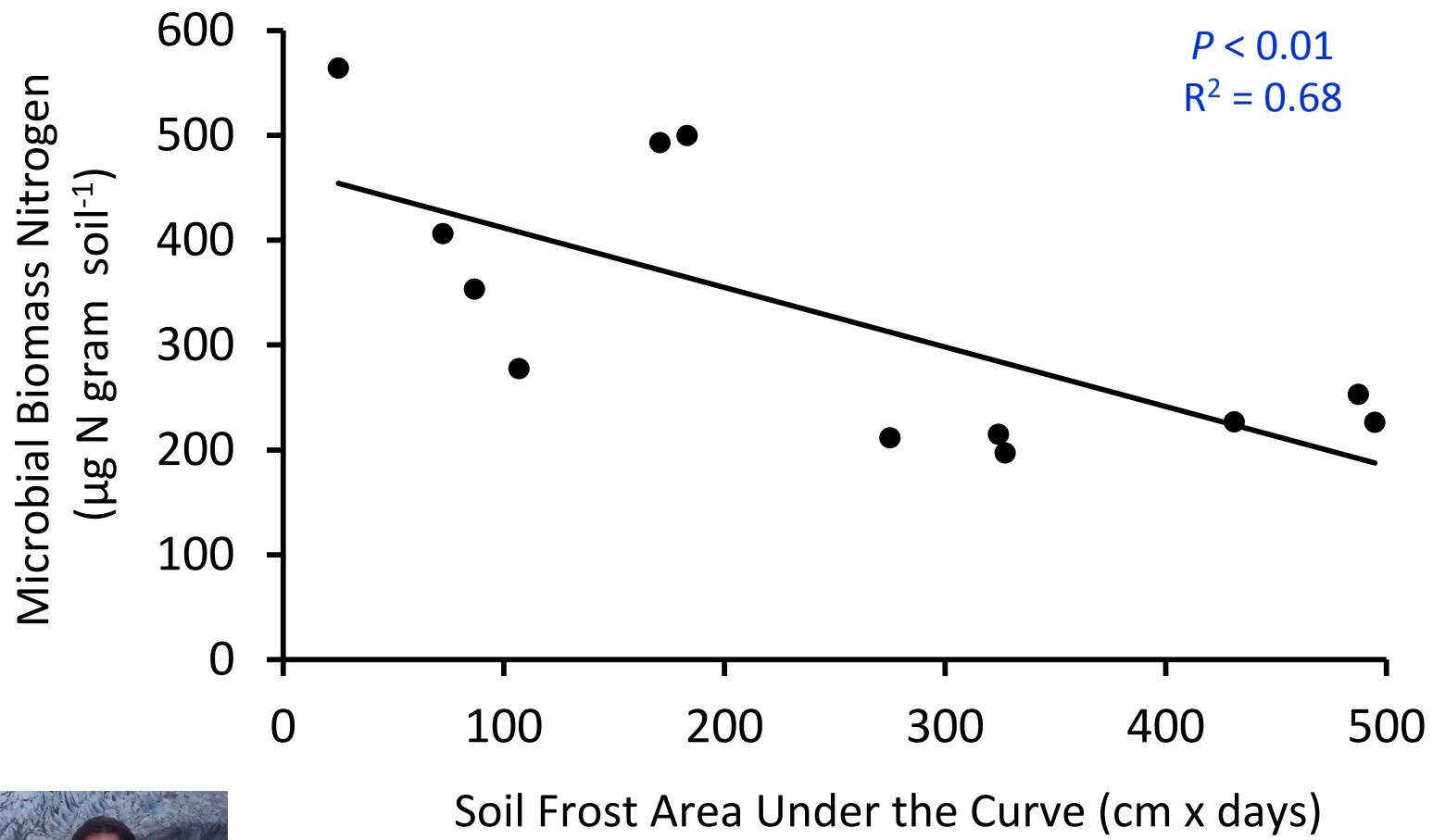
■ Reference
■ Snow Removal



Soil Frost Reduces Arthropod Richness & Diversity



Soil Frost Decreases Microbial Biomass



Reduced Snowpack and Increased Soil Freezing

- increase NO_3^- leaching due to root damage and reduced N uptake by trees (*Comerford et al. 2013; Campbell et al. 2014*)
- reduce forest C storage (*Reinmann and Templer 2016*)
- reduce arthropod abundance and diversity (*Templer et al. 2012*)
- Reduce soil microbial biomass and exoenzyme activity (*Sorensen et al. 2016*)



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Why are results important?

- 55% land mass of northern hemisphere has soil freezing
- Temperatures warming
- Soil freeze/thaw cycles increasing

What are combined effects of colder soils in winter + warmer soils in the growing season?



Climate Change Across Season Effects Experiment



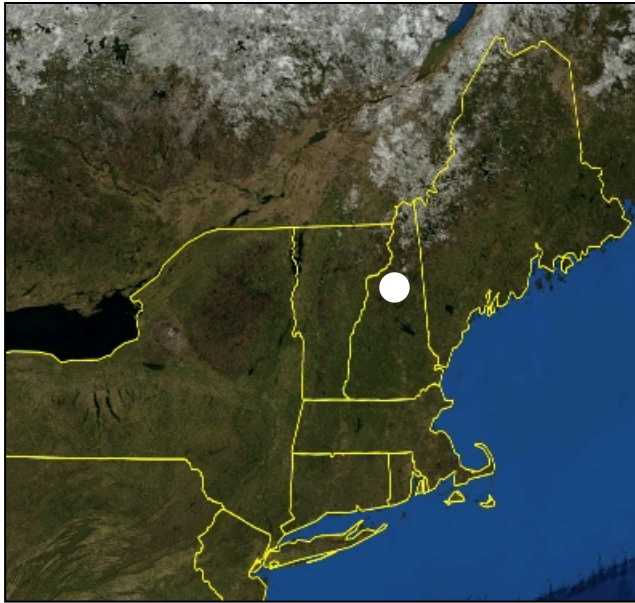
Climate Change Across Season Effects Experiment



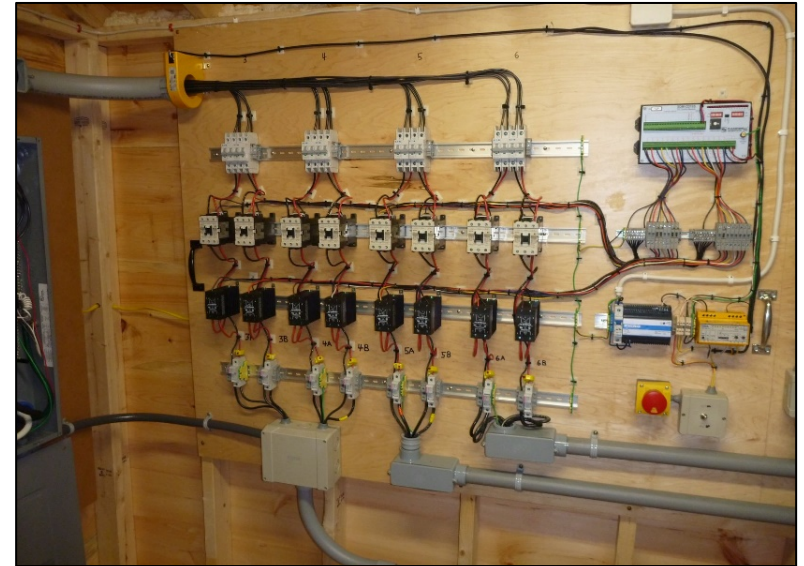
CCASE Experiment at Hubbard Brook

14 X 11m² plots

- 2 plots: reference
- 2 plots: soils warmed 5⁰C in growing season
- 2 plots: soils warmed 5⁰C in growing season and snow removed in winter to induce soil freeze/thaw cycles



CCASE Experiment at Hubbard Brook

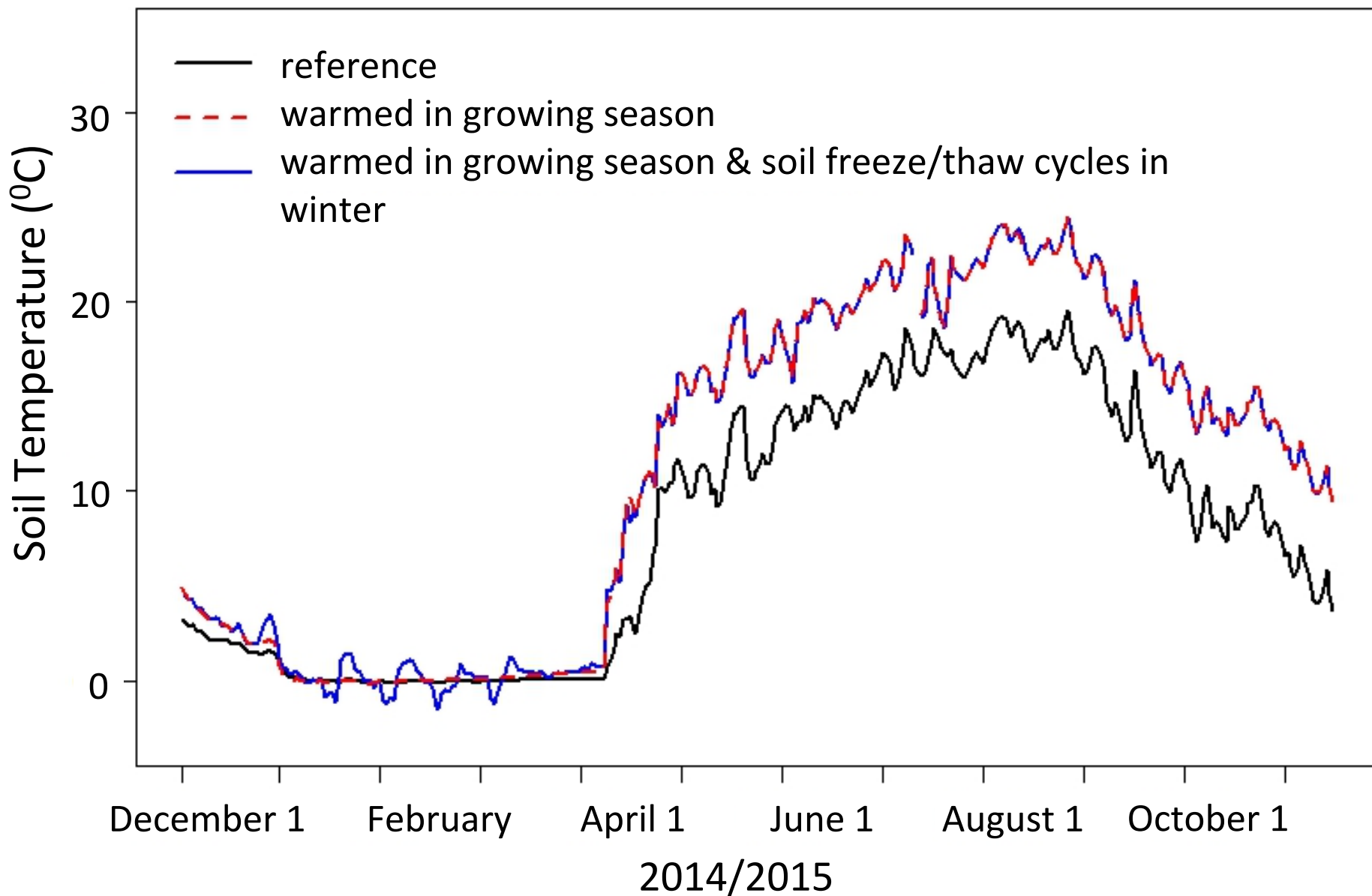


CCASE Experiment at Hubbard Brook

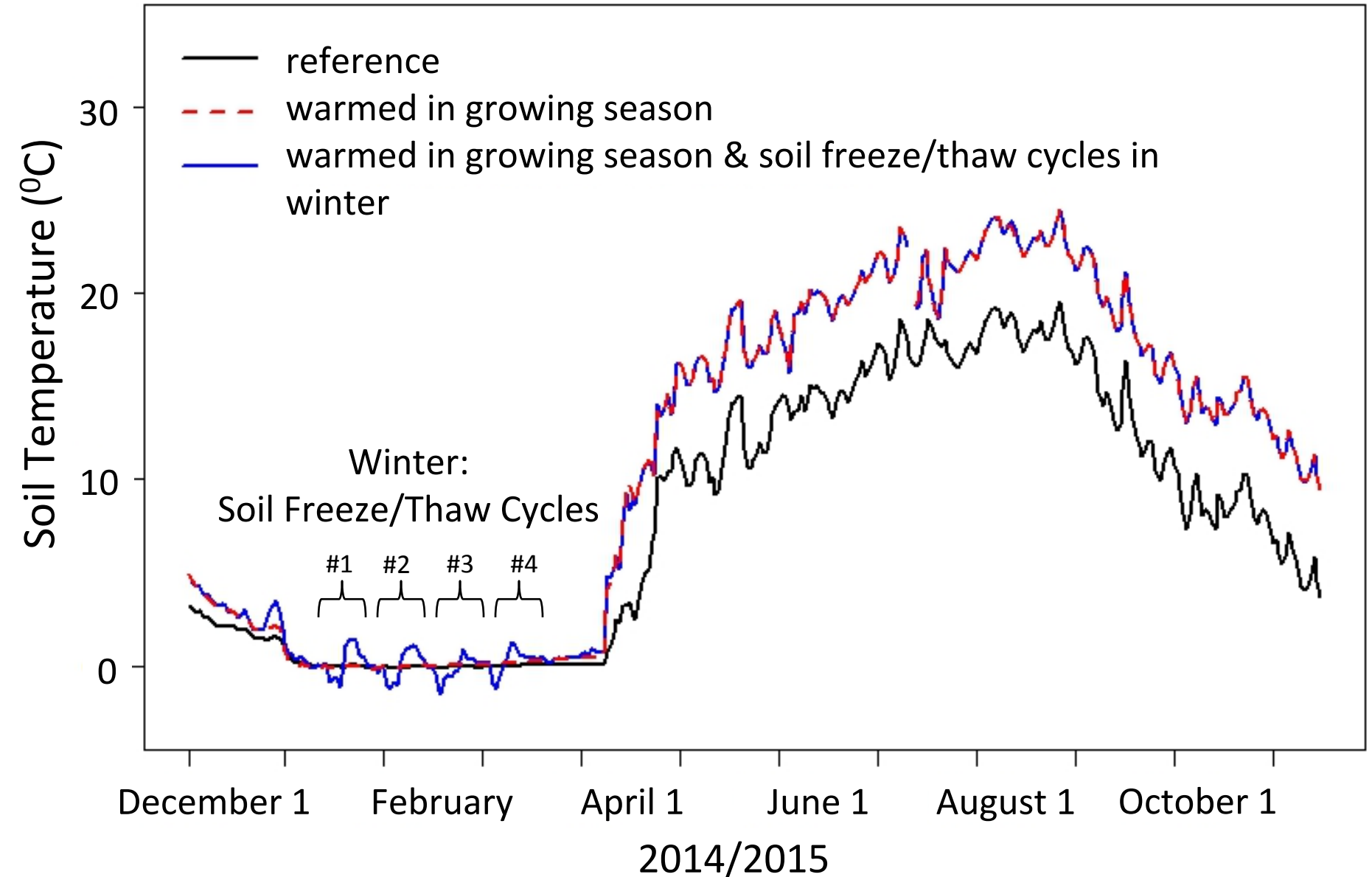


Photo Credit: Mary Martin

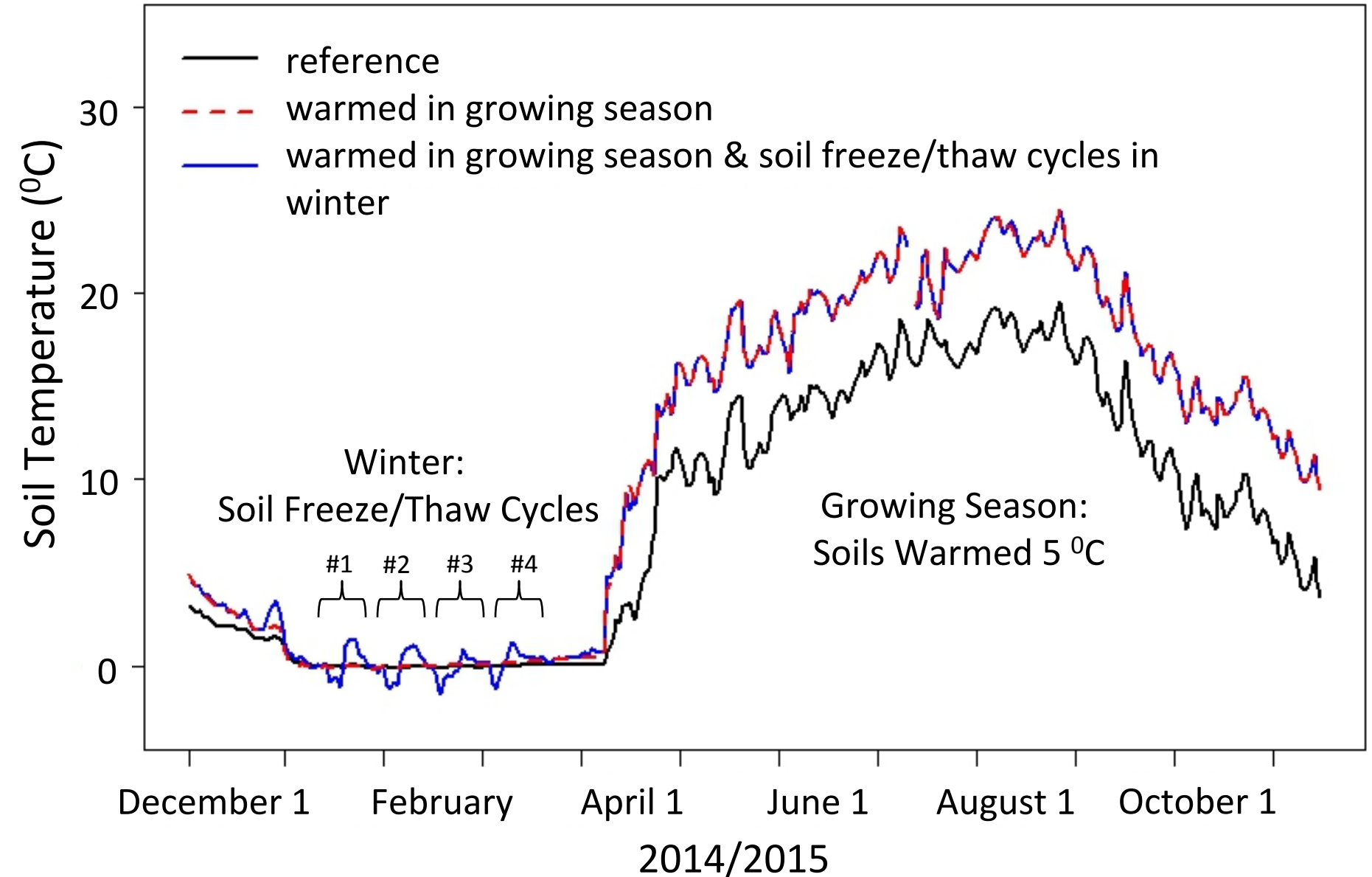
Soil Temperature at CCASE



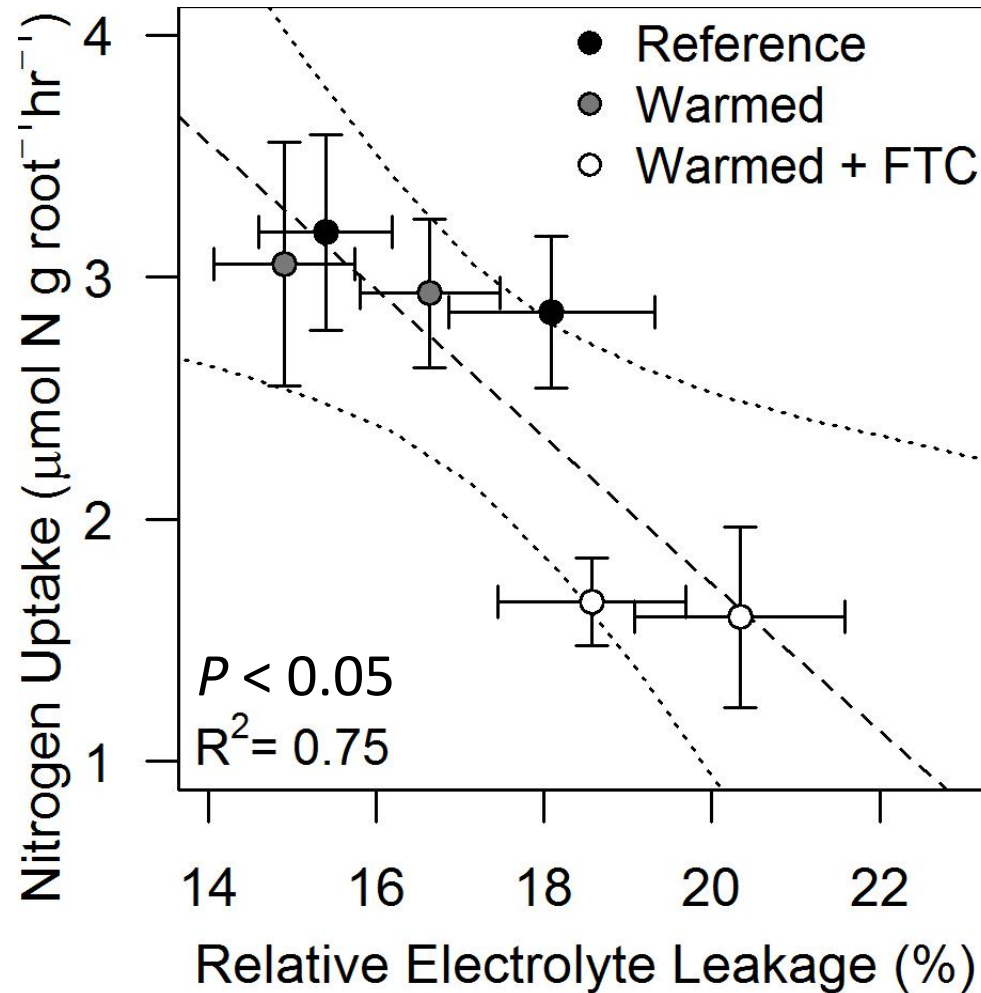
Soil Temperature at CCASE



Soil Temperature at CCASE



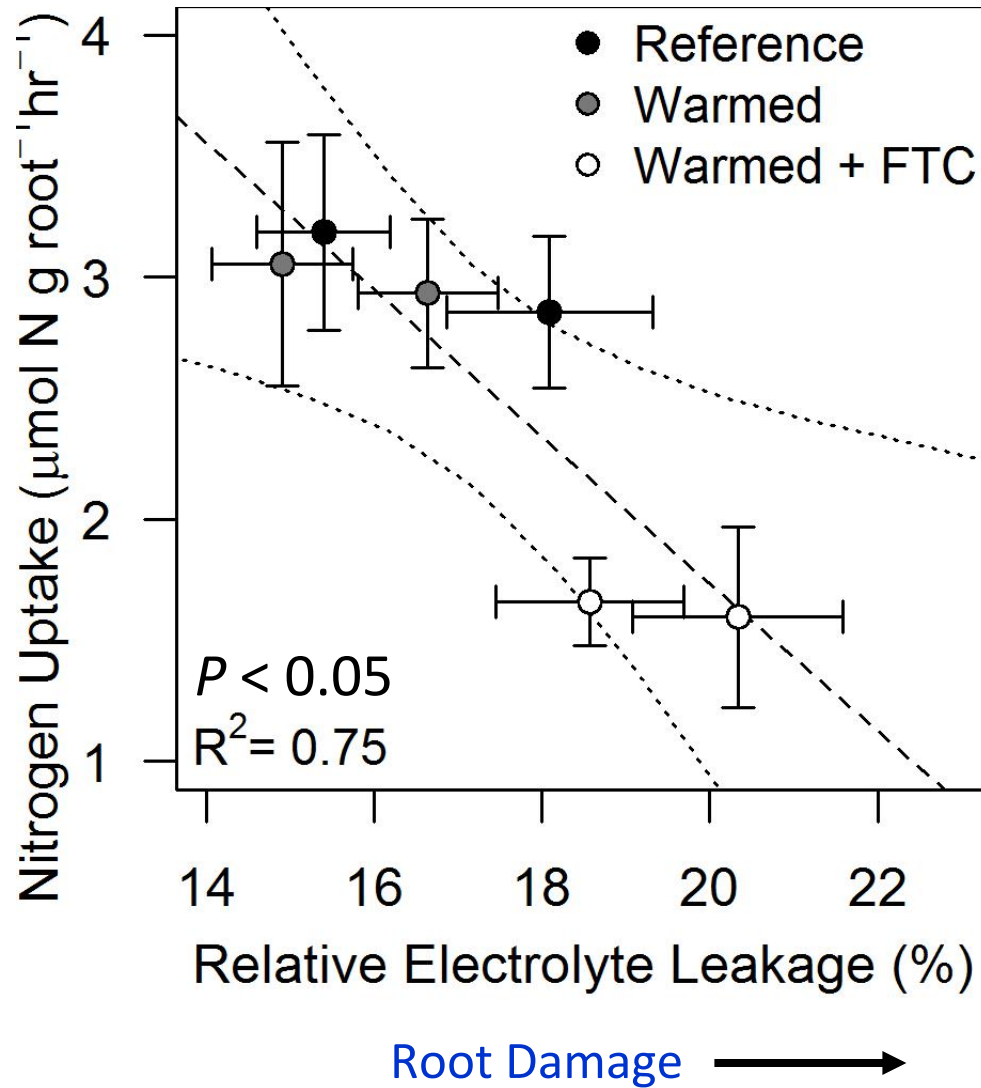
Soil Frost Damages Roots and Reduces N Uptake



Rebecca Sanders-Demott (PhD)



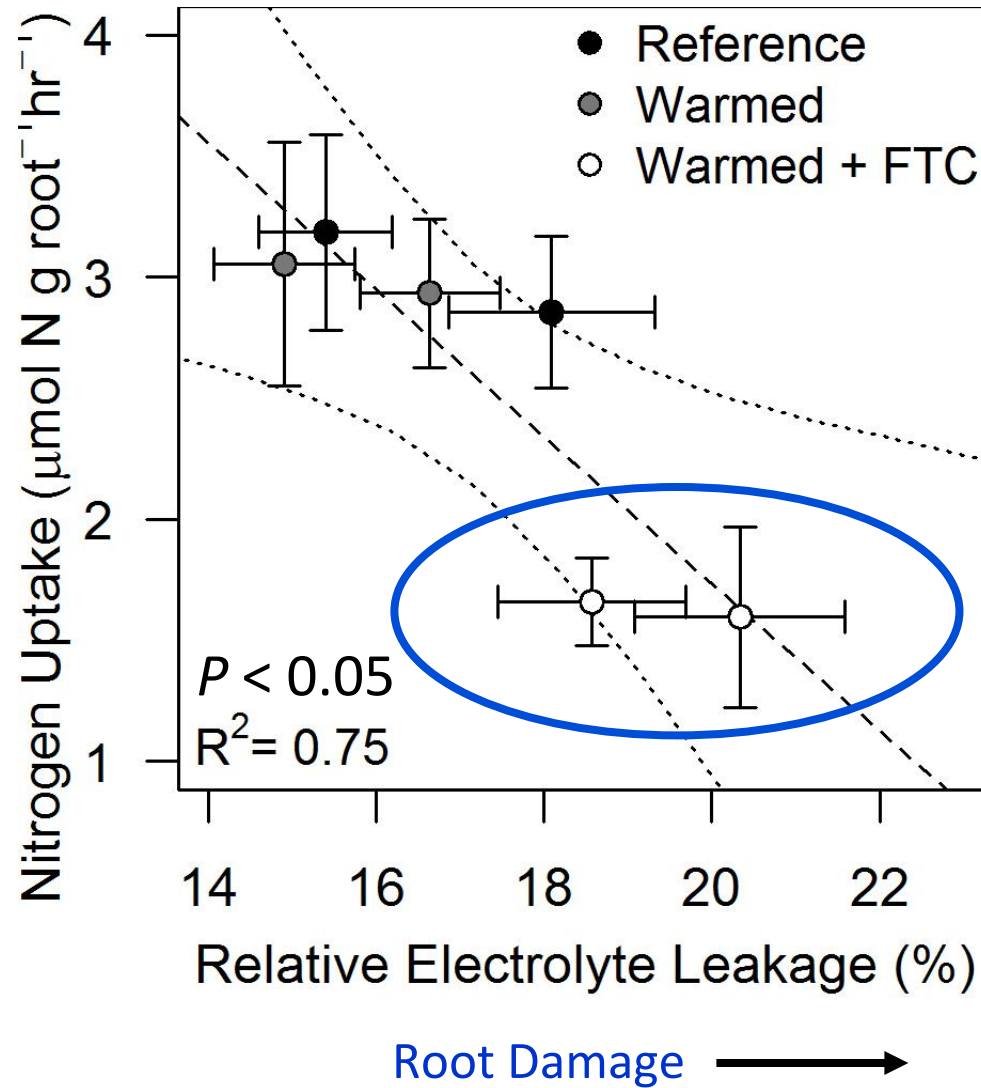
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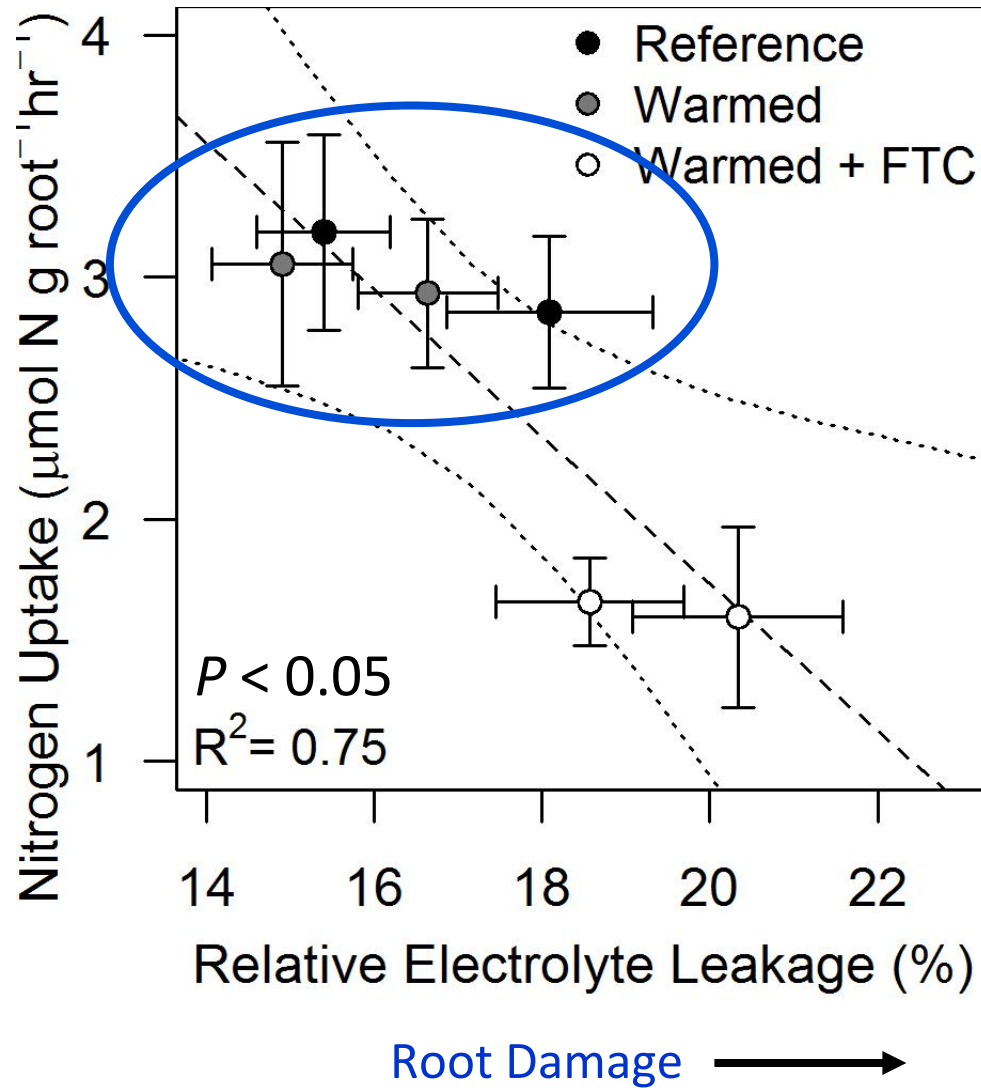
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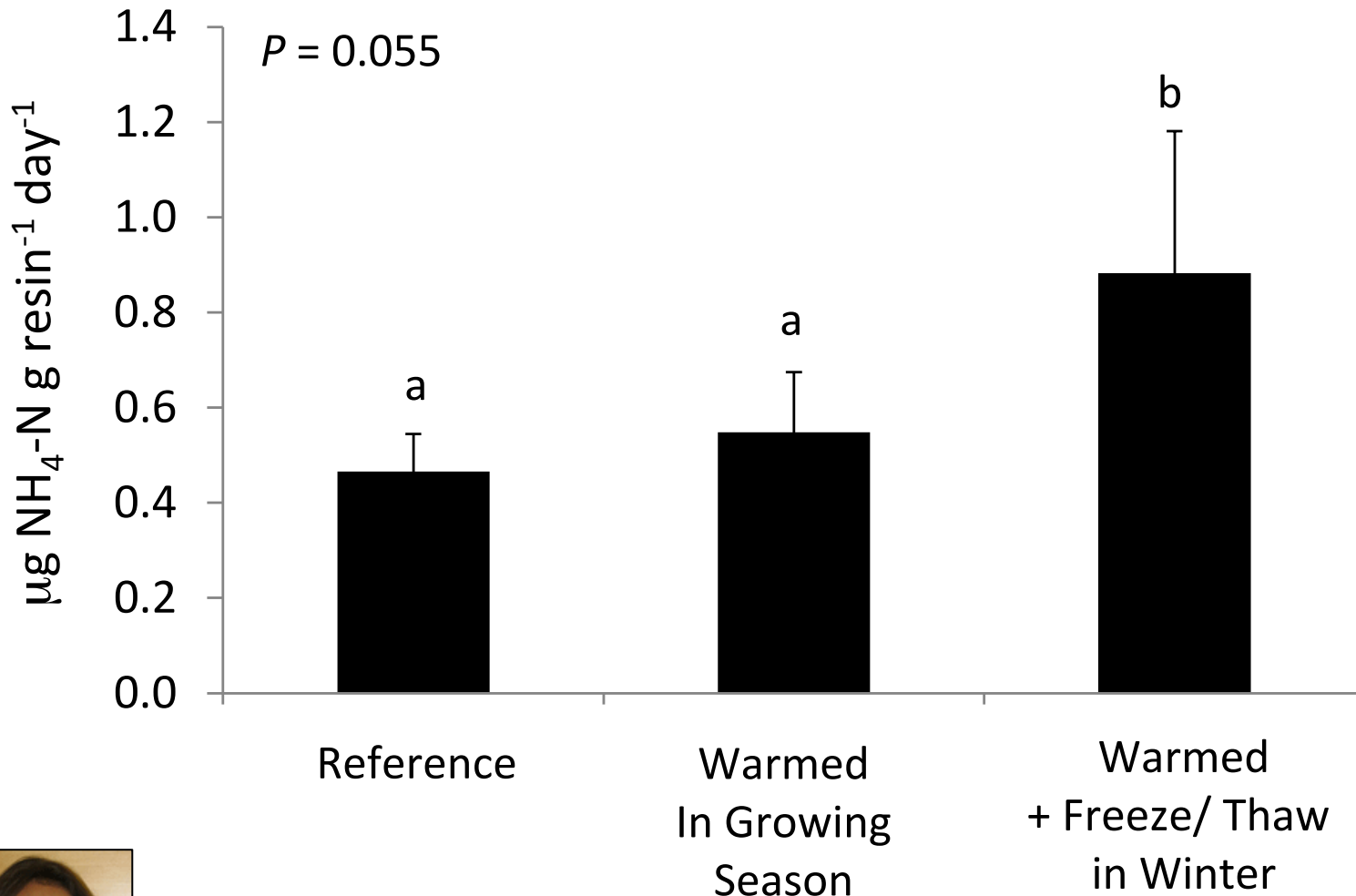
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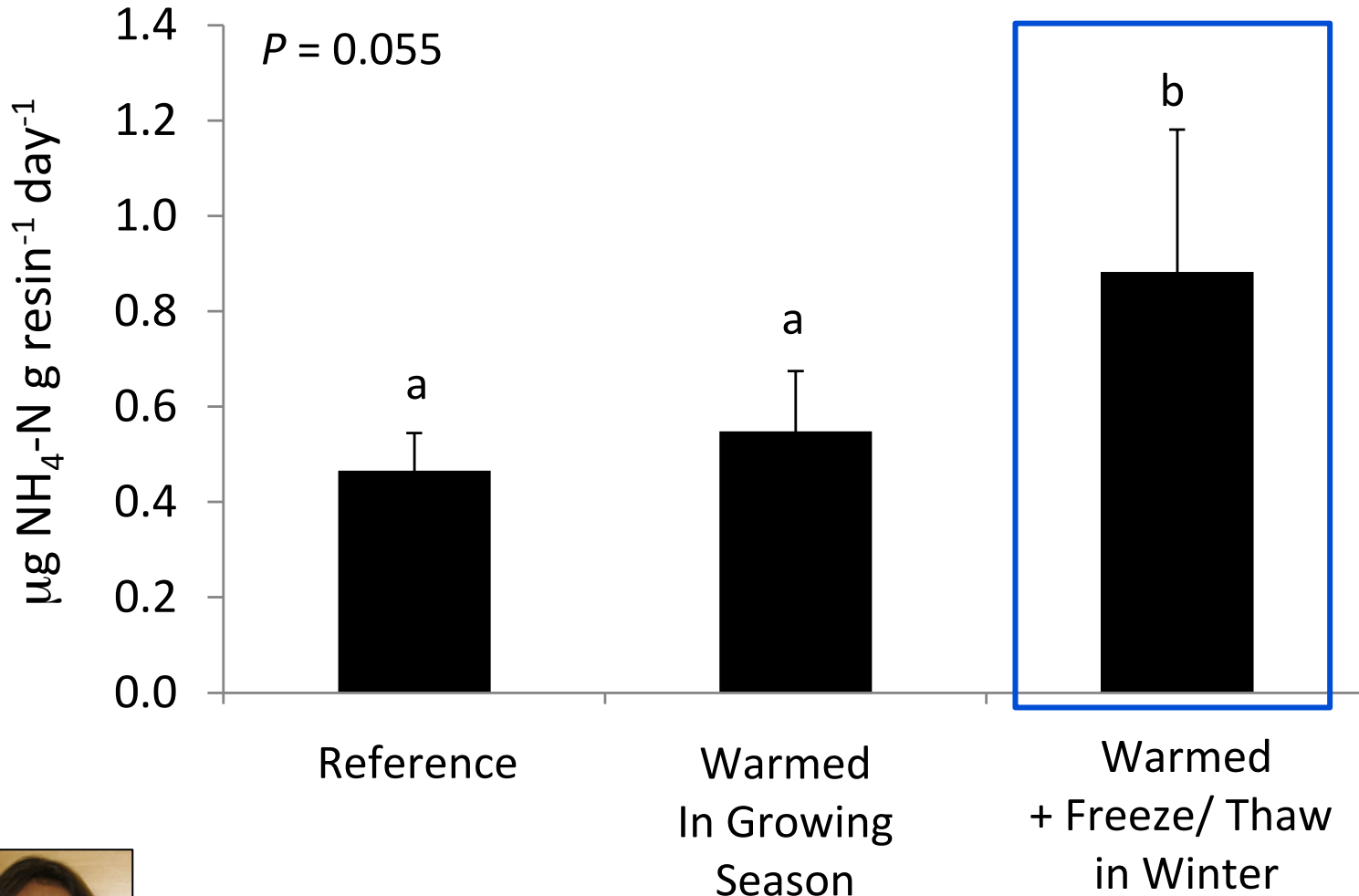
Soil Frost Induces Nitrogen Losses




Rebecca Sanders-Demott (PhD)

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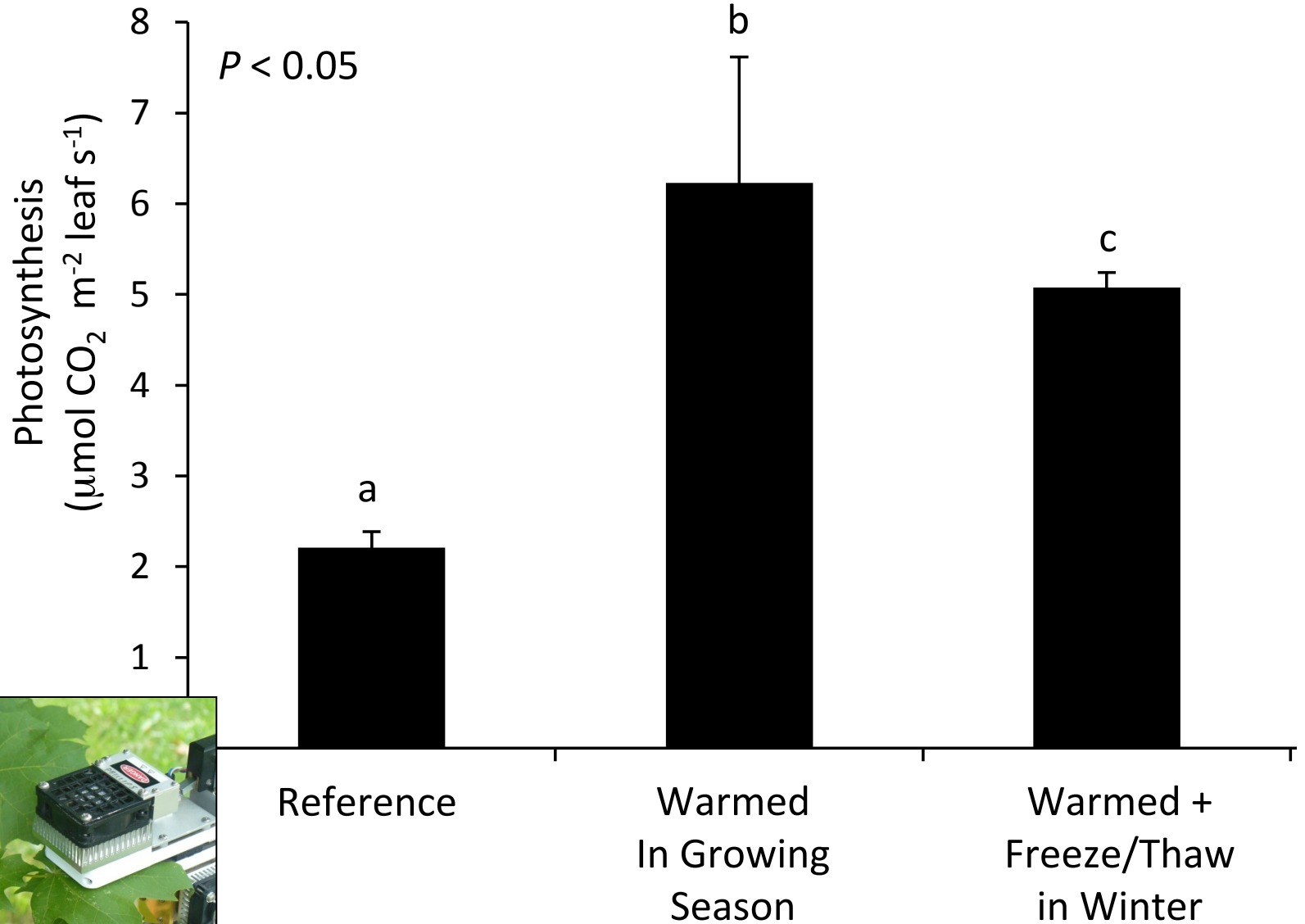
Soil Frost Induces Nitrogen Losses



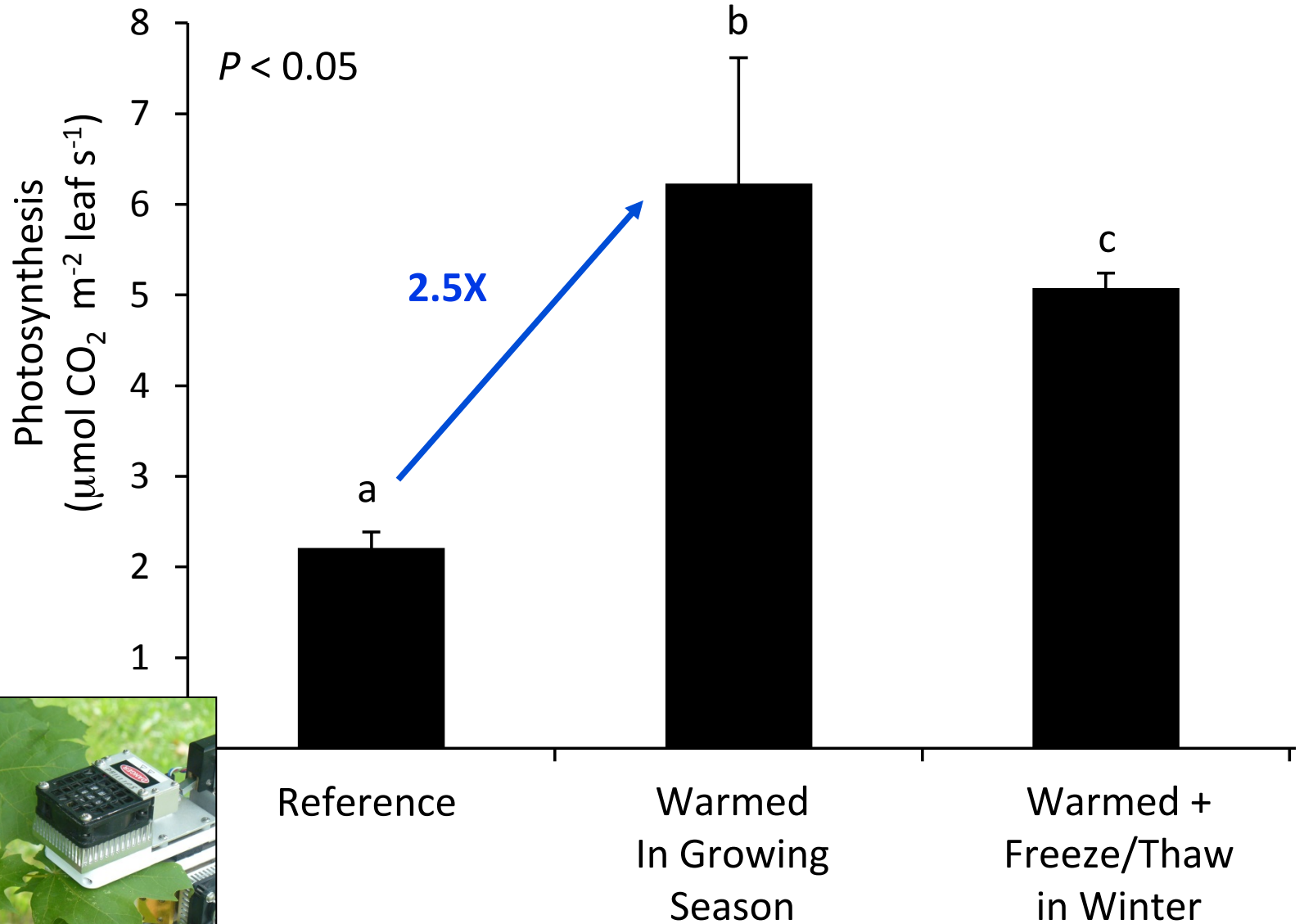
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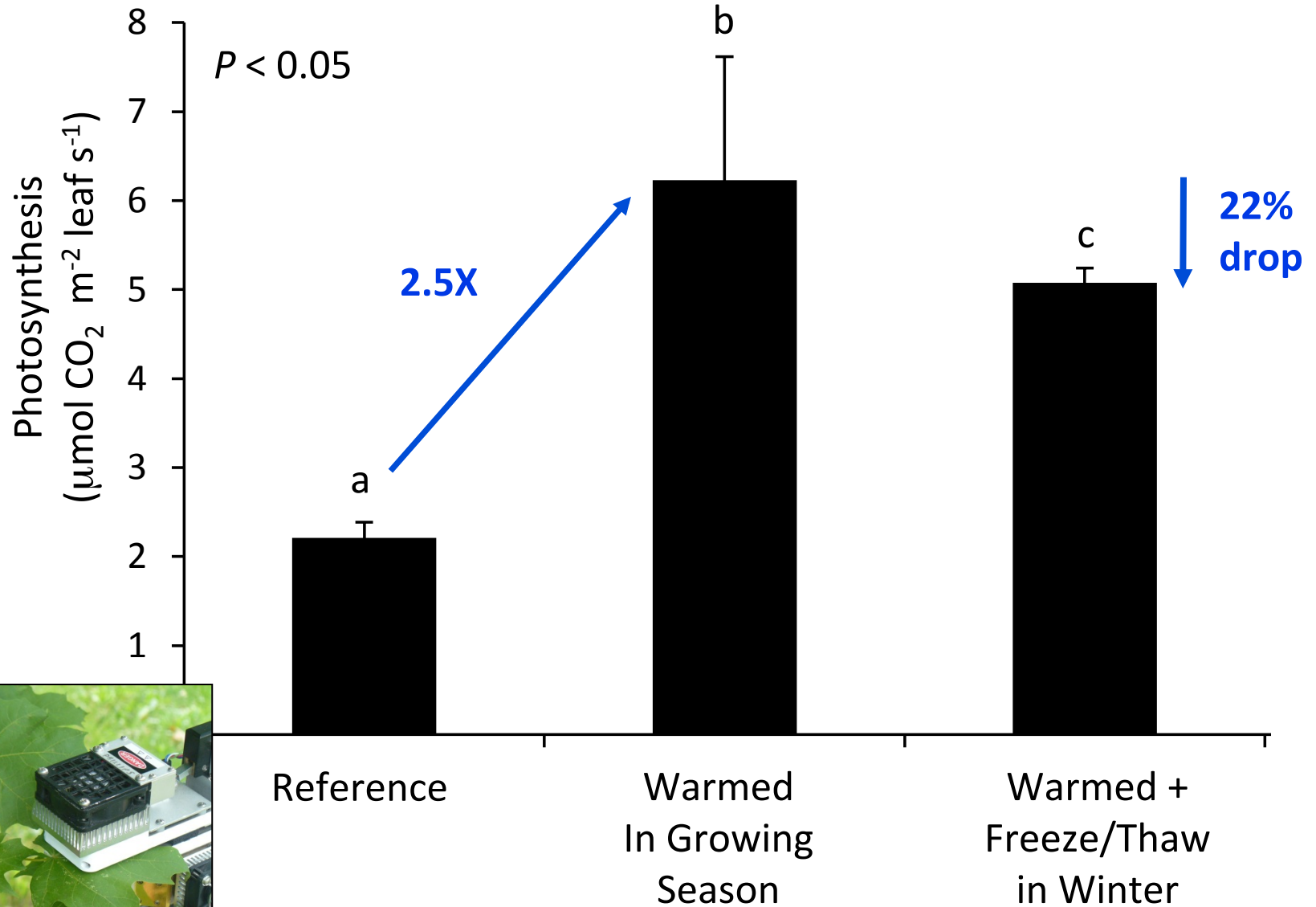
Red Maple Photosynthesis



Red Maple Photosynthesis



Red Maple Photosynthesis



Other Measures of Carbon Exchange

Stem Respiration



Photo Credit: BU Today

Soil Respiration



Other Measures of Carbon Exchange

Stem Respiration



Photo Credit: BU Today

Soil Respiration



Non-Structural Carbohydrates



Ongoing CCASE Measurements

- Tree phenology and transpiration
- Nitrogen and carbon uptake by trees and microbes
- Forest productivity
- Soil microbial community composition
- Arthropods and salamanders
- Maple sap production and quality



Ongoing CCASE Measurements

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How does climate change alter sugar maple
sap volume and quality?

How does climate change alter sugar maple sap volume and quality?

SAPNET.org



Sap Net

Home Research Goals Get Involved

Maple sugar production is changing.

We're doing research to determine how climate change affects maple sugar production. You can get involved and help us understand the future of this industry.

[Learn More](#)



Climate change and maple sugar production

Maple sugar production in the US was valued at **\$132 million** in 2013. How will increasing temperatures change operations and the quantity and quality of maple sugar production?

[View details »](#)



The impact of a smaller winter snowpack

We're investigating how a smaller snowpack and colder soils affect maple sugar production.

[View details »](#)



Providing strategic foresight

Understanding the effects of climate change in both winter and the growing season on maple trees may provide strategic foresight for maple sugar producers.

[View details »](#)

How does climate change alter sugar maple sap volume and quality?

SAPNET.org



Seek Collaborators:

- Record sap volume and quality
- Track snow and soil frost depth
- Other data streams?

Other Ongoing Climate Change Experiments: Sapling Experiment at Hubbard Brook



Rebecca Sanders-Demott (PhD)



Other Ongoing Climate Change Experiments: DroughtNet at Hubbard Brook

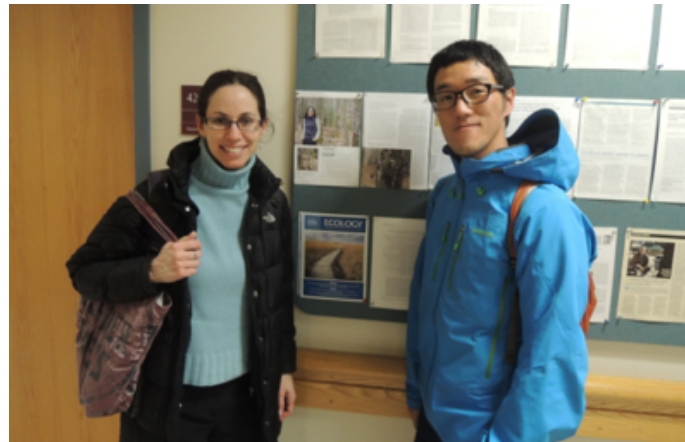


Collaborators:
Heidi Asbjornsen (UNH) and Lindsey Rustad (USFS)

Other Ongoing Climate Change Experiments: Smaller Snowpack in Hokkaido, Japan



Collaborator:
Makoto Kobayashi



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