Spruce: DRIED

Density Reduction and Imposed Extreme Drought

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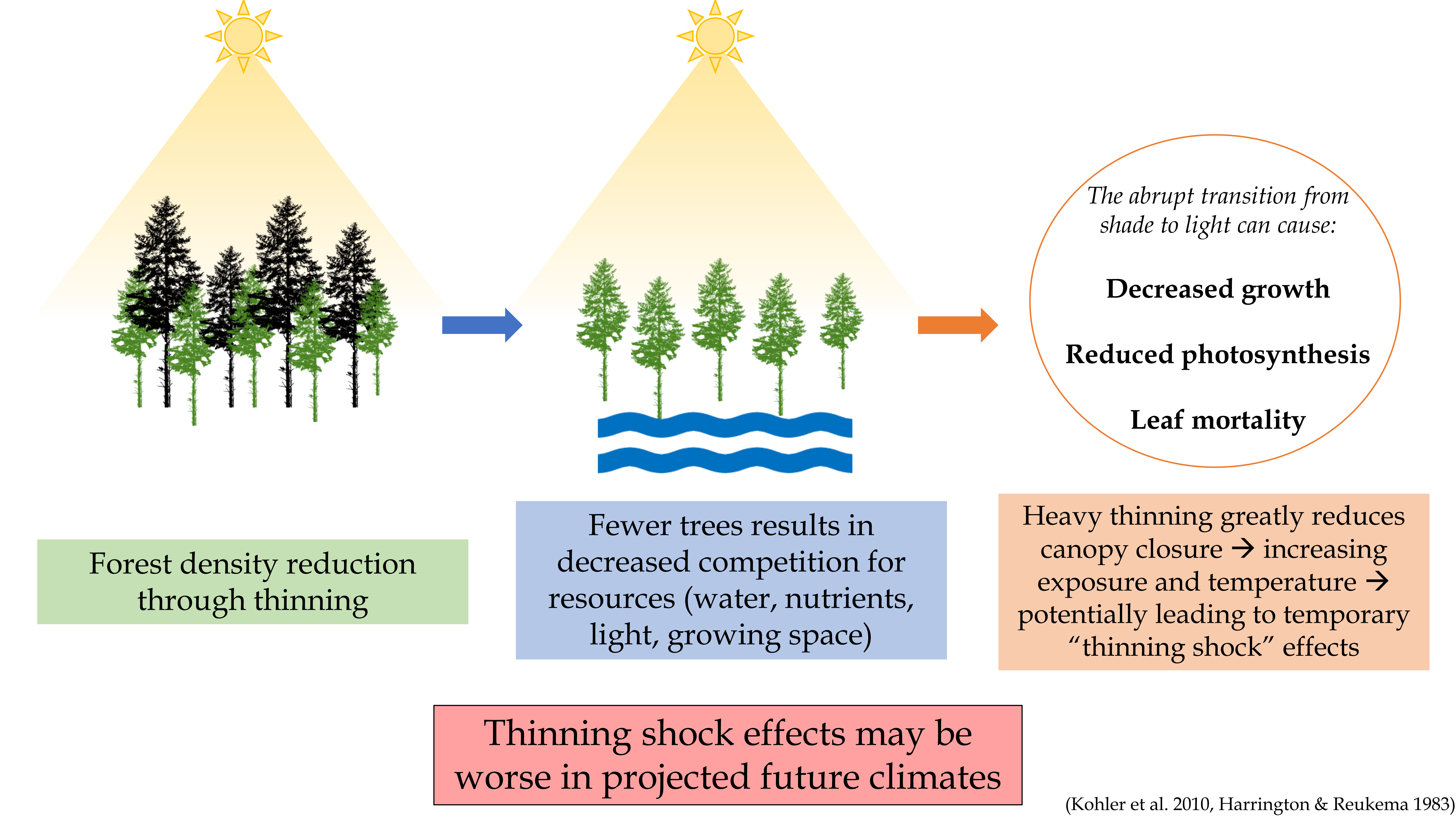
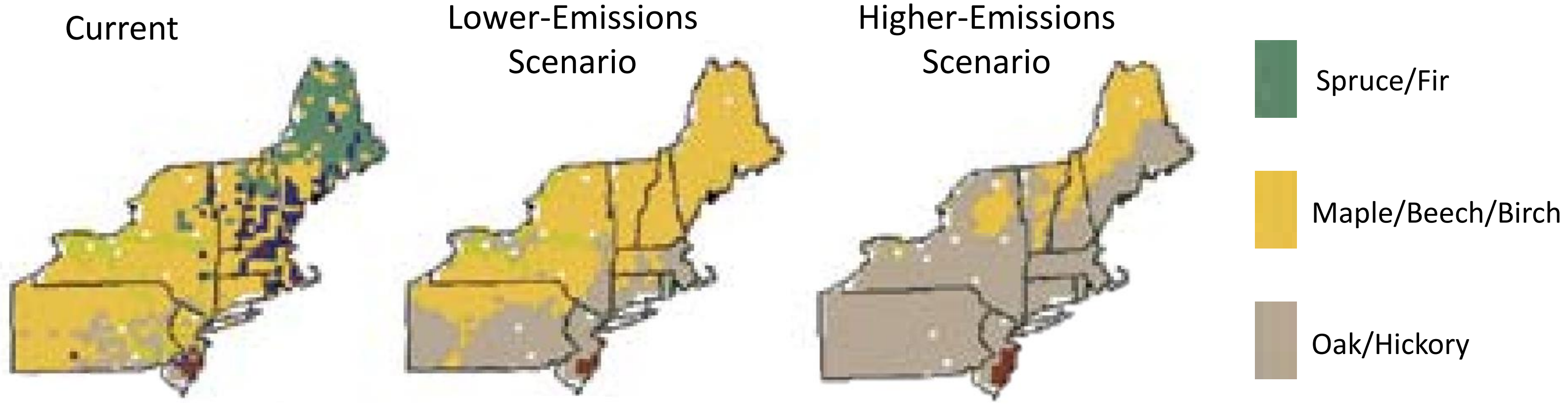

The abrupt transition from shade to light can cause:
Decreased growth
Reduced photosynthesis
Leaf mortality
Forest density reduction through thinning
Fewer trees results in decreased competition for resources (water, nutrients, light, growing space)
Heavy thinning greatly reduces canopy closure → increasing exposure and temperature → potentially leading to temporary "thinning shock" effects
Thinning shock effects may be worse in projected future climates
(Kohler et al. 2010, Harrington & Reukema 1983)

Projected Shifts in Northeastern Tree Species Over the Next Century



Adapted from U.S. Global Change Research Program, 2009

- Climate change is expected to drive increased temperatures, increased vapor pressure deficit, and drought frequency
  - Annual precipitation projected to increase, but so is risk of seasonal drought in summer/fall
- Even small changes in temperature/precipitation could have large impacts on mesic forests
- Red spruce growth is negatively correlated with maximum summer temperature, positively correlated with spring and fall maximum precipitation

(Hayhoe et al. 2007; Dale et al. 2001, Wason et al. 2019)

Goal - Improve our understanding of how thinning and extreme drought influence the physiology of red spruce, to better inform management of this species with climate change.

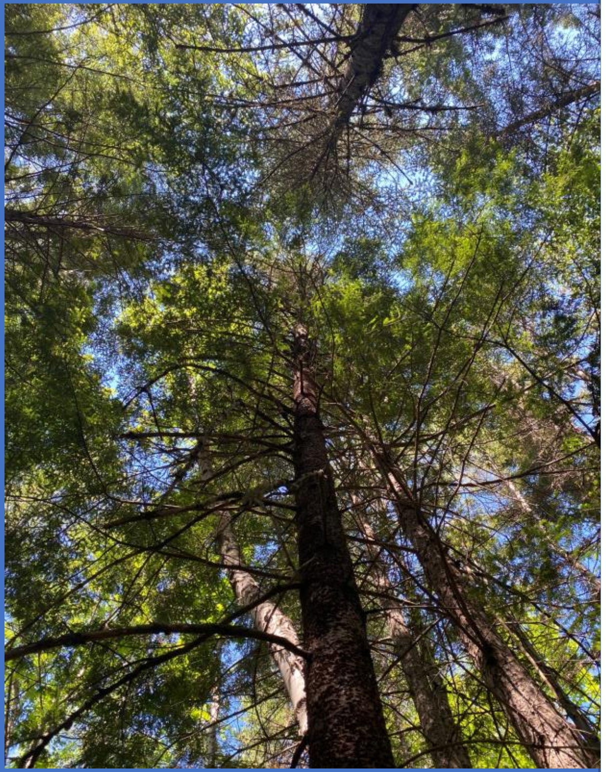
Thinning	Objective 1: Investigate immediate impacts of thinning on mature red spruce, quantifying physiological evidence of thinning shock.
Drought	Objective 2: Examine how red spruce respond physiologically over time to an experimentally imposed extreme drought.

8 focal red spruce trees
Crown-suppressed
16-26 cm DBH

2 X 2 Factorial Design

Monitored tree water use (sap flow), water potential, relative water content, leaf photochemistry, stomatal conductance, and microclimate

Thinned

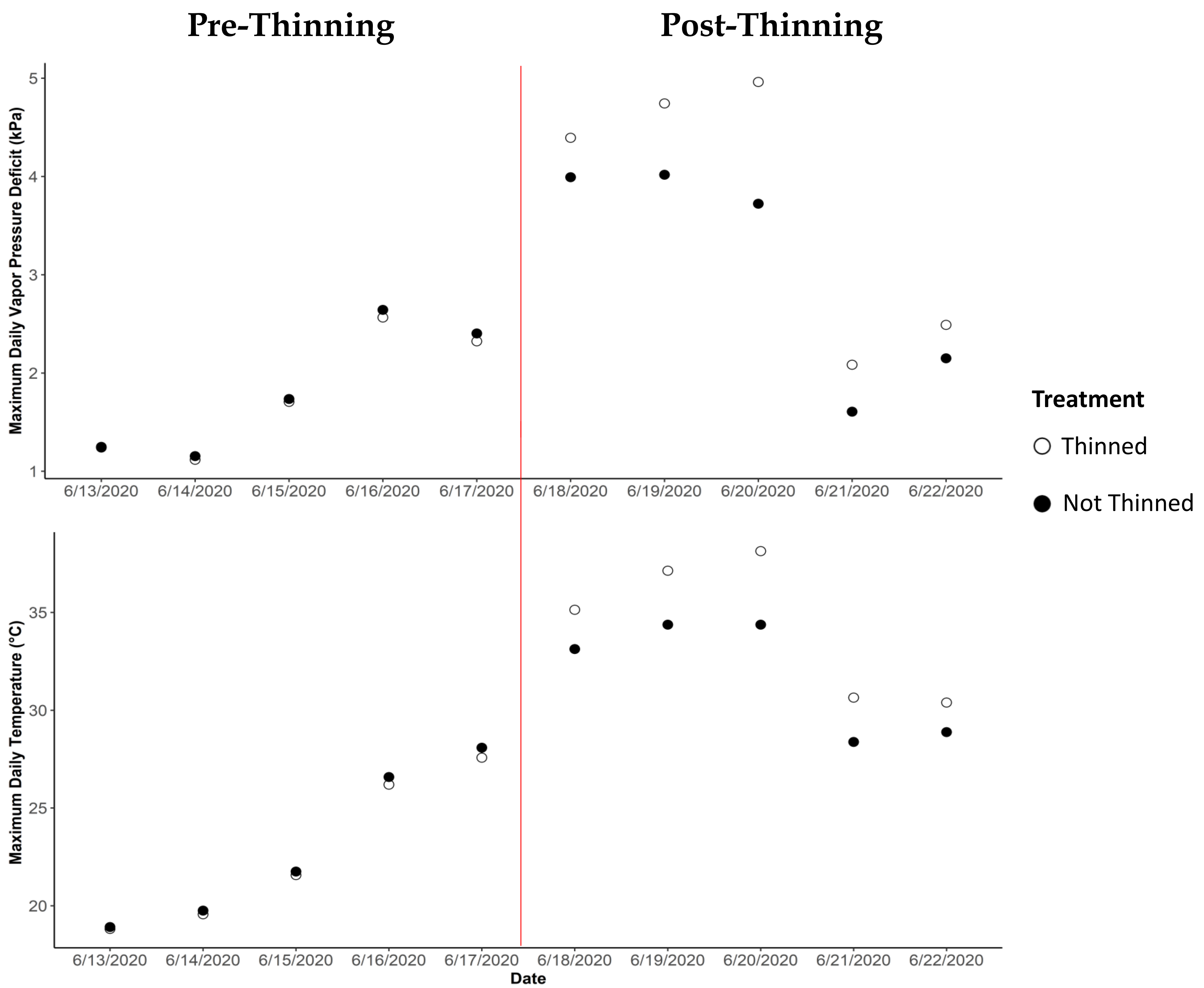


Not Thinned

Phloem Girdled

Sapwood Cut

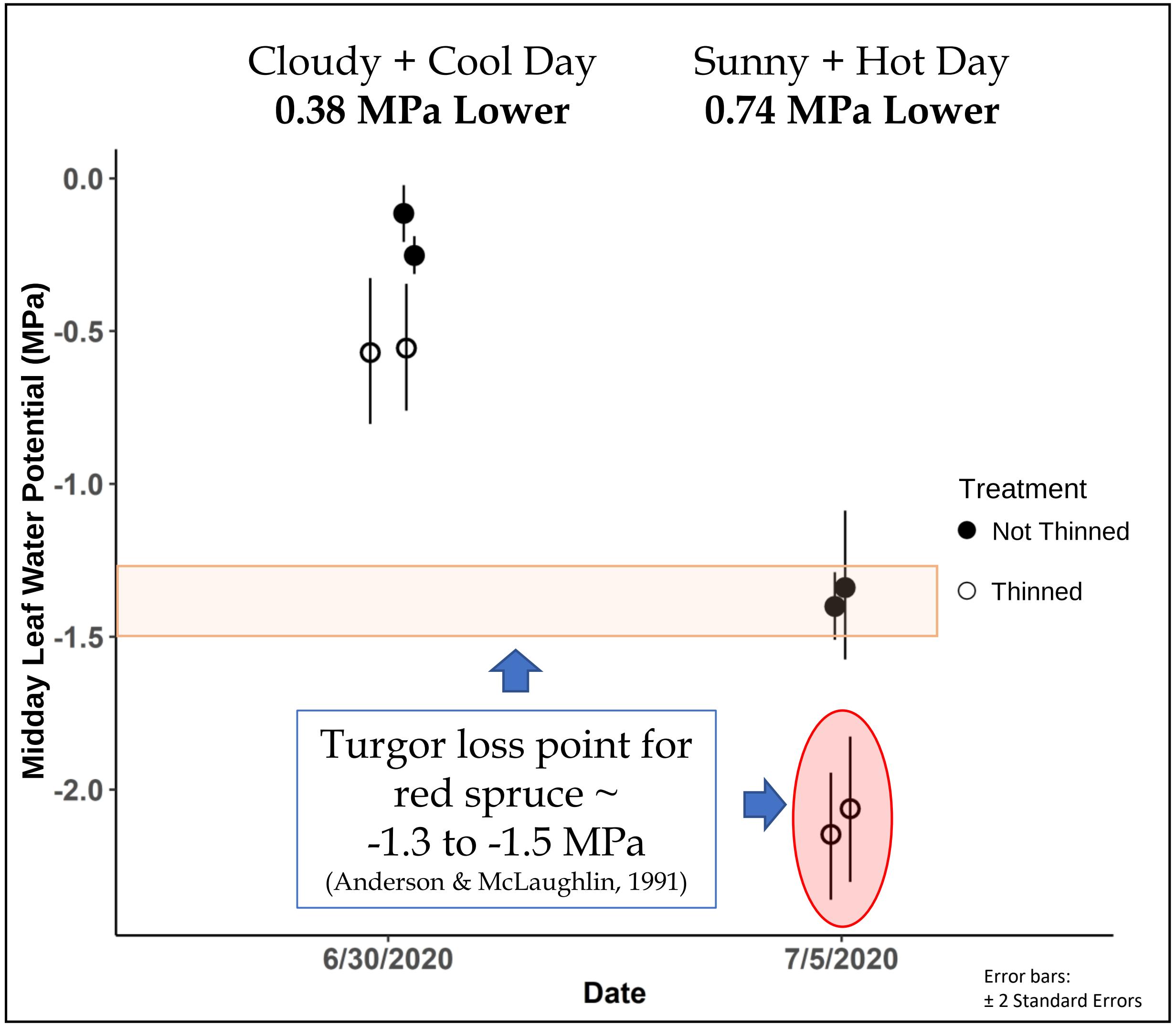
Impacts of thinning

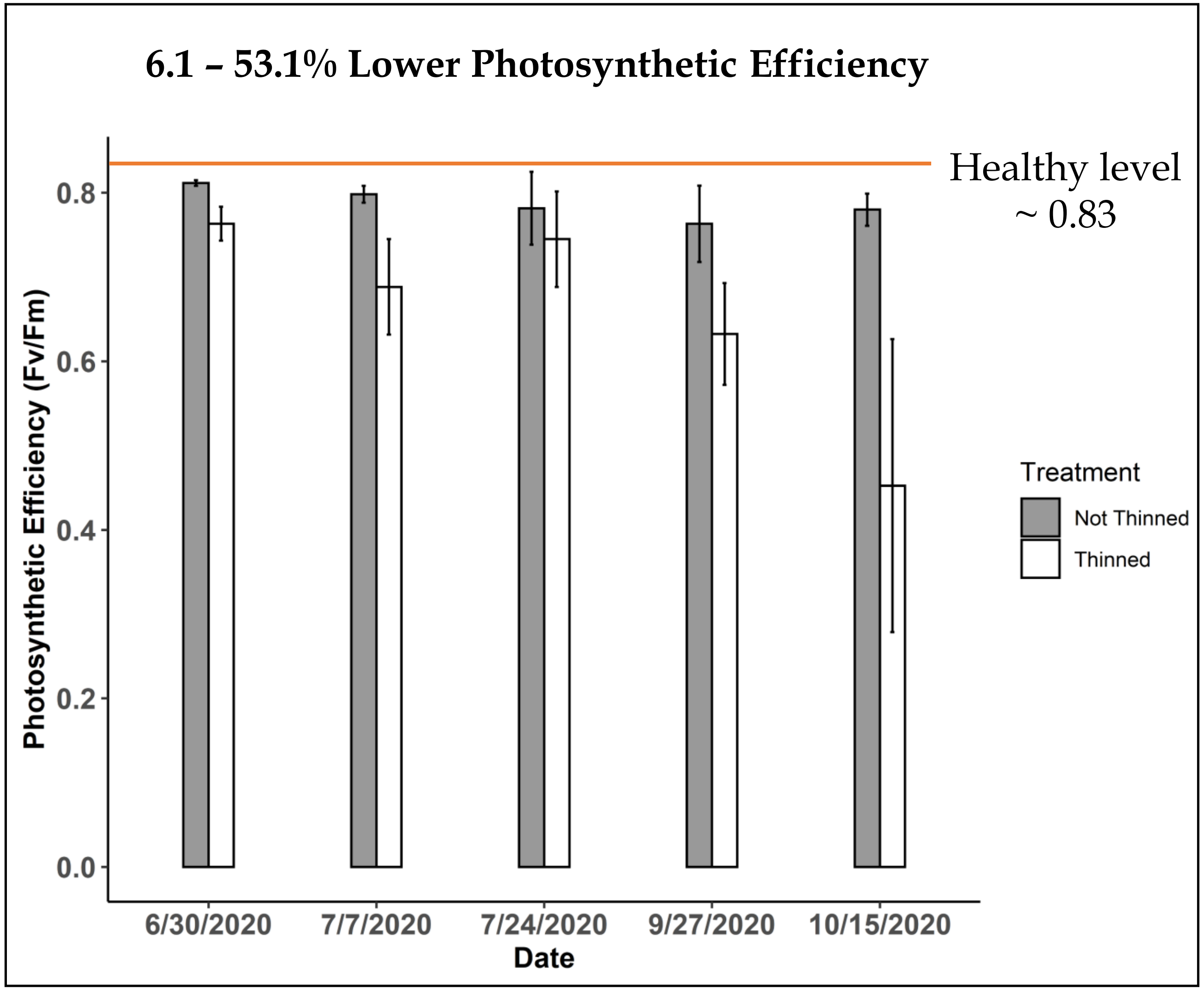


Thinning Drives Increased Temperature and Vapor Pressure Deficit

Temp + 2.46 °C
VPD + 0.64 kPa

Evidence of Thinning Shock: Lowered Midday Water Potentials & Decreased Photosynthetic Efficiency



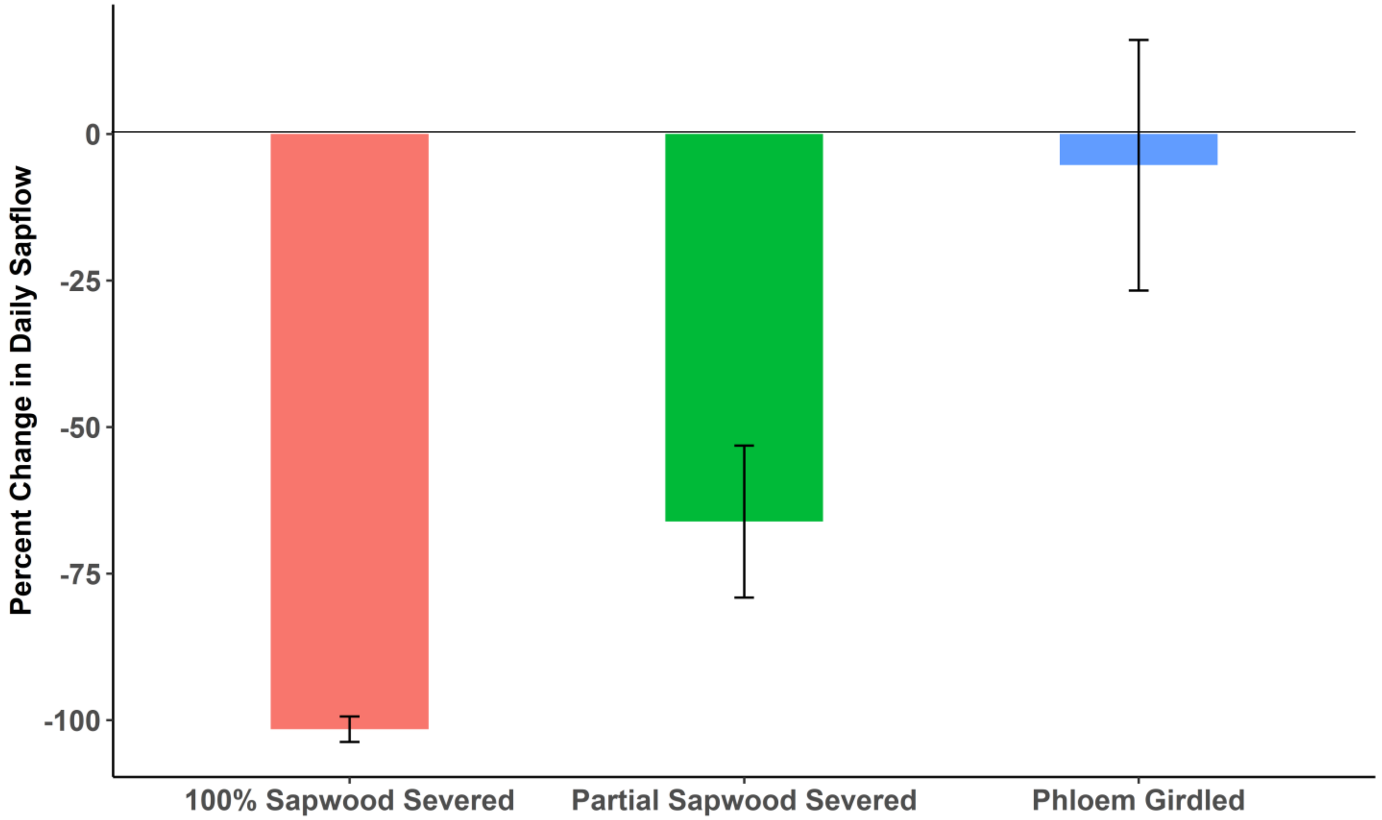


Impacts of experimentally imposed drought

Imposed 2 weeks after thinning

No interactive effect of thinning X drought

5 Days Pre-Treatment vs.
5 Days Post-Treatment
Changes in Sap Flow



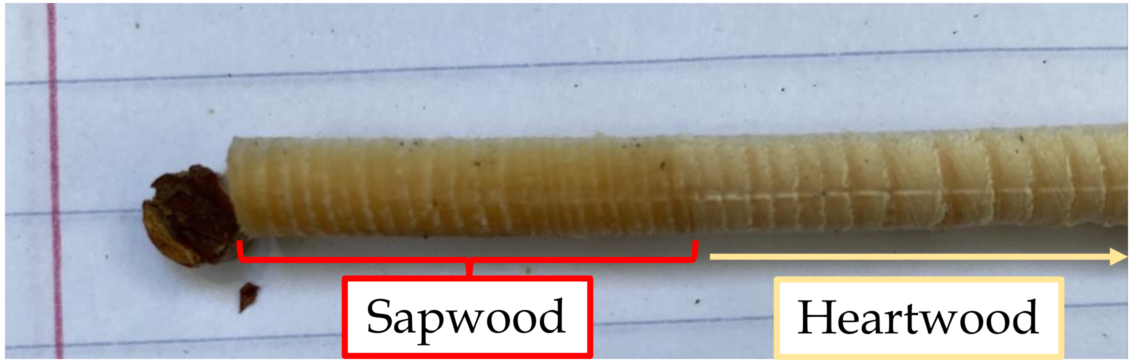
n=2 n=2 n=4

Error bars:
± 2 Standard Errors

Severing Sapwood Caused Immediate Reductions in Sap Flow – Only 100% Reduction in Sap Flow Imposed Extreme Drought

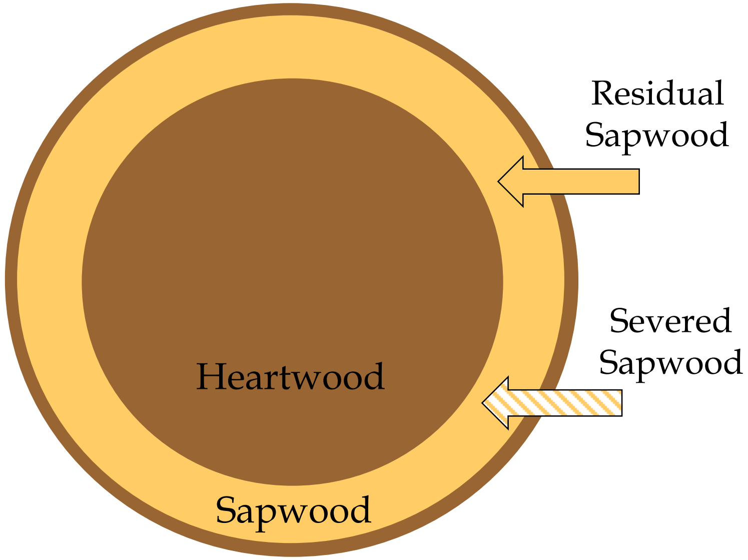
Partially severing sapwood, causing a 60-73% decline in sap flow, did not cause noticeable water stress

Measured visible sapwood depth on increment cores, set circular saw cut depth to 1.5X estimated sapwood depth



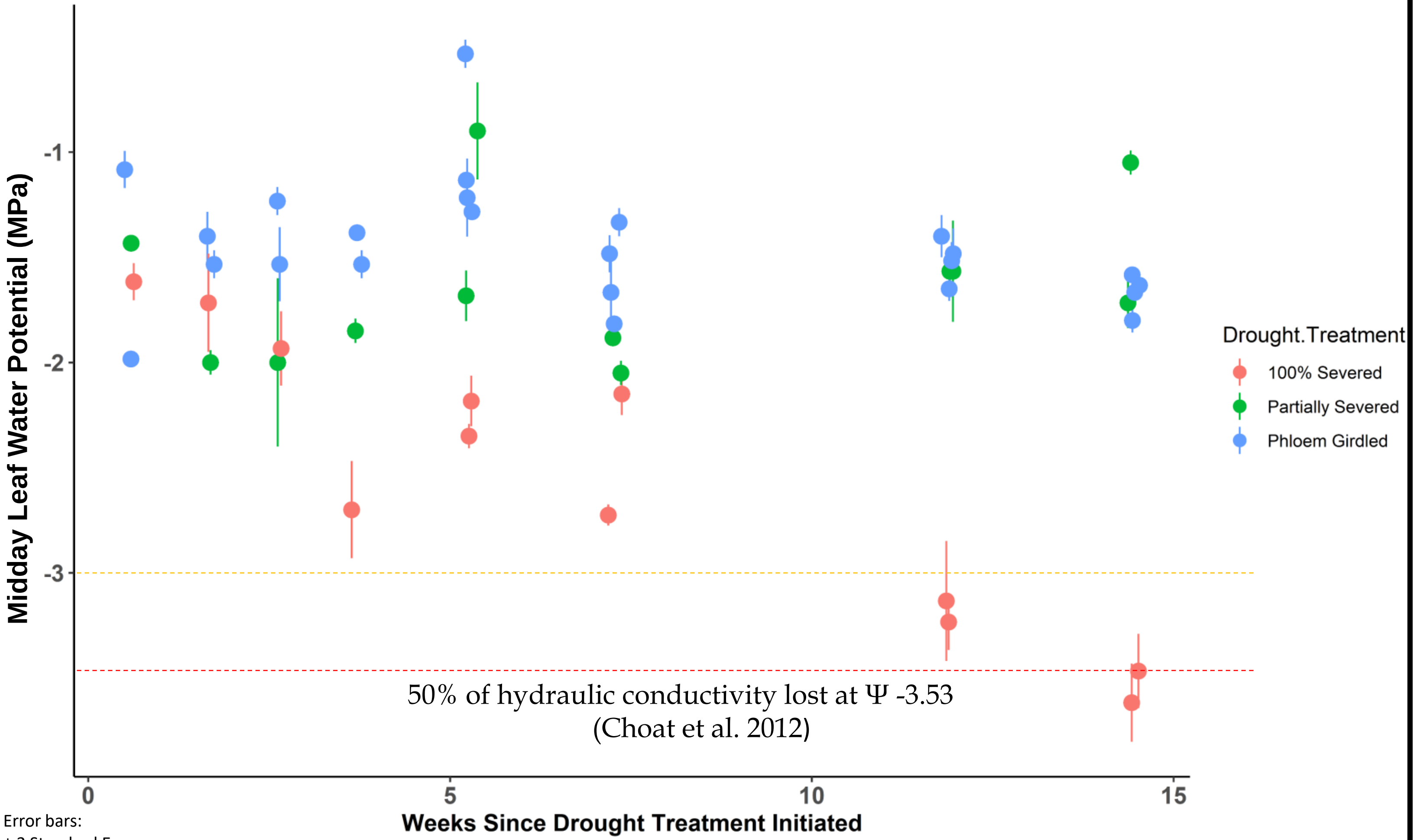
- Saw inaccuracy caused only partially severed sapwood in two trees
- Partially severed trees never experienced water potential decline, trunk-wood RWC decline, or reduced stomatal conductance

Sapwood Area Intact
Tree 1: **5.33%**
Tree 5: **1.91%**
Tree 2: 0%
Tree 8: 0%



Droughted Trees Lasted At Least 12 Weeks Without Evidence of Water Stress

Midday leaf water potentials decline, but do not reach water stressed levels until end of September



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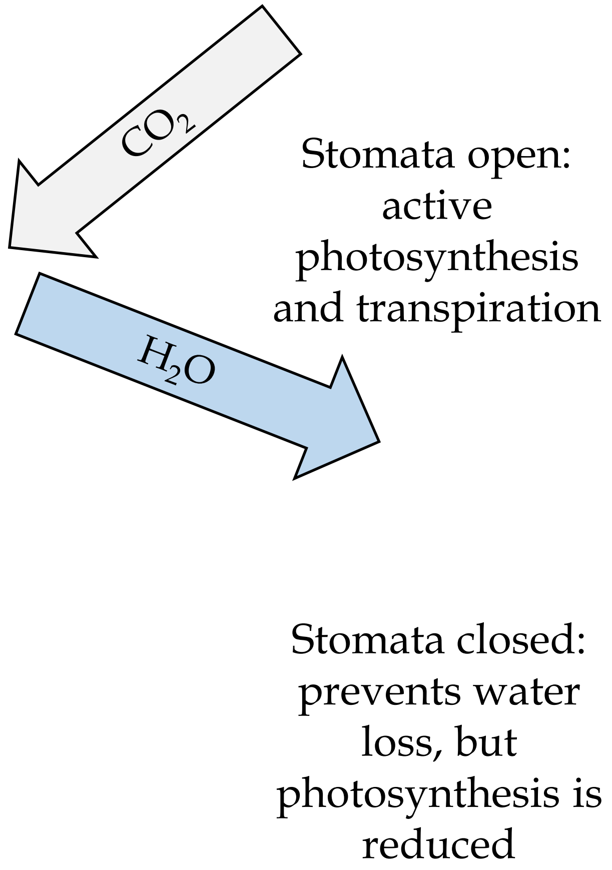
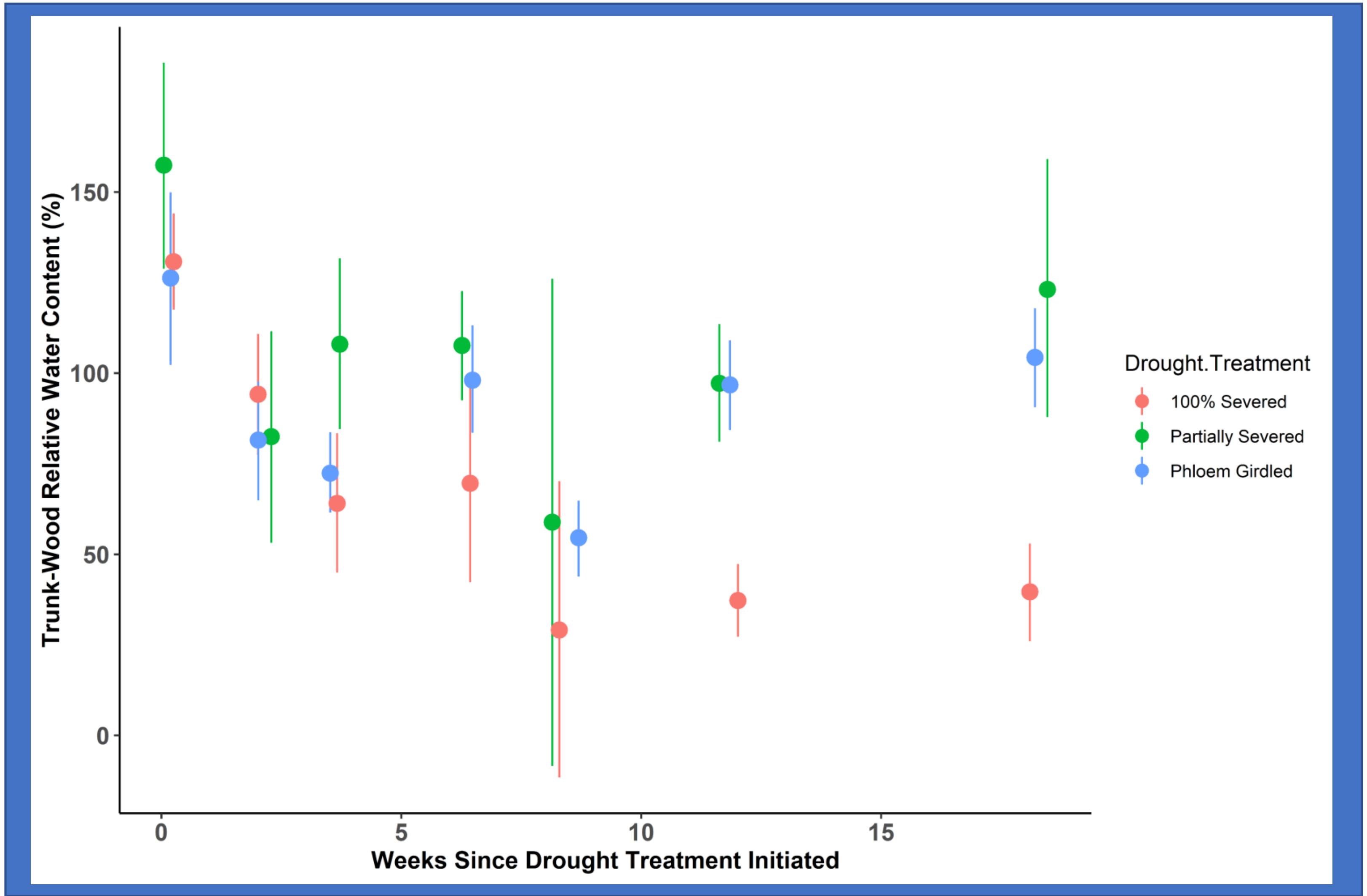
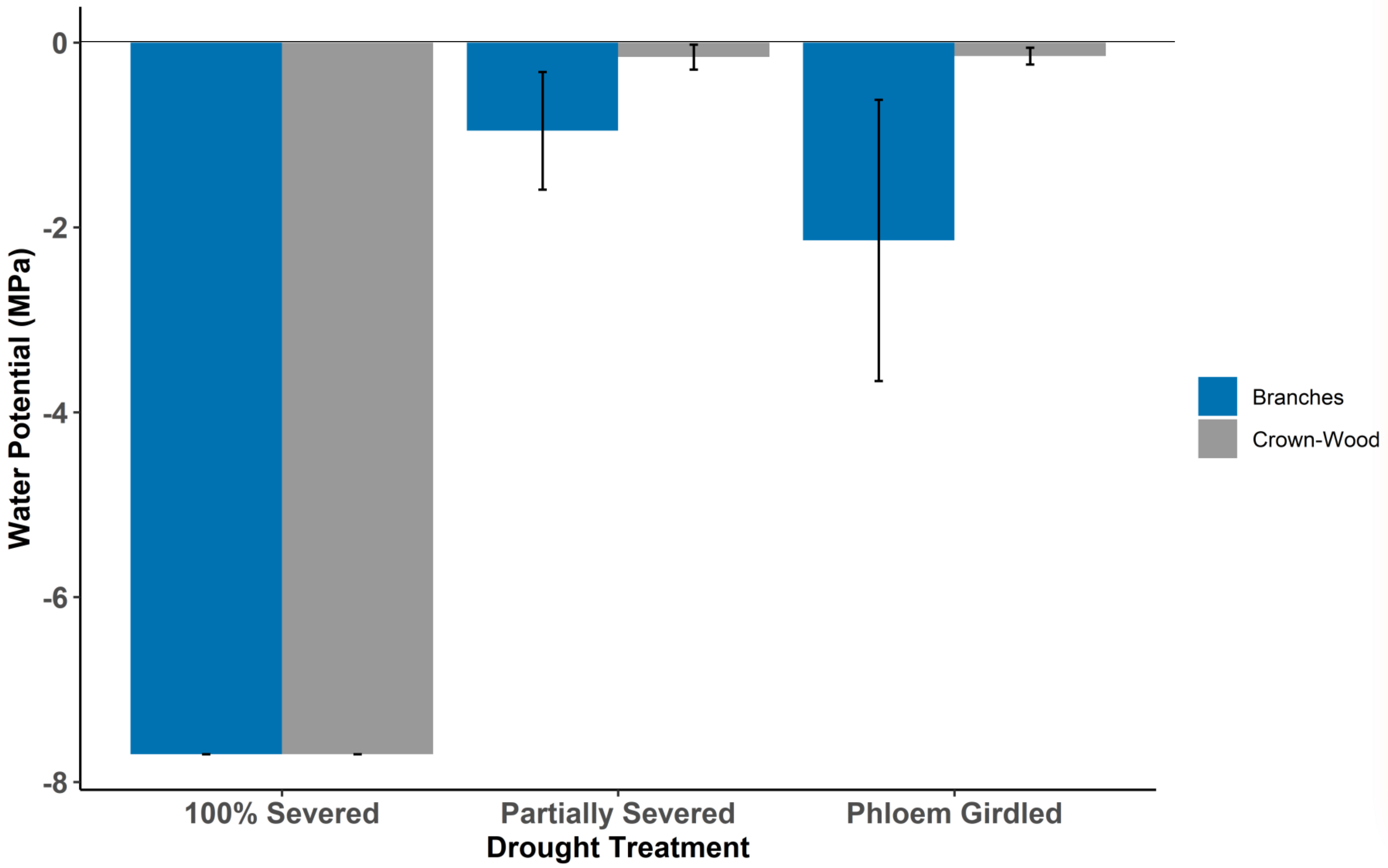
Droughted trees had reduced stomatal conductance, indicating stomatal closure



Droughted Trees Showed Reduced Relative Water Content in Trunk-Wood



Seasonal variations in RWC held constant among all 8 trees, but the droughted trees did not recover at the end of the growing season



Droughted Trees Did Eventually Die

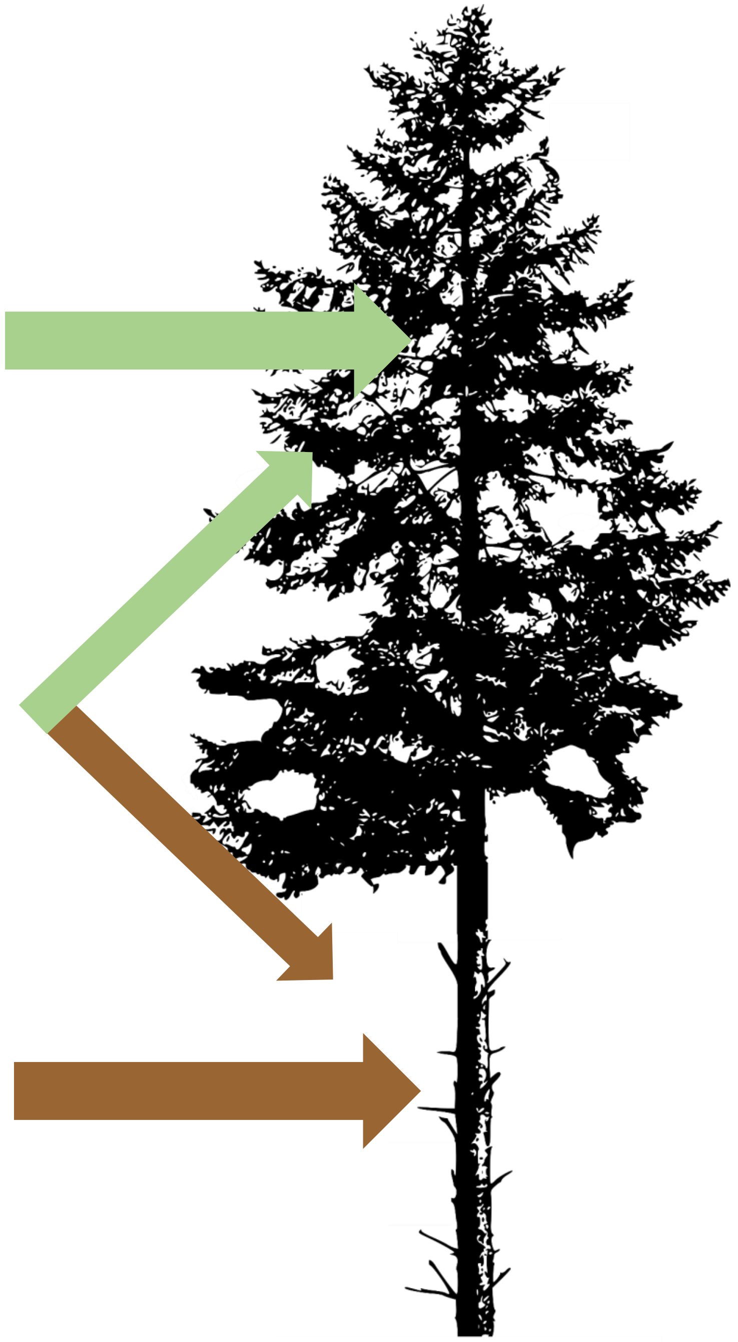
Branch and Crown-Wood Ψ Reached Catastrophic Levels at Experiment's End

Conclusions

Thinning shock due to increased temperature/VPD was observed in needles – lower leaf mid-day ψ and decreased photosynthetic efficiency

No clear signs of water stress in needles or trunk for 12 weeks, even in trees experiencing an extreme drought with a 100% reduction in sap flow

As little as ~2% of sapwood intact is sufficient to transport ~30% prior daily sap flow volumes, which was enough to prevent water stress throughout this study



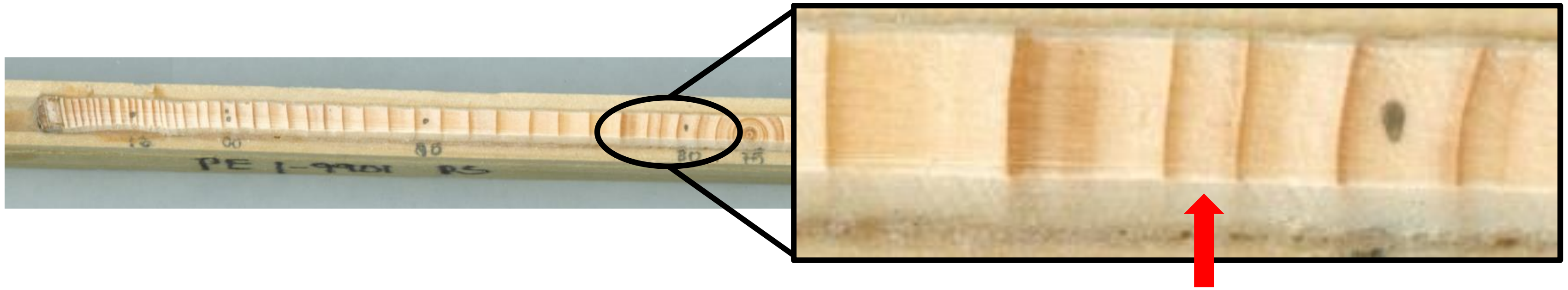
Implications

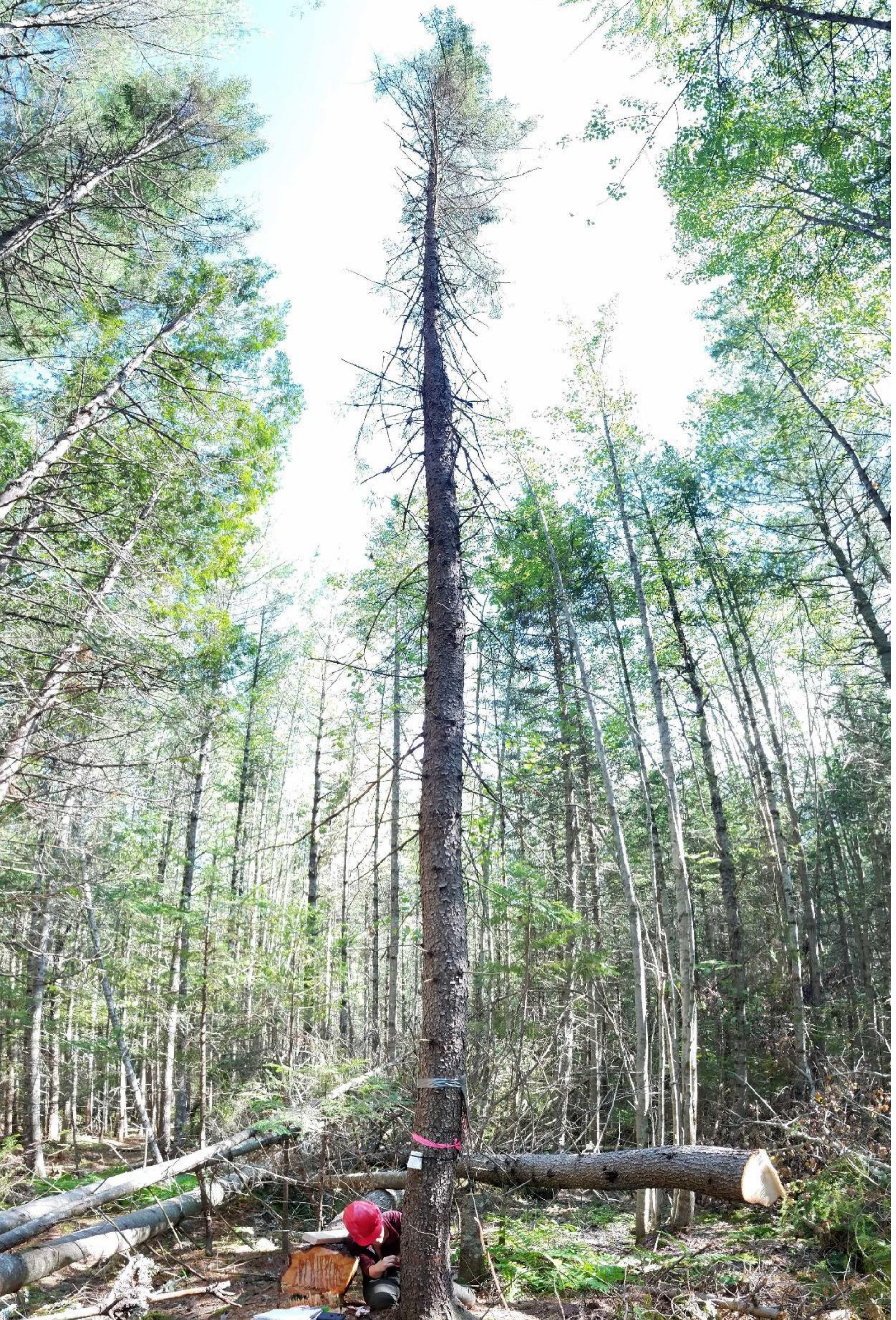
Heavily thinning spruce-fir forests in future projected climates could further increase stand temperature and VPD

- More study needed on how this will affect physiology, water relations, tree growth
- How might this influence management strategies?

Red spruce shows strong signs of drought resistance – but this is due to a tradeoff between photosynthesis and water conservation

- Major opportunity cost for carbon gain due to closed stomata
- Still sensitive: survival of natural droughts → reduced radial/height growth & legacy effects





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Thank you!

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Sap flow sensors
(HRM)
iButtons