

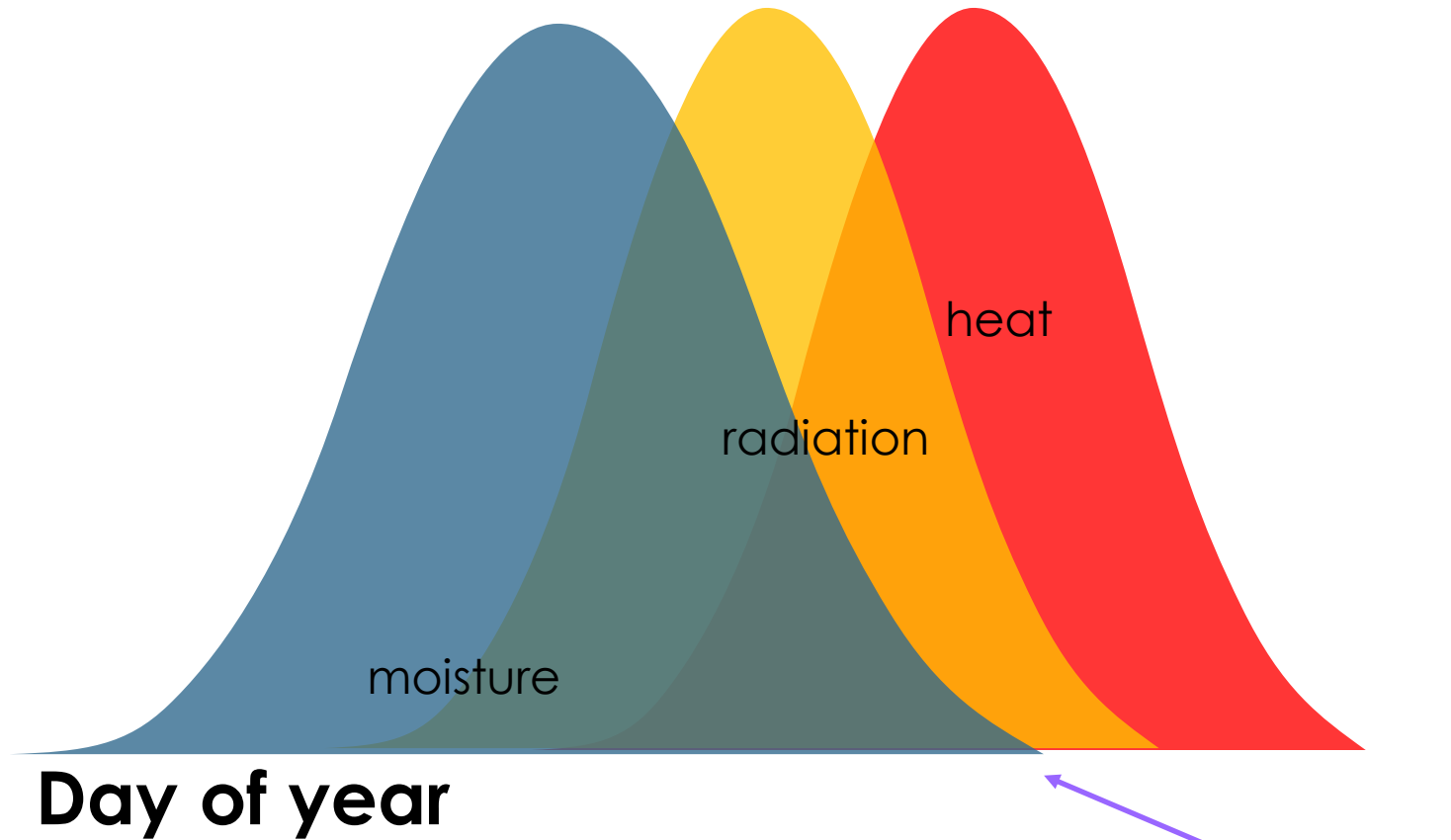
# Does earlier = more? Exploring the links between phenology and productivity

Sarah Elmendorf & Bob Hollister  
Jane Smith & Chiara Forrester  
University of Colorado & Grand Valley State University  
ITEX meeting  
April 2024



Photo credit: J. Smith

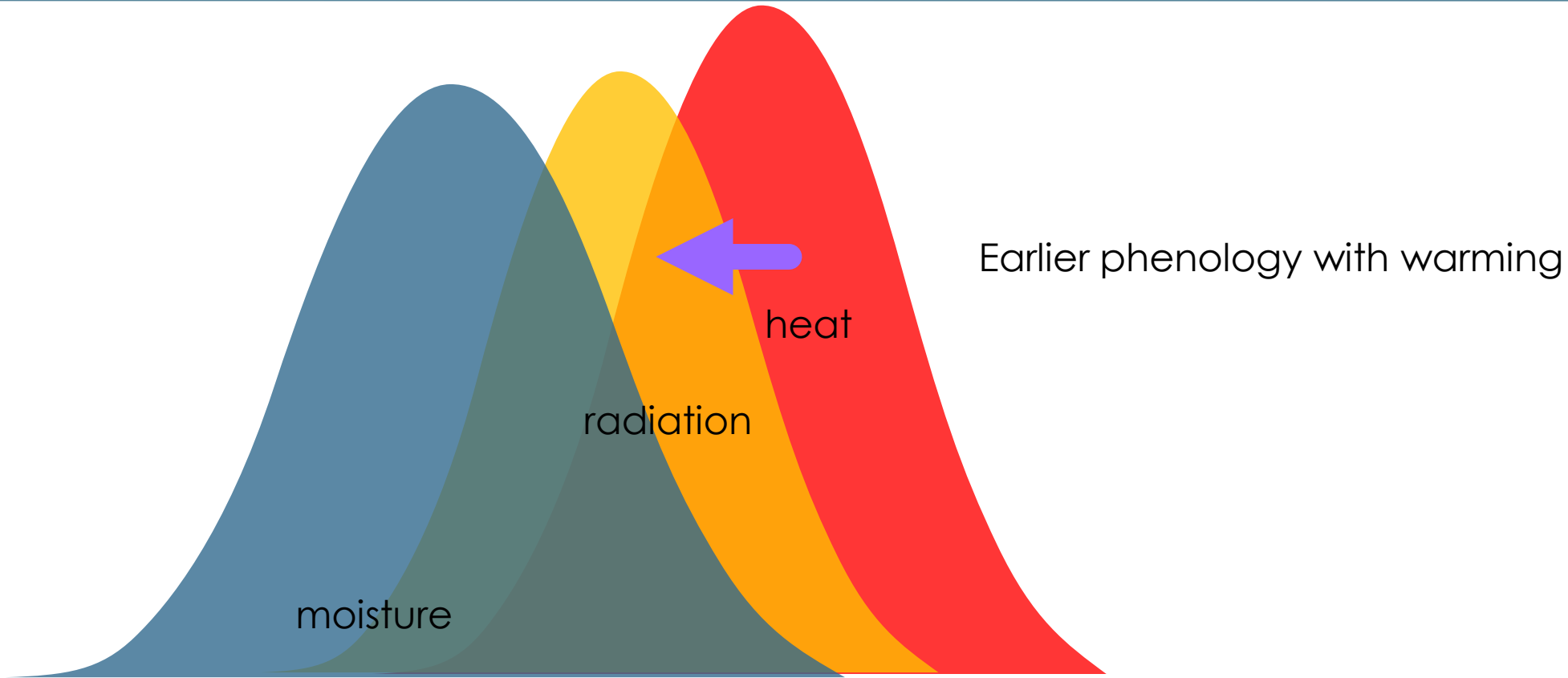
# Laws of minimum – why ecophysiologicalists expect a greening tundra



Current timing of maximum photosynthesis in a typical tundra ecosystem

after Park *et al.* 2019 GCB

# Laws of minimum – why ecophysiologicalists expect a greening tundra

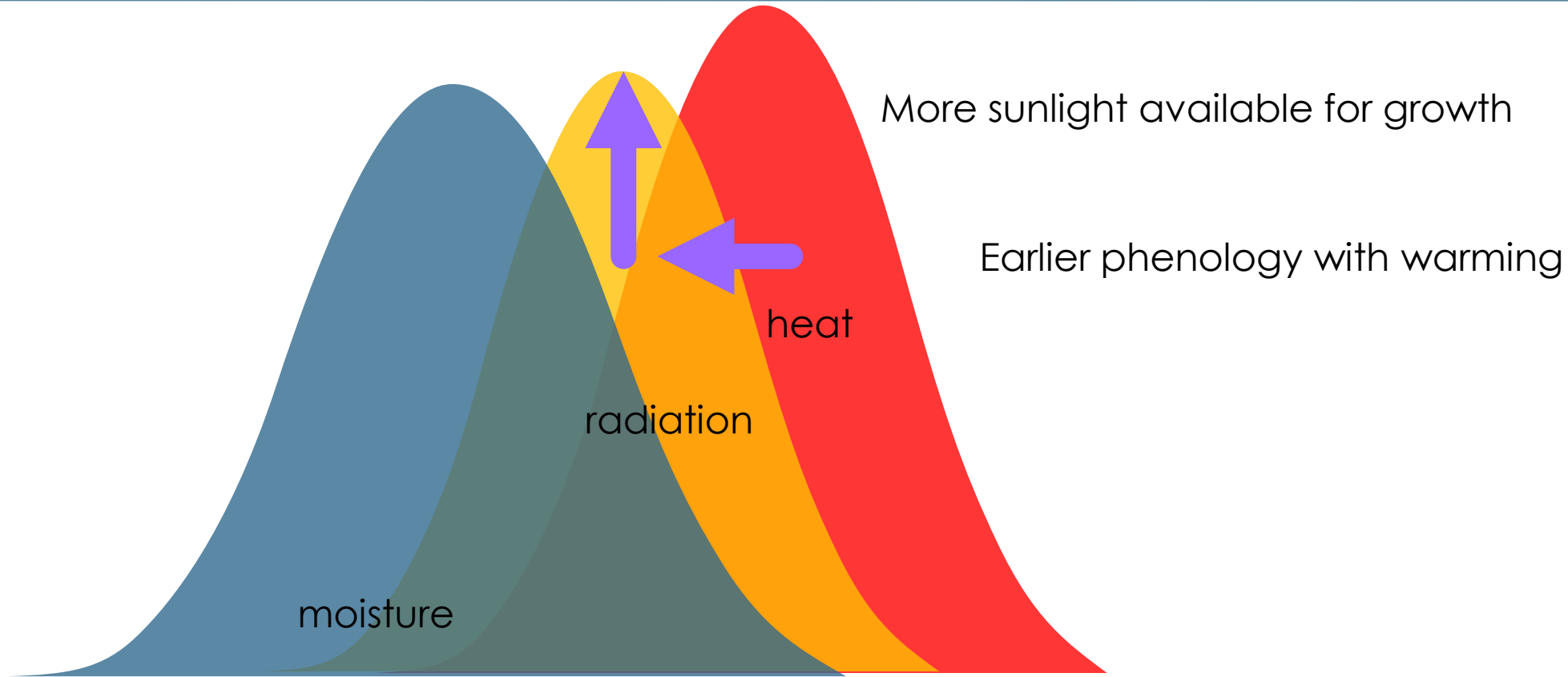


**Day of year**

Current timing of maximum photosynthesis in a typical tundra ecosystem

after Park *et al.* 2019 GCB

# Laws of minimum – why ecophysiologicalists expect a greening tundra

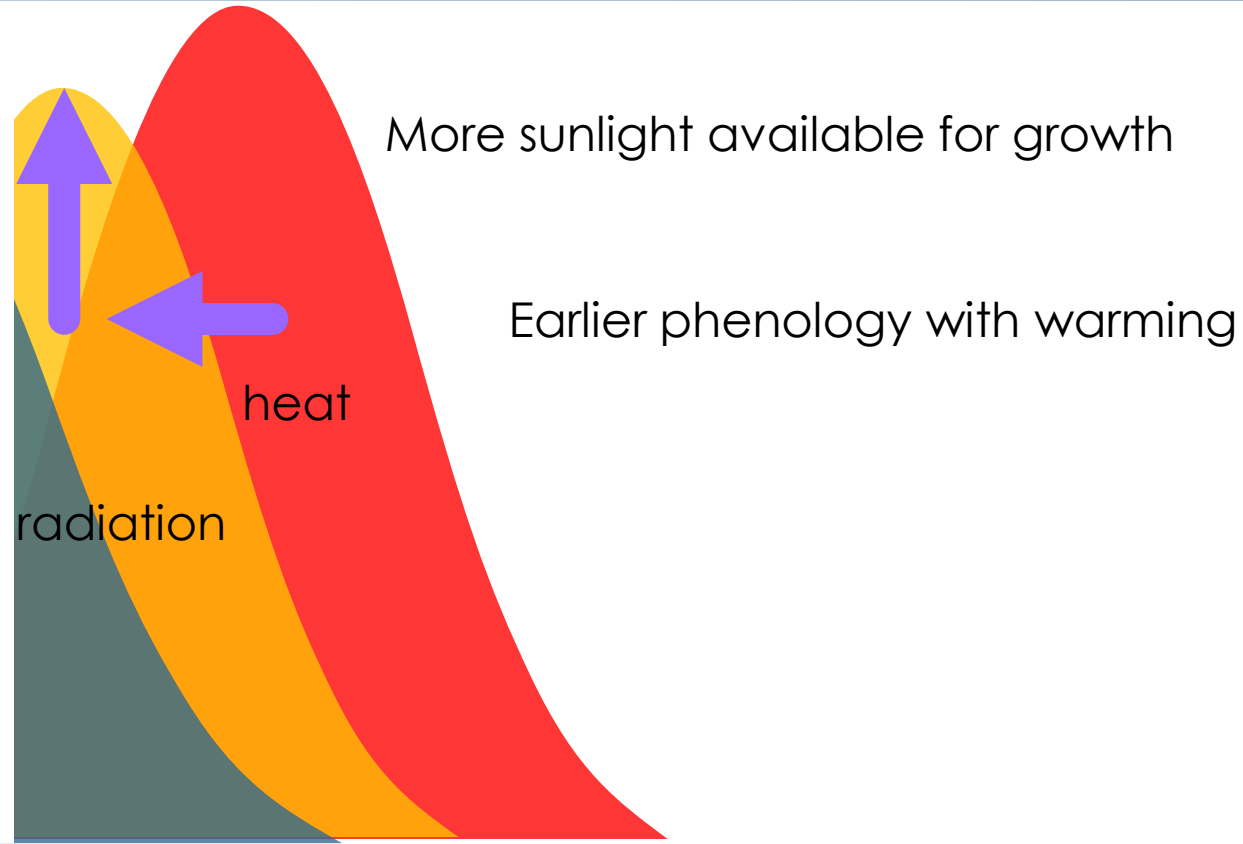


**Day of year**

Current timing of maximum photosynthesis in a typical tundra ecosystem

after Park *et al.* 2019 GCB

# Laws of minimum – why ecophysiologicalists expect a greening tundra



Day of year

Current timing of maximum photosynthesis in a typical tundra ecosystem

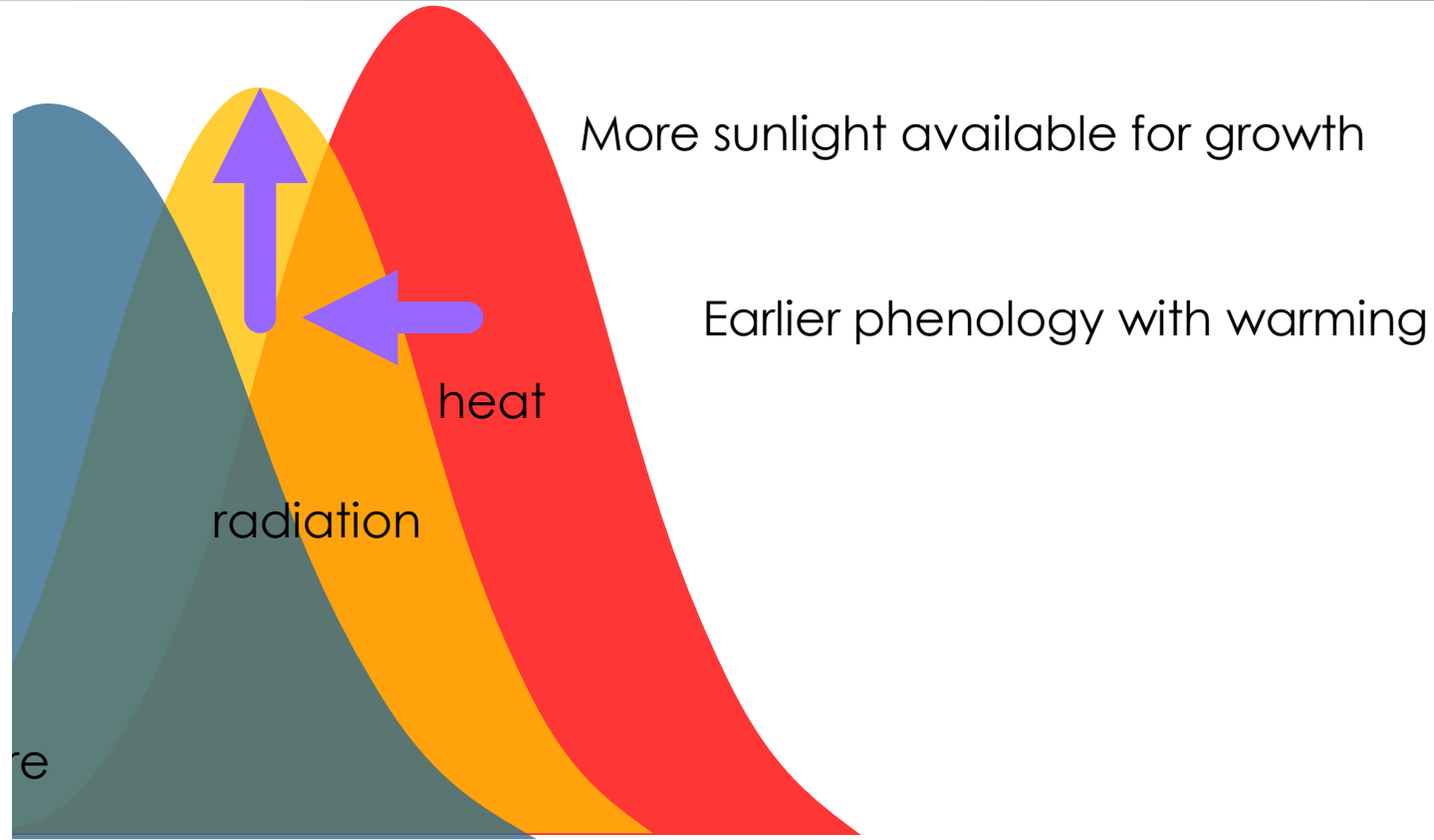
after Park *et al.* 2019 *GCB*

# Laws of minimum – why ecophysiologicalists expect a greening tundra



**Day of year**

Earlier snowmelt



Current timing of maximum photosynthesis in a typical tundra ecosystem

after Park *et al.* 2019 GCB

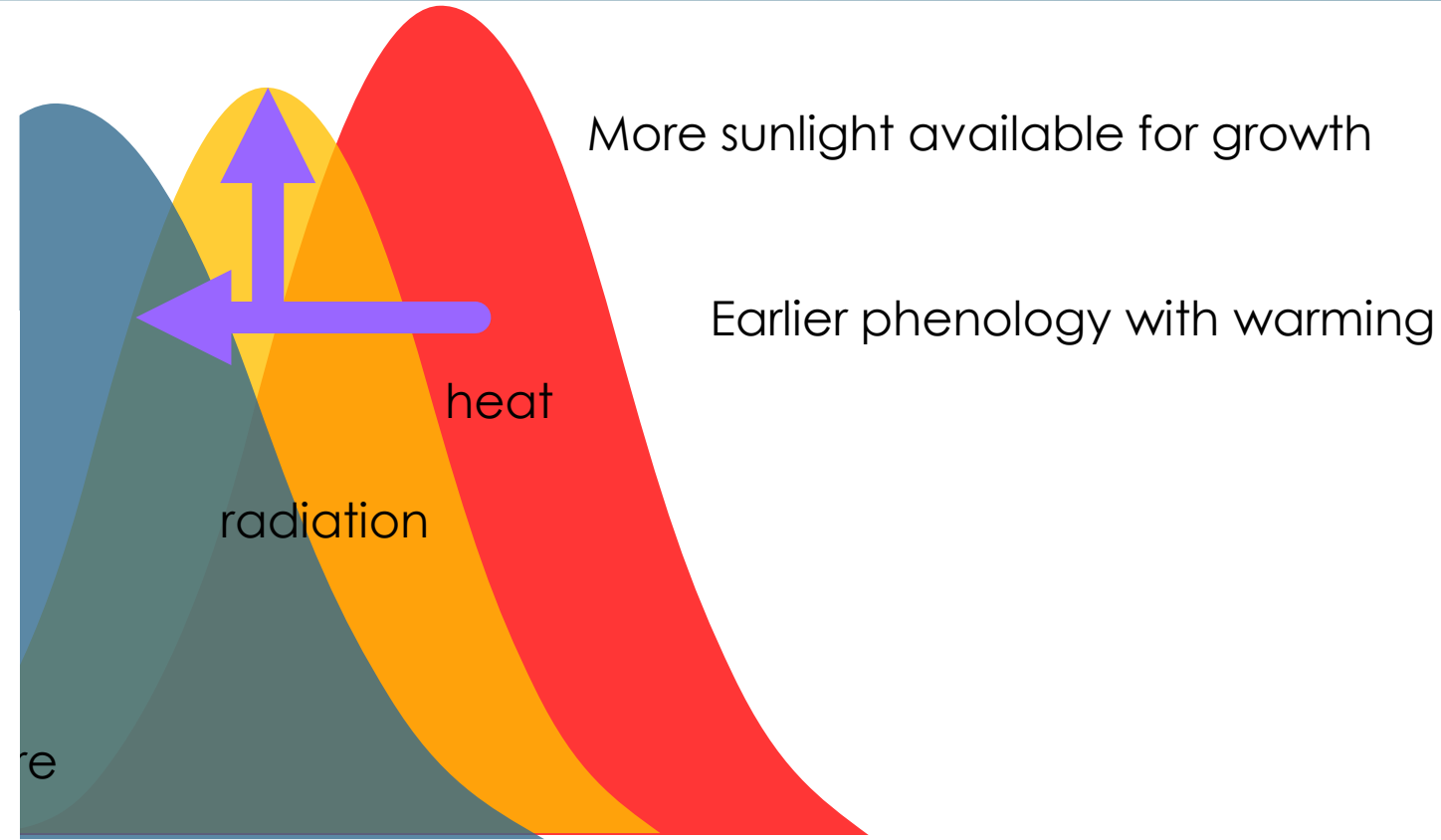
# Laws of minimum – why ecophysiologicalists expect a greening tundra

Even more sunlight available for growth



**Day of year**

Earlier snowmelt



Current timing of maximum photosynthesis in a typical tundra ecosystem

after Park *et al.* 2019 GCB



# Climate impacts on phenology and growth


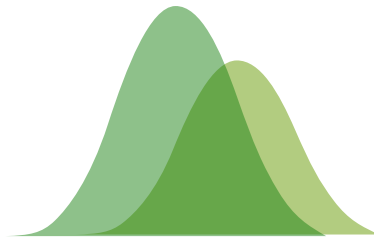
Current tundra  
growing season



Future tundra climate

- Warmer temperatures
- Earlier snowmelt

Earlier -> More



**DO**  
**MORE**  
**BETTER**  
**FASTER**

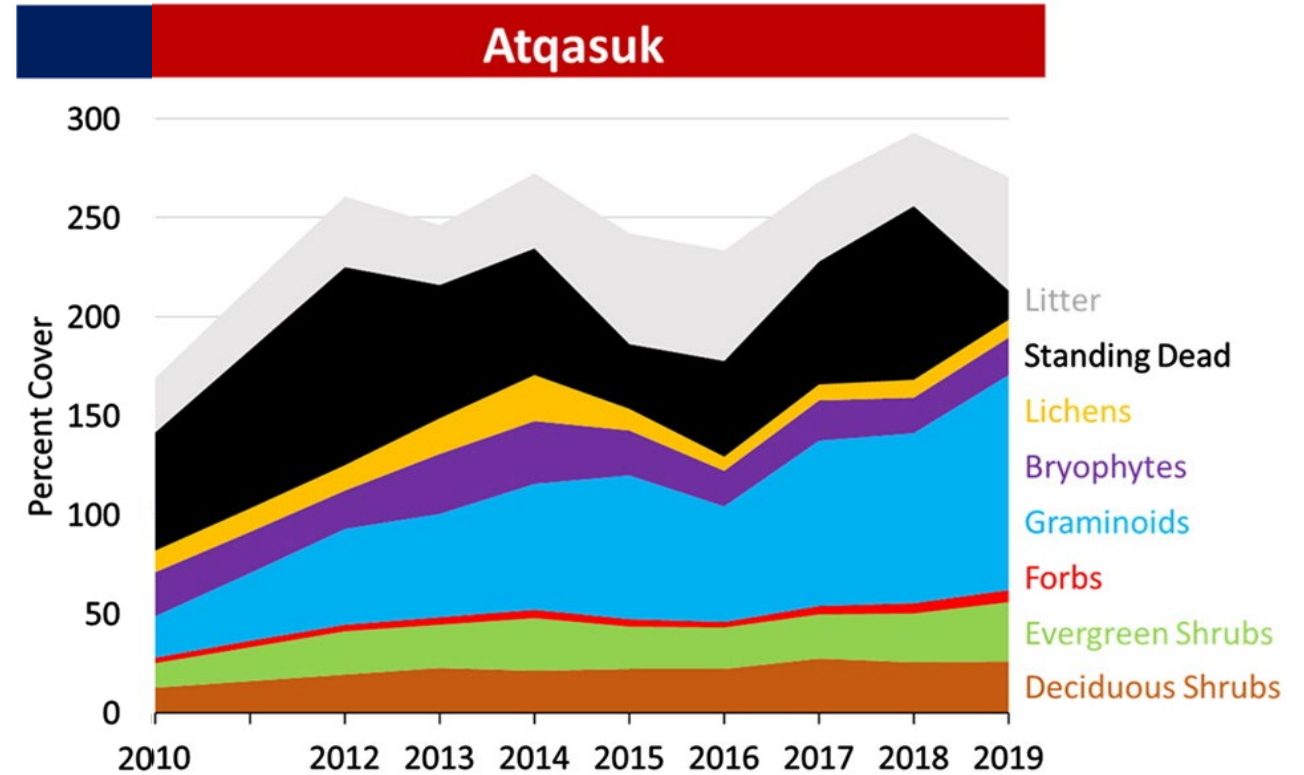
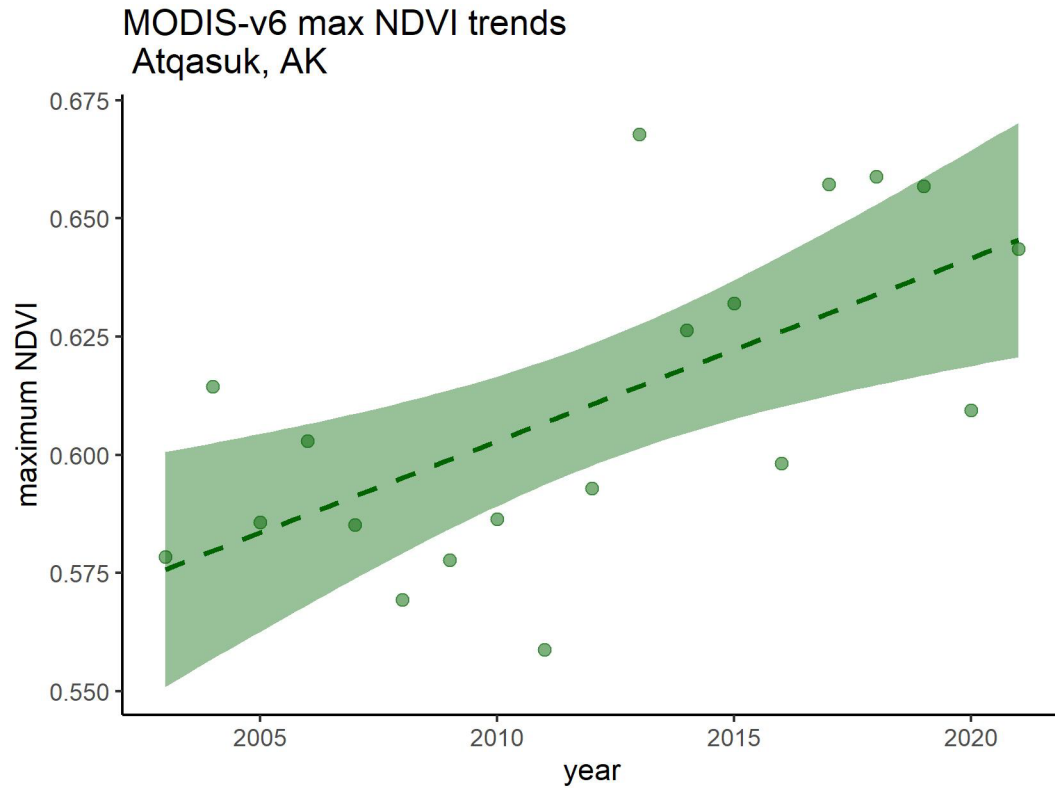
*The Optimal Outcomes Approach*  
on  
*How to be More Productive*  
and  
*Get More Done in Less Time*  
Dan Kristoph



# Does earlier => more?

- Strong greening trend visible in satellite and field measurements

## Atqasuk, AK



# Does earlier => more?

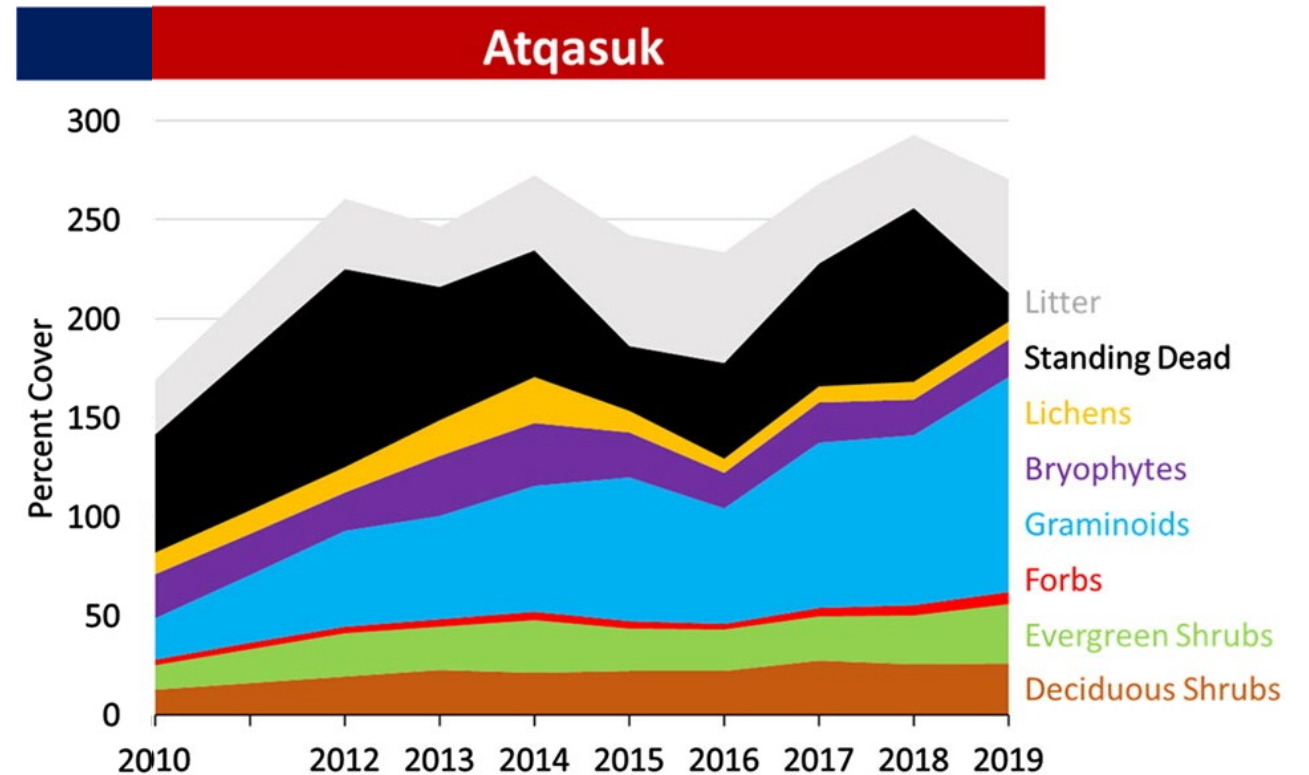
- Strong greening trend visible in satellite and field measurements

Atqasuk, AK



*Carex aquatilis*

Image credit: Wikicommons



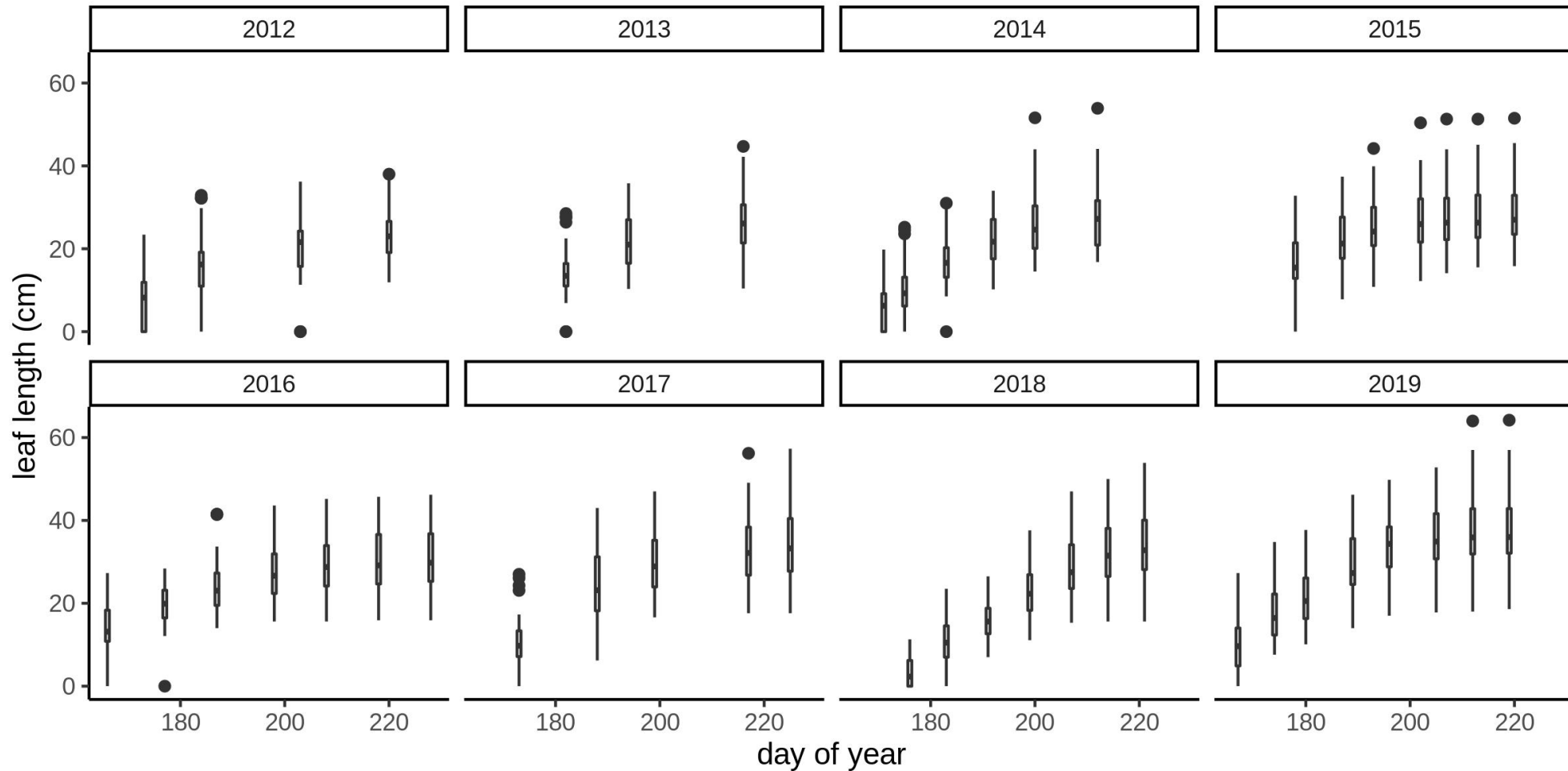
Harris et al. 2021 Arctic Science

# Does earlier => more?



Bob Hollister

~ Weekly measurements of *C. aquatilis* leaf length

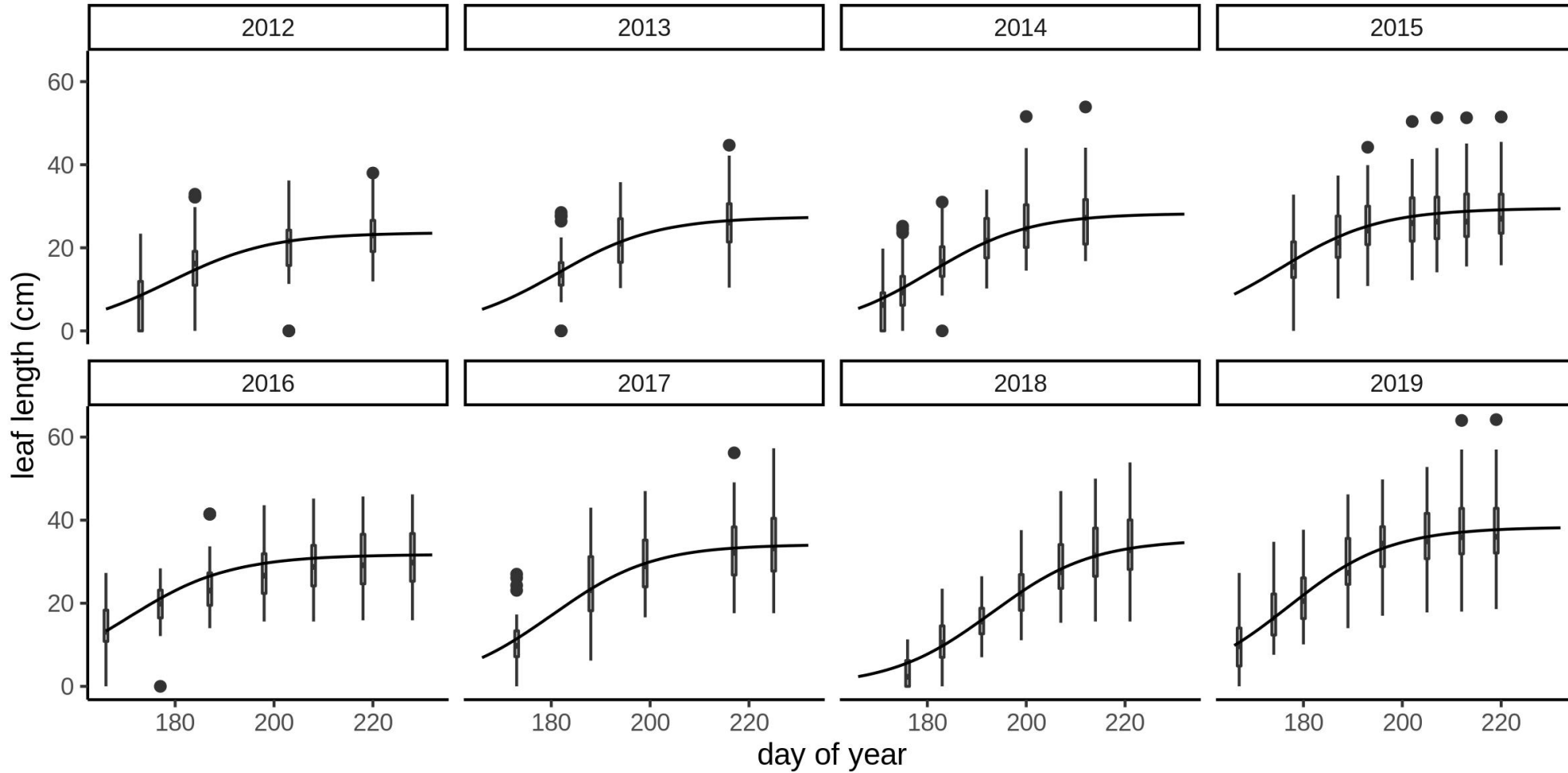


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Bob Hollister

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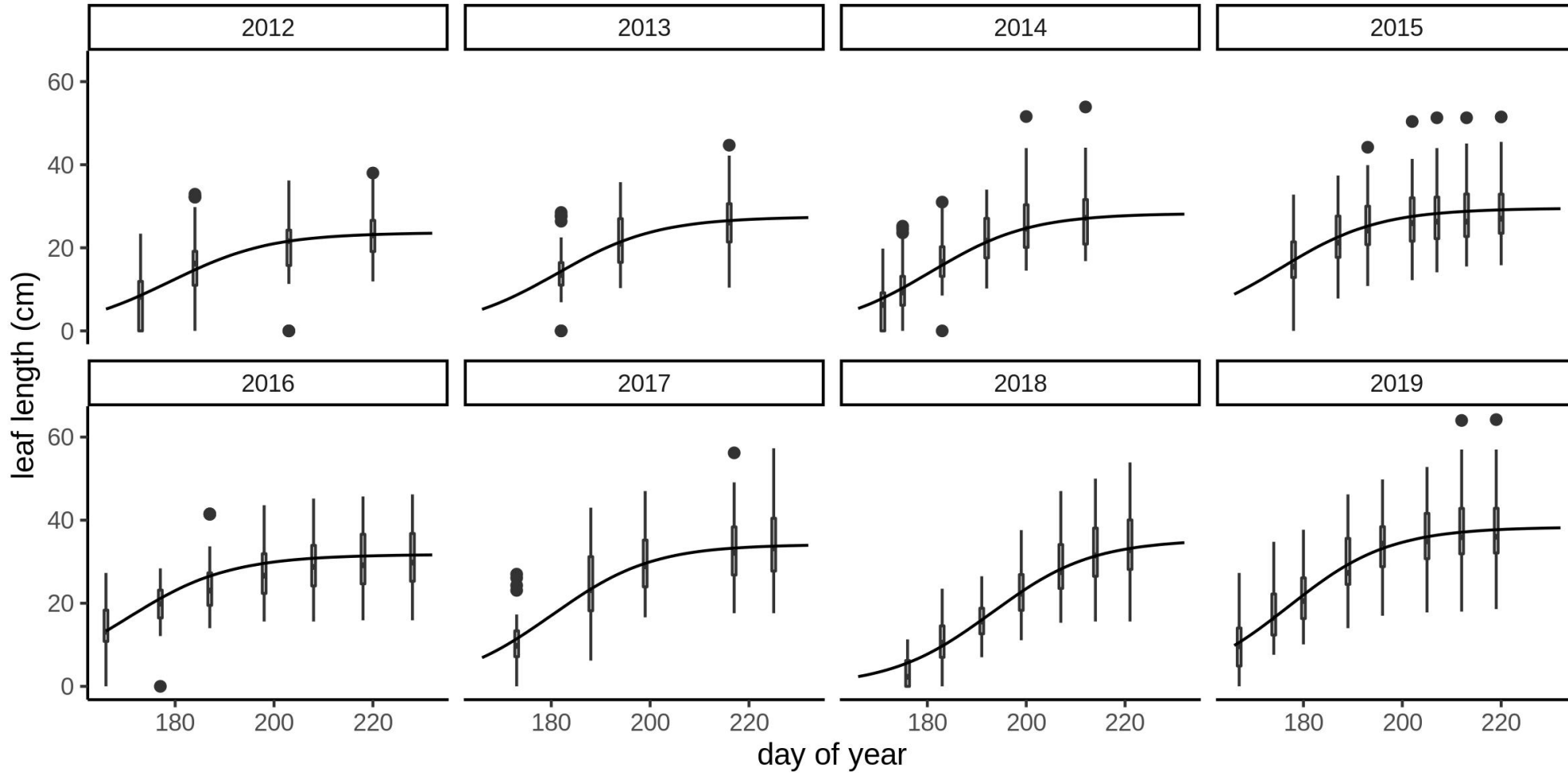


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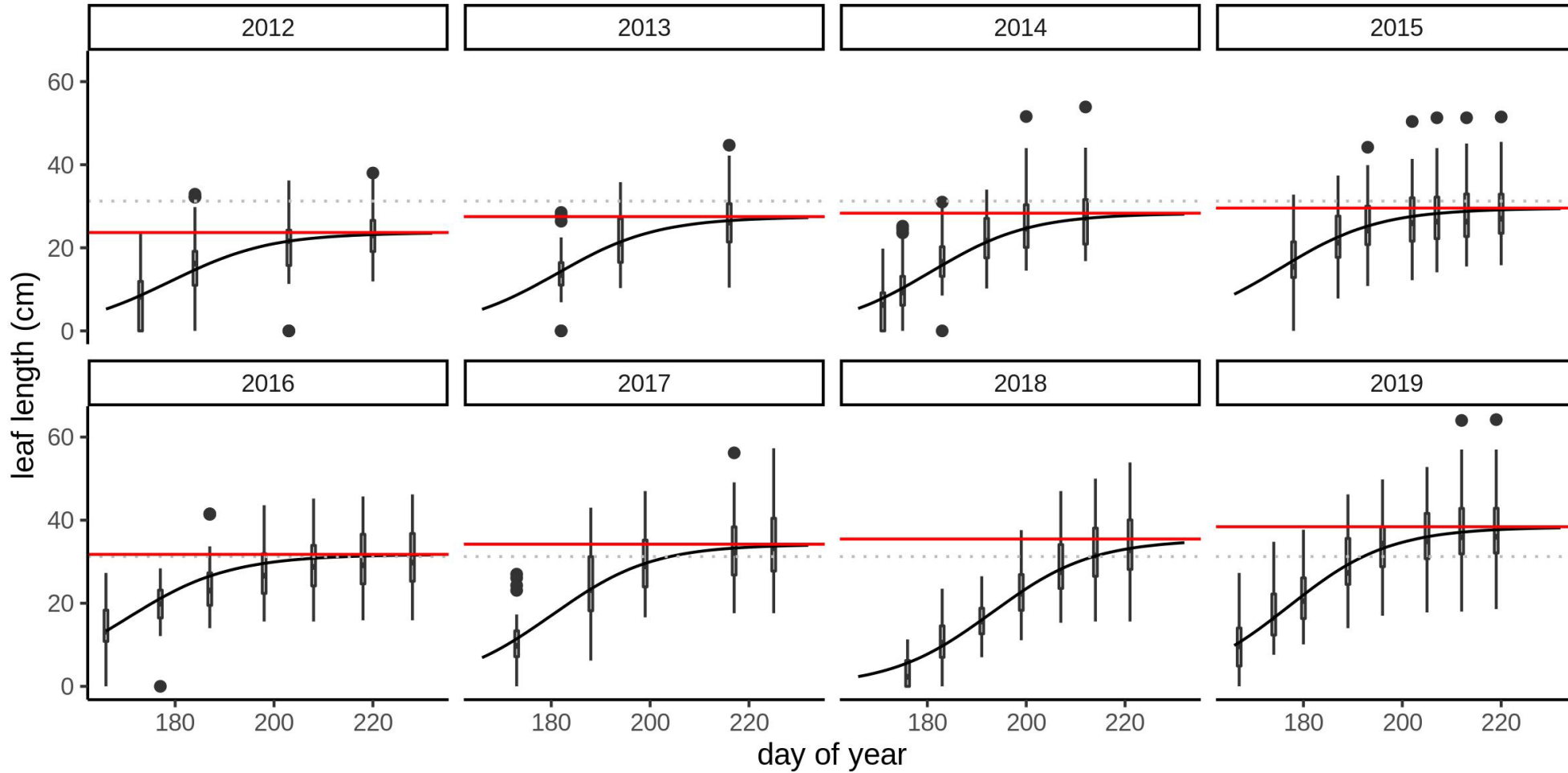


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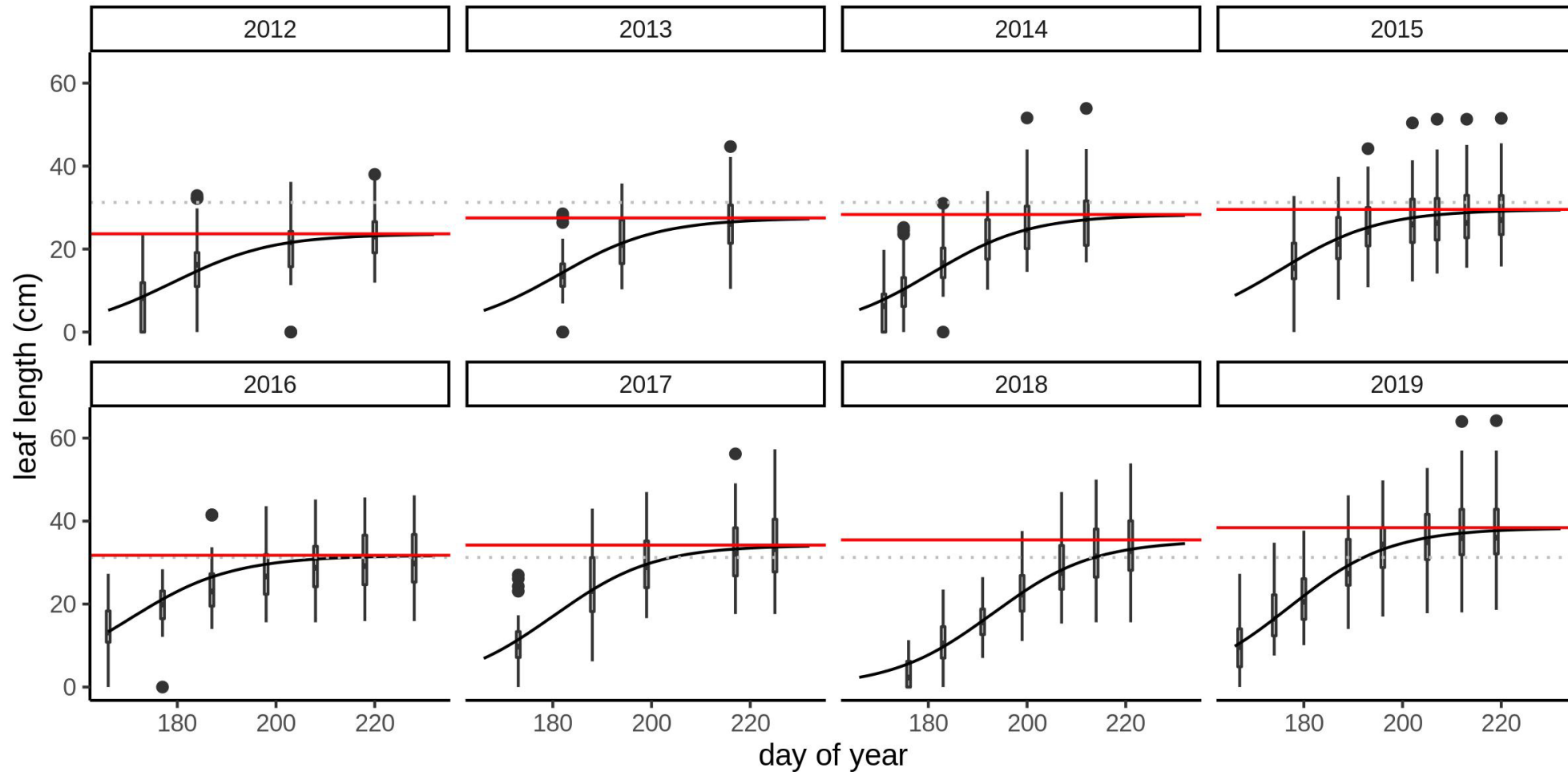


# Does earlier => more?



Bob Hollister

- Leaf length has increased ~50% over 8 years



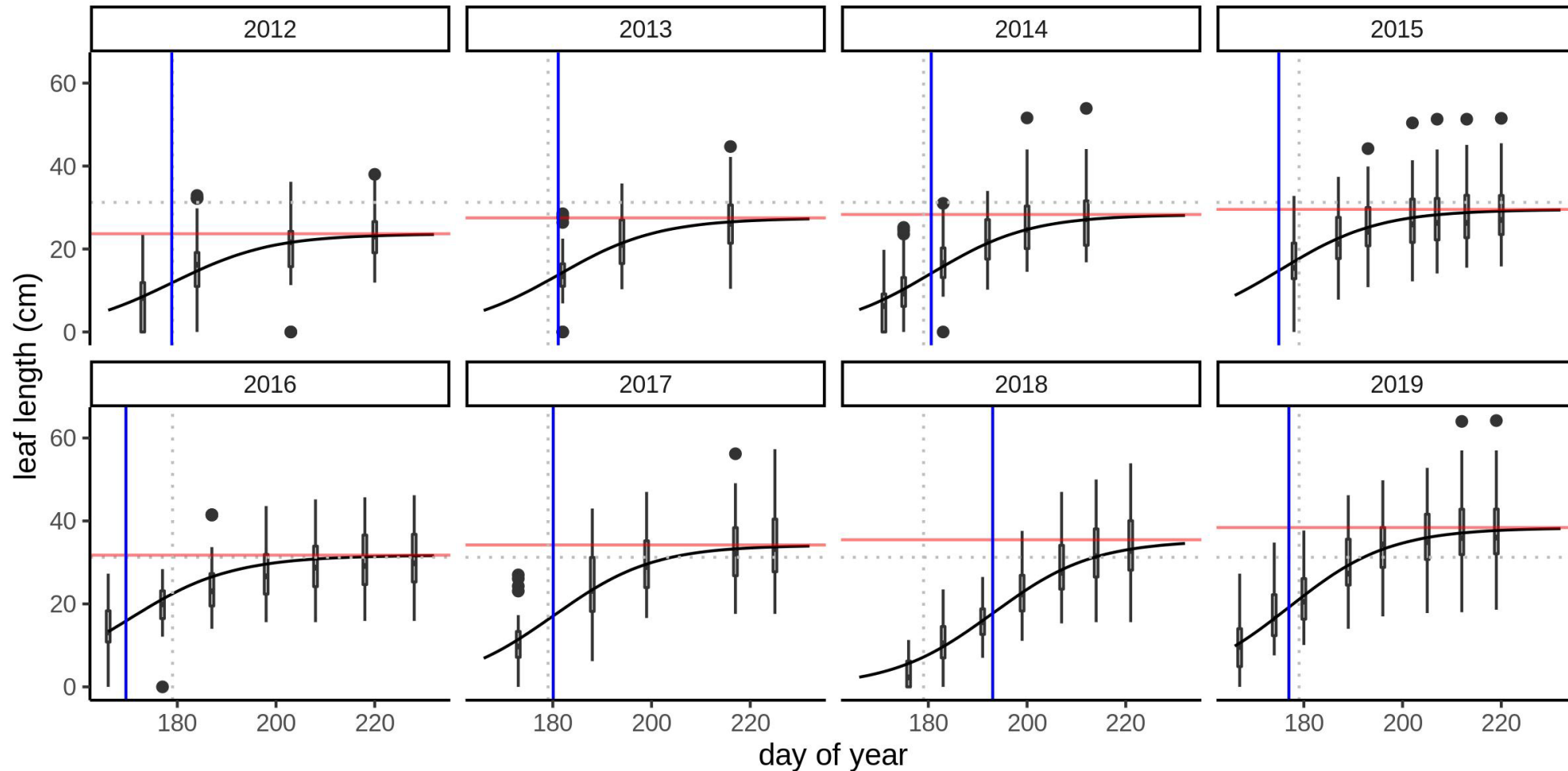


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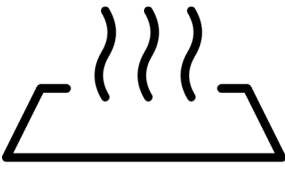


Bob Hollister

- Leaf length has increased ~50% over 8 years
- Timing of growth shows high interannual variability but no temporal trend

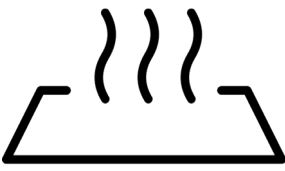


# Does earlier => more?

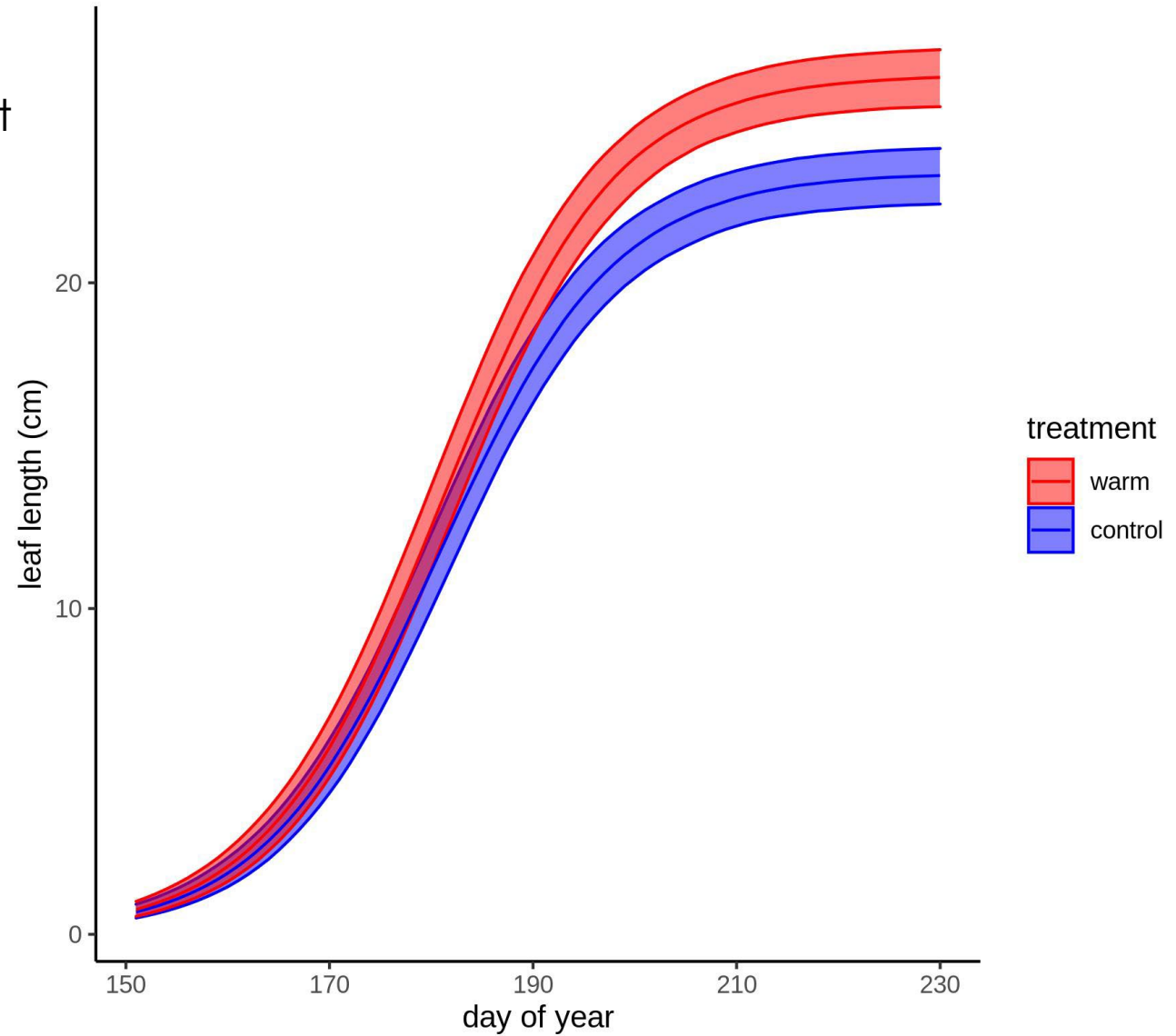


~ Weekly measurements of *C. aquatilis* leaf length **inside and outside of warming chambers**

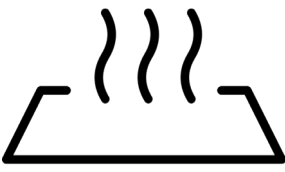
# Does earlier => more?



- Annual leaf length of *C. aquatilis* is increased in warming chambers but timing is unchanged

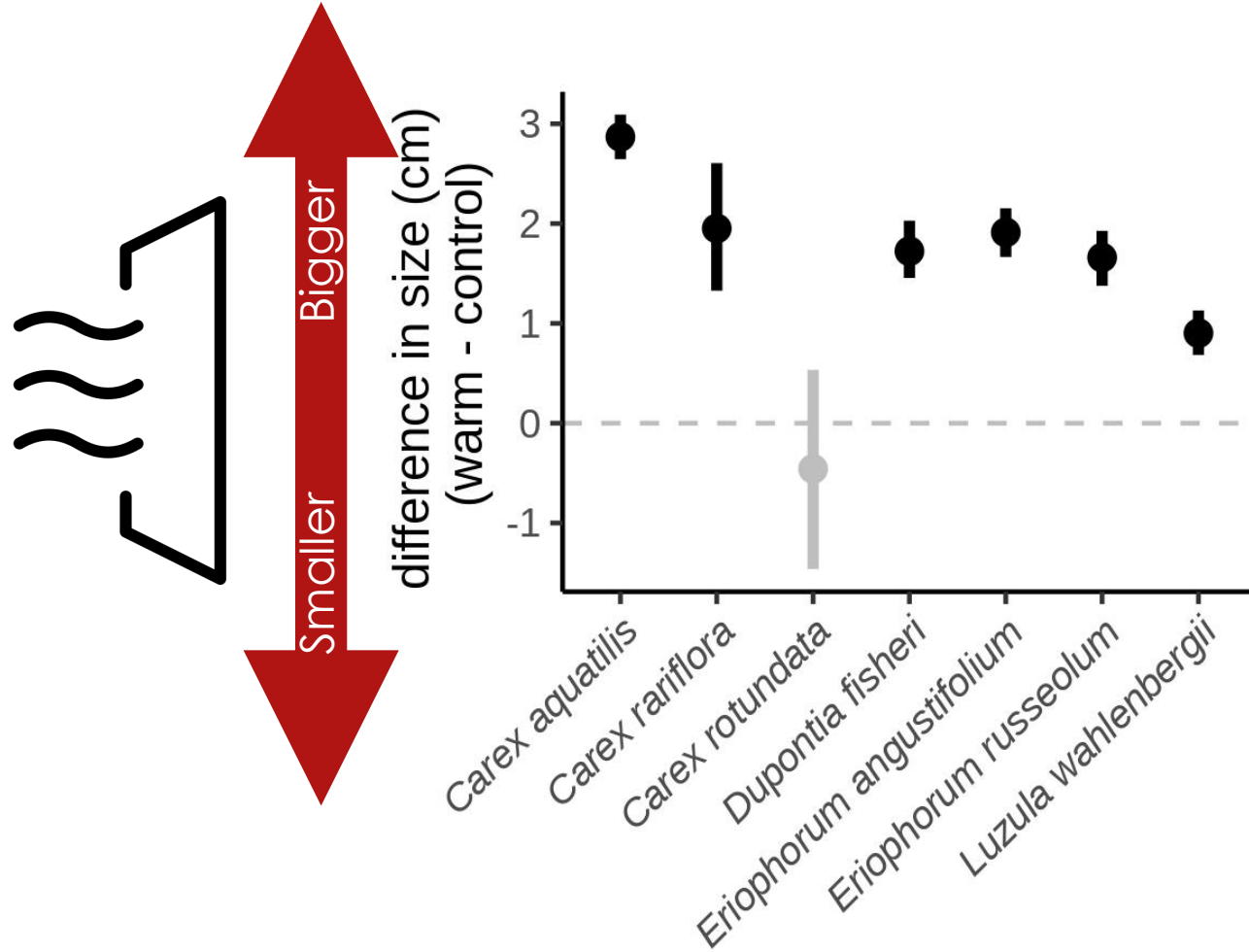


# Does earlier => more?

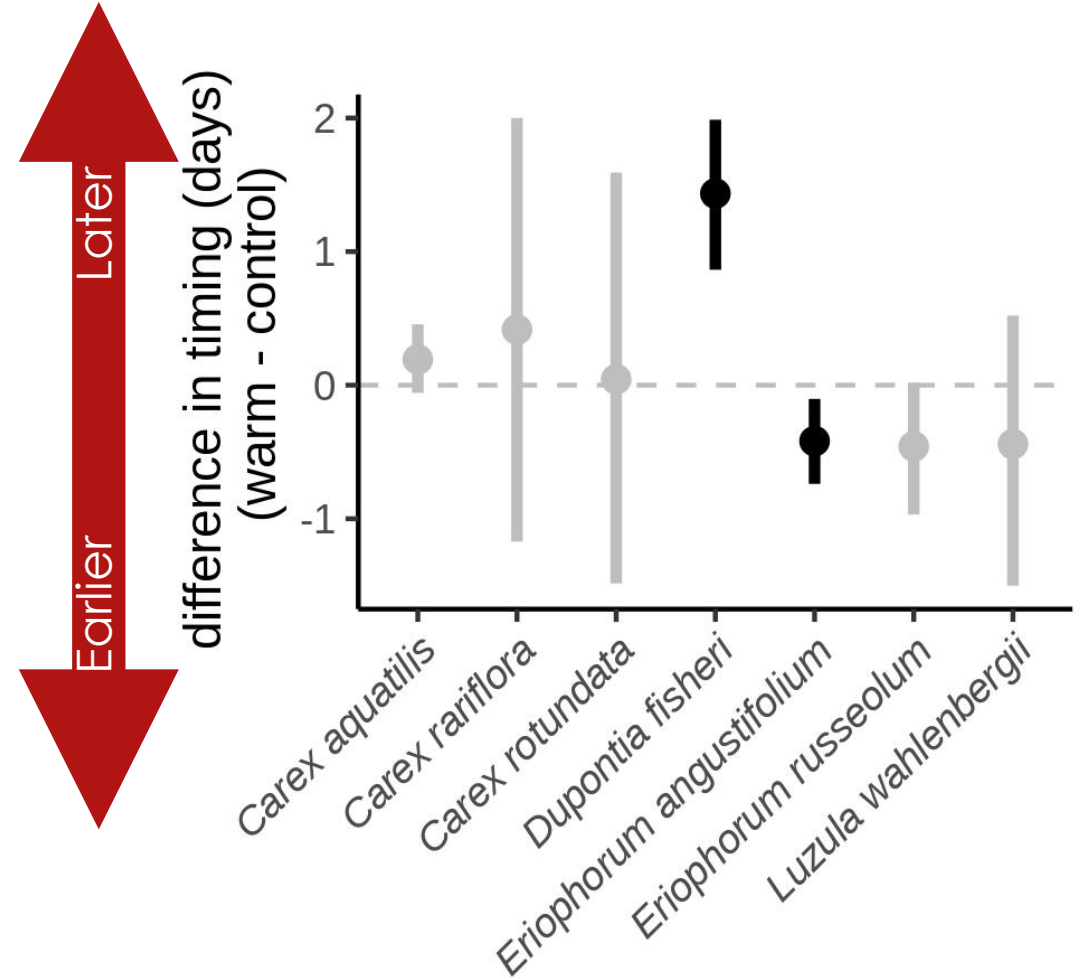


Warming effects on growth of **all common graminoids**

- Consistently **more** growth under warming



- But **not** due to earlier growth



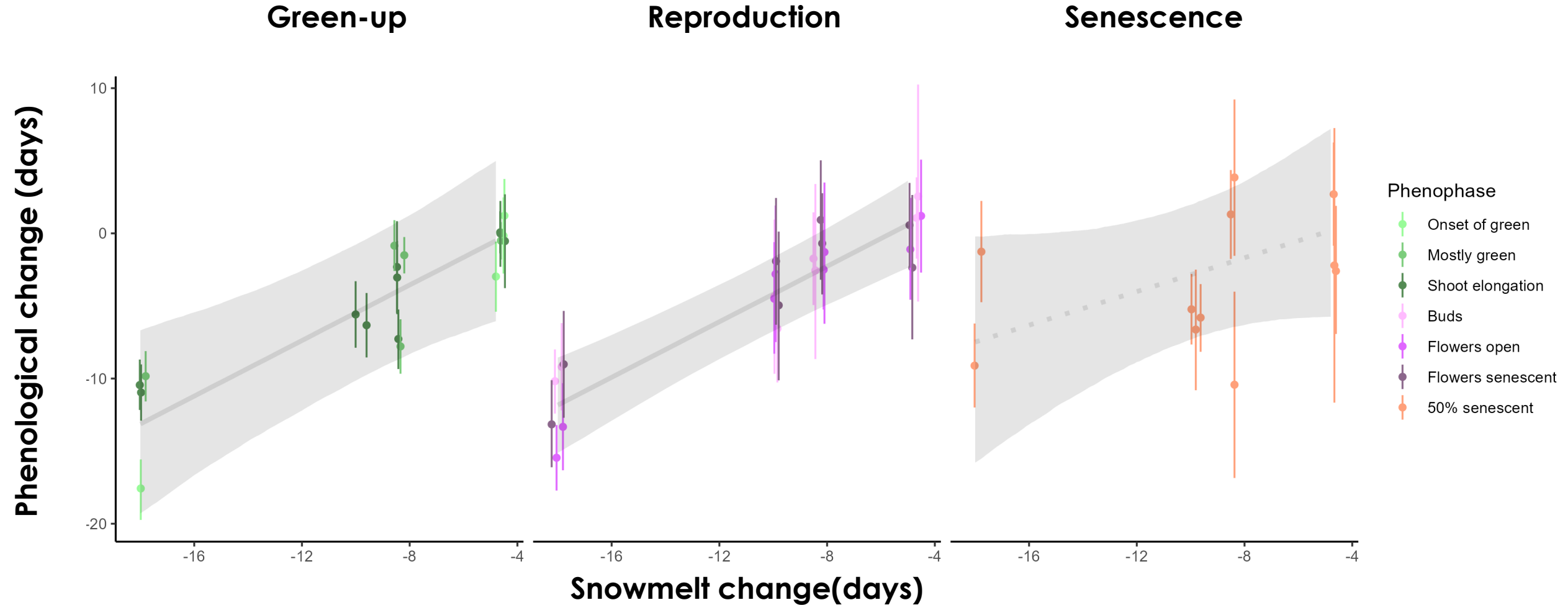
# Does earlier => more? A test with snowmelt



Created by ProSymbols  
from Noun Project



# Earlier snowmelt -> earlier greenup & reproduction



**Largest advances in phenology where the “dust” event most advanced snowmelt  
(greatest snowmelt treatment effect)**

# Productivity?



Created by ProSymbols  
from Noun Project



Greatest  
snowmelt  
treatment  
effect

Audubon

Trough

Lefty

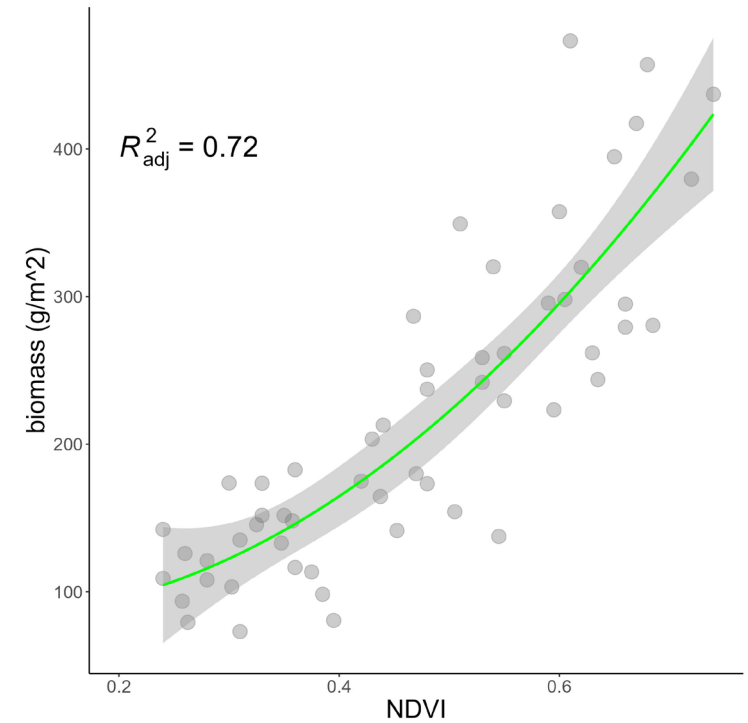
East\_Knoll

Soddie

Least  
snowmelt  
treatment  
effect



Jane Smith



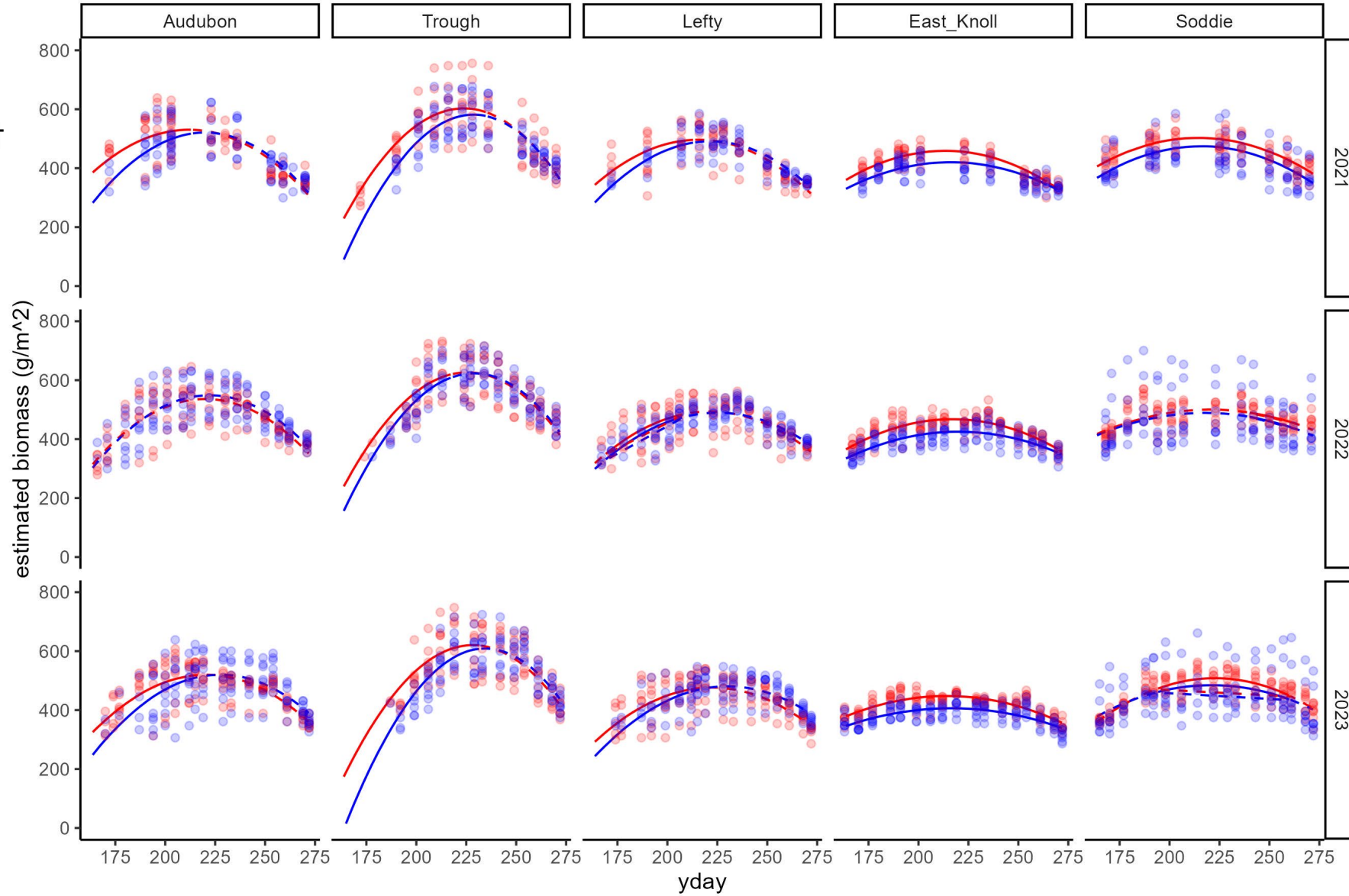


# Productivity?

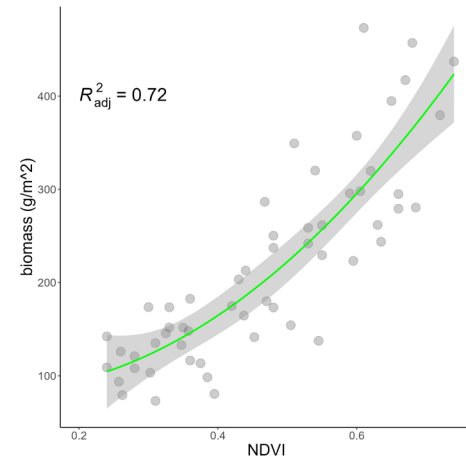


Created by ProSymbols from Noun Project

Greatest snowmelt treatment effect



Least snowmelt treatment effect

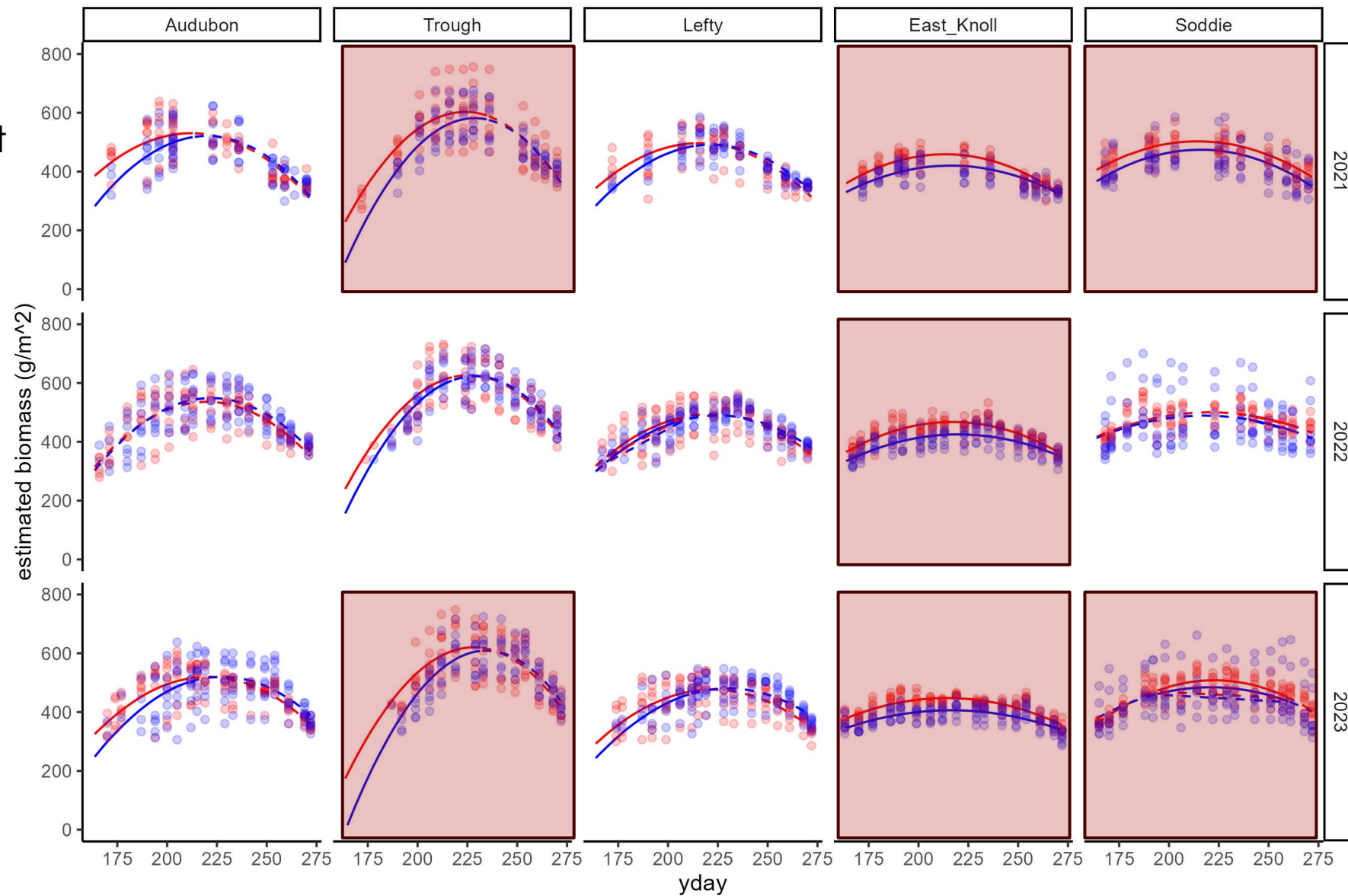


# Productivity?

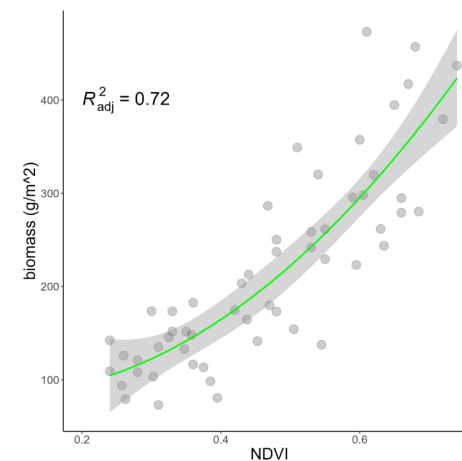


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from Noun Project

Greatest  
snowmelt  
treatment  
effect

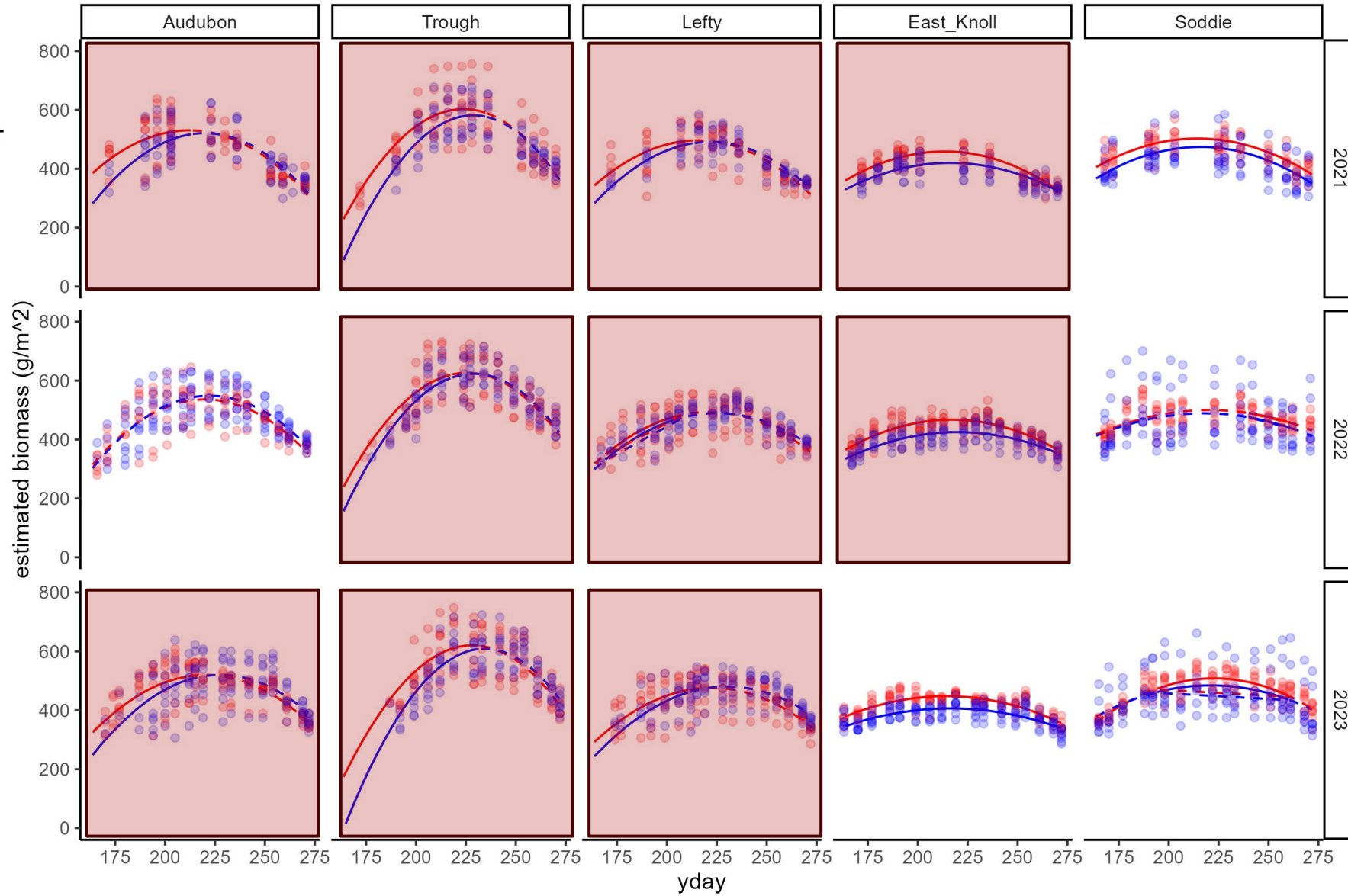


Least  
snowmelt  
treatment  
effect

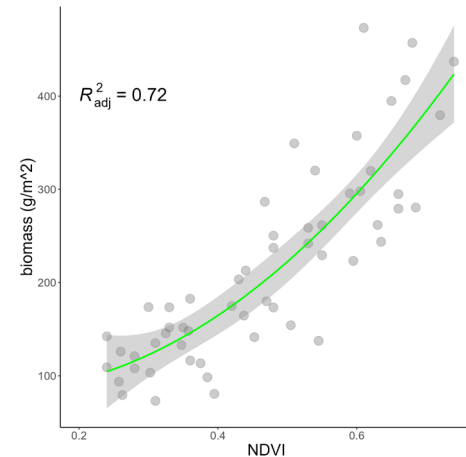


# Earlier biomass production decoupled from total productivity

Greatest snowmelt treatment effect



Least snowmelt treatment effect



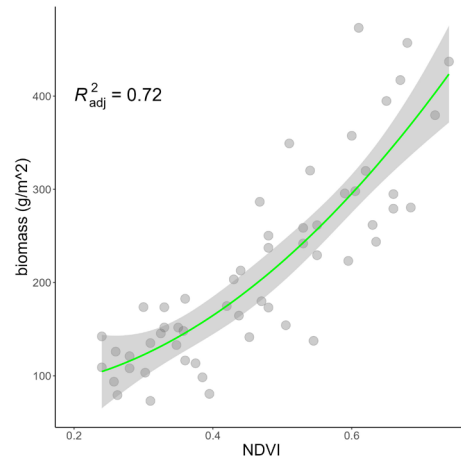
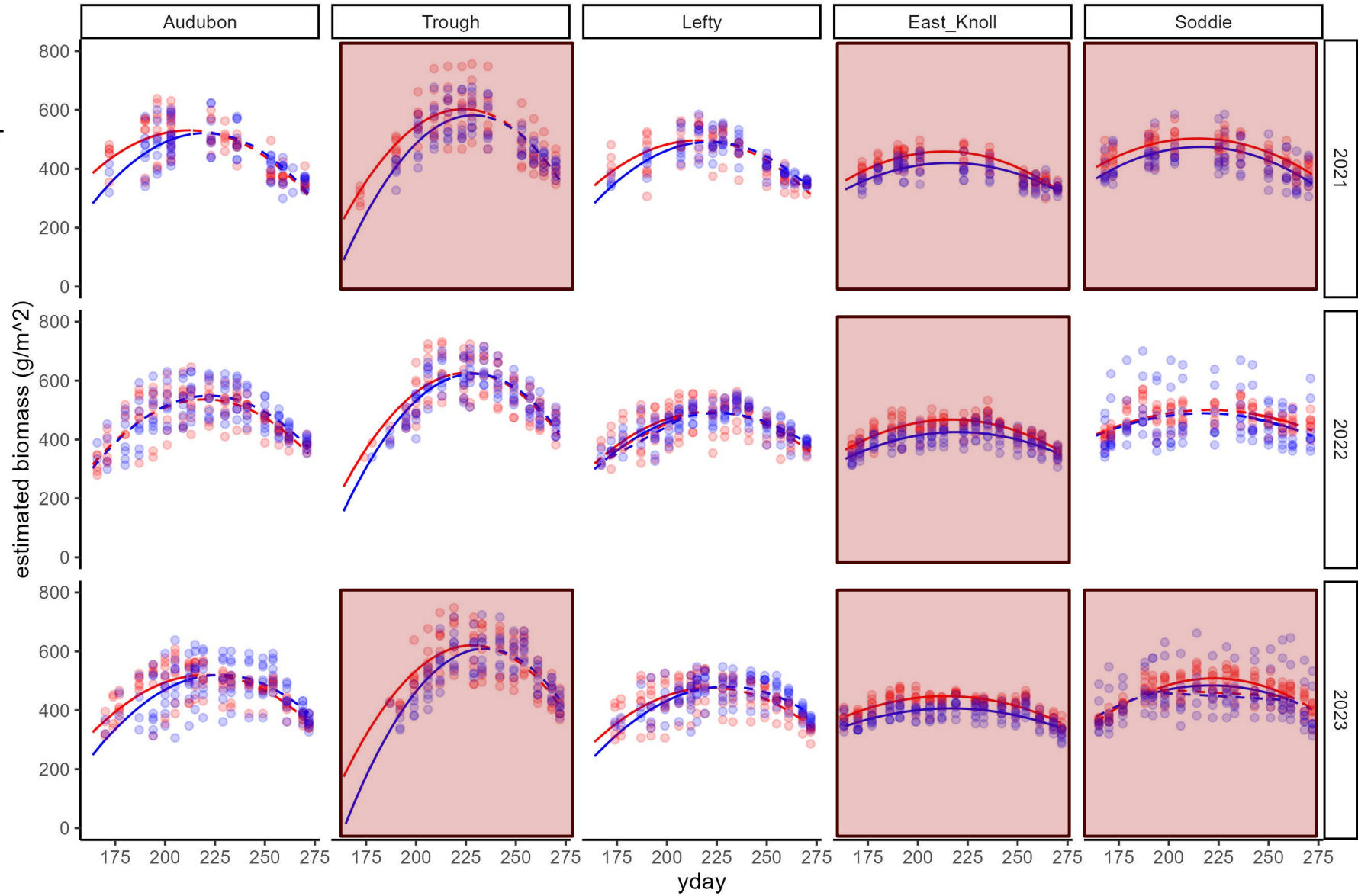
# Earlier biomass production decoupled from total productivity



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Greatest snowmelt treatment effect

Least snowmelt treatment effect



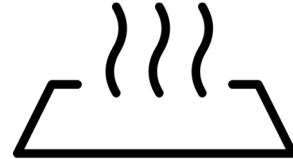


# Conclusions

**Increases in total growth with climate change may occur even without pronounced shifts or extensions of the vegetative growing season**



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from Noun Project



**ITEX-AON**  
Understanding Tundra Ecosystem Change

