RH: Interactive cues and spring phenology

Concept paper on understanding interactive cues and climate change (with growth chamber studies)

How interactive cues will drive climate change responses

Spring warming, winter warming or daylength: What cue will be most limiting in future tree phenology

The lab[1,2]

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Abstract

Climate change has shifted plant phenology globally, with average shifts of 4-6 days/°C and some species shifting several weeks. Globally, such shifts have been some of the most reported and most predictable biological impacts of climate change. This predictability comes from decades of research, which have outlined the major cues that drive most studied plant phenology: temperatures (including spring warming and winter chilling) and daylength. Further simplifying predictions, spring temperatures are often the dominant cue in nature, making linear models of heat sums often excellent at predicting interannual variation in phenology. Yet as climate change has marched on, new research has uncovered failures to predict the current observed changes, with many shifts appearing more muted over certain time periods or in certain locations. Here we argue that such inaccurate predictions are most likely due to simple models that neglect to consider other major cues—especially winter chilling and daylength, which moderate and shape plant phenological responses to spring warming. We highlight how over 60 years of research in controlled environments can improve predictions for when, where and how the interactive effects of other cues will impact simple linear predictions. Finally, we discuss how a new generation of controlled environment experiments could rapidly improve our predictive capacity for woody plant phenology in coming decades.

Main message (and, really, it's important): if you want to project climate change impacts, you need to focus on relevant changes in all three cues. The relevant changes part is about comparing cues, the all three cues is about interactive cues.

(Keywords: phenology, climate change, spring warming, forcing, chilling, daylength, photoperiod, non-linear responses, leafout, budburst)

Where to add potential new PhenoFit figure?

1. Introduction

   (a) Climate change: it means all that work on phenology comes due ... now! (Short opening paragraph)

   (b) There has been a lot of focus on forcing but really it's more complicated

      i. Think about one tree[1]

      ii. Look at its distribution![2]

      iii. Cues are adapted to high climate variation! (New term? Cue range limits? As in the limits of cues as seen over a species' range, what do you think?)

   (c) These cues may create critical non-linear responses that most current methods cannot predict, but measuring them and thinking about how they will interactively produce future phenology is hard because:

      i. They are expected to interact; cues may compensate for other cues; meaning they mask one another

      ii. They vary across species and possibly within species across the range

      iii. They are hard to measure.[3]

      iv. To some extent, you haven't really had to measure them to get decent predictions (CITES Primack linear paper)

   (d) Add in paragraph here on predictions starting to fail (CITES Fu paper, Tibet etc.), see abstract

   (e) How do you measure them there cues?

      i. Methods especially lame at understanding these cues (and thus predicting non-linearities): models from long-term observational data ... somehow mention experiments maybe?

      ii. Try to comment on the two issues at play here: the data type (e.g., long-term) versus the model type (e.g., linear and sans interactions?)

      iii. The one method designed to look at all these cues is controlled environment (generally growth chamber) studies

   (f) Growth chamber studies

      i. Can manipulate all three cues (and even more, humidity etc. nod?)

      ii. Are often focused on interactions (unlike other methods)

      iii. Have been done *forever*. But oddly, never really reviewed.

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[1]Here we pick one PEP725 species that is well-represented spatially for leafout or budburst data (Cat?)

[2]Here, we show a distribution map (Nacho?), maybe with some spring climate and/or phenology mapped on it.

[3]Somewhere in here need to sneak in that we will focus on woody species phenology, because it's where we understand things best and thus should build from there.

iv. ...and are often poorly integrated into current climate change literature. Including debates where they are critical, like about photoperiod.

(g) Our aim is to:

   i. Review how three major phenological cues for woody plant phenology will shift in coming decades with anthropogenic climate change

   ii. Review of the three major phenological cues from growth chamber studies over the past 60 (70?) years

   iii. Highlight their critical relevance to climate change research

   iv. Compare treatments from controlled environment studies to predicted shifts in cues with climate change.

   v. Showcase how growth chamber studies can be best designed to better understand these interactive cues (paths forward).

2. Review how cues will shift with climate change (we could have figures of change in temp across the distibution here?)

(a) Forcing: the world will get warmer

   i. Higher altitude and arctic places will warm more

   ii. Give range of warming depending on different scenarios

   iii. Minima warm more than maxima (night-time temps)

(b) Chilling, see forcing but ...

   i. Chilling only occurs between certain temps so some places accumulate more chilling with warming

   ii. And there is so much we don't know about how chilling works and interacts with forcing (sequential model, parallel models etc.)

(c) Photoperiod: Shifts with phenology

   i. Changes in forcing and chilling will alter the photoperiod that matters so to speak

   ii. Need more here ...

3. Review of the three major phenological cues from growth chamber studies over the last 67 years

(a) Quick intro to the data, how long, which cues ....

   i. Fig: Number of studies by year (OSPREE)[4]

   ii. Fig: Map of studies, color coded or such by which of the three cues they manipulated

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[4]Other ideas: number of species studied by year. Show crops or remove or show separately?

(b) For each of the three cues:

    i. X% of studies manipulated that cue

    ii. Variation across space, continent and time (and species)?

    iii. Fig: Variation in treatments across space (photo/chill/force)

    iv. Fig: Variation in treatments across time (graph with year on x-axis or divide time in half or such?

(c) X% of studies manipulated which interacting cues? (i.e., how many studies manipulate 1 cues, 2 cues, 3 cues ... of those manipulating 1 cue, what is the breakdown by cue etc.)

4. Random other bits to fit in

(a) Say something about material (seeds/saplings/cuttings)?

(b) We need better non-linear models.

5. What cues will be most limiting with climate change? How do these studies compare?

(a) Consider both the range of a species and the climate change projections ...

    i. Take each PEP725 datapoint within our selected species' range and calculate:

        A. Min daily temp for 1-2 months before leafout

        B. Max daily temp for 1-2 months before leafout

        C. Most directly comparable to OSPREE would be daily min and max temperatures I think; might also be important to use daily min/max if we are focused so closely on getting things accurate.

(b) Other things to consider

    i. Don't forget: you need the extremes to parameterize models (you need to know where the zeros are)

    ii. Thermal tolerances/limits (and where is the species optimum?) ...look at treatments beyond the variation seen within a species' range and see if there is abrupt change or you see continuous change, if no abrupt change then something else must limit range (e.g., biotic cues, minima temperature after which species)

    iii. Nacho's point about now that climate change is here we do need to focus on refining experiments to address what the cue impacts of climate change will really

(c) Paths forward

    i. Manipulating one cue may be less useful esp. in comparisons with long-term data

    ii. Carefully select the cues you study and make your reasoning clear...

iii. If you don't work within the range or projected cue range limits of a species, then be sure to work on informative extremes (I could use some help with this).

iv. Report all cues (even the ones you don't measure)

(d) Wrap-up....