Spatial and temporal shifts in photoperiod with climate change

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1. *Introduction*

   (a) Photoperiod is a critical cue used by organisms, and many studies exist demonstrating this. (could focus just on phenology or on other things too?)

   (b) As species undergo climate change-induced shifts in space and/or time, the the daylength they experience will be altered.

   (c) Many experiments have altered photoperiod, often interacting with temperature changes; however, photoperiod treatments in these experiments are not typically designed to be applied to climate change forecasting.

   (d) Here, we ask:

      i. How will climate change alter the photoperiod experienced by organisms, given observed (and forecasted?) biological shifts (both spatial and temporal)?

      ii. What are the implications of these altered photoperiods for forecasts of climate change impacts?

      iii. Can the large quantity of experiments altering photoperiod be applied to forecasting biological implications of climate change (i.e. do they occur at the appropriate scale)?

2. *How will climate change alter the photoperiod experienced by organisms?*

   (a) Spatial shifts in species ranges and temporal shifts in species phenology and activity will alter the photoperiods experienced by organisms under climate change.

   (b) Temporal shifts yield bigger changes in photoperiod than spatial shifts (Figures 1,2).

   (c) Shifts in photoperiod may vary with latitude (Figure 2).

   (d) Vartiation in phenology also varies with latitude (cite a pretty map showing variation in spring index or greenup?), so it is unclear how these two things interact....

3. *What are the implications of these altered photoperiods for forecasts of climate change impacts?*

   (a) Phenology will be affected, given that daylength is known to affect cell elongation and budburst (Linkosalo and Lechowicz, 2006; Erwin, 1998; Sidaway-Lee et al., 2010).

   (b) It has been proposed that photoperiod may eventually become limiting a factor, constraining the ability of trees to shift their phenology with warming (**?**Vitasse and Basler, 2013; Morin et al., 2010).

   (c) Interactions between photoperiod and forcing and chilling could result in muted or exaggerated phenological shifts, compared to what would be expected based on temperature change alone.

4. *Can existing experiments be applied to forecasting?*

   (a) Table of OSPREE experiments that manipulate photoperiod, their daylength treatments, their findings, and perhaps how the treatment corresponds to spatial/temporal shifts?

(b) Most experiments manipulate photoperiod much more dramatically than will occur with climate change (but see (Basler and Körner, 2012)), so it is difficult to extrapolate findings.

(c) Magnitude of effects of photoperiod may be small, in comparison to warming effects, but we don't really know...

5. *Conclusions*

   (a) Organisms may experience large changes to the photoperiod they experience, under climate change, even if they do not shift their ranges.

   (b) More studies needed with fine-scale changes in photoperiod

To do if we like this format:

1. Make a map showing annual variation in global greenup (to make the point that it greenup up is more stable at some latitudes than others?)
2. Make Table of studies and treatments
3. Focus on phenology only? (or use it as a case study?)
4. What other points do we want to make about photoperiod?

References

Basler, D., and C. Körner. 2012. Photoperiod sensitivity of bud burst in 14 temperate forest tree species. Agricultural and Forest Meteorology 165:73–81.

Erwin, J. E. 1998. Temperature and light effects on stem elongation (plant growth regulation by physical and mechanical stimuli, for further development of horticulture in east asia). Journal of the Japanese Society for Horticultural Science 67:1113–1120.

Linkosalo, T., and M. J. Lechowicz. 2006. Twilight far-red treatment advances leaf bud burst of silver birch (betula pendula). Tree physiology 26:1249–1256.

Morin, X., J. Roy, L. Sonié, and I. Chuine. 2010. Changes in leaf phenology of three european oak species in response to experimental climate change. New Phytologist 186:900–910.

Sidaway-Lee, K., E.-M. Josse, A. Brown, Y. Gan, K. J. Halliday, I. A. Graham, and S. Penfield. 2010. Spatula links daytime temperature and plant growth rate. Current biology 20:1493–1497.

Vitasse, Y., and D. Basler. 2013. What role for photoperiod in the bud burst phenology of european beech. European Journal of Forest Research 132:1–8.

Tables

Table 1: **Growth chamber experiments and their photoperiod treatments.** From OSPREE. For now, I used 45.5 lat to estimate spatial and temporal equivalents and Y/N for sensitivity but might be better to have a magnitude of sensitivity found?

Study	**Photoperiod treatments (or delta)**	**Spatial equivalent**	**Temporal equivalent**	**Finding (sensitive?)**
basler12	9.5, 11 (1.5)	600 km up	30 days earlier	Yes (late successional only)
laube14a	8,16 (8)	3200 km up	160 days earlier	Yes (some species)
other studies				

Figures

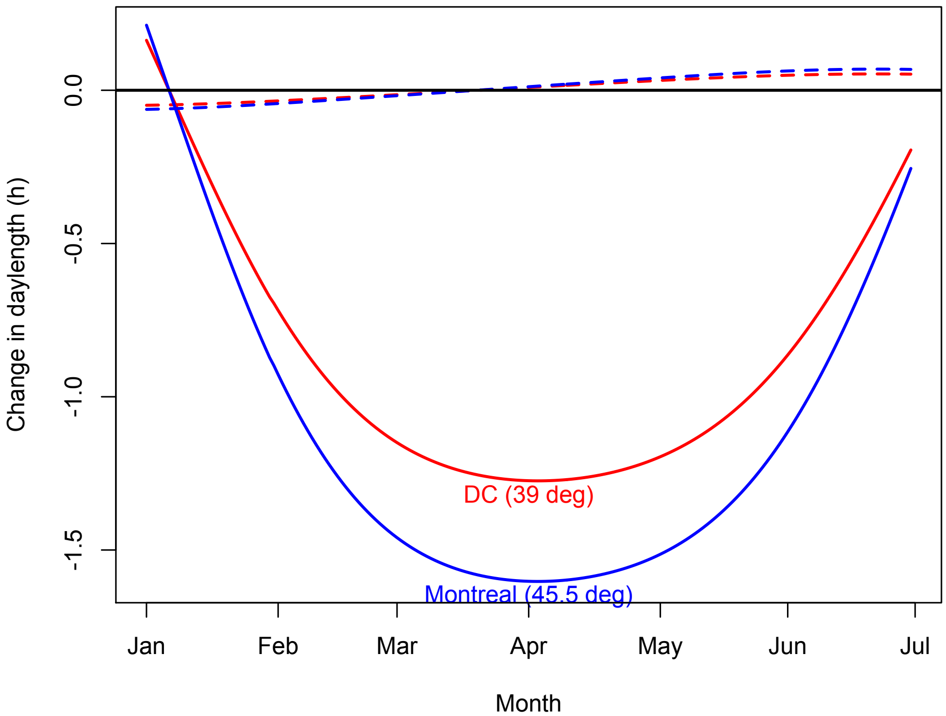

Figure 1: **Shifts in the photoperiod organisms will experience with climate change, at two latitudes (Washington, DC and Montreal).** With warming, species are likely to shift their ranges poleward and/or shift their spring activity earlier, resulting in alterations to the photoperiod they experience. We compare changes to photoperiod in 100 years if species shift spatially (i.e. shifting their ranges 6km,or 0.05 degree, per decade poleward, solid lines) versus temporally (shifting activity earlier 3 days per decade, dashed lines).

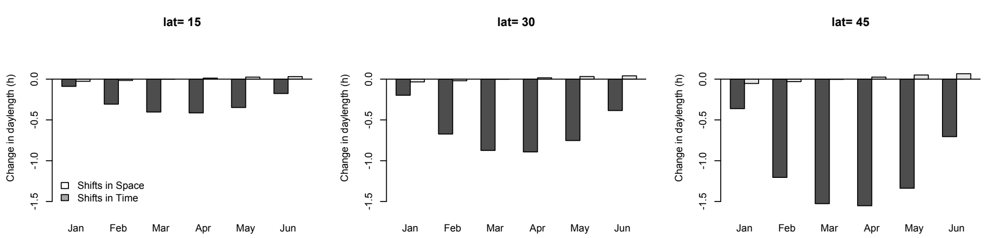

Figure 2: **Shifts in the photoperiod organisms will experience with climate change, across latitude.** With warming, species are likely to shift their ranges poleward and/or shift their spring activity earlier, resulting in alterations to the photoperiod they experience. We compare changes to photoperiod in 100 years if species shift spatially (i.e. shifting their ranges 6km,or 0.05 degree, per decade poleward) versus temporally (shifting activity earlier 3 days per decade).