Supplemental Materials: Spatial and temporal shifts in photoperiod with climate change

A.K. Ettinger, D. Buonaiuto, C. Chamberlain, I. Morales-Castilla, E. Wolkovich

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Methods

Photoperiod at "green-up" date (Figure 2)

Satellite imaginery are combined with algorithms—e.g. MODIS Land Cover Dynamics— to identify the dates on which phenophases transition from one to the next. Using data from the MODIS sensor (available at: http... DAN, could you please provide the website from where the maps were extracted), we extracted spatial data for North American and Western European green-up—the beginning of seasonal greening—for the years 2009 and 2012. Green-up dates are calculated on the basis of the onset of the Enhanced Vegetation Index (Huete et al., 2002). From green-up maps for each year we derived the photoperiod corresponding to each pixel (according to its geographic coordinates and day of the year), using R function XXX in package XXX (please Dan, fill these gaps) (see Fig. 2a,b in main text). Finally, we mapped spatial patterns of temporal shifts in green-up comparing an early and late spring years. To do so, we simply substracted the 2013 green-up map to the 2009 one. The spatial resolution corresponding to the maps is of 0.1 x 0.1 degrees.

Photoperiod response curves for woody plants (Figure 3)

To quantify how budburst day in woody plant responds to photoperiod, we compiled all experiments with three or more photoperiod treatment levels within the same, from the OSPREE database (cite database on KNB). This yielded three experiments ((Heide, 1993; Ashby et al., 1962; Caffarra et al., 2011)) across three species, which were used in Figure 3. Forcing treatments were consistent across experints (21-22°C). Chilling treatments, on the other hand, varied considerably across the experiments, and were therefore grouped into four categories: No Chilling (<31 Chill Portions),Low Chilling (31-80 Chill Portions), Medium Chilling (81-130 Chill Portions) and High Chilling(>130 Chill Portions) **Experimental photoperiod treatments and their equivalent spatial and temporalshifts (Figure 4)**

We wanted to put experimental photoperiod treatments in the context of shifts in photoperiod that organisms may experience with climate change, due to altered phenology or distributions. To do this, we identified all experiments in the OSPREE database that manipulate photoperiod (i.e., they had atleast two photoperiod treatments in the experiment). We used the minimum difference between treatments in OSPREE experiments to calculate the change in experimental photoperiod. To calculate the required spatial or temporal shift equivalent to each experimental photoperiod, we used observed rates with recent warming: 16.9 kilometers per decade (or approximately 1.5 °in 100 years) for spatial shifts (Chen et al., 2011) and 2.3 days per decade (or 23 days in 100 years) for temporal shifts (Parmesan and Yohe, 2003).

Comparing experimental photoperiod treatments to experienced photoperiod in current and future ranges (Figure 5)

We wanted to compare photoperiod treatments from growth chamber experiments to photoperiod experienced in current ranges and in forecasted future ranges with climate change (Figure 5). To do this, we acquired budburst data (1981-2000) and model projections of budburst day of year (2081-2100) using the A1Fi scenario for two species – *Fagus sylvatica* and *Quercus robur* using the PHENOFIT model (Duputié et al., 2015; Chuine and Beaubien, 2001). We compared these data and forecasts to experimental photoperiod treatments from studies in the OSPREE database(cite database on KNB). The OSPREE day of budburst estimates were calculated from the start of the experiment, rather than from the start of the year. In order to render these points comparable to the current observations and the model projections, we scaled the days to budburst by adding the day of budburst from the first PHENOFIT observation to all of the OSPREE data points. We only used PHENOFIT estimates that had both current and projection data.

References

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Supplemental Tables

Table 1: **Growth chamber experiments and their photoperiod treatments**. We note whether or not photoperiod had a significant effect ('effect' column) and compared treatments to the spatial and temporal shifts required for organisms to experiments photoperiod changes equivalent to those treatments. For shifts in space, 'ER' indicates that the photoperiod treatments exceeds the change of photoperiod from moving up to 40 degrees latitudinally on June 21. For shifts in time, 'ER' indicates that the range of photoperiod treatments exceeds the change in daylengths at that latitude during the entire year. 'max NA' indicates that the maximum daylength treatment does not exist at that latitude; 'min NA'indicates that the minimum daylength treatment does not exist at that latitude.

idstudy	continent	lat	long	effect	day_range	delta	space	time
ashby62_exp1	north america	42.99	-89.41	Y	8-16	4.00	18.2	-87*
basler14_exp1	europe	46.31	8.27	Y	9.2-16	1.00	6	-22
caffarra11b_exp2	europe	52.32	-6.93	Y	10-16	2.00	7.5	-30
falusi90_exp1	europe	46.03	10.75	N	9-13	4.00	16	-82
falusi96_exp3	europe	38.27	15.99	Y	9-13	4.00	21.6	-111
ghelardini10_exp1	europe	43.72	11.37	N	8-16	8.00	21.9	ER
heide05_exp1	europe	56.18	-4.32	Y/N	10-24	14.00	ER	ER
heide08_exp1	europe	48.40	11.72	Y	10-24	14.00	ER	ER
heide11_exp1	europe	59.67	10.67	N	10-20	10.00	ER	-117*
heide12_exp1	europe	56.50	-3.06	Y	10-24	5.00	8.9	-64
heide15_exp2	europe	56.50	-3.06	Y	10-15	1.00	3.2	-13
heide93_exp1	europe	59.50	10.77	Y	8-24	16.00	ER	ER
heide93a_exp1	europe	59.67	10.83	Y	8-24	16.00	ER	ER
heide93a_exp3	europe	47.50	7.60	Y	13-16	1.00	5.7	-18
howe95_exp1	north america	40.55	-124.10	Y	9-24	2.00	13.1	-64
laube14a_exp1	europe	48.40	11.71	N	8-16	4.00	14.3	-87
myking95_exp1	europe	56.10	9.15	Y	8-24	16.00	ER	ER
nienstaedt66_exp1	north america	44.17	-103.92	Y	8-20	12.00	ER	ER
okie11_exp1	north america	32.12	-83.12	Y	0-12	12.00	ER	ER
partanen01_exp1	europe	61.93	26.68	Y	6-16	10.00	ER	-105
partanen05_exp1	europe	61.82	29.32	Y	5-20	5.00	ER	-67
partanen98_exp1	europe	60.03	23.05	Y	8.66-12	3.34	5.1	-37
pettersen71_exp1	europe	59.66	10.77	N	10-24	2.00	4	-23
Sanz-Perez09_exp1	europe	40.40	-3.48	Y	10-16	6.00	23.6	ER
viheraaarnio06_exp1	europe	60.45	24.93	Y	16-17	1.00	2.1	-12
viheraaarnio06_exp1	europe	67.73	24.93	Y	20-21	1.00	ER	-5
viheraaarnio06_exp2	europe	60.45	24.93	Y	15-19	4.00	5.1	-62
viheraaarnio06_exp2	europe	67.73	24.93	Y	22-23	1.00	ER	-3
worrall67_exp 3	north america	41.31	-72.93	Y	8-16	8.00	24.3	ER
zohner16_Exp1	europe	48.16	11.50	Y	8-16	8.00	ER	ER
hawkins12_				Y				