

# 1 Tables

Species	Family	flower-leaf sequence classification
<i>Acer pensylvanicum</i>	Sapindaceae	flowers after leaves
<i>Acer rubrum</i>	Sapindaceae	flowers before leaves
<i>Corylus cornuta</i>	Betulaceae	flowers before leaves
<i>Comptonia peregrina</i>	Myrtaceae	flowers before leaves
<i>Ilex mucronata</i>	Aquifoliaceae	flowers with leaves
<i>Ilex verticillata</i>	Aquifoliaceae	flowers after leaves
<i>Prunus pensylvanica</i>	Rosaceae	flowers with leaves
<i>Prunus virginiana</i>	Rosaceae	flowers with/after leaves
<i>Vaccinium corymbosum</i>	Ericaceae	flowers after leaves
<i>Viburnum acerifolium</i>	Adoxaceae	flowers after leaves

Table S1: Descriptive flower-leaf sequences classifications for 10 temperate woody species based on Barnes & Wagner (1981,2004) and Barnes *et al.* (2016).

	Estimate	Havard_Forest	sd	Chamber_30_days	Chamber_60_days
1	Utah Model	979.64	248.34	720.00	1440.00
2	Chill Hours	1170.71	273.07	720.00	1440.00
3	Dynamic Model	86.56	16.64	21.25	43.50

Table S2: Comparisons between the average amount of chilling accumulated by woody plants at Harvard Forest between 15-October and 15-April in the field and our experimental experimental treatments using three alternative methods for calculating chilling.

	Estimate	Est.Error	Q2.5	Q25	Q75	Q97.5
Intercept	70.81	9.18	52.99	64.94	76.88	88.08
Chill	-30.41	5.40	-40.45	-33.89	-27.15	-19.25
Light	5.87	5.13	-4.17	2.42	9.16	15.92
Force	-17.76	5.21	-28.21	-21.10	-14.29	-8.22
Chill:Light	-5.17	4.35	-13.62	-8.03	-2.31	3.56
Chill:Force	12.37	4.84	2.62	9.26	15.51	21.85
Light:Force	-12.62	4.10	-20.50	-15.37	-9.87	-4.79

Table S3: Mean effects of forcing temperature, chilling duration, and photoperiod and all two-way interactions on budburst of 10 woody plant species

	Estimate	Est.Error	Q2.5	Q25	Q75	Q97.5
Intercept	77.53	9.92	58.14	71.05	83.88	97.18
Chill	-21.23	7.42	-35.35	-26.14	-16.32	-6.07
Light	-5.72	5.70	-18.28	-9.01	-2.03	4.86
Force	-18.98	6.51	-32.09	-23.02	-14.93	-6.37
Chill:Light	-0.88	6.11	-13.59	-4.72	3.21	10.55
Chill:Force	7.01	6.62	-6.35	2.98	11.11	20.31
Light:Force	-5.61	6.42	-19.08	-9.51	-1.46	6.37

Table S4: Mean effects of forcing temperature, chilling duration, and photoperiod and all two-way interactions on flowering of 10 woody plant species

	Species	Estimate	error	Q2.5	Q25	Q75	Q97.5	phase	sequence
1	ACE.PEN	-10.71	3.92	-17.87	-13.48	-8.19	-2.28	leaf	first
2	ACE.PEN	-17.43	6.15	-30.48	-20.68	-14.00	-5.59	flower	second
3	ACE.RUB	-16.76	7.25	-33.11	-20.21	-13.09	-2.88	flower	first
4	ACE.RUB	-28.39	6.22	-40.52	-32.69	-24.08	-16.20	leaf	second
5	COM.PER	-13.28	3.33	-19.62	-15.50	-11.17	-6.60	flower	first
6	COM.PER	-15.47	3.69	-23.06	-17.82	-13.01	-8.53	leaf	second
7	COR.COR	-15.55	4.50	-24.71	-18.13	-12.87	-6.79	flower	first
8	COR.COR	-19.82	4.04	-28.13	-22.41	-17.10	-11.99	leaf	second
9	ILE.MUC	-10.44	3.81	-17.42	-13.09	-8.05	-2.45	leaf	first
10	ILE.MUC	-16.05	4.06	-24.19	-18.58	-13.47	-7.94	flower	second
11	ILE.VER	-8.66	3.73	-15.58	-11.19	-6.19	-1.12	leaf	first
12	ILE.VER	-20.43	10.72	-43.88	-25.92	-14.18	-2.14	flower	second
13	PRU.PEN	-10.24	4.14	-18.67	-12.99	-7.50	-2.14	leaf	first
14	PRU.PEN	-13.85	4.02	-21.59	-16.46	-11.40	-5.39	flower	second
15	PRU.VIR	-26.68	5.11	-37.14	-30.02	-23.09	-17.20	leaf	first
16	PRU.VIR	-23.69	7.67	-40.07	-28.74	-17.84	-10.95	flower	second
17	VAC.COR	-7.06	3.85	-14.45	-9.62	-4.56	0.66	leaf	first
18	VAC.COR	-13.10	3.60	-20.30	-15.49	-10.79	-5.99	flower	second
19	VIB.ACE	-12.68	3.78	-19.97	-15.14	-10.29	-5.10	leaf	first
20	VIB.ACE	-21.60	8.52	-39.63	-26.63	-16.00	-6.85	flower	second

Table S5: Mean effects of forcing temperature on the phenology of flower and leaf buds of 10 temperate woody plant species when under long photoperiod and long chilling duration experimental treatments

## <sup>2</sup> **Figures**

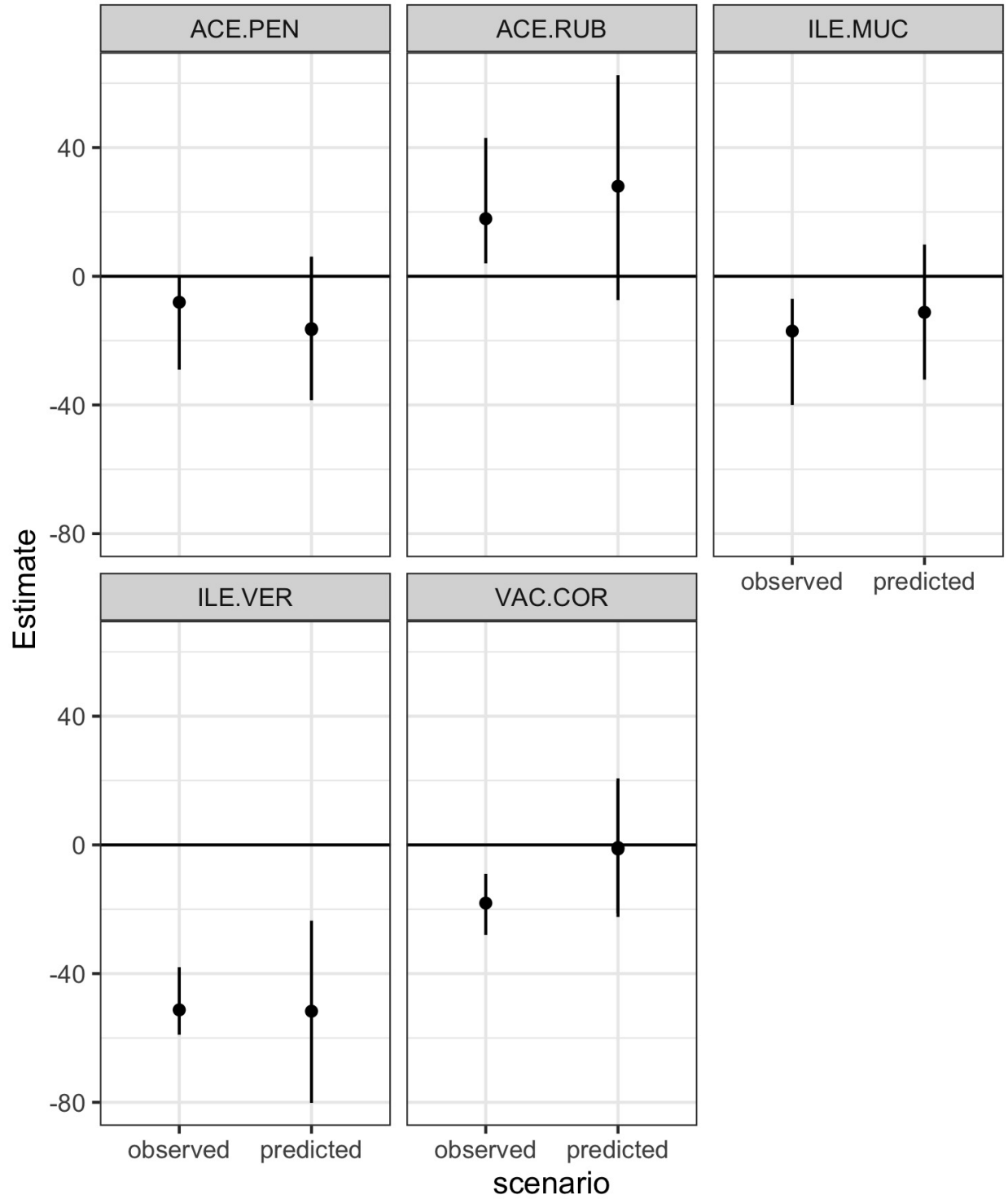


Figure S1: A comparison of the estimated mean flower-leaf sequence interphases (days between phenophase) for six woody plant species under artificial conditions designed to approximate "average" field conditions and observed mean FLS interphases in the field at Harvard Forest in Pertersham MA. Dots represent means FLS interphase in both datasets, and lines represent the 89% credible intervals and the full range of observations for our model predictions and Harvard Forest data respectively. Harvard Forest phenological records are from O'Keefe (2015).

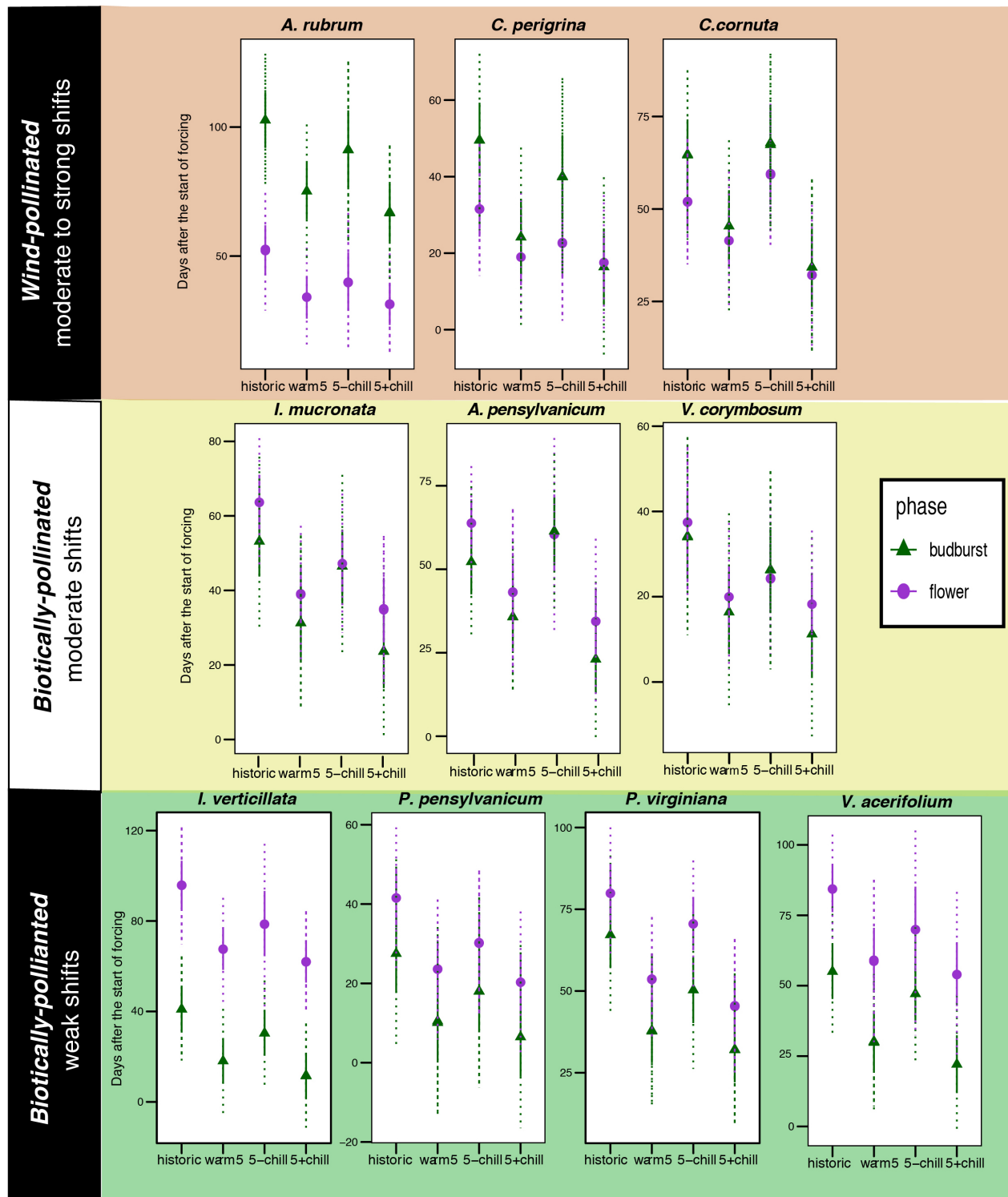


Figure S2: Projected shifts in flower-leaf sequences under historic environmental conditions and three climate change scenarios differ among species, the three major FLS types, and pollination syndromes. Estimates come from Bayesian, hierarchical models comparing flower and leaf bud responses to variable chilling duration and forcing temperatures. Points represent the mean estimates and lines represent the 50% credible intervals.

## Supplemental Methods

### Simulations

To better understand the patterns of phenological sensitivity generated by the forcing hierarchy hypothesis (FHH) and the differential sensitivity hypothesis (DSH) respectively, we mathematically simulated the underlying physiology of each hypothesis, and these simulations to generate flower and leaf phenology under two levels of chilling, forcing and photoperiod in a fully factorial simulation.

For the FHH we assigned flowering and leafing a critical heat sum threshold ( $F^*$ ) above which the phenological event would take place. We did this using a growing degree model with a base temperature of  $5^{\circ}\text{C}$  (). For the FHH simulations, we assigned flowering an  $F^*$  of 200 GDDs and leafing an  $F^*$  of 400 GDDs. In this scenario we let increased both chilling and photoperiod reduce the  $F^*$  value for each phenophase by 100 and 20 respectively.

For the DSH we assigned flowering and leafing identical  $F^*$  values of 400. As in the previous scenario, we let increased chilling and photoperiod reduce the  $F^*$  values, but these cues reduced the  $F^*$  for leafing by 200 and 0 respectively and for flowering by 100 and 20.

We also included a third scenario that included both initial  $F^*$  differences of the FHH (flowering: 200 and leafing: 400) and the differential response to chilling and photoperiod of the DSH (flowering: -100 chilling, -20 photoperiod, leafing -200 chilling, 0 photoperiod).

### References

- Barnes, B.V., Dick, C.W. & Gunn, M.E. (2016) *Michigan Shrubs Vines: A guide to species of the Great Lakes Region*. University of Michigan Press, Ann Arbor, MI, USA.
- Barnes, B.V. & Wagner, W.H.J. (1981,2004) *Michigan Trees: A guide to the Trees of the Great Lakes Region*. University of Michigan Press, Ann Arbor, MI, USA.

- <sup>27</sup> O'Keefe, J. (2015) *Phenology of Woody Species at Harvard Forest since 1990*. Harvard Forest Data Archive:
- <sup>28</sup> HF003., Petersham, MA, USA.