Supplementary Material: Current environments and evolutionary history shape forest temporal assembly

Deirdre Loughnan[1,2,3] and E M Wolkovich[1]

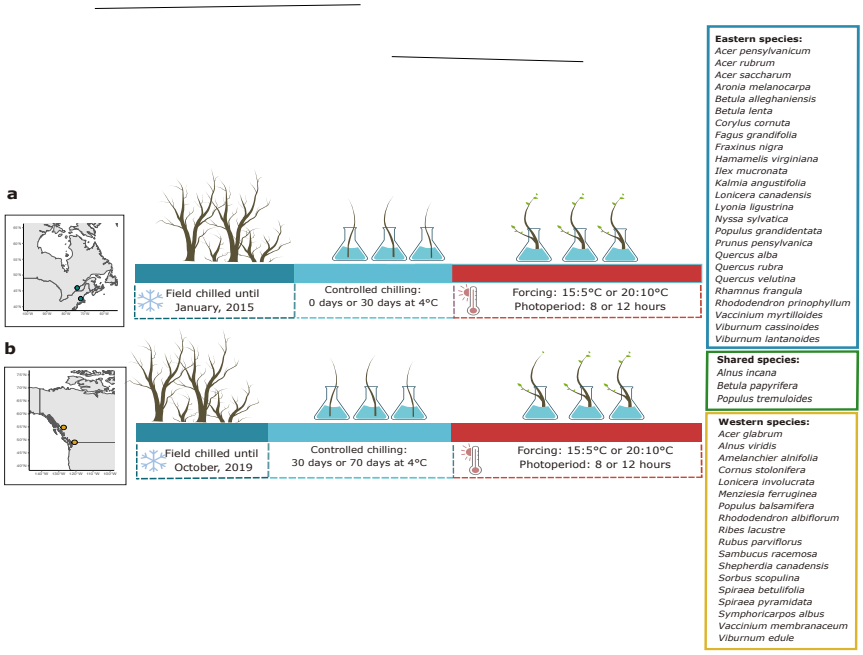

Figure S1: We combined data from two controlled environment studies of temperature and photoperiod cues for budburst in temperate woody species **a,** from two forest communities in eastern North America that span a 4° latitudinal gradient and **b,** two communities in western North America that span a 6° latitudinal gradient. Combined, our dataset includes 28 tree and shrub species from eastern communities and 21 species from western communities, with three species occurring across all four populations. Both studies used a factorial design with chilling treatments consisting of a combination of field and different durations of chamber chilling, a cool and warm spring treatment (low and high forcing), and a short or long photoperiod treatment. Observations of budburst were made during the forcing treatment, using the BBCH scale to classify stages of bud development.

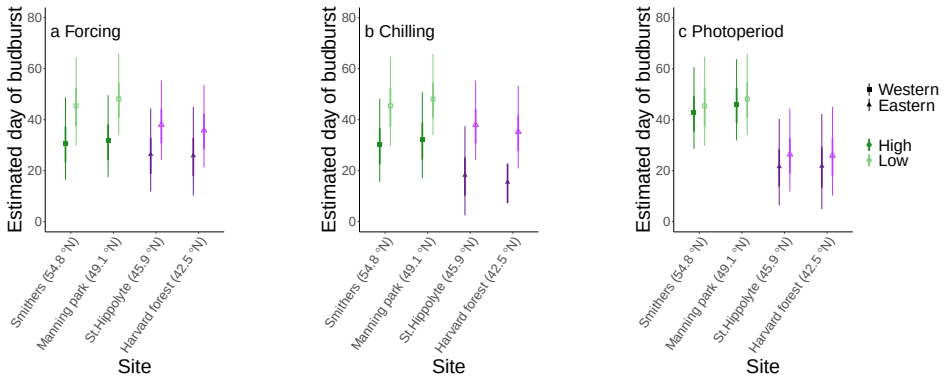

Figure S2: Estimated day of budburst in response to **a,** forcing across sites under low chilling and short photoperiods, **b,** chilling across sites under low forcing and short photoperiods, and **c,** across photoperiods under low forcing and chilling for species sampled from our four sites. The thin bars represent the 90% uncertainty interval, while the thicker bars represent the 50% uncertainty interval, and symbols the mean.

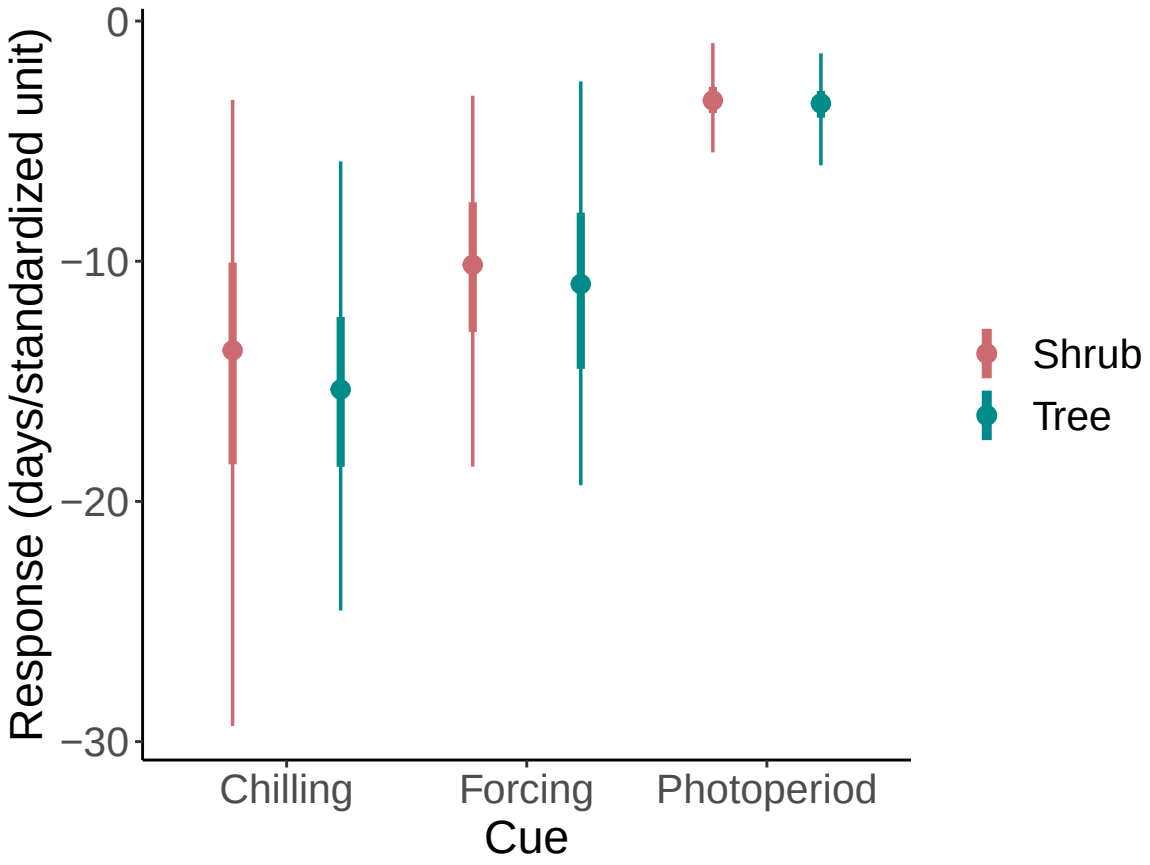

Figure S3: Comparisons of posterior distributions for cue estimates between shrub and tree species. Circles represent the mean, while the thicker error bars represent the 50% uncertainty interval, and thinner line the 90% quantile interval.

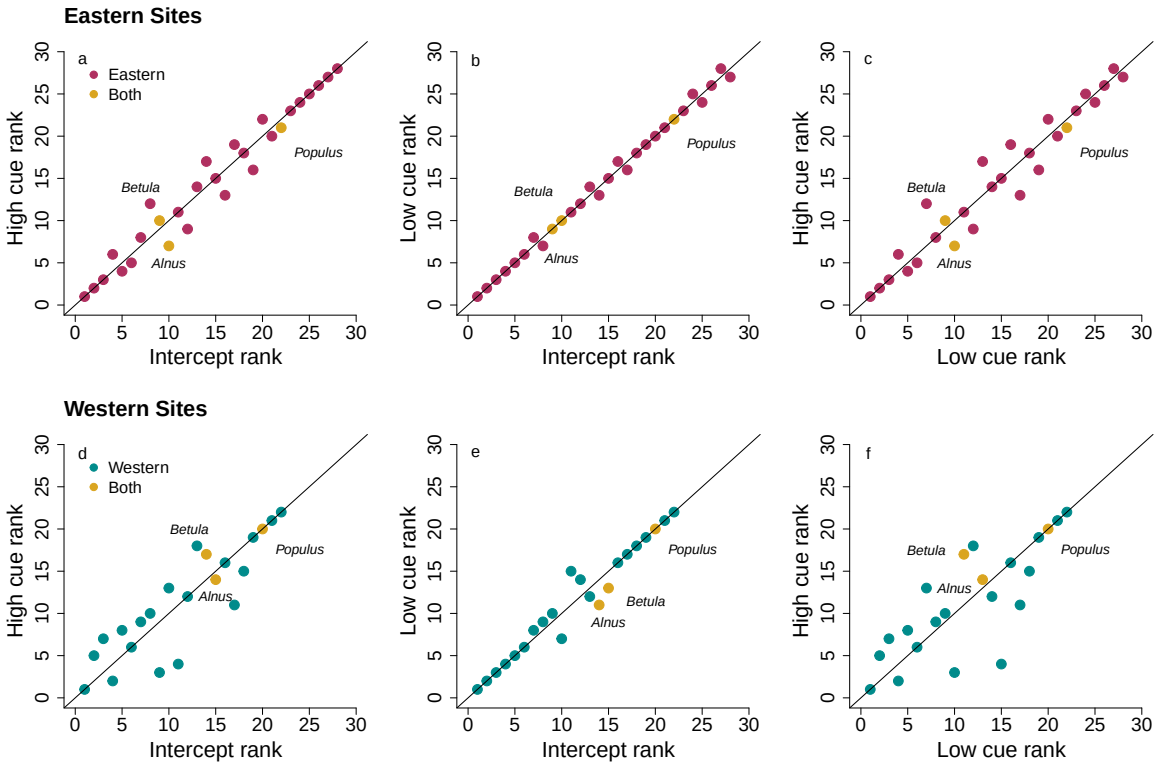

Figure S4: Comparisons of the estimated changes in species ranked budburst order, **a** & **d** between species-level effects (species intercept) and under high cues, species-level effects and under low cues, **b** & **e**, and under low versus high cues, **c** & **f**, for our eastern species (in red, **a-c**) and western species (in blue, **d-f**). For the three species that occur in both transect (shown in yellow), *Alnus incana* exhibited the greatest rank change with a difference of three, while *Betula papyrifera* had a rank difference of two and *Populus tremuloides* a rank difference of one.

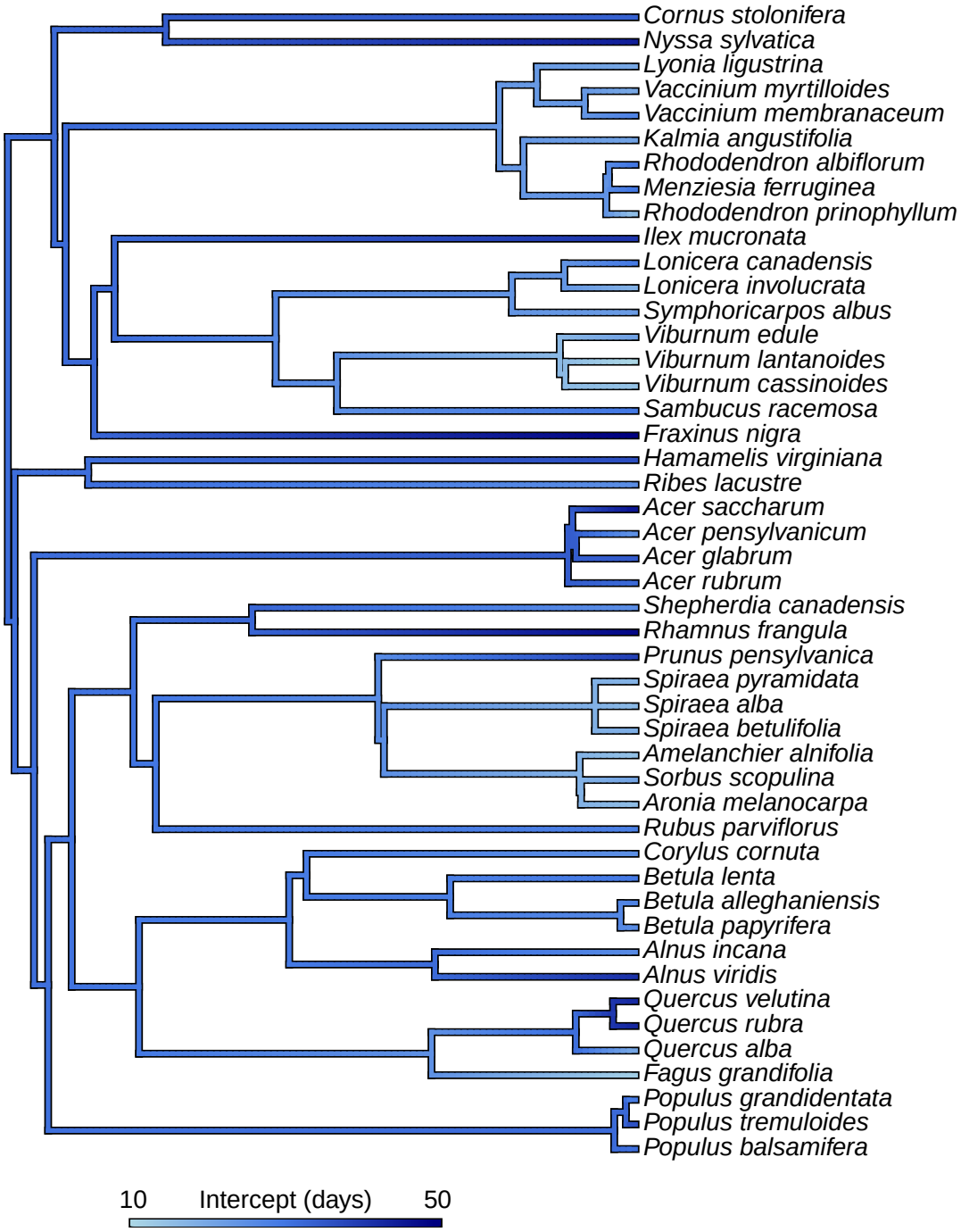

Figure S5: Species differences were accounted for by including phylogenetic effects on the species intercept in a model estimating days to budburst after the start of forcing treatments. We pruned to our species subset an existing phylogeny for flowering plants developed by Smith and Brown (2018).

Table S1: Mean budburst dates across all treatments from raw observation data of 47 species at our two western sites, E.C. Manning park and Smithers B.C., Canada, and our two eastern sites, Harvard Forest, USA and St. Hippolyte, Canada.

Species	Harvard forest	St. Hippoltye	Manning park	Smithers
Acer glabrum			36	39
Acer pensylvanicum	16	18		
Acer rubrum	22	25		
Acer saccharum	45	36		
Alnus incana			28	30
Alnus incana	33	25		
Alnus viridis			44	43
Amelanchier alnifolia			19	18
Aronia melanocarpa	14			
Betula alleghaniensis	20	21		
Betula lenta	30			
Betula papyrifera				31
Betula papyrifera	17	18		
Corylus cornuta	25	19		
Cornus stolonifera			15	17
Fagus grandifolia	42	43		
Fraxinus nigra	38	38		
Hamamelis virginiana	44			
Ilex mucronata	16	15		
Kalmia angustifolia	30	32		
Lonicera canadensis	17	16		
Lonicera involucrata			22	20
Lyonia ligustrina	31			
Menziesia ferruginea			43	46
Nyssa sylvatica	32			
Populus balsamifera			30	31
Populus grandidentata	33	31		
Populus tremuloides			46	35
Prunus pensylvanica	18	16		
Quercus alba	45			
Quercus rubra	36	34		
Quercus velutina	52			
Rhamnus frangula	32			
Rhododendron albiflorum			19	
Rhododendron prinophyllum	29			
Ribes lacustre			29	23
Rubus parviflorus			28	30
Sambucus racemosa			33	
Shepherdia canadensis			25	24
Sorbus scopulina			21	19
Spiraea alba	18	20		
Spiraea betulifolia			24	18
Spiraea pyramidata			26	22
Symphoricarpos albus			27	32
Vaccinium membranaceum			22	23
Vaccinium myrtilloides	13	17		
Viburnum cassinoides	15	18		
Viburnum edule			19	8
Viburnum lantanoides	31	28		

Table S2: Approximate chill units from our two western sites, E.C. Manning park and Smithers B.C., Canada, and our two eastern sites, Harvard Forest, USA and St. Hippolyte, Canada. Weather data for the fall of 2019 and winter 2020 was obtained from the Hope Slide weather station for our E.C. Manning park estimates and the Smithers airport weather station for our Smithers communities. For our eastern communities, weather data for the fall of 2014 and winter 2015 was obtained from weather stations at Harvard Forest and in St. Hippolyte.

Site	Chilling treatment	Chill hours	Utah model	Chill portions
Harvard forest	Field chilling	892	814.50	56.62
Harvard forest	Field chilling + 30 d at 4°C	2140	2062.50	94.06
St. Hippoltye	Field chilling	682	599.50	44.63
St. Hippoltye	Field chilling + 30 d at 4°C	1930	1847.50	82.06
Smithers	Field chilling + 30 d at 4°C	1317	1368.00	54.95
Smithers	Field chilling + 70 d at 4°C	1965	2016.00	74.67
Manning park	Field chilling + 30 d at 4°C	1213	1377.00	55.09
Manning park	Field chilling + 70 d at 4°C	1861	2025.00	75.33

Table S3: Summary output from a phylogenetic Bayesian model in which species are partially pooled and phylogeny is included on the intercept. See the statistical analysis section of the methods for more detail.

	mean	5%	95%	n_eff	Rhat
α_{sp}	30.30	25.90	35.10	3691.90	1.00
λ	0.40	0.10	0.70	2805.40	1.00
$\beta_{forcing}$	-10.60	-16.70	-12.90	1192.50	1.00
$\beta_{photoperiod}$	-3.30	-11.90	-9.30	3349.30	1.00
$\beta_{chilling}$	-14.80	-4.00	-2.70	1996.50	1.00
$\beta_{Manning\ park}$	2.10	1.50	2.70	4468.30	1.00
$\beta_{Harvard\ forest}$	-6.10	-7.70	-4.50	599.70	1.00
$\beta_{St.\ Hippolyte}$	-8.30	-9.80	-6.80	613.40	1.00
$\beta_{forcing \times photoperiod}$	0.90	-0.40	2.20	2977.90	1.00
$\beta_{forcing \times chilling}$	8.40	7.00	9.80	3255.90	1.00
$\beta_{photoperiod \times chilling}$	-0.70	-2.10	0.70	2804.90	1.00
$\beta_{forcing \times Manning\ park}$	-1.80	-3.10	-0.50	3761.60	1.00
$\beta_{photoperiod \times Manning\ park}$	0.60	-0.70	1.90	2772.30	1.00
$\beta_{chilling \times Manning\ park}$	-0.40	-3.00	2.10	1841.30	1.00
$\beta_{forcing \times Harvard\ forest}$	3.70	1.70	5.80	1452.20	1.00
$\beta_{photoperiod \times Harvard\ forest}$	-1.60	-3.00	-0.10	2010.80	1.00
$\beta_{chilling \times Harvard\ forest}$	8.80	5.90	11.70	1023.20	1.00
$\beta_{forcing \times St.\ Hippolyte}$	4.80	2.80	6.90	1580.30	1.00
$\beta_{photoperiod \times St.\ Hippolyte}$	-2.20	-3.60	-0.80	2689.60	1.00
$\beta_{chilling \times St.\ Hippolyte}$	7.30	4.90	9.90	1141.50	1.00

Table S4: Proportion of surviving samples per species for which budburst was observed in our western controlled enviornment study. See Flynn and Wolkovich (2018) for survival in our eastern study.

Species name	Proportion budburst	Plant type
Acer glabrum	0.83	tree
Alnus incana	1.00	shrub
Alnus viridis	0.92	shrub
Amelanchier alnifolia	0.99	shrub
Betula papyrifera	1.00	tree
Cornus stolonifera	0.99	shrub
Lonicera involucrata	0.87	shrub
Menziesia ferruginea	0.80	shrub
Populus balsamifera	0.98	tree
Populus tremuloides	0.90	tree
Rhododendron albiflorum	1.00	shrub
Ribes lacustre	0.82	shrub
Rubus parviflorus	0.94	shrub
Sambucus racemosa	0.95	shrub
Shepherdia canadensis	1.00	shrub
Sorbus scopulina	0.99	shrub
Spiraea betulifolia	0.94	shrub
Spiraea pyramidata	0.92	shrub
Symphoricarpos albus	0.84	shrub
Vaccinium membranaceum	0.90	shrub
Viburnum edule	1.00	shrub