

1 Supplementary Information: How temperature, photoperiod
2 and evolutionary history shape forest leafout

3 Deirdre Loughnan^{1,2,3} and E M Wolkovich¹

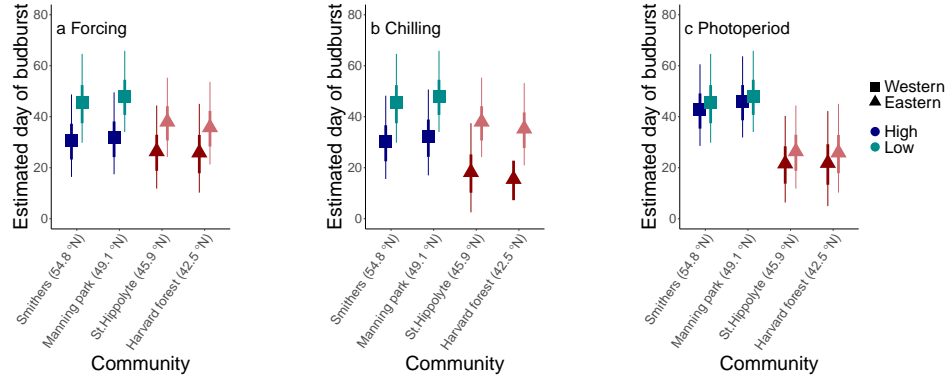


Figure S1: Estimated day of budburst in response to **a**, forcing across sites under low chilling and short photoperiods, **b**, chilling across sites under low forcing and short photoperiods, and **c**, across photoperiods under low forcing and chilling for species sampled from our four sites. The thin bars represent the 90% uncertainty interval, while the thicker bars represent the 50% uncertainty interval, and symbols the mean.

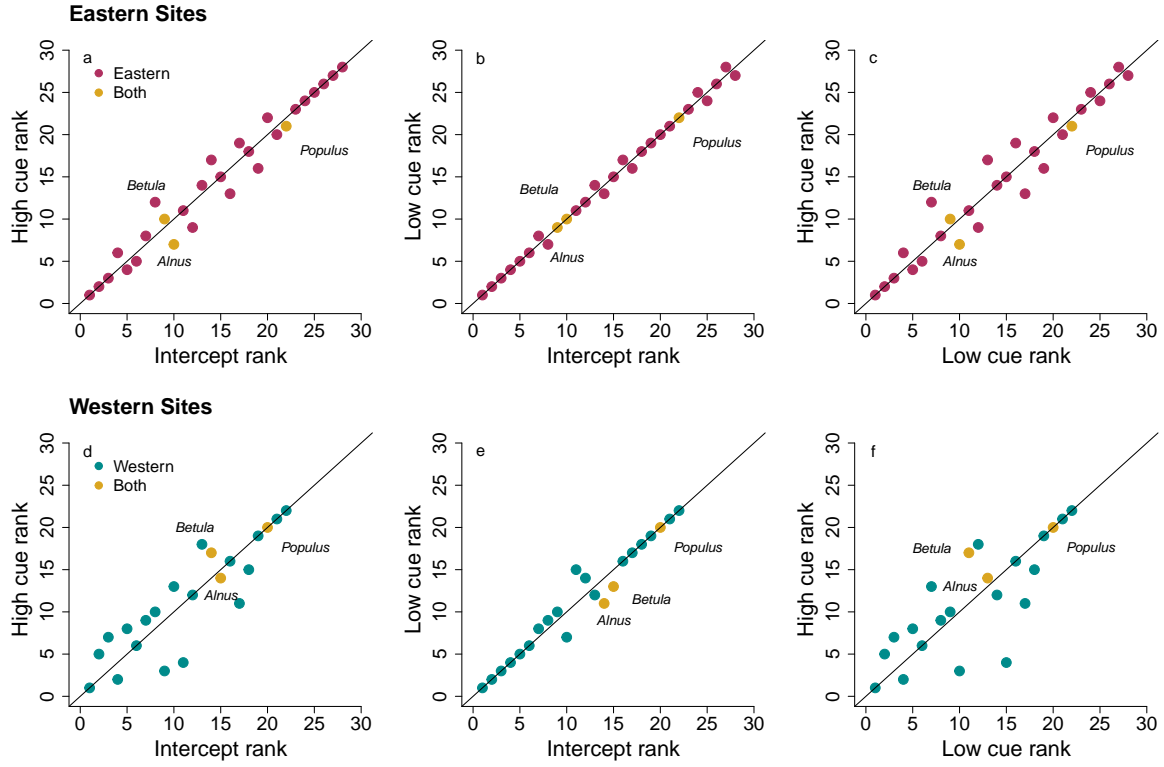


Figure S2: Comparisons of the estimated changes in species ranked budburst order, **a** & **d** between species-level effects (species intercept) and under high cues, species-level effects and under low cues, **b** & **e**, and under low versus high cues, **c** & **f**, for our eastern species (in red, **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.

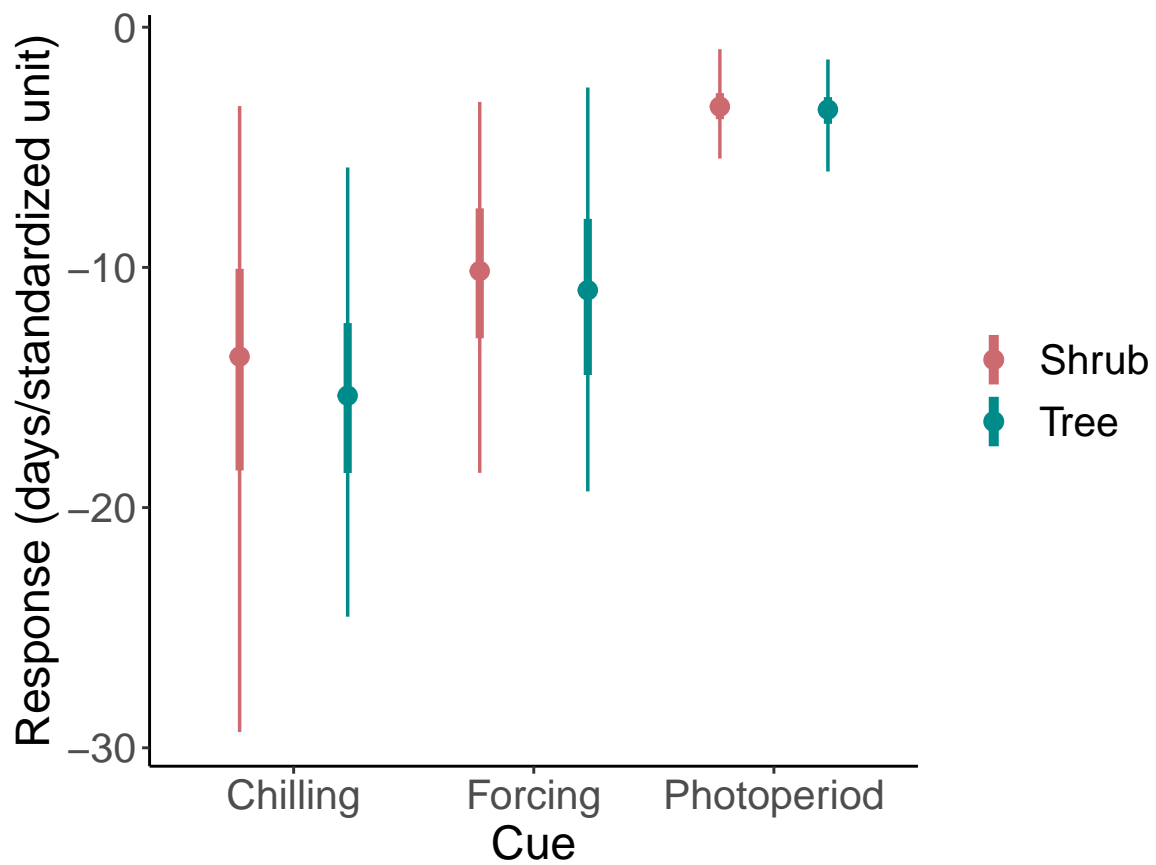


Figure S3: Comparisons of posterior distributions for cue estimates between shrub and tree species. Circles represent the mean, while the thicker error bars represent the 50% uncertainty interval, and thinner line the 90% quantile interval.

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. Hippolyte | Manning park | Smithers |
|----------------------------------|----------------|---------------|--------------|----------|
| <i>Acer glabrum</i> | | | 36 | 39 |
| <i>Acer pensylvanicum</i> | 16 | 18 | | |
| <i>Acer rubrum</i> | 22 | 25 | | |
| <i>Acer saccharum</i> | 45 | 36 | | |
| <i>Alnus incana</i> | | | 28 | 30 |
| <i>Alnus incana</i> | 33 | 25 | | |
| <i>Alnus viridis</i> | | | 44 | 43 |
| <i>Amelanchier alnifolia</i> | | | 19 | 18 |
| <i>Aronia melanocarpa</i> | 14 | | | |
| <i>Betula alleghaniensis</i> | 20 | 21 | | |
| <i>Betula lenta</i> | 30 | | | |
| <i>Betula papyrifera</i> | | | | 31 |
| <i>Betula papyrifera</i> | 17 | 18 | | |
| <i>Corylus cornuta</i> | 25 | 19 | | |
| <i>Cornus stolonifera</i> | | | 15 | 17 |
| <i>Fagus grandifolia</i> | 42 | 43 | | |
| <i>Fraxinus nigra</i> | 38 | 38 | | |
| <i>Hamamelis virginiana</i> | 44 | | | |
| <i>Ilex mucronata</i> | 16 | 15 | | |
| <i>Kalmia angustifolia</i> | 30 | 32 | | |
| <i>Lonicera canadensis</i> | 17 | 16 | | |
| <i>Lonicera involucrata</i> | | | 22 | 20 |
| <i>Lyonia ligustrina</i> | 31 | | | |
| <i>Menziesia ferruginea</i> | | | 43 | 46 |
| <i>Nyssa sylvatica</i> | 32 | | | |
| <i>Populus balsamifera</i> | | | 30 | 31 |
| <i>Populus grandidentata</i> | 33 | 31 | | |
| <i>Populus tremuloides</i> | | | 46 | 35 |
| <i>Prunus pensylvanica</i> | 18 | 16 | | |
| <i>Quercus alba</i> | 45 | | | |
| <i>Quercus rubra</i> | 36 | 34 | | |
| <i>Quercus velutina</i> | 52 | | | |
| <i>Rhamnus frangula</i> | 32 | | | |
| <i>Rhododendron albiflorum</i> | | | 19 | |
| <i>Rhododendron prinophyllum</i> | 29 | | | |
| <i>Ribes lacustre</i> | | | 29 | 23 |
| <i>Rubus parviflorus</i> | | | 28 | 30 |
| <i>Sambucus racemosa</i> | | | 33 | |
| <i>Shepherdia canadensis</i> | | | 25 | 24 |
| <i>Sorbus scopulina</i> | | | 21 | 19 |
| <i>Spiraea alba</i> | 18 | 20 | | |
| <i>Spiraea betulifolia</i> | | | 24 | 18 |
| <i>Spiraea pyramidata</i> | | | 26 | 22 |
| <i>Symphoricarpos albus</i> | | | 27 | 32 |
| <i>Vaccinium membranaceum</i> | | | 22 | 23 |
| <i>Vaccinium myrtilloides</i> | 13 | 17 | | |
| <i>Viburnum cassinoides</i> | 15 | 18 | | |
| <i>Viburnum edule</i> | | | 19 | 8 |
| <i>Viburnum lantanoides</i> | 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. Hippolyte | Field chilling | 682 | 599.50 | 44.63 |
| St. Hippolyte | Field chilling + 30 d at 4°C | 1930 | 1847.50 | 82.06 |
| Smithers | Field chilling + 21 d at 4°C | 1317 | 1368.00 | 54.95 |
| Smithers | Field chilling + 56 d at 4°C | 1965 | 2016.00 | 74.67 |
| Manning park | Field chilling + 21 d at 4°C | 1213 | 1377.00 | 55.09 |
| Manning park | Field chilling + 56 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 environment study. See Flynn and Wolkovich (2018) for survival in our eastern study.

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