Species differences in cue responses in woody plants of North America

Deirdre Loughnan[1] and E M Wolkovich[1]

March 27, 2023

[1] Department of Forest and Conservation, Faculty of Forestry, University of British Columbia, 2424 Main Mall Vancouver, BC, Canada, V6T 1Z4.

Corresponding Author: Deirdre Loughnan, deirdre.loughnan@ubc.ca

Research questions

1. Are species responses to chilling, forcing and photoperiod cues phylogenetically structured?
2. How do species in deciduous forests across North America to these varying cues?

Results + figures

1. Cue responses and interactions...
   (a) On average, species budburst on the 27.7 day after the start of forcing, but ranged from 13.6 for *Aronia melanocarpa* to 52.1 for *Quercus velutina*
   (b) Species budburst = strongly phylogenetically structured (λ of 0.8 (0.6, 1), root trait value of 12.3 (7.3, 17.5).
   (c) All cues did lead to an advance in budburst date, chilling being strongest and photoperiod weakest
   (d) But strong interactions between cues and between cues and sites.
   (e) Forcing by chilling = strong delaying effect = low chilling offset by high forcing (Fig. S2 a).
2. Populations differed in their their overall budburst dates, but interacted with cues — effects were clearly divided between eastern and western populations.
   (a) Overall: Low forcing, chilling, and shorter photoperiods resulted in later budburst dates than higher temperature and longer photoperiod treatments across all sites (Fig. 1b-d)
   (b) Between the two transects eastern budburst dates were consistently earlier (Fig. 1).
   (c) Forcing at eastern lower latitude site = slightly later bb than high latitude site — but western sites only differed slightly at low forcing (Fig. 1b)
   (d) This latitudinal effect was not found for chilling — chilling responses = similar for high and low chilling in eastern transect, but much later for field only chilling (no chilling) treatment — but eestern transect = strong difference between high and low chilling and not sites (Fig. 1c).

   (e) Photoperiod effects = greatest in eastern populations and weak in western populations — low latitude site had slightly later bb in eastern transect, but neglibile difference in the west. (Fig. 1d)

3. Individual species show distinct differences in their timing of bb and realtive importance of cues.
   (a) Both chilling and forcing varied with budburst, with later bbing species having stronger responses to each cue respectively (Fig. 5).
   (b) But gradients were not as strong as expected (Fig. 4 and Fig. 5)
   (c) Species level differences (intercept) explain considerable portion of bb, explaining 60.5% of the estimated bb for western species and 67.3% of the estimated bb for eastern species (Fig. 4)

4. Species differences are not due to plant architecture — shrubs and trees = very similar responses overall (Fig. 3)
   (a) Many of our earliest bb species are shrub species, e.g. *Cornus stolonifera* — fits our predicted profile of weak chilling and forcing cues
   (b) But other shrub species do not — e.g. *Menziesia ferruginea* and *Symphoricarpos alba* = latest bb, but also higher chill and forcing cue estimates (Fig. S2).
   (c) Tree species = no strong trends, but e.g. *Quercus velutina* = stronger chilling and photoperiod cues as predicted, and *Fagus grandifolia* = strongest photoperiod response
   (d) Unexpected spp responses are partially due to having stronger cue responses, but also driven by large spp intercpets — suggests other factors that species archictural growth driving diff cue responses

Discussion

1. Across all species, relative importance of cue = varied = unique temporal niches (Fig. **??**)
2. Large portion of bb due to spp differences - need more research to understand this, if not cues what causes it? Could introduce traits and foreshadow the third chapter
3. The experimental design (which is impressive) combined with your models means that most other things some models would assign to the intercept are assigned to site, species, chill, force etc. here... and still the intercept is big. Wow!!

1 Tables and figures

Table 1: Summary output from a phylogenetic mixed-effect model in which species are partially pooled and phylogeny is included on the intercept. The model includes photoperiod, forcing, and site as dummy variables, while the chilling effect is included as continuous chill portions.

	mean	sd	2.5%	50%	97.5%	n_eff	Rhat
Root trait intercept	12.24	3.12	6.22	12.23	18.24	12238.58	1.00
Lambda	0.79	0.12	0.49	0.81	0.95	10387.34	1.00
Forcing	-8.79	0.73	-10.21	-8.80	-7.35	12616.03	1.00
Photoperiod	-3.45	0.42	-4.27	-3.45	-2.64	10309.11	1.00
Chilling	-15.14	1.27	-17.68	-15.13	-12.65	6496.74	1.00
Manning Park	1.90	0.35	1.21	1.90	2.58	16138.58	1.00
Harvard Forest	-4.18	1.05	-6.27	-4.17	-2.18	1641.45	1.00
St. Hippolyte	-7.16	0.99	-9.15	-7.15	-5.24	1632.10	1.00
Forcing x photoperiod	-0.19	0.66	-1.45	-0.19	1.12	13735.69	1.00
Forcing x chilling	8.64	0.87	6.97	8.63	10.39	8764.40	1.00
Photoperiod x chilling	-0.75	0.89	-2.54	-0.74	1.02	7283.02	1.00
Forcing x Manning Park	-1.79	0.77	-3.29	-1.79	-0.28	12317.18	1.00
Photoperiod x Manning Park	0.54	0.80	-1.02	0.55	2.10	10772.65	1.00
Chilling x Manning Park	-0.31	1.64	-3.64	-0.28	2.90	6942.19	1.00
Forcing x Harvard Forest	3.53	1.15	1.28	3.52	5.81	5324.15	1.00
Photoperiod x Harvard Forest	-2.24	0.88	-3.94	-2.24	-0.48	9744.45	1.00
Chilling x Harvard Forest	7.16	2.13	2.89	7.22	11.25	3869.17	1.00
Forcing x St. Hippolyte	4.86	1.15	2.62	4.86	7.11	4853.50	1.00
Photoperiod x St. Hippolyte	-2.36	0.87	-4.05	-2.37	-0.66	9547.88	1.00
Chilling x St. Hippolyte	6.21	1.71	2.77	6.22	9.52	4761.63	1.00

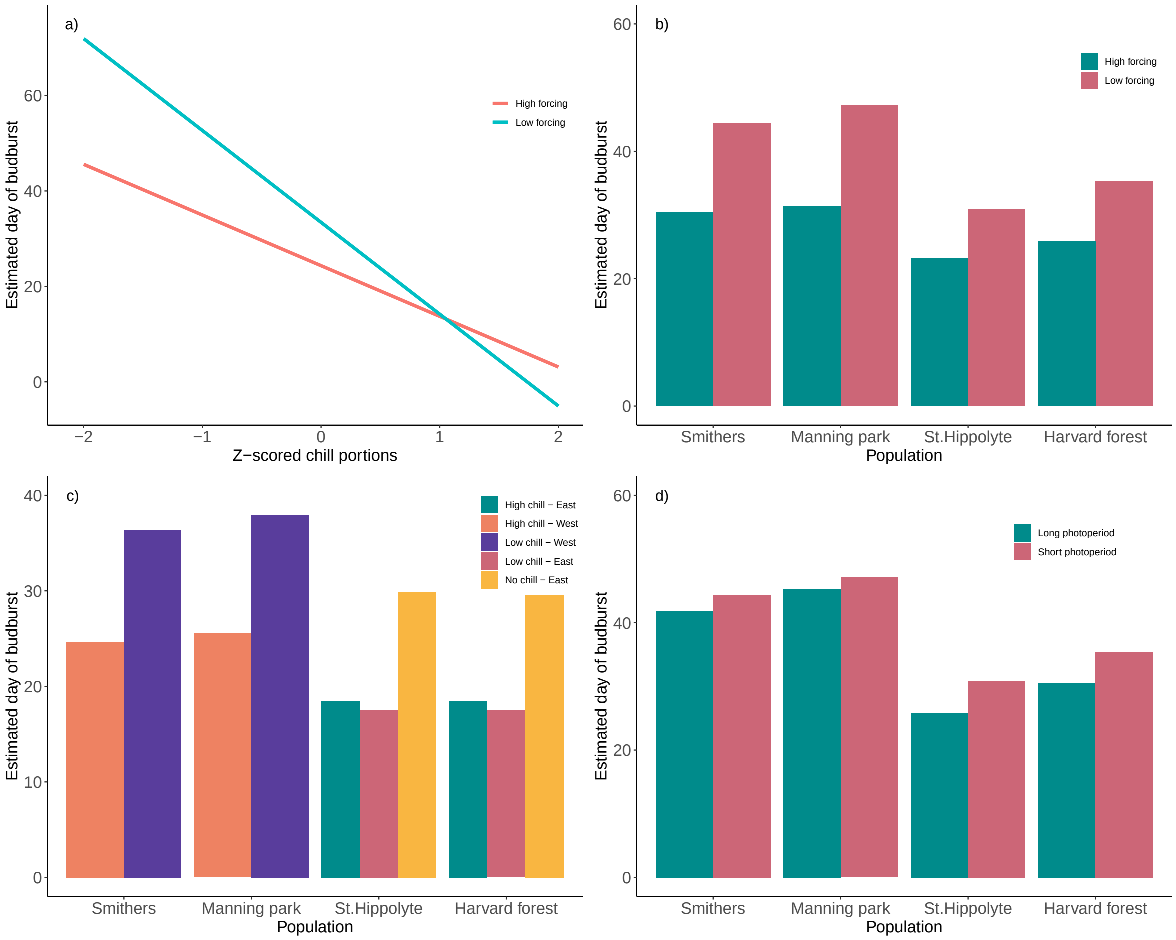

Figure 1: Interaction plots of day of budburst of first bud in response chill portions and forcing (a), forcing cues(b), chilling cues (c), and photoperiod cues (d) and species sampled from St. Hippolyte, Harvard Forest, Manning park, and Smithers.

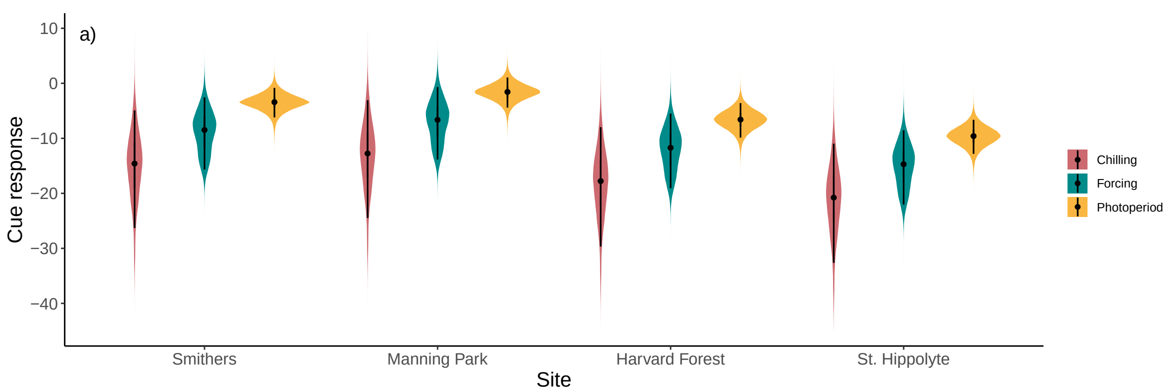

Figure 2: Posterior distributions of estimated cue responses with site level effects for individual sites, depicting a) chilling, b) forcing, and c) photoperiod cue responses. Black circles represent the median cue response, while the thinner black line the 90% quantile interval. The coloured distribution is the the posterior density of the posteriors of the cue responses and site level responses for all species at a given site. The y-axis spans the entire range of the data.

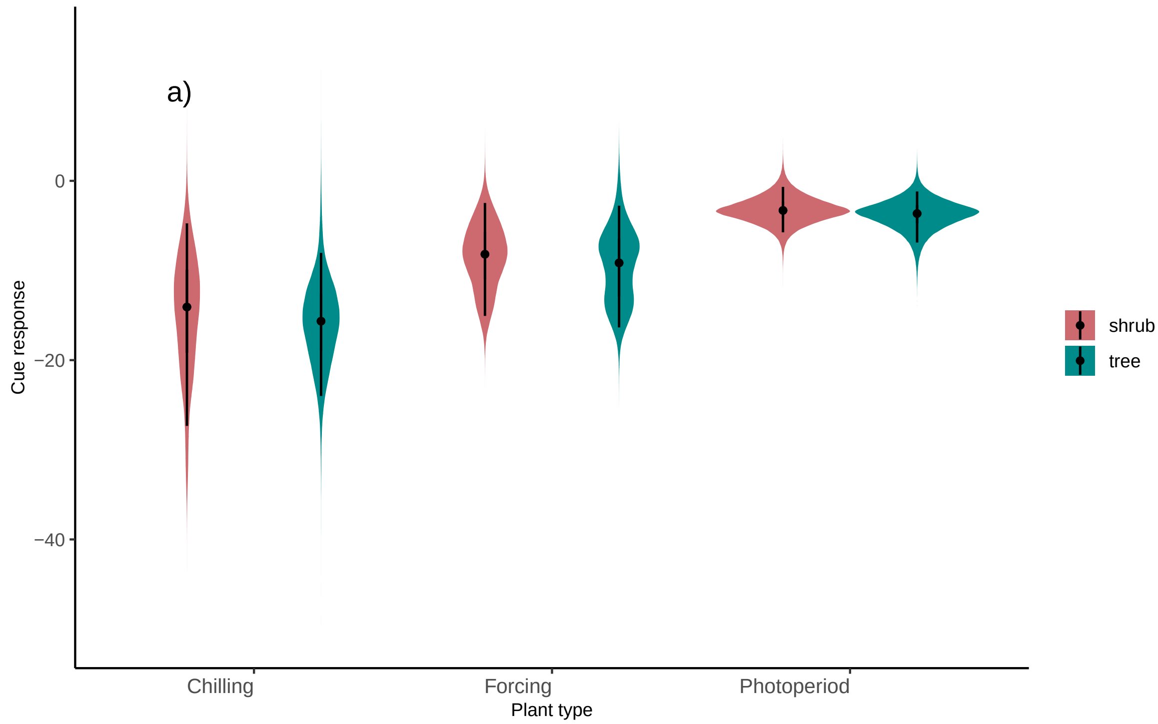

Figure 3: Comparisons of posterior distributions for cues estimates between shrub and tree species. Black circles represent the median cue response, while the thinner black line the 90% quantile interval. The coloured distribution is the the posterior density of the posteriors of the cue responses for all species within a given architectural type. The y-axis spans the entire range of the data.

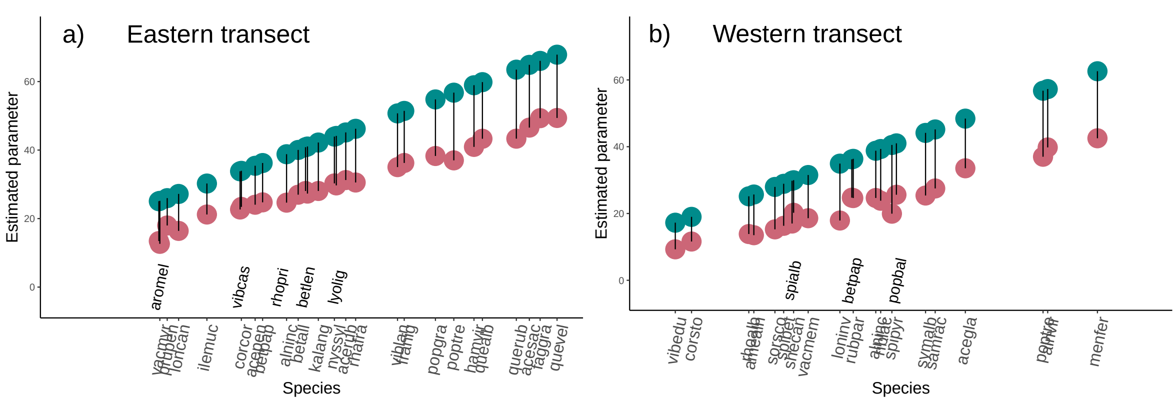

Figure 4: Estimated budburst, shown in blue, and species intercepts, shown in red, ranked by budburst dates for both the eastern (a) and western (b) transects.

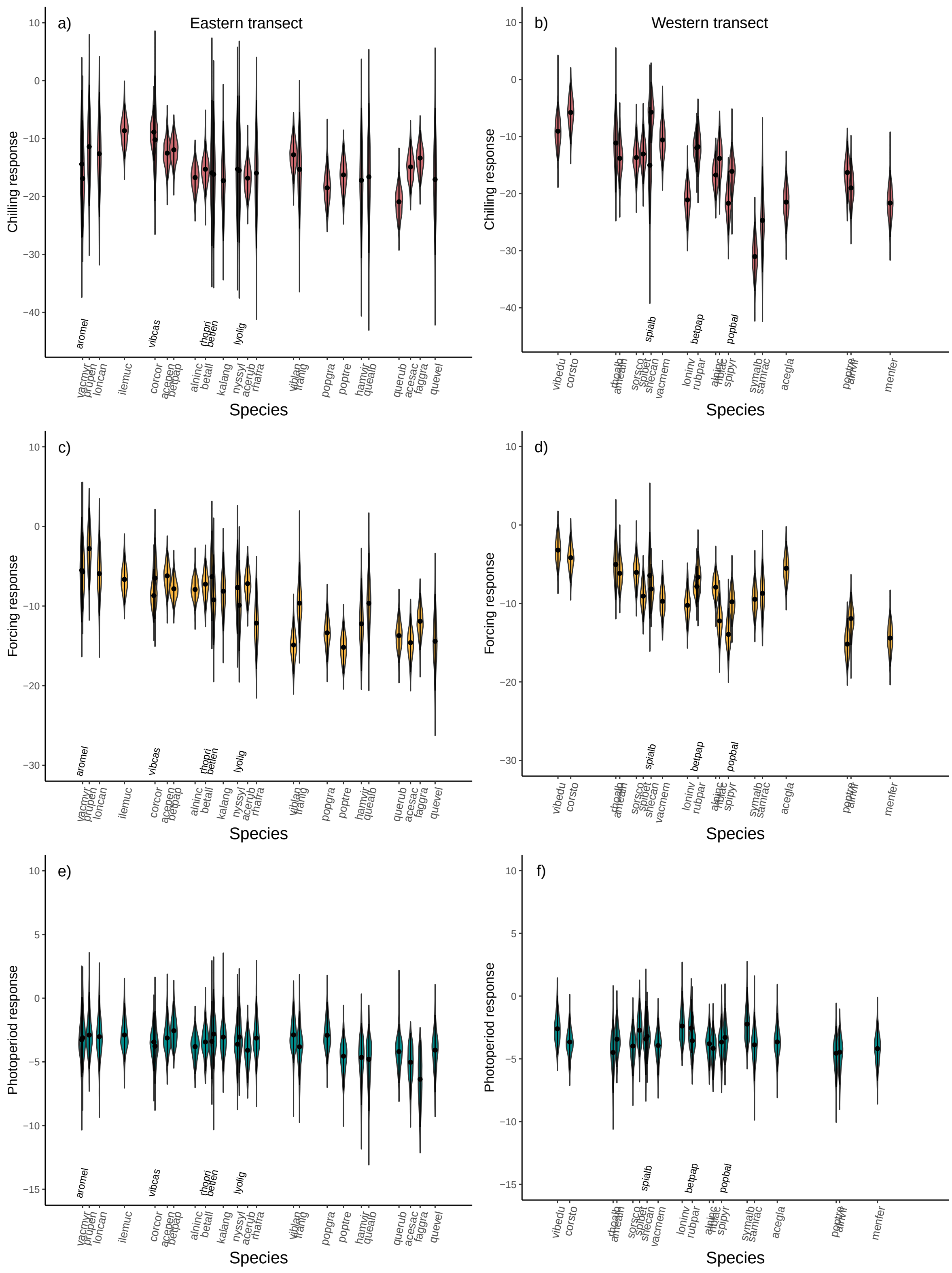

Figure 5: Species' chilling (a,b), forcing (c,d) and photoperiod (e,f) cue responses ranked by estimated budburst dates for both the eastern (a, c, e) and western (b, d, f) transects.