# Species differences in cue responses in woody plants of North America

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## General thoughts

1. "Producing unique temporal niches" — cool, can you expand on this at all? Maybe finally make up some 'control' environmental conditions and plot the species via that (pt 1)
2. Control environment: average conditions perhaps - mean winter chilling, spring temps, 12/12 photoperiod
3. Group results: "cue interactions", "diff across sites", "spp differences"
4. Stronger photoperiod cues Eastern sites - defense agains false spring events?
5. Site by forcing: bc of chilling? Positive at SH - where there was more chilling therefore needing less forcing, but negative at other sites (MP and HF) - less clear
6. move interaction plots to supp
7. Figure changes:
8. fig:siteCues - plot on same fig so cue differences pop
9. muplot in supp
10. Spp plot add a line with the overall estimate mean to each and think of ways to group (along x axis)... maybe by clade and then color by east/west? Or order by pt 1 and color by clade (especially as you have a convincing east/west comparison plot already)?
11. Not sure you need Fig 7-8?
12. overall message: see a lot of spp differences, but not a lot of site level differences - even with the biases introudced by our differences in winter chilling and collection methods

## 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) Species budburst = strongly phylogenetically structured ($\lambda$ of 0.8 (90% uncertainty interval: 0.6, 1), root trait value of 12.2 (90% uncertainty interval: 7.2, 17.4).
   (b) All cues did lead to an advance in budburst date
   (c) Strong interactions between cues and between cues and sites.
   (d) Forcing and chilling = strong delaying effect = low chilling offset by high forcing (Fig. S2 a).
2. Differences across sites...
   (a) delaying interactions between:
      i. forcing and St.Hippolyte ($b_{forcexsite3}$)
      ii. forcing and Harvard forest ($b_{forcexsite4}$)
      iii. chilling by St. Hippolyte ($b_{chillxsite3}$)
      iv. chilling by Harvard forest ($b_{chillxsite4}$)
   (b) Unique site by cue responses:
      i. St. Hippolyte = earlier budburst than our western sites — high forcing leading to earlier budburst
      ii. Harvard Forest = later budburst than Smithers at low forcing— but more responsive to high forcing = earlier budburst
      iii. Manning park (surprisingly) = earlier budburst at low forcing, but delayed w/ high forcing
   (c) All sites— low chilling = advances budburst
      i. strongest response for St. Hippolyte — advanced budburst at high chilling
      ii. Chilling at both Harvard forest and Manning park had delayed budburst relative to Smithers.
      iii. Suggests latitudinal differences may shape chilling cue responses
   (d) photoperiod by site interactions differed with transect
      i. Interaction with eastern sites support a moderate advancing effect — longer photoperiods = budburst dates to advance more, negligible response under short photoperiods
      ii. Manning park = opposite and stronger responses: with short photoperiod = earlier budburst relative to Smithers and long photoperiods = slightly delayed budburst. (Fig. S2 d).
   (e) Differences in cue responses across sites are weak when site effects are accounted for (Fig. 1)
   (f) Did not observe differences across different plant architectures, with both shrubs and trees having very similar cue responses (Fig. 2)
3. Individual species show more distinct trends
   (a) Across all species, cue responses = strongest for chilling and forcing versus photoperiod, but relative importance of cue = varied across species = unique temporal niches (3)
   (b) No strong evidence of generalizable trends in cue responses across the transects or between tree and shrub species.

   (c) But some understory species, e.g. *Cornus stolonifera* do fit profile of both weak chilling and forcing cues, but others e.g. *Menziesia ferruginea* exhibit strong responses to all three cues (Fig. 3.

   (d) Tree species = no strong trends, but e.g. *Quercus velutina* = stronger chilling and forcing cues as well as photoperiod as predicted, but others like *Prunus pensylvanica* have consistently weak cue responses (Fig. 3.

   (e) Estimates do support commonly observed trends, e.g. *Fagus grandifolia* = strongest photoperiod response, but the shrub *Symphoricarpos alba* had the strongest chilling response —surprisingly.

4. Species budburst did show a considerable gradient across our assemblage of species, but this was not well explained by variation in trait responses (Fig. 4 and 5.

   (a) Substantial portion of species budburst date is explained by species-level differences (Fig. 4 c and d)

   (b) We do see slight gradients iwth later species having stronger chilling and forcing responses, especially in the western transect

   (c) But no real trend with photoperiod

# 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 |

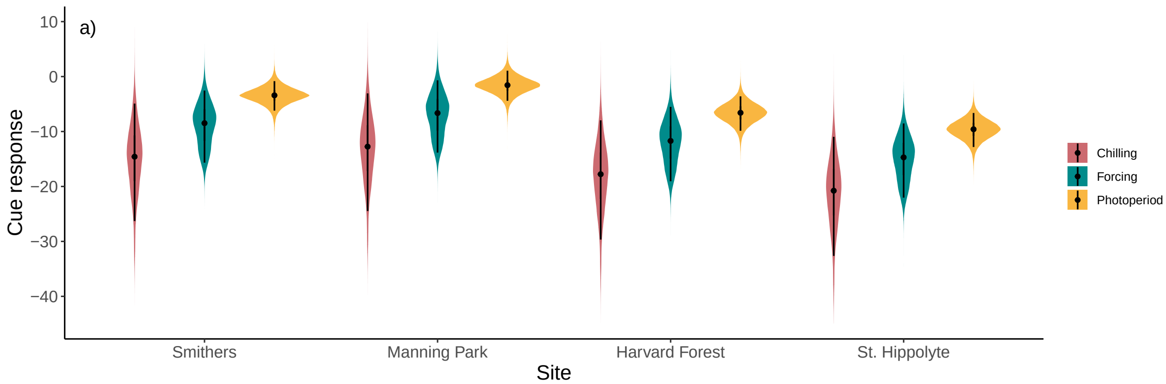


Figure 1: Posterior distributions of estimated cue responses with site level effects for individual sites, depicting a) chilling, b) forcing, and c) photoperiod cue responses. Black circles represent the median cue response, while the thinner black line the 90% quantile interval. The coloured distribution 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.

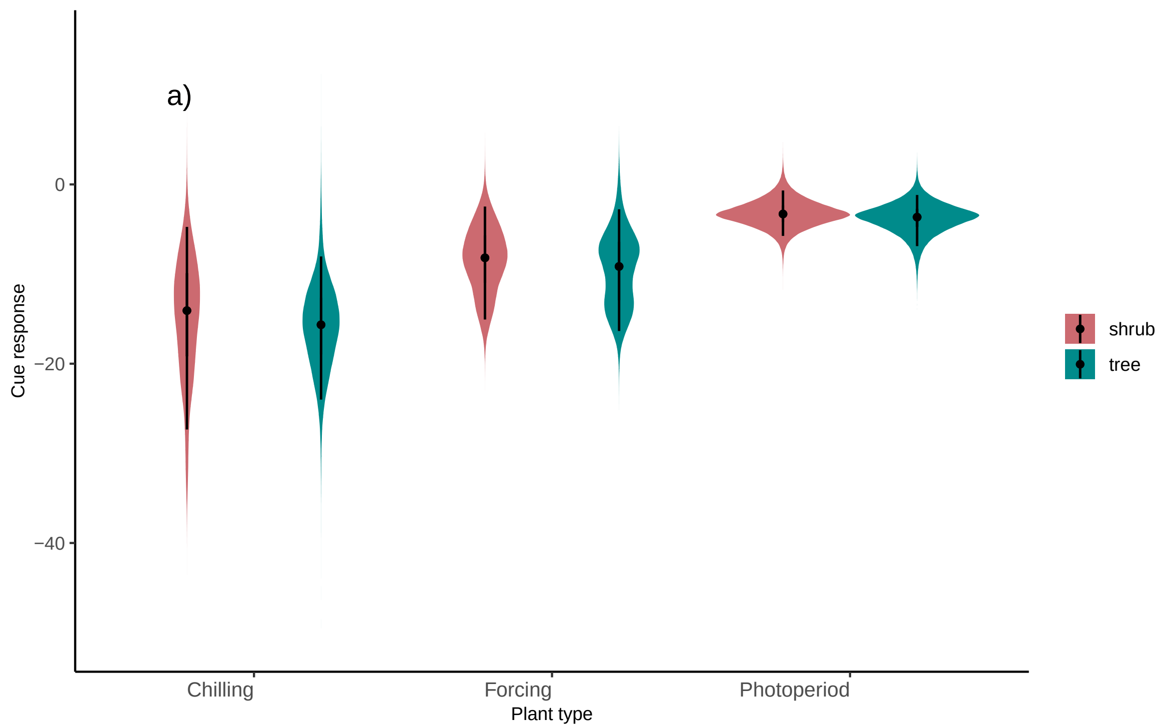


Figure 2: Comparisons of posterior distributions for cues estimates between shrub and tree species. Black circles represent the median cue response, while the thinner black line the 90% quantile interval. The coloured distribution is the the posterior density of the posteriors of the cue responses for all species within a given architectural type. The y-axis spans the entire range of the data.

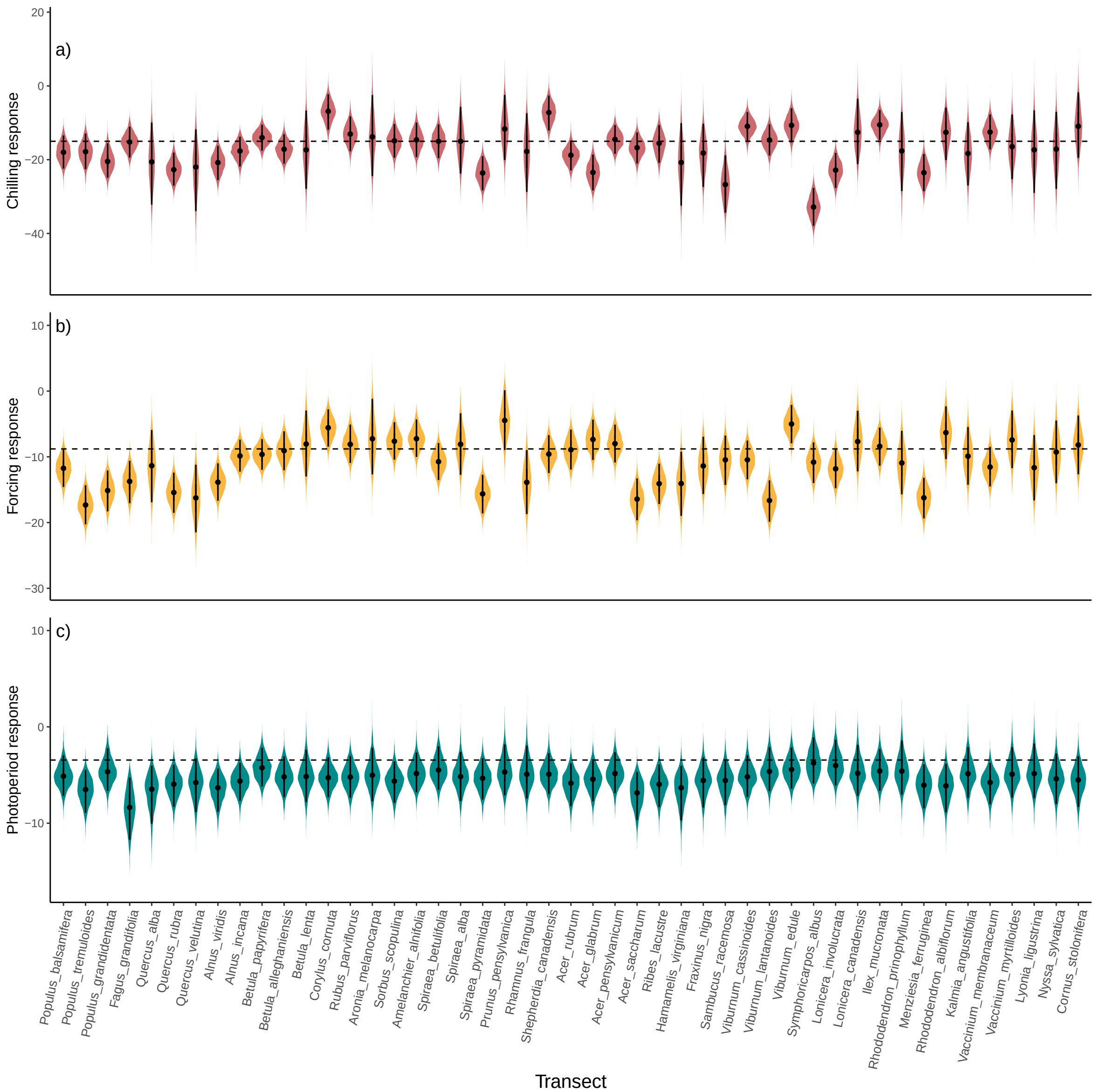


Figure 3: Species differences in cue estimate posterior distributions, comparing species differences across a) chilling, b) forcing, and c) photoperiod cues. The median cue response is illustrated by the black circle, while the 90% quantile interval is illustrated by the black line. The coloured distribution depicts the shape of the posterior density for all samples of a given species.

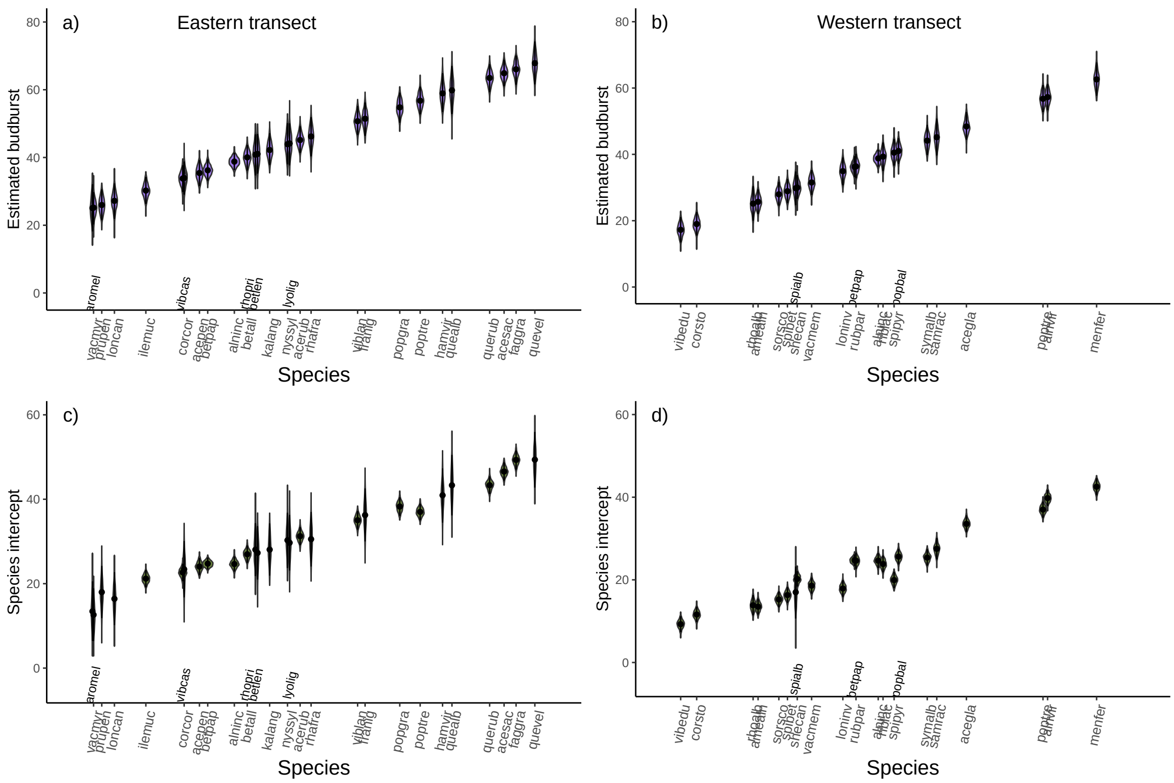


Figure 4: Estimated budburst (a, b) and species intercepts (c, d) ranked by budburst dates for both the eastern (a, c) and western (b, d) transects.

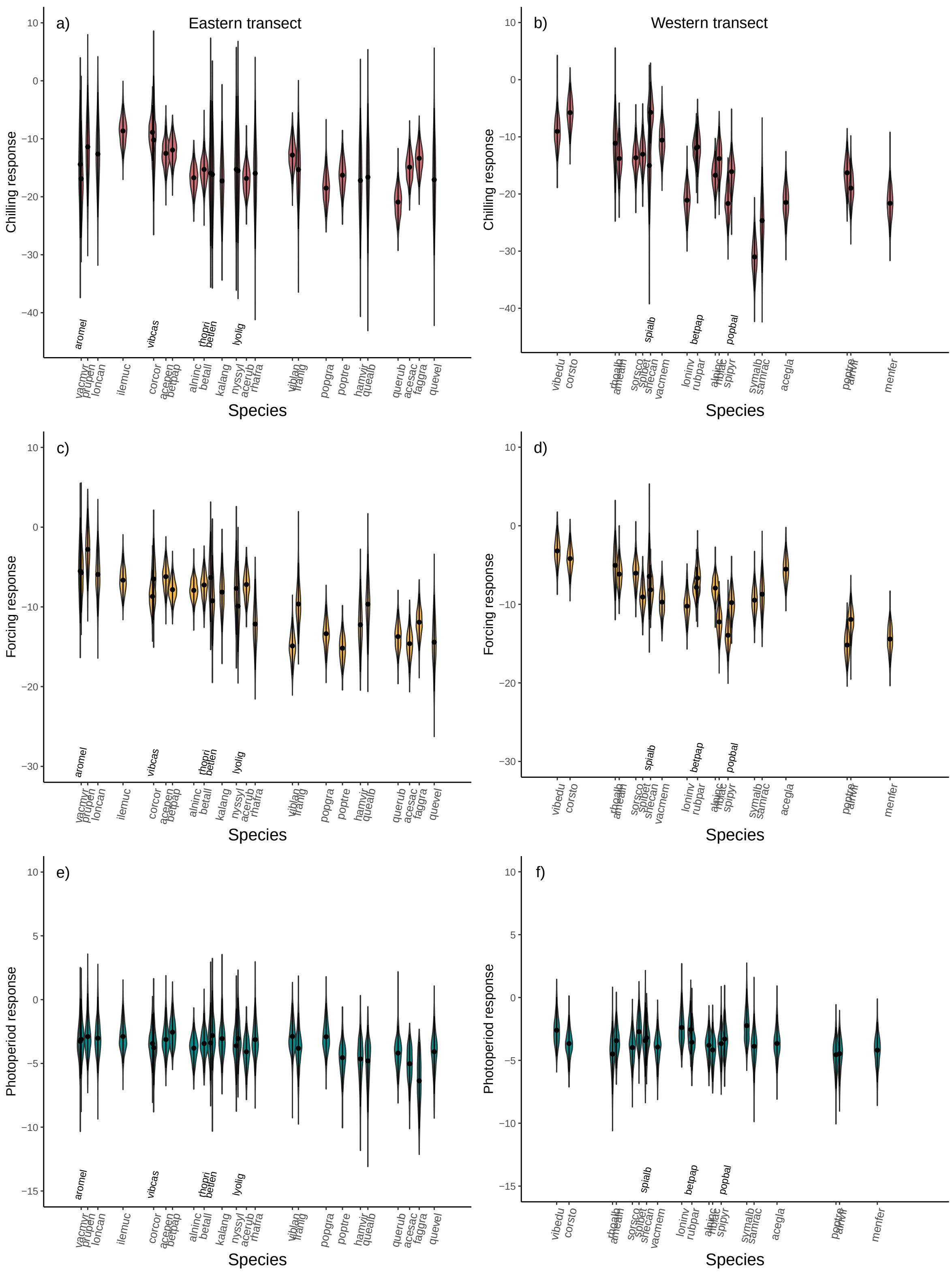


Figure 5: Species' chilling (a,b), forcing (c,d) and photoperiod (e,f) cue responses ranked by estimated budburst dates for both the eastern (a, c, e) and western (b, d, f) transects.