

1 Woody plant phenological responses are strongly associated  
2 with key functional traits

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# 1 Summary

Key Words: Budburst phenology, functional traits, Trees, climate change

## 2 Introduction

**Some text for intro and methods...**

A major goal of trait ecology has been to predict species-level characteristics by their traits alone; to do this, we need to be able to replace species distinctions in models with species' traits. To that aim, our models are designed to attribute phenological variation (days to budburst) to species' trait values, while allowing for residual variation explained by species (partially-pooled). When traits explain a significant portion of variation, species will explain only a small amount, and suggest we may be able to predict species for which we only have trait values.

While phenology in observational data is often considered highly variable, it is actually highly predictable in experiments where the major cues (forcing, chilling, photoperiod) are known and thus we focus on cues here.

## 3 Methods

## 4 Results

1. Quick overview of models again ... (but try not to repeat ourselves from methods)

- (a) Our models jointly estimated species traits and phenological cues to predict phenological variation in days to budburst.
- (b) Because we drew on large trait databases for our analyses we partitioned trait variation due to species versus study-level effects, then used the species-level estimates of traits (with study removed) to examine how traits predicted phenological cues (which in turn predict budburst), while allowing for residual variation in cues to be explained by a species effect.
- (c) (Maybe move to methods): This model is a departure from current efforts in several ways: first, while these steps are often done separately, while our models allow them to be jointly estimated at once which uniquely allow separating out the trait versus residual species effect; second, we focus on phenological cues as predictors for day of budburst and thus allow traits to influence each cue.

2. Review of trait model part ... comparing study variation to species level variation

- (a) Across our models, we found important study-level variation across traits.
- (b) In our height model, study level variation was greater (7.51) than species level variation (7.51) (Fig. 1).
- (c) In contrast, study level variation in our SLA model was approximately half the value of the species level variations (7.78 and 3.27 respectively).
- (d) In the seed mass and LNC models it was considerably less than that of the species level variation (seed mass: 1.62, 0.97; LNC: 7.78, 3.27 for species and study level variation respectively) (Fig. 1).

3. Very short paragraph reminding audience of the model and connecting figure on cue-trait relationships.

- (a) We next combined these trait-level estimates (Fig. 2) with data on forcing, chilling and photoperiod values from a large meta-analysis of experiments to test if traits (height, SLA, seed mass, LNC) predicted phenological cues (Fig. 3).

- (b) For some traits we found much of the variation in phenological cues across species could be explained by trait variation (see panel a-c in Fig 3), while for others traits were weak predictors (see g-i in Fig 3).
4. Discuss how Height and SLA were partially in line with predictions
- (a) Across traits, height and SLA showed the greatest responses to changes in cues level, though the direction of responses were not consistent across cues for either trait.
- (b) Taller species had extremely weak responses to forcing (0.2 m per standardized forcing; -0.1, 0.5).
- (c) However, as we predicted, taller species had larger responses to chilling (-0.5 m per standardized chilling; 90% uncertainty interval interval: -1, -0.1) and photoperiod (-0.3 m per standardized photoperiod; -0.6, 0, two cues that would generally lead to later budburst and fit within an overall conservative strategy.
- (d) High SLA species, which produce thin leaves with a relatively lower investment in leaf mass, had weaker forcing and chilling cues (0.2 mm<sup>2</sup>/mg per standardized forcing; -0.1, 0.4, 0.3 mm<sup>2</sup>/mg per standardized chilling; -0.1, 0.7
- (e) But stronger photoperiod cues (-0.2 mm<sup>2</sup>/mg per standardized photoperiod; -0.4, 0)
5. ...But Seed mass and LNC were not
- (a) In contrast to height and SLA, seed mass and LNC had very weak responses.
- (b) As we predicted, we found that species that produce leaves with high nitrogen content, which reflects high photosynthetic rates, showed weak trait responses, and weak responses to both forcing and chilling cues at 0.5 mg/g per standardized forcing; 0.1, 0.9) and (0.7 mg/g per standardized chilling; 0.2, 1.2, and 0.3 mg/g per standardized photoperiod; 0, 0.7
- (c) Contrary to our predictions, we did not find a relationship between seed mass and cue responses for any of our three cues (-1.1 mg per standardized chilling; -2.8, 0.7, -0.6 mg per standardized photoperiod; -1.6, 0.4, (-0.3 mg per standardized forcing; -1.4, 0.8))

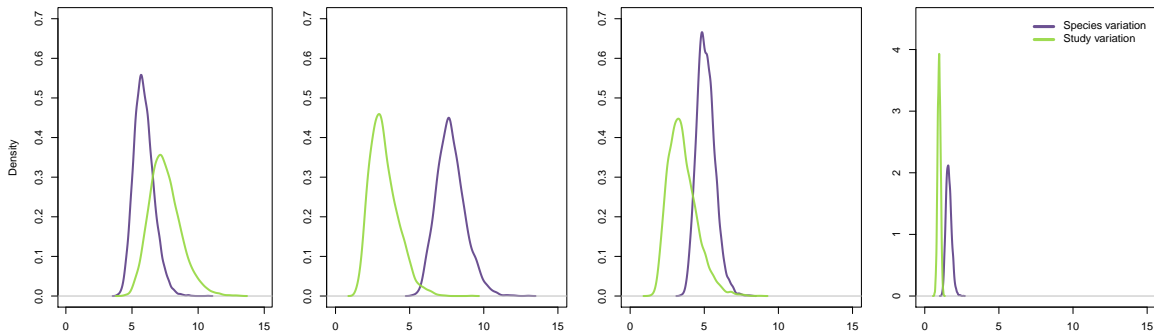


Figure 1: Comparison of the posterior densities for the species level variation and study level variation of a. height, b. SLA, c. LNC, and d. seed mass.

## 5 Discussion

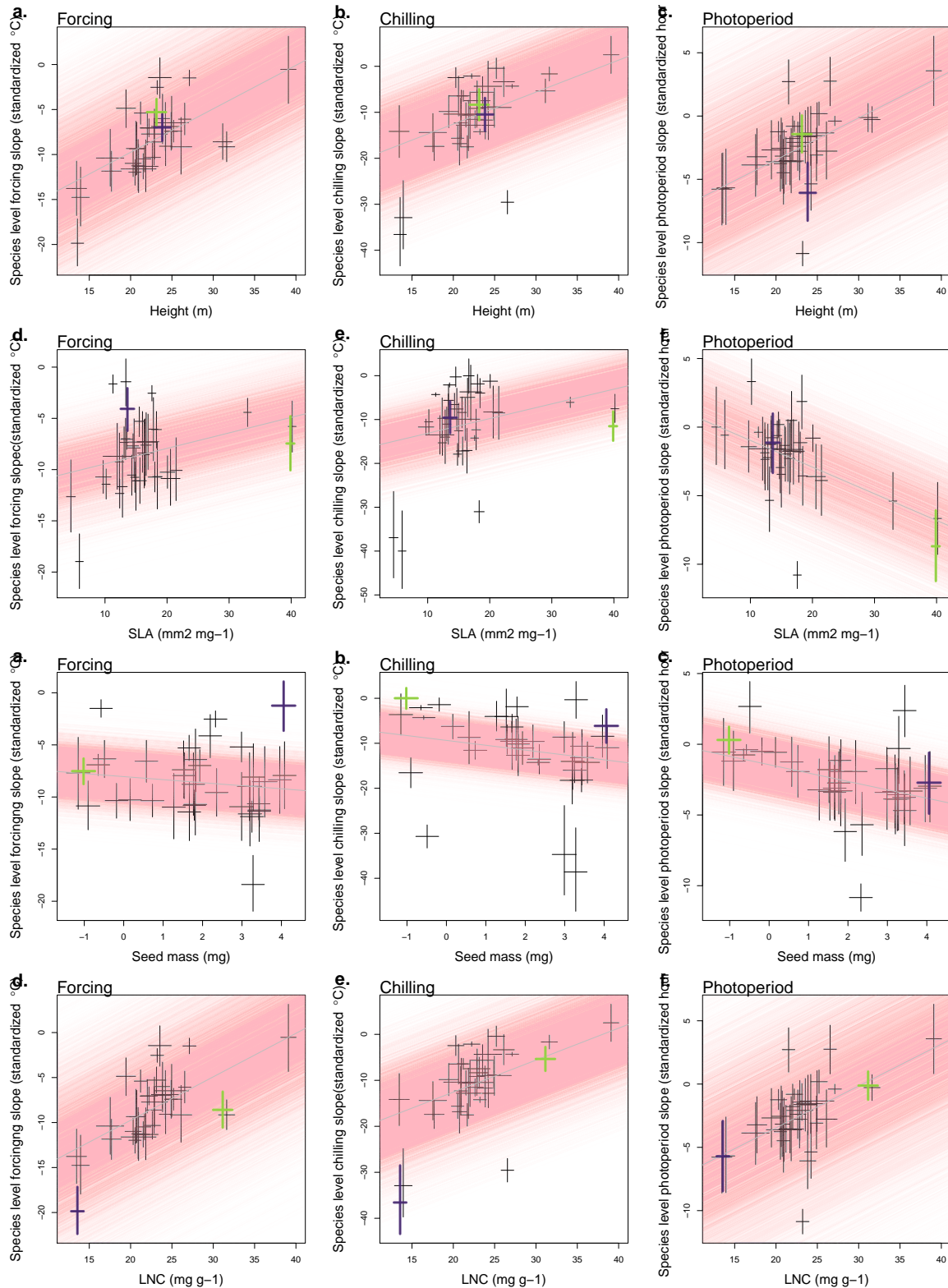


Figure 2: Estimated trait values for height (a-c) and SLA (d-f) traits, correlated against species level cue responses to forcing (a & d), chilling (b & e), and photoperiod cues (c & f). Parameters were estimated using our joint trait-phenology model, with the grey line depicting the mean linear relationship between estimated trait effects and the slope of the cue response. The pink shading represents the distribution of the posterior estimates. The species depicted in Fig 3 are highlighted in each panel, with the acquisitive species shown in green, and the conservative species, shown in purple.

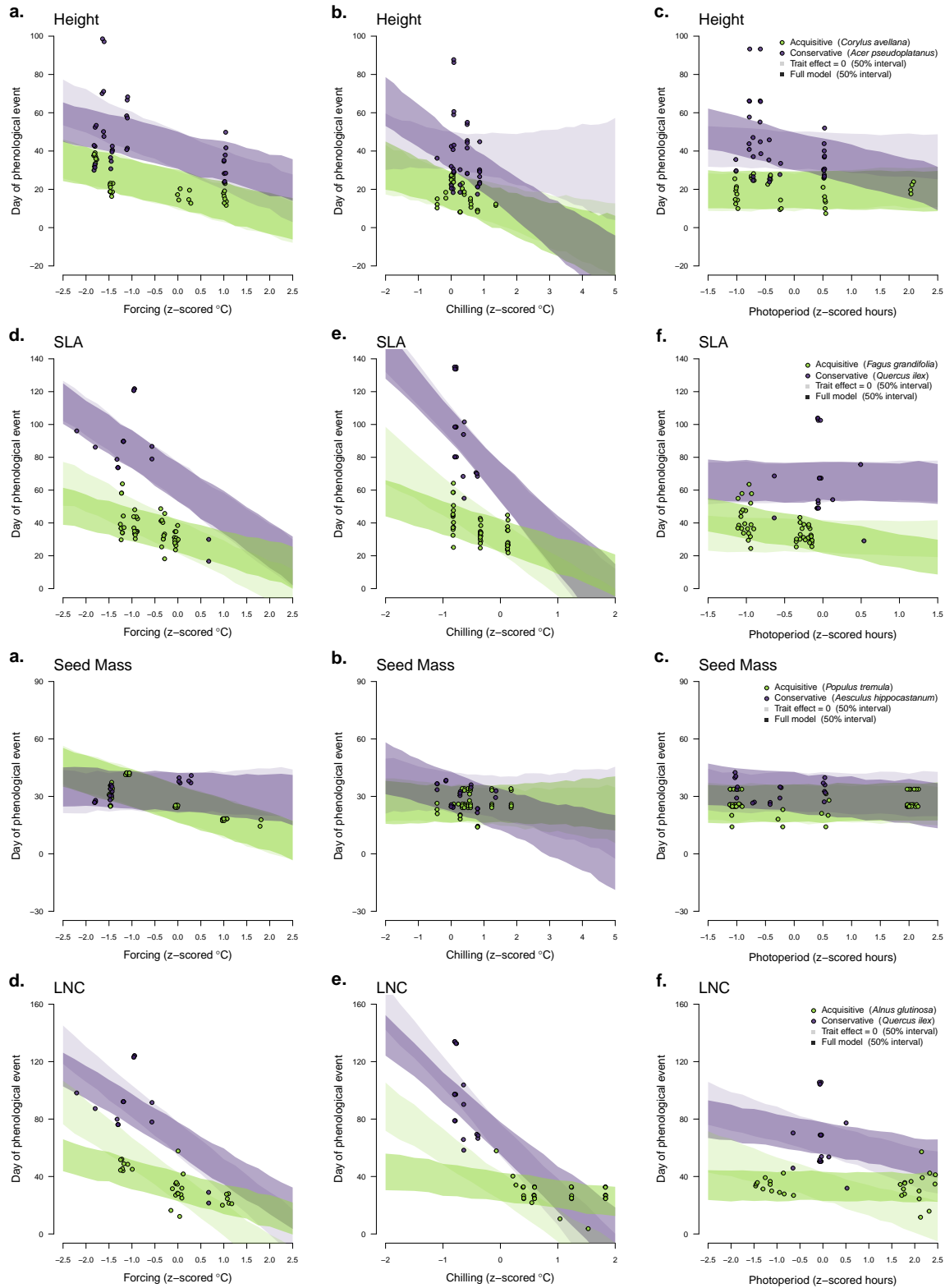


Figure 3: Comparisons of estimated cue responses of a representative species with a trait value associated with acquisitive growth strategies, shown in green, or conservative growth strategies, shown in purple. Some traits strongly predicted phenological responses to cues, as seen by comparing the model estimates including trait (darker bands represent the 50% uncertainty interval for the posterior cue estimates for the full model) versus without (lighter bands represent the 50% uncertainty interval for the posterior cue estimates with a trait effect of zero), which is especially obvious in the species with the higher trait value. Points represent the raw budburst data for each respective species. We show the full range of all treatment values (x axis) though most species cover only a portion.

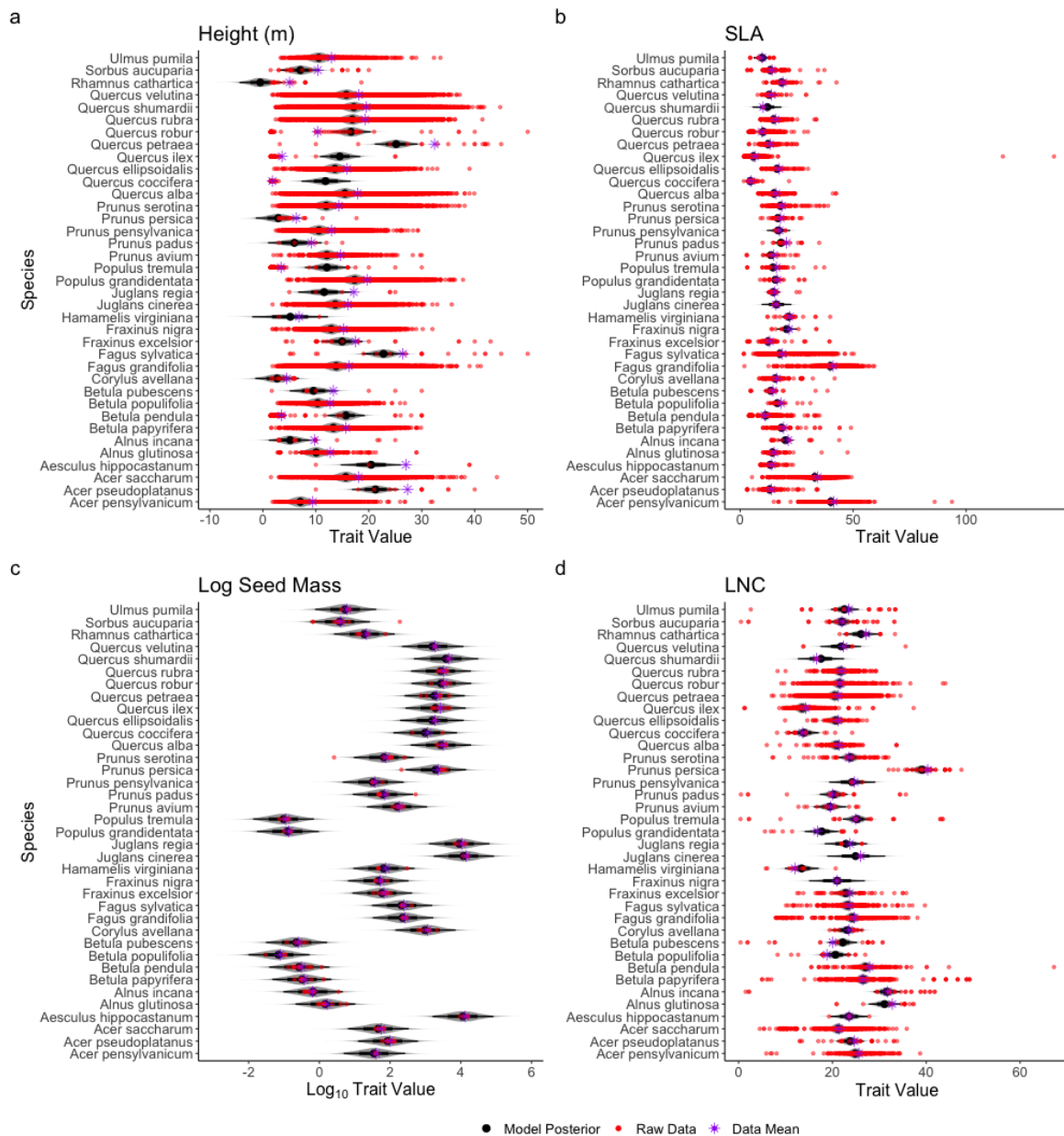


Figure 4: Comparisons of estimated model fits and raw data from joint models of trait effects on budburst phenological cues for 37 species of woody deciduous plants. Four functional traits – a. height, b. SLA, c. seed mass, and d. LNC – were modelled individually, with the calculated trait value being used to jointly model species responses to standardized chilling, forcing, and photoperiod cues. Model posteriors are shown in black, with the thicker line depicting the 66% interval and the thinner black line the 97% interval. Overall species level model posterior distributions were well aligned with the raw data, shown in red, and the species level means from the raw data, denoted as a purple stars.