Phenological cue use varies with functional traits in North American woody plan communities

Deirdre Loughnan[1], Faith A M Jones[1], and E M Wolkovich[1]

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[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

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[1] "/Users/deirdreloughnan/Documents/github/Treetraits/docs"
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Research questions

1. Do phenological cue-trait relationships change across transects? Populations?
2. How do budburst cues relate to functional traits in temperate woody species?
3. How do shrub and tree species differ in their cue-trait relationships?

Materials and Methods

These plots and tables are using the model output from the model with a dummy variable for transect (east = 1) and an interaction between transect and latitude. Latitude is included as a continuous variable, but based on the prior predictive checks, I decided to z-scored it. 90% UI given in text.

Results

1. Our study = one of the first to combine trait data with phenological cue responses for the same individuals and across species distributions.
   (a) Includes plant communities in eastern and western deciduous forests of North America
   (b) Samples collected from multiple populations—modelling approach that accounts for variation across populations and transects
   (c) Joint modelling approach = use sp-level estimates for traits to understand phenological cue responses and budburst timing
   (d) Taking a community-level approach—with woody tree and shrub species = different growth strategies and presumably suites of traits
2. Most traits = small population effects but interaction between pop and transect for some.
   (a) Found moderate to strong interaction between latitude and transect—but effects differed by trait

   (b) Both height and ssd = smaller trait values at higher latitudes = but ssd showed weak effects (-0.1, UI: -0.3,0 for height, 0, UI: -0.2,0.2 for SSD)
   (c) DBH = strongest response—0, UI: -0.2,0.2—largest diameters occurred in our more Northern populations
   (d) C:N also increased with latitude—but relatively weak (1.1, UI: 1.0,1.3)
   (e) Only C:N and LMA = no effect (0.9, UI: 0.8,1.1 for both traits)
   (f) Fig. 1

3. Found only two of our five traits were related to budburst phenology
   (a) Only height and DBH correlated with budburst cues—responses were consistent across the two traits
   (b) Smaller, short trees had stronger forcing responses (0.5, UI: -1.0, 2 for height and 3.3, UI: -0.7, 7.4, Fig. 5 a and g)
   (c) But weaker responses to photoperiod (-3.4, UI: -2.7, -0.3 for height and -3.2, UI: -5.5, -1.0, Fig. 5 c and i)

4. Other three traits = no relationship to chilling, forcing, or photoperiod cues
   (a) LMA, SSD, C:N = no relationship—posterior centered around zero (Fig. 5)
   (b) our estimates of the betaTraitxCue parameters for these traits = fully informed by prior not the data (Fig. 4)
   (c) Also no correlation between between ring porosity of wood with our three cues—based on spp means using posterior estimates 7.

5. Regardless of trait effects—our joint modeling approach still estimated phenological cue responses in line with previous work.
   (a) All models produced positive phenological responses to cues
   (b) Individual spp varied in both their timing and cue responses.
   (c) But in general spp responses were strongest for chilling and weakest for photoperiod.

6. Including height and DBH trait effects better informed spp level estimates of phenology
   (a) Estimates bb using our model parameters show clear differences in bb timing between tree and shrub spp (Fig. 6)
   (b) Shrub spp were estimated to bb earlier—especially under stronger cues—tree spp were later
   (c) But species-level effects vary across traits = unique effects on cue responses—estimated order of spp bb order differs between the two models

Figures

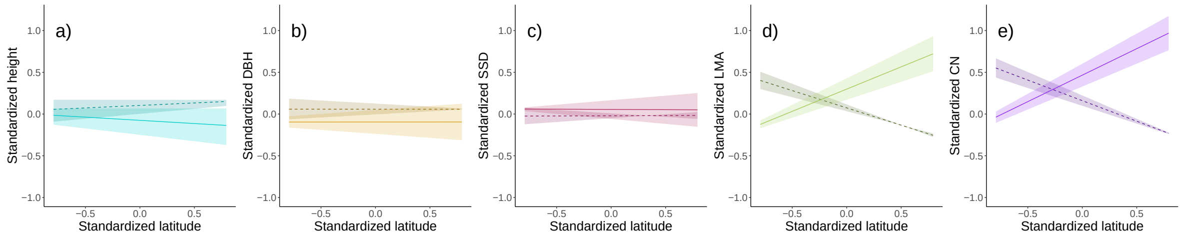

Figure 1: We only found biogeographic differences for four of our functional traits, with the direction of the relationship varying across traits. Both height a. height and b. diameter at base height showed strong interactions between latitude and trait values, while c. leaf mass area has the weakest response, and d. stem specific density, and e. carbon:nitrogen moderate interactive effects.

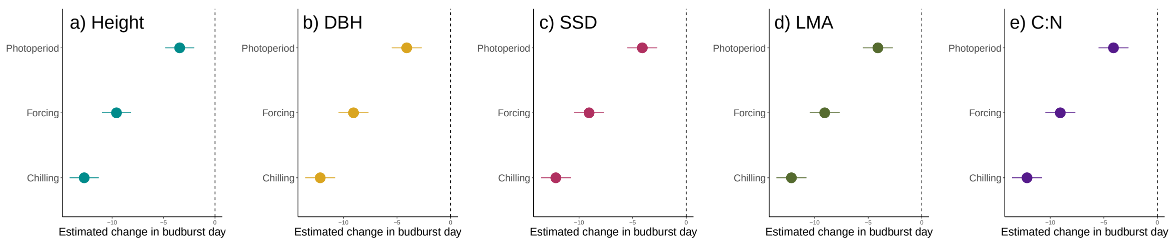

Figure 2: We found consistent estimates for budburst cue responses to chilling, forcing, and photoperiod for each of our trait models: a. height, b. diameter at breast height, c. stem specific density, d. leaf mass area, and e. carbon:nitrogen. Lines represent 90% uncertainty intervals.

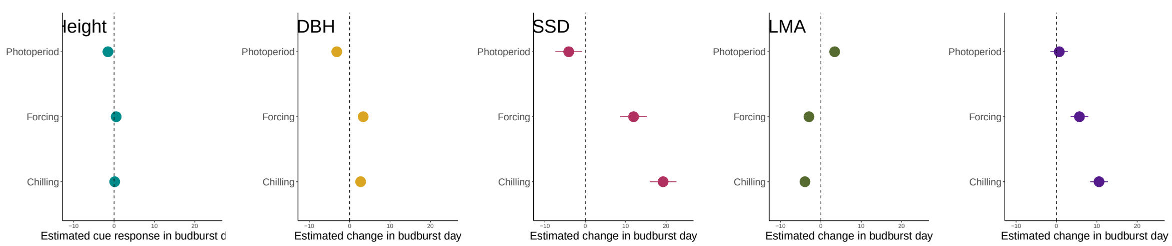

Figure 3: The relationships between traits and cue responses varied considerably across each of our trait models, a. height, b. diameter at breast height, c. stem specific density, d. leaf mass area, and e. carbon:nitrogen, and for individual cues. Lines represent 90% uncertainty intervals.

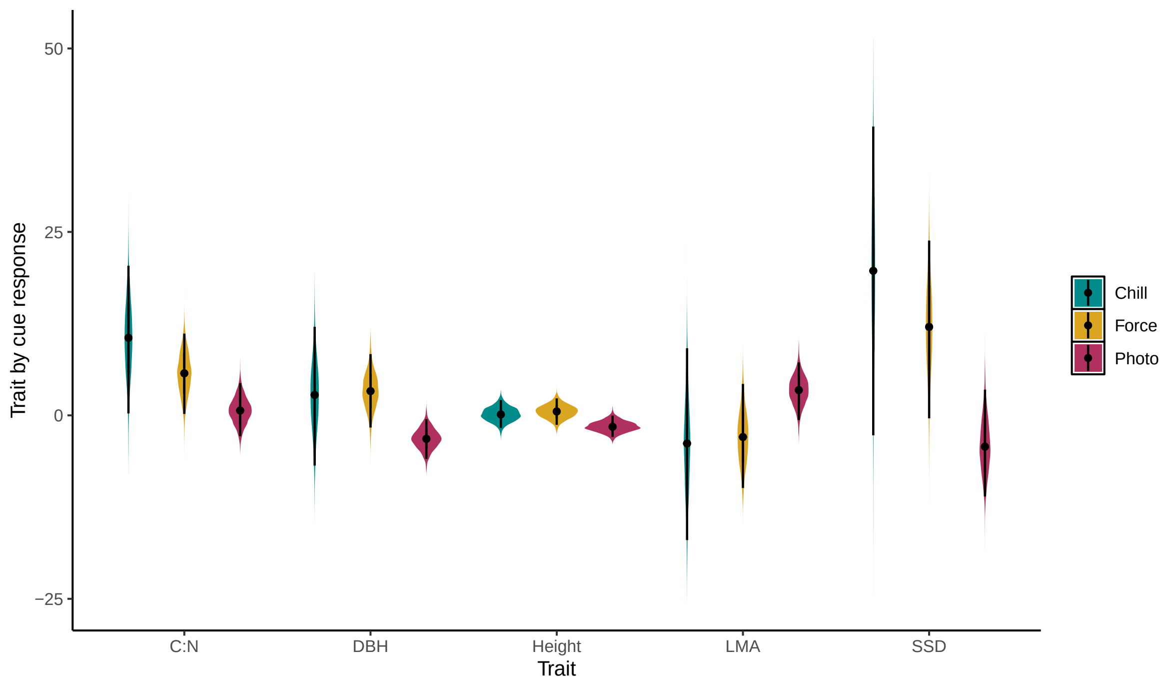

Figure 4: Only some traits were related to budburst phenological cues. For leaf mass area, stem specific density, and the ratio of carbon to nitrogen, traits no effect on budburst timing.

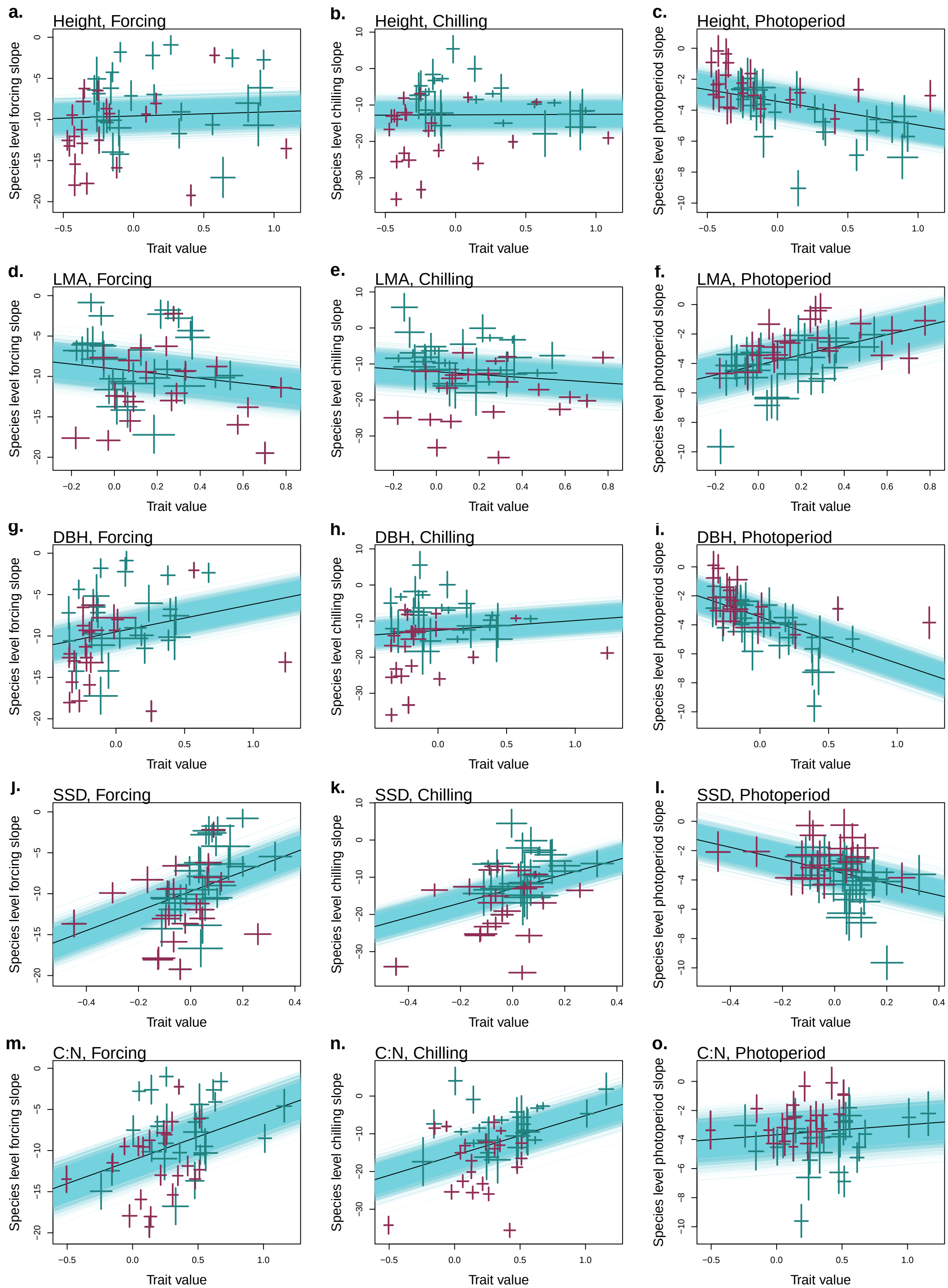

Figure 5: Relationship between species traits and cue responses, for height (a-c), leaf mass area (d-f), diameter at breast height (g-i), stem specific density (j-l), and the carbon to nitrogen ratio (m-o). Point colours representing different species groups, tree species are depicted in maroon and shrub species in teal.

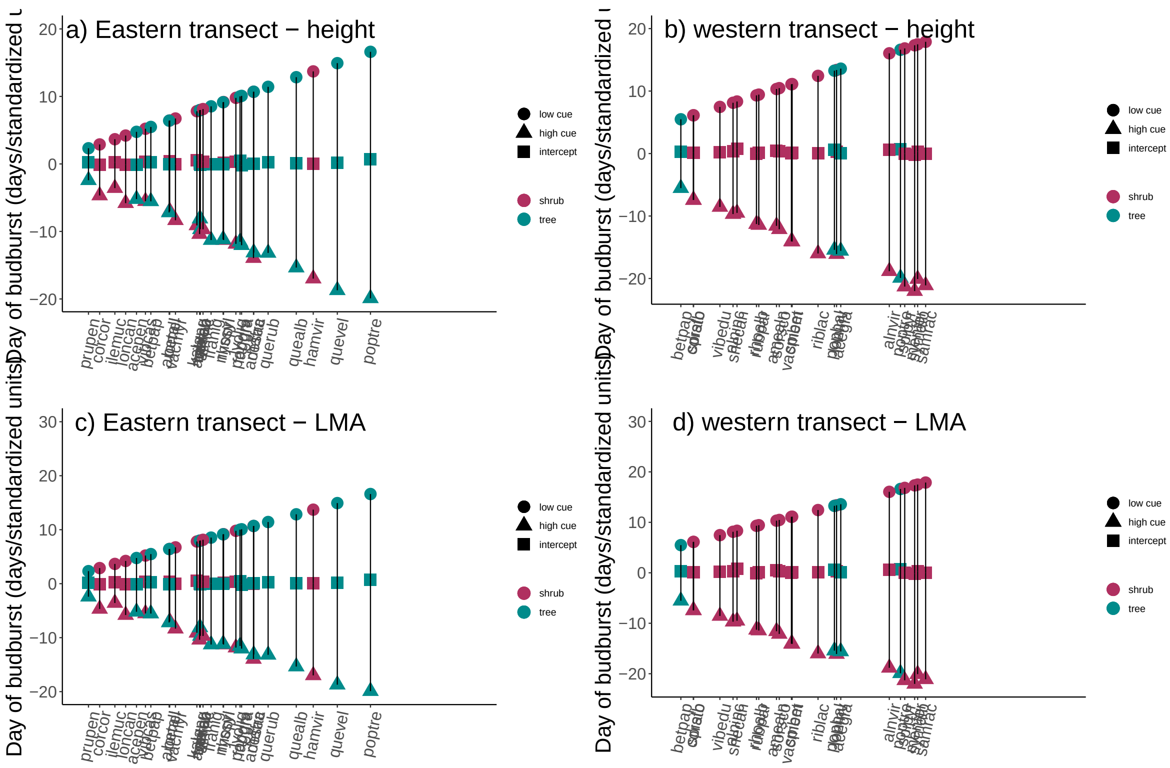

Figure 6: We found budburst estimates differed between our full model (intercept plus cues, depicted as triangles for high cues and circles for low cues), versus the intercepts only model (without cues, shown as squares). Species are ordered in increasing budburst dates for both the eastern (a and b) and western (c and d) populations, spanning from early budbursting shrubs, in red, to late budbursting trees, in blue.

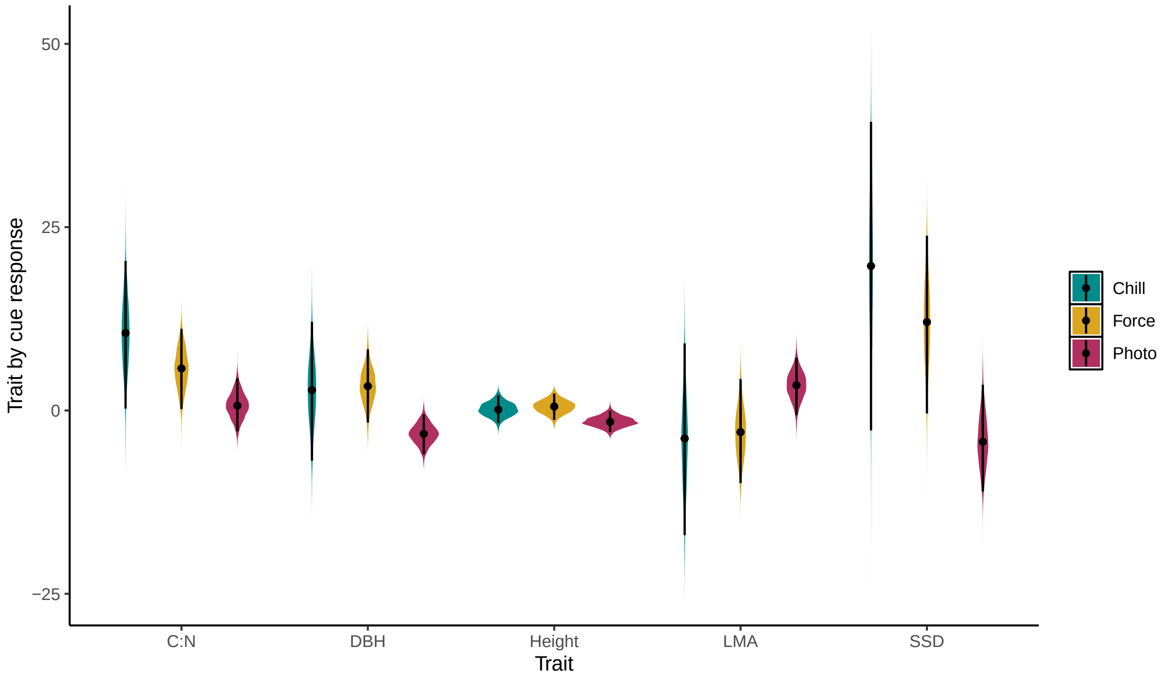

Figure 7: Despite differing in their wood structures and growth strategies, we did not find this trait to correlate with differences in cue responses across species.

Tables

Table 1: Summary of a joint model for height

	mean	X2.5.	X25.	X50.	X75.	X97.5.
mu_grand	0.01	-0.13	-0.04	0.01	0.06	0.15
b_tranE	-0.18	-0.26	-0.21	-0.18	-0.15	-0.09
b_tranlat	-0.14	-0.30	-0.19	-0.13	-0.08	0.03
muForceSp	-9.58	-11.25	-10.15	-9.58	-9.00	-7.93
muChillSp	-12.72	-15.93	-13.82	-12.71	-11.64	-9.46
muPhotoSp	-3.44	-4.37	-3.73	-3.43	-3.13	-2.53
muPhenoSp	27.03	24.22	26.07	27.06	27.98	29.89
betaTraitxForce	0.52	-1.29	-0.11	0.53	1.15	2.32
betaTraitxChill	0.15	-1.72	-0.52	0.12	0.83	2.09
betaTraitxPhoto	-1.52	-2.94	-2.02	-1.56	-1.03	-0.02
sigma_traity	0.31	0.29	0.30	0.31	0.31	0.32
sigma_sp	0.46	0.37	0.42	0.45	0.49	0.57
sigmaForceSp	5.19	4.00	4.72	5.13	5.60	6.71
sigmaChillSp	9.52	7.32	8.65	9.47	10.29	12.07
sigmaPhotoSp	2.14	1.31	1.82	2.10	2.44	3.17
sigmaPhenoSp	9.77	8.01	9.03	9.70	10.44	12.02
sigmapheno_y	9.50	9.29	9.42	9.50	9.57	9.71

Table 2: Summary of a joint model for leaf mass area

	mean	X2.5.	X25.	X50.	X75.	X97.5.
mu_grand	0.17	0.08	0.14	0.17	0.20	0.27
b_tranE	0.22	0.12	0.19	0.22	0.26	0.33
b_tranlat	0.94	0.72	0.86	0.94	1.02	1.16
muForceSp	-9.06	-11.26	-9.77	-9.04	-8.36	-6.95
muChillSp	-12.17	-16.09	-13.48	-12.19	-10.85	-8.16
muPhotoSp	-4.10	-5.35	-4.50	-4.09	-3.68	-2.88
muPhenoSp	27.06	24.11	26.11	27.06	28.01	29.99
betaTraitxForce	-2.95	-9.90	-5.48	-2.95	-0.54	4.28
betaTraitxChill	-3.94	-16.99	-8.36	-3.83	0.41	9.14
betaTraitxPhoto	3.41	-0.64	2.14	3.44	4.78	7.21
sigma_traity	0.42	0.41	0.42	0.42	0.43	0.44
sigma_sp	0.26	0.21	0.24	0.26	0.28	0.33
sigmaForceSp	5.24	4.01	4.75	5.19	5.67	6.70
sigmaChillSp	9.55	7.39	8.68	9.46	10.33	12.17
sigmaPhotoSp	2.24	1.32	1.92	2.22	2.56	3.29
sigmaPhenoSp	9.76	7.94	9.03	9.67	10.36	12.12
sigmapheno_y	9.50	9.29	9.43	9.50	9.57	9.70

Table 3: Summary of a joint model for diameter at base height

	mean	X2.5.	X25.	X50.	X75.	X97.5.
mu_grand	-0.01	-0.12	-0.05	-0.01	0.03	0.11
b_tranE	-0.15	-0.25	-0.18	-0.15	-0.12	-0.06
b_tranlat	0.00	-0.19	-0.07	-0.00	0.07	0.20
muForceSp	-9.51	-11.20	-10.07	-9.50	-8.94	-7.83
muChillSp	-12.56	-15.48	-13.60	-12.60	-11.57	-9.35
muPhotoSp	-3.45	-4.42	-3.77	-3.45	-3.12	-2.48
muPhenoSp	27.03	24.14	26.06	27.04	27.99	29.85
betaTraitxForce	3.34	-1.65	1.72	3.31	5.04	8.34
betaTraitxChill	2.71	-6.84	-0.40	2.79	5.90	12.08
betaTraitxPhoto	-3.20	-5.94	-4.10	-3.19	-2.28	-0.52
sigma_traity	0.35	0.34	0.35	0.35	0.36	0.37
sigma_sp	0.35	0.28	0.32	0.35	0.38	0.44
sigmaForceSp	5.15	3.97	4.67	5.10	5.57	6.63
sigmaChillSp	9.56	7.28	8.61	9.45	10.38	12.46
sigmaPhotoSp	2.23	1.38	1.91	2.21	2.53	3.26
sigmaPhenoSp	9.79	7.96	9.03	9.73	10.46	12.02
sigmapheno_y	9.50	9.28	9.43	9.50	9.57	9.71

Table 4: Summary of a joint model for stem specific density

	mean	X2.5.	X25.	X50.	X75.	X97.5.
mu_grand	0.01	-0.06	-0.01	0.01	0.04	0.09
b_tranE	0.08	-0.02	0.04	0.08	0.11	0.17
b_tranlat	-0.01	-0.25	-0.09	-0.01	0.07	0.23
muForceSp	-9.72	-11.59	-10.31	-9.72	-9.11	-7.93
muChillSp	-13.08	-16.19	-14.15	-13.07	-11.98	-9.83
muPhotoSp	-3.41	-4.42	-3.74	-3.41	-3.08	-2.43
muPhenoSp	27.07	24.19	26.12	27.05	28.00	29.97
betaTraitxForce	11.97	-0.40	7.94	12.05	16.18	23.83
betaTraitxChill	19.28	-2.72	12.24	19.70	26.84	39.36
betaTraitxPhoto	-4.10	-11.06	-6.74	-4.26	-1.59	3.50
sigma_traity	0.47	0.45	0.46	0.47	0.47	0.49
sigma_sp	0.16	0.12	0.14	0.16	0.18	0.21
sigmaForceSp	4.88	3.64	4.41	4.82	5.31	6.39
sigmaChillSp	8.84	6.61	7.93	8.75	9.69	11.56
sigmaPhotoSp	2.33	1.42	1.99	2.31	2.66	3.43
sigmaPhenoSp	9.72	7.89	8.98	9.64	10.36	12.08
sigmapheno_y	9.50	9.30	9.43	9.50	9.57	9.70

Table 5: Summary of a joint model for carbon to nitrogen ratio

	mean	X2.5.	X25.	X50.	X75.	X97.5.
mu_grand	0.29	0.18	0.26	0.29	0.33	0.41
b_tranE	0.30	0.21	0.27	0.30	0.33	0.39
b_tranlat	1.12	0.94	1.05	1.12	1.18	1.30
muForceSp	-11.17	-13.47	-11.96	-11.15	-10.39	-8.88
muChillSp	-15.74	-19.87	-17.16	-15.74	-14.34	-11.73
muPhotoSp	-3.67	-5.10	-4.15	-3.66	-3.18	-2.32
muPhenoSp	27.14	24.26	26.17	27.14	28.09	30.02
betaTraitxForce	5.69	0.19	3.78	5.73	7.69	11.14
betaTraitxChill	10.55	0.26	7.05	10.57	14.01	20.39
betaTraitxPhoto	0.69	-2.84	-0.51	0.66	1.85	4.40
sigma_traity	0.35	0.34	0.34	0.35	0.35	0.36
sigma_sp	0.32	0.26	0.29	0.32	0.34	0.41
sigmaForceSp	5.00	3.87	4.54	4.96	5.40	6.47
sigmaChillSp	9.07	6.94	8.23	8.97	9.84	11.72
sigmaPhotoSp	2.47	1.57	2.13	2.44	2.78	3.54
sigmaPhenoSp	9.69	7.92	8.97	9.60	10.34	11.93
sigmapheno_y	9.50	9.30	9.43	9.50	9.57	9.71