Pieris virginiensis progress report 06

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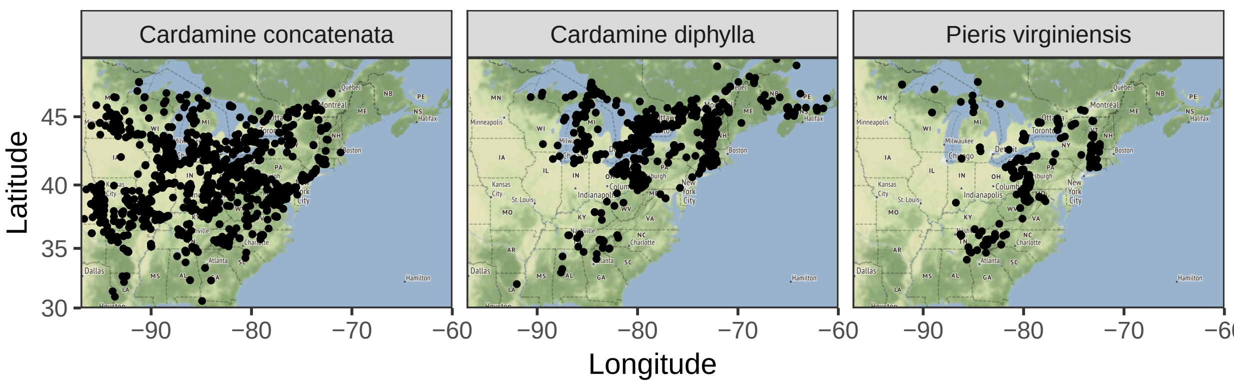
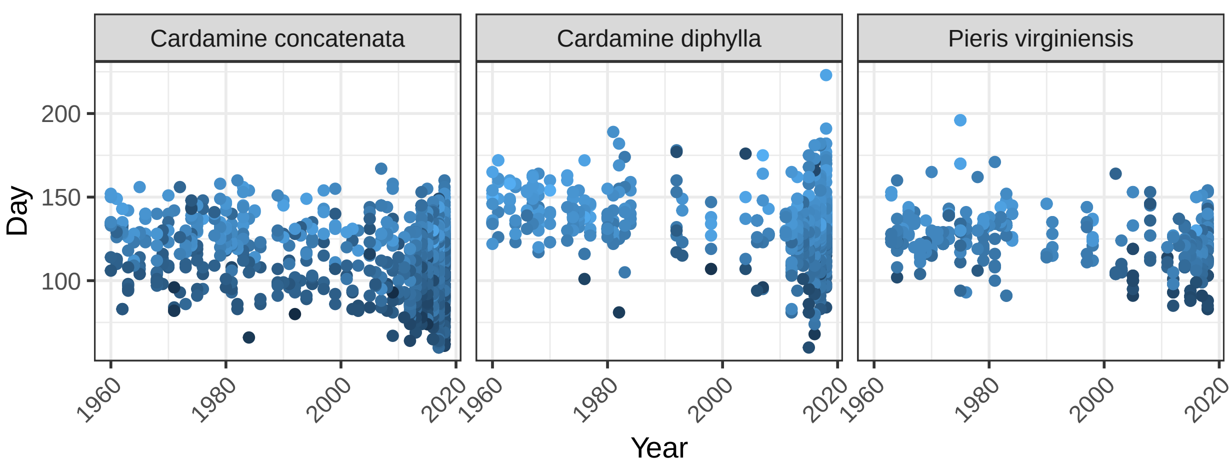
Retrieval from iNaturalist and GBIF returned 3369 total observations.

Following date and sample size filtering, observation counts for species:

- *Pieris virginiensis*: 544 observations
- *Cardamine concatenata*: 1963 observations
- *Cardamine diphylla*: 862 observations

Observations for 1960 - 2018 (total of 3369 observations following date and sample size filtering):





Note in lower plot, **darker** points are from lower latitudes, while **lighter** points are from higher latitudes.

Models allowing species x latitude interactions

Previous models only included species x year interactions, but since these things all have different altitudinal ranges, would be useful to include that interaction as well.

$$Julian\ day = \beta_0 + \beta_1 Year + \beta_2 Latitude + \beta_3 Species + \beta_4 Year \times Species + \beta_5 Latitude \times Species$$

Expanding *Species* because there are *three* levels, this becomes:

However, because there are **three** levels to *Species*, a more accurate representation of this model would be

$$Julian\ day = \beta_0 + \beta_1 Year + \beta_2 Latitude + \beta_3 concatenata + \beta_4 diphylla + \beta_5 Year \times concatenata + \beta_6 Year \times diphylla + \beta_7 Latitude \times c$$

(so long as *P. virginensis* is reference).

The model for *P. virginensis* remains the same:

$$Julian\ day = \beta_0 + \beta_1 Year + \beta_2 Latitude$$

And rearranging:

$$Julian\ day = \beta_0 + \beta_2 Latitude + \beta_1 Year$$

For a single value of *Latitude*, the first two terms constitute the intercept ($\beta_0 + \beta_2 Latitude$) and the last coefficient is the slope (β_1).

For the host lines, there are two models, one for each species of host. For *C. concatenata*:

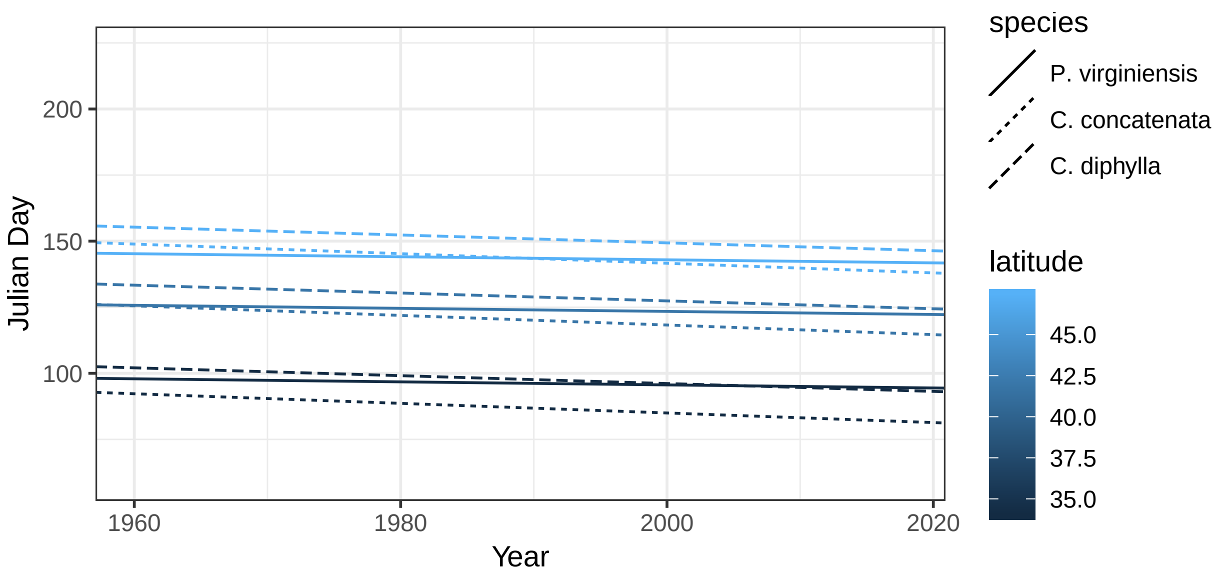
$$Julian\ day = \beta_0 + \beta_1 Year + \beta_2 Latitude + \beta_3 + \beta_5 Year + \beta_7 Latitude$$

Rearranging:

$$Julian\ day = \beta_0 + \beta_3 + (\beta_1 + \beta_5) Year + (\beta_2 + \beta_7) Latitude$$

So for a single value of *Latitude*, the model for *C. concatenata* has an intercept of $\beta_0 + \beta_3 + (\beta_2 + \beta_7) Latitude$ and a slope of β_1 and β_5.

Similarly, the model for *C. diphylla* can be simplified to an intercept of $\beta_0 + \beta_4 + (\beta_2 + \beta_8) Latitude$ and a slope of $\beta_1 + \beta_6$.



Considering the slopes, we see that controlling for latitude, observations are getting earlier, but the change is happening faster in the host plants than in *P. virginiensis*:

Species	Change
P. virginiensis	0.058 days/year
C. concatenata	0.182 days/year
C. diphylla	0.149 days/year