

# Changes in Phenology of Flowering, Correlation with Climate Variability, and Response of Honeybees

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# Motivation

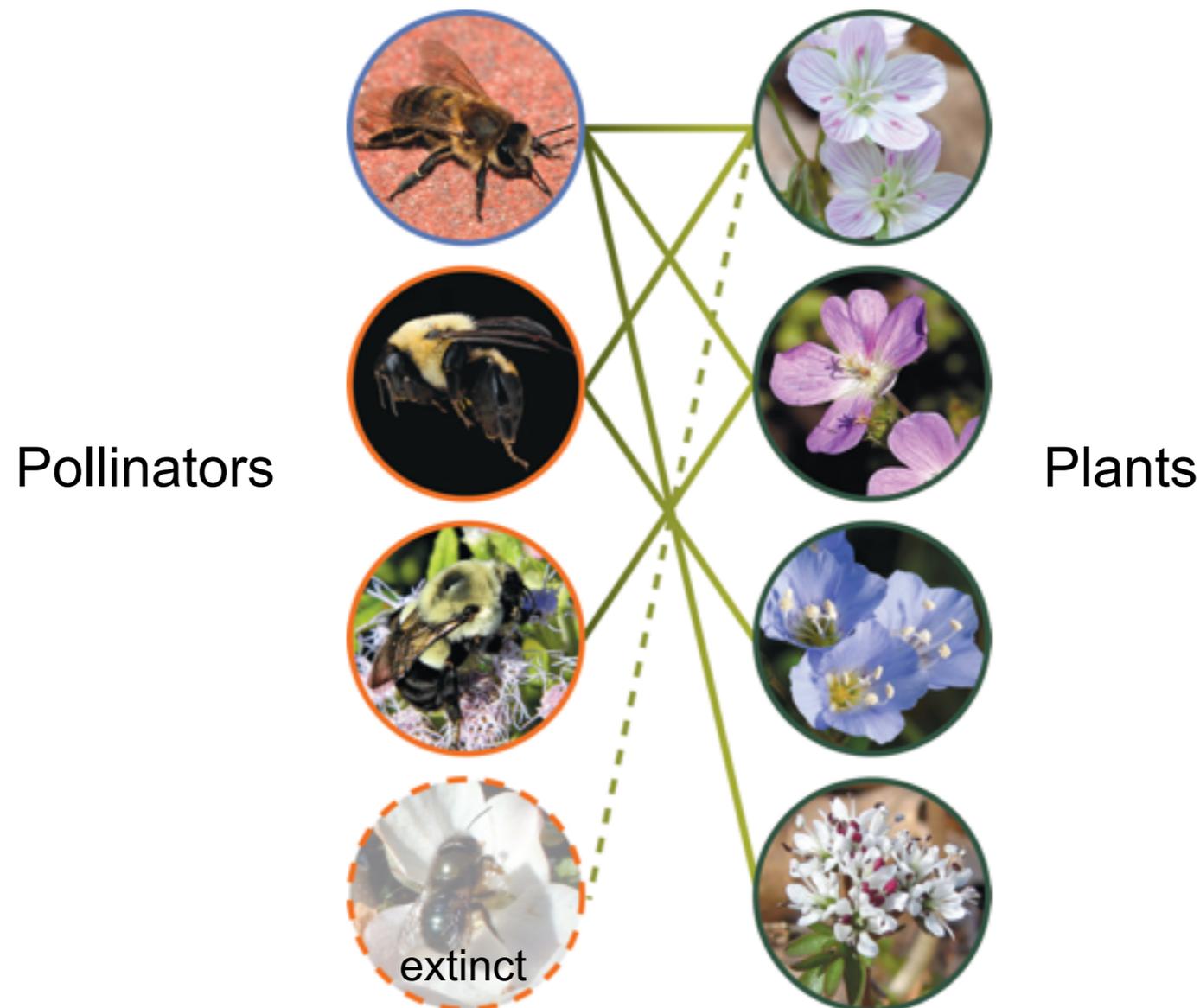
- Plant-pollinator networks are being disrupted by climate change, intensive agriculture, landscape alteration, invasive species, and spread of pathogens

(Gonzalez-Varo, 2013)

- 35% of global food crops rely on animal pollinators

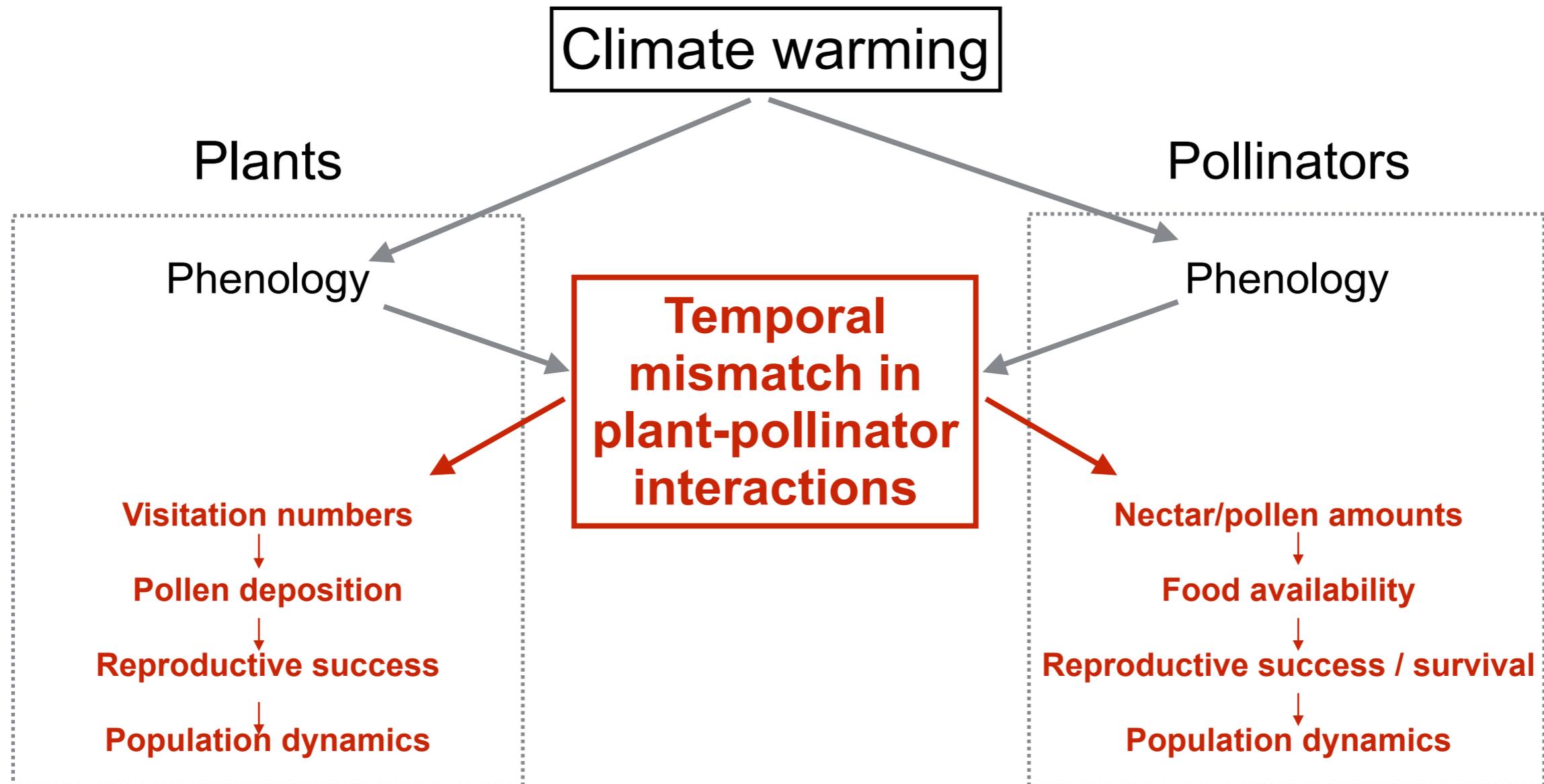


(Wikimedia Commons)



(Tylianakis, 2013)

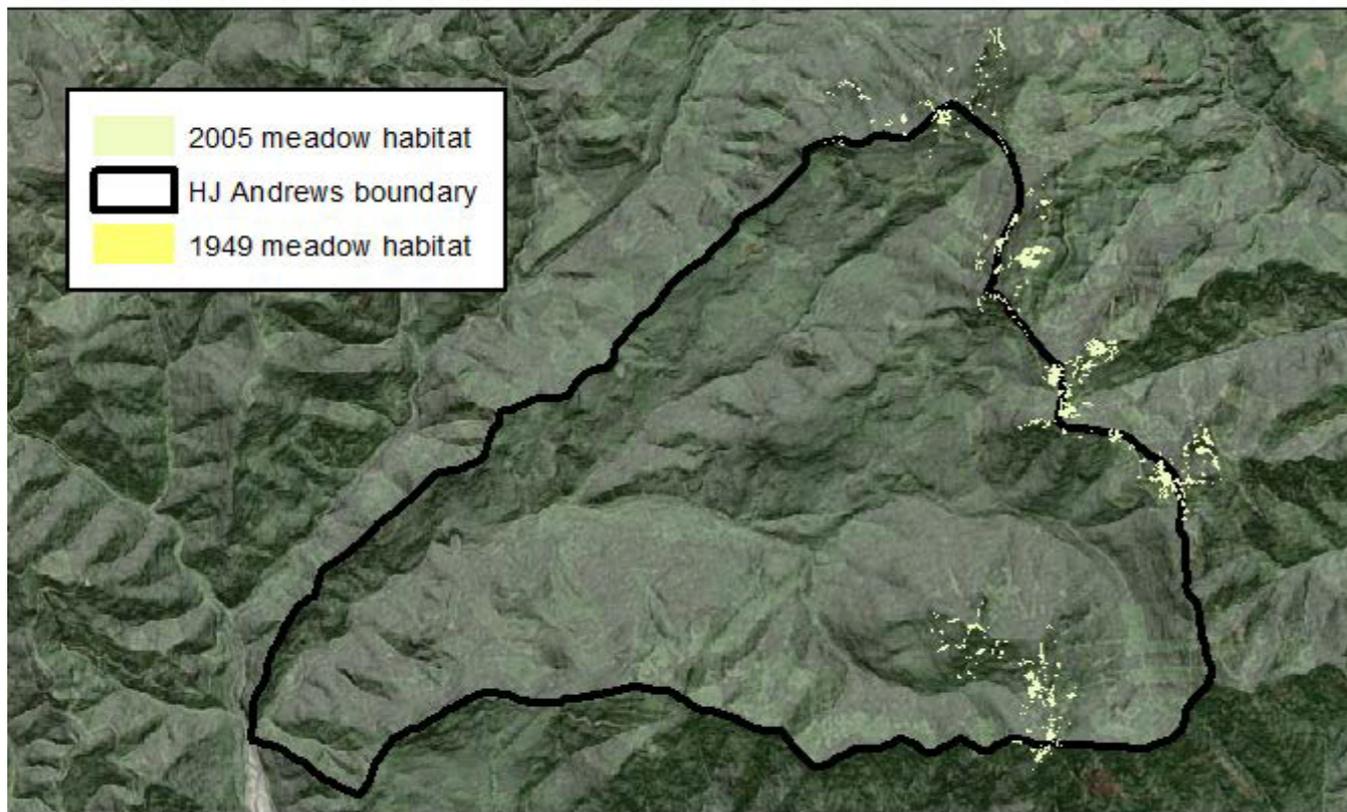
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# Study Site

HJ Andrews Experimental Forest in the Western Cascades of Oregon

12 montane meadows

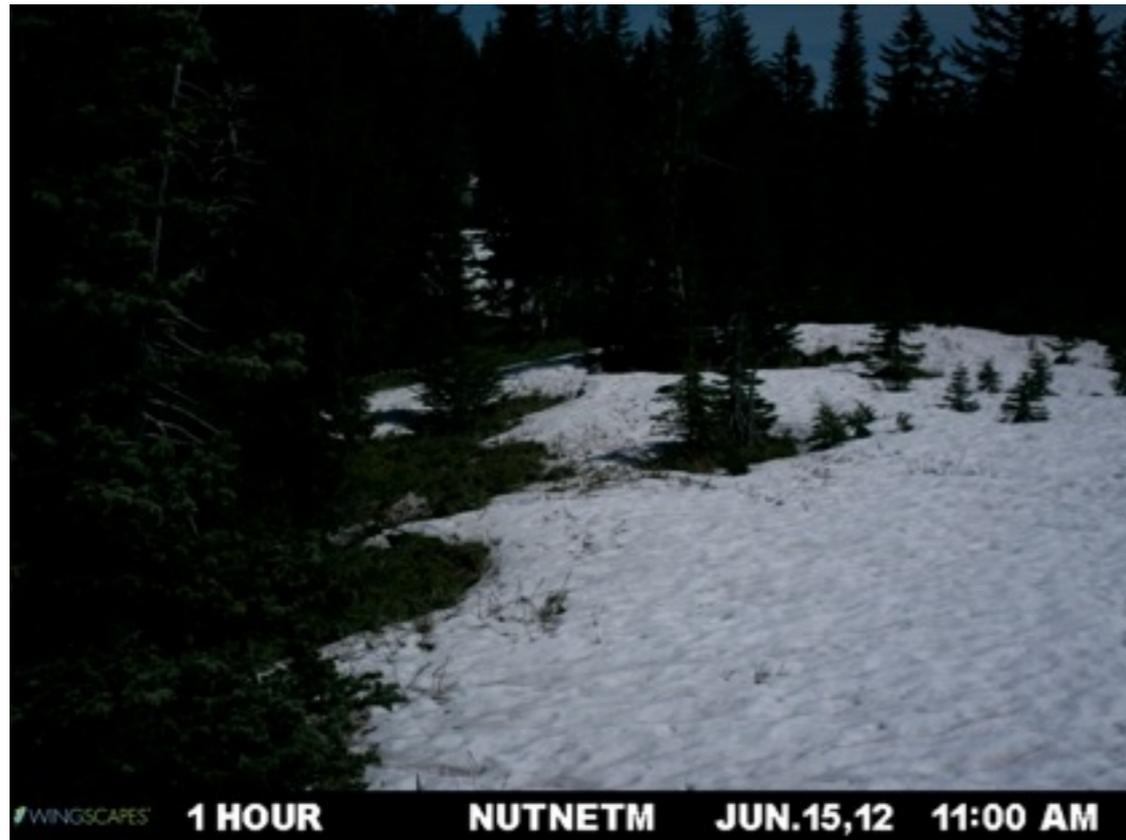


*Image from Edward Helderop*



*Upper Lookout Mountain. Photograph by Al Levno*

# Research Questions



June 15, 2012



June 15, 2015

- 1) How has the timing of flowering in montane meadows in the Andrews Forest responded to climate variability?
- 2) Have changes in timing of flowering created asynchrony with pollinator activity?

# Field Methods

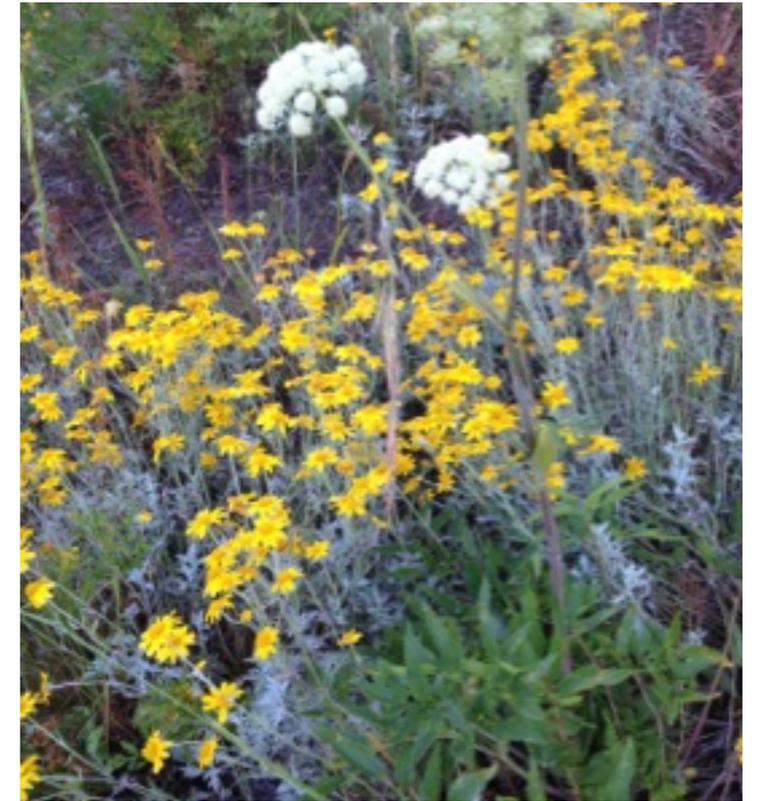
- Each meadow divided into ten 3x3 m plots
- Data collected for 5-7 weekly watches each summer



# Data Used

## 1) Flower Surveys

- Records of each plant species and its flower abundance in a plot



## 2) Plant-Pollinator Interactions

- Observations of the interactions between plant species and pollinator species that occurred during a 15-minute watch of a plot



Photo by John Severns

# Computational Methods

1. **Estimates of flower timing** for each meadow and species: first, peak, and last flowering

\* Used top 24 flower species with sufficient data for estimates

2. **Climate characteristics** for each year:

❄ Last day of snowpack

☀ Cumulative degree days March 1 to June 1

$$DD_d = (T_{\max} - T_{\min})/2 - 5$$

💧 Avg Antecedent Precipitation Index May 1 to June 1 (a proxy for soil moisture)

$$API_d = P_d + 0.9 * API_{d-1}$$

3. **Honeybee Activity:**

- Estimated the timing of peak # interactions between *Apis mellifera* and *Eriophyllum lanatum*

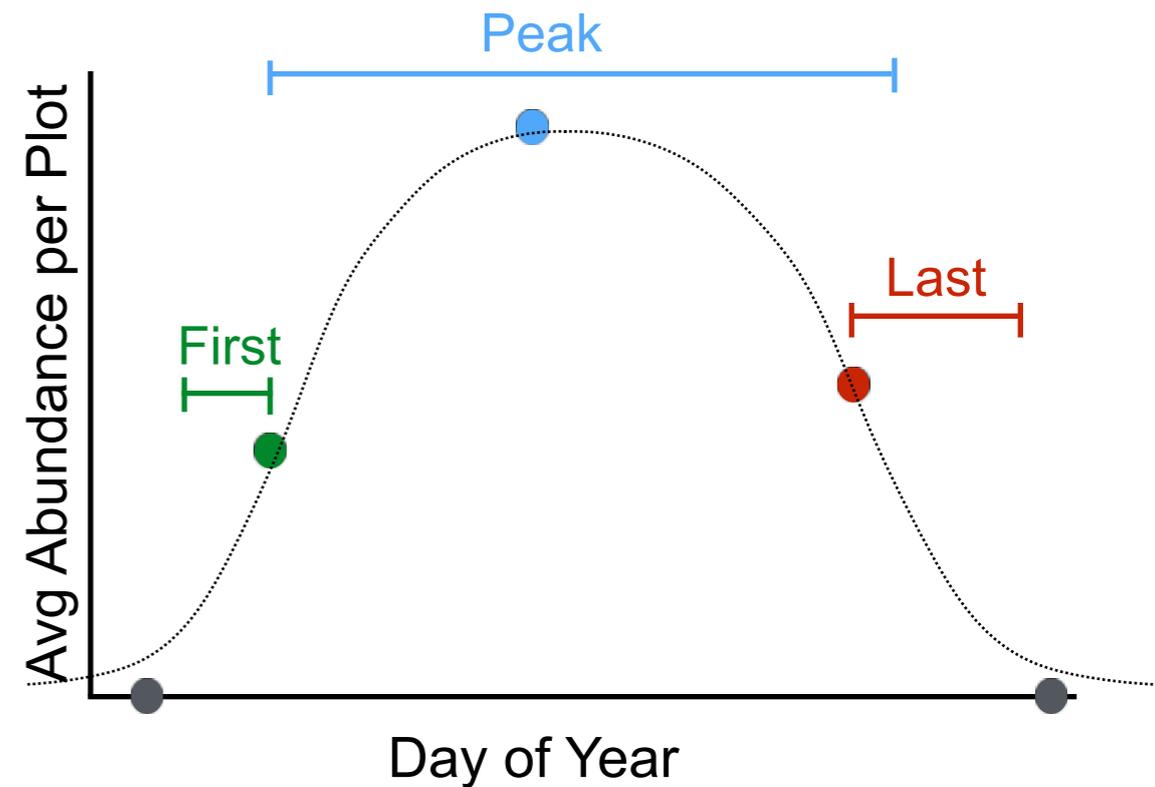


Photo from Emelie

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$$DD_d = (T_{\max} - T_{\min})/2 - 5 \quad (=0 \text{ if negative})$$

💧 Avg Antecedent Precipitation Index May 1 to June 1 (a proxy for soil moisture)

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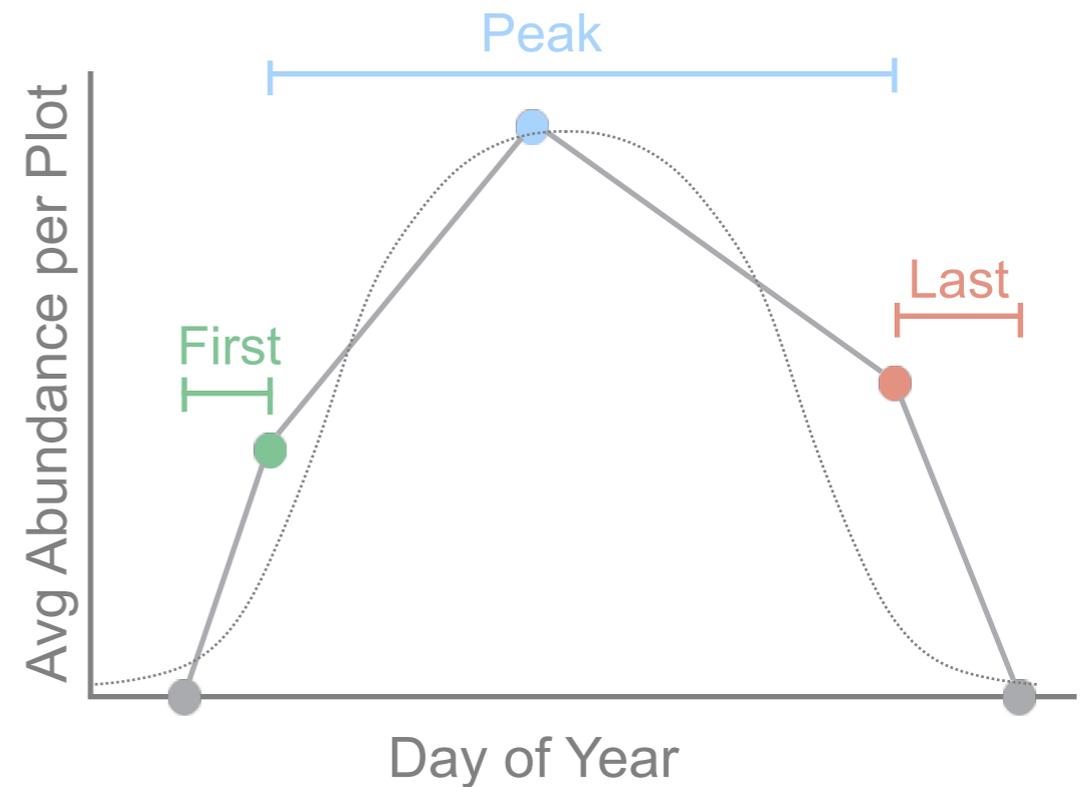


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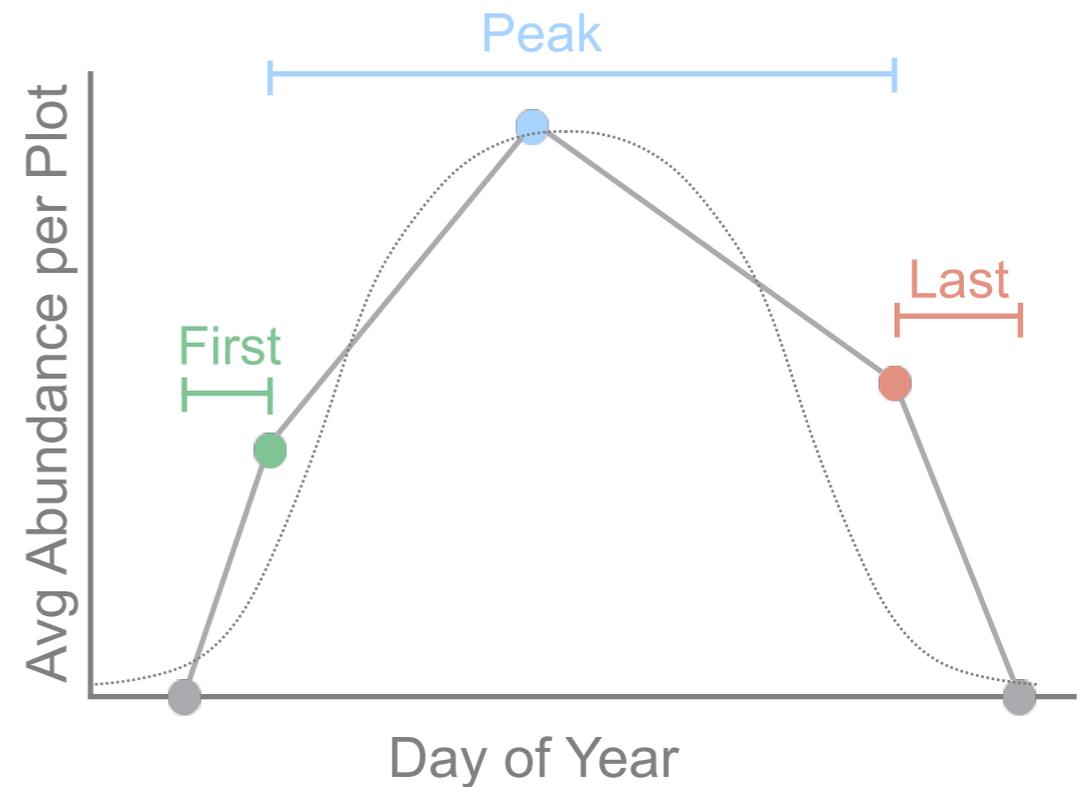


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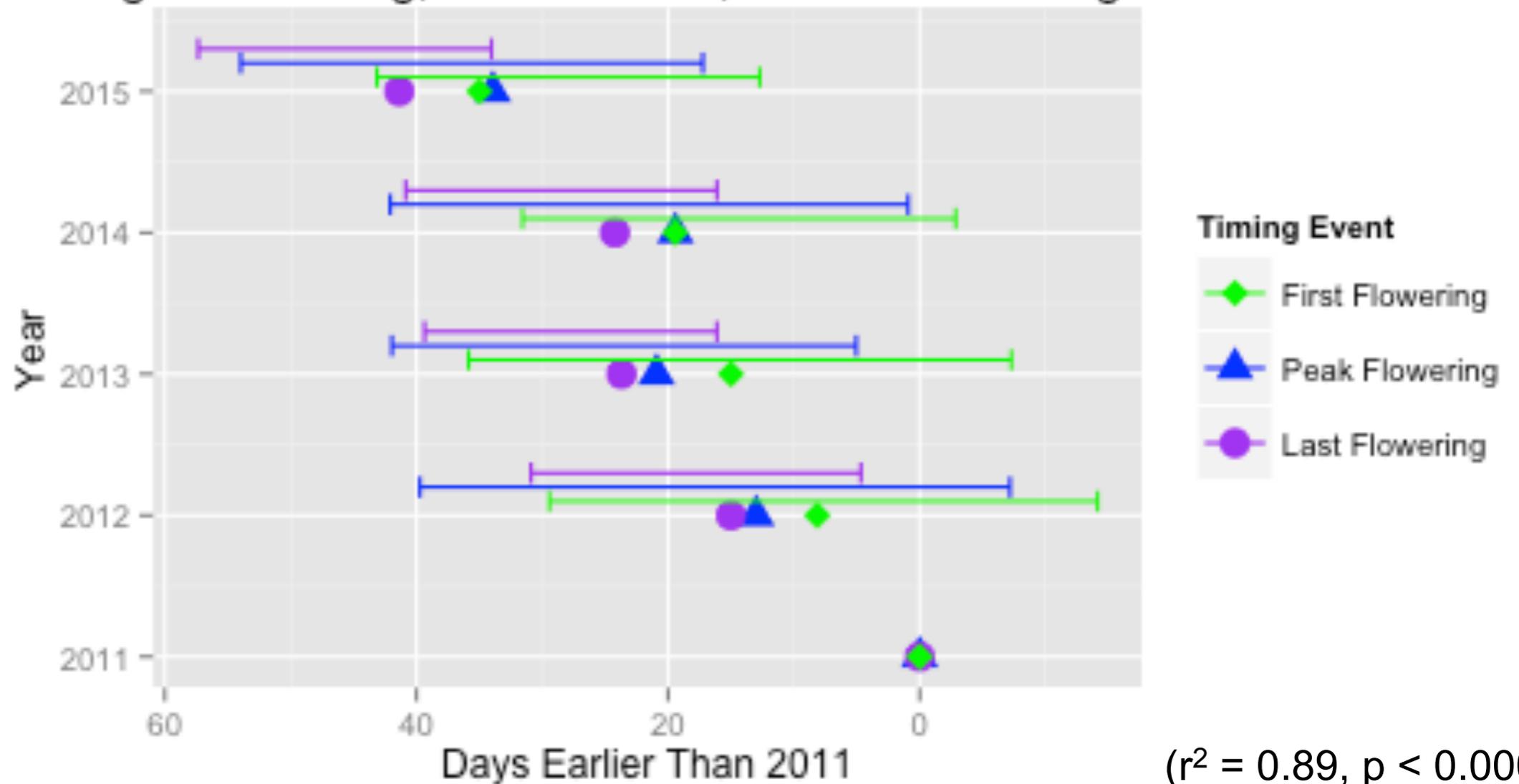
# Results

## 1) Timing of flowering shifted earlier over time

On average, timing of flowering in 2015 was 37 days earlier than in 2011

(uncertainty range: 21 - 52 days earlier than 2011)

Timing of Flowering, 2011 to 2015, Relative to Timing in 2011



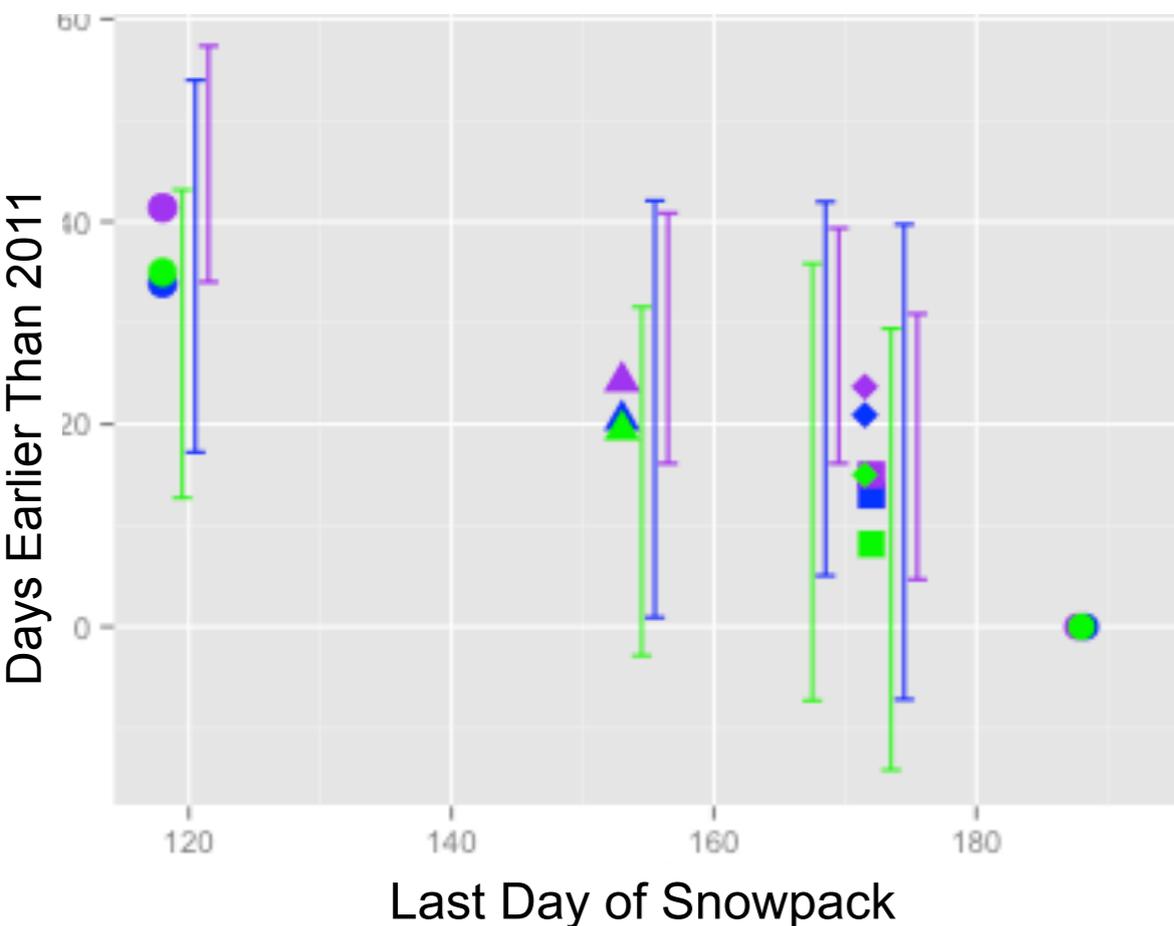
( $r^2 = 0.89$ ,  $p < 0.0001$ )

( $r^2 = 0.78$  when not averaged)

# Results

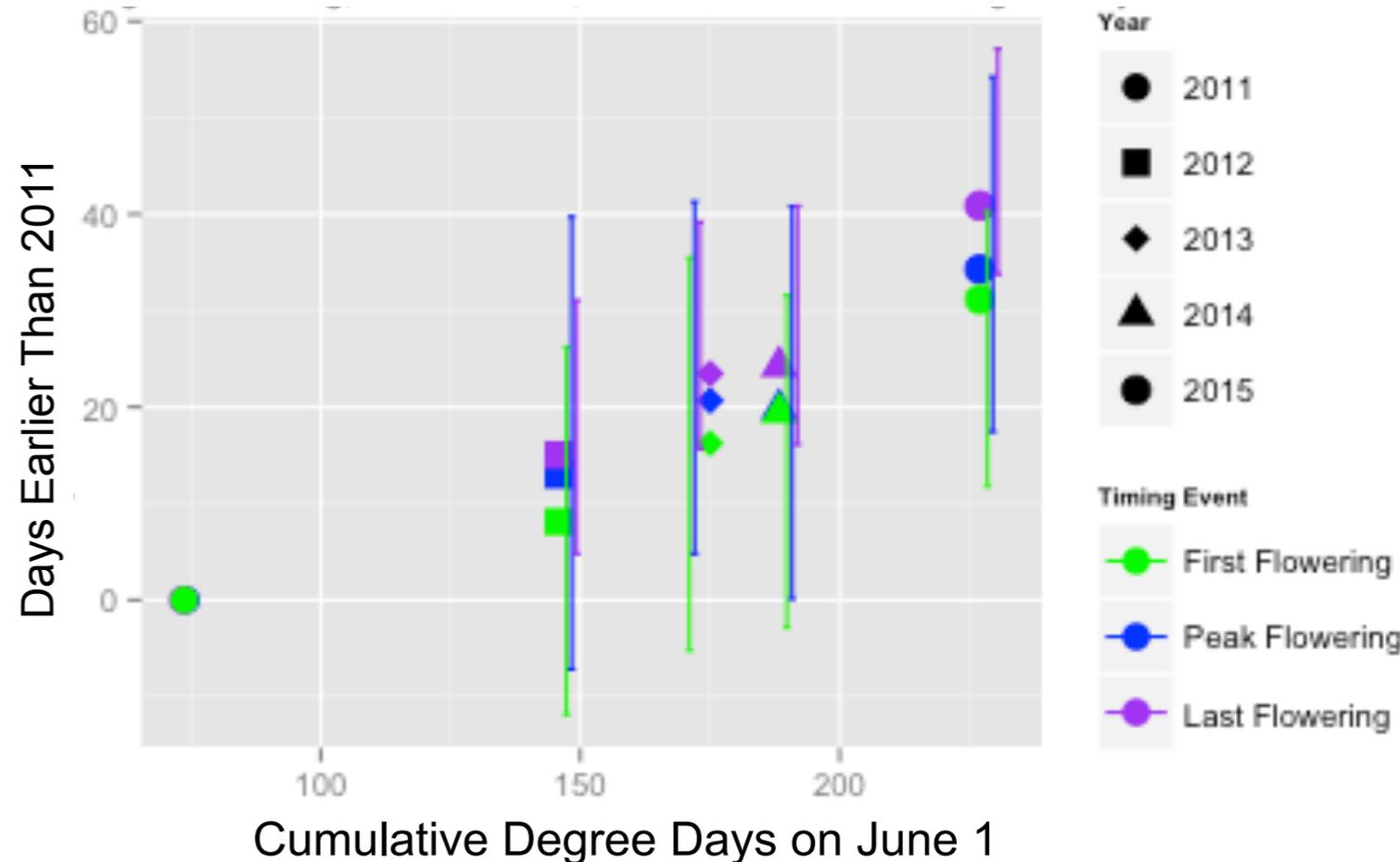
2a) The earlier the snowmelt and the higher the cumulative degree days, the earlier the timing of flowering

Timing of Flowering, 2011 to 2015,  
as a Function of Snowmelt



( $r^2 = 0.85$ ,  $p < 0.0001$ )  
( $r^2 = 0.69$  when not averaged)

Timing of Flowering, 2011 to 2015,  
as a Function of Cumulative Degree Days

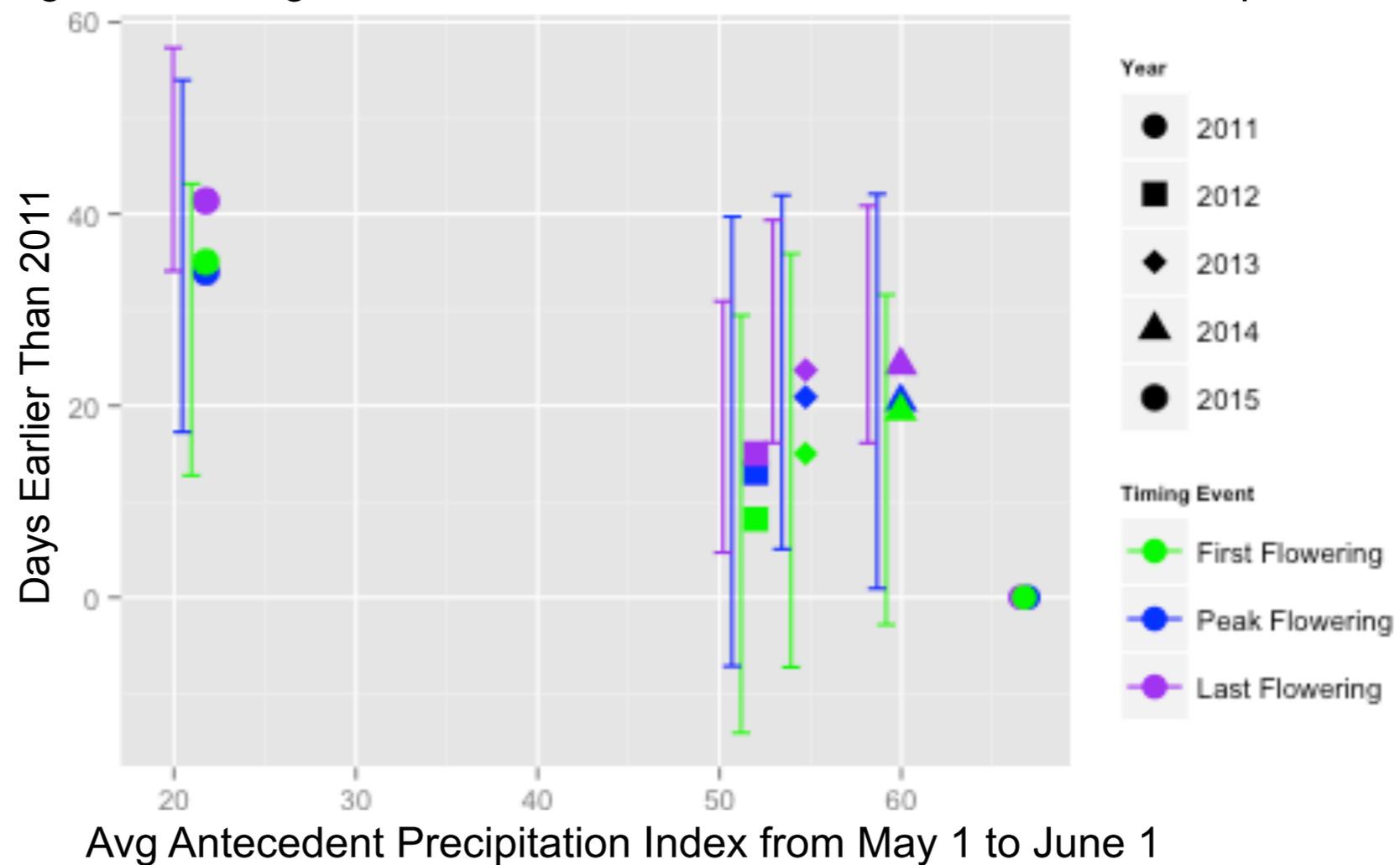


( $r^2 = 0.91$ ,  $p < 0.0001$ )  
( $r^2 = 0.62$  when not averaged)

# Results

## 2b) Timing of flowering was not as highly correlated with antecedent precipitation (soil moisture)

Timing of Flowering, 2011 to 2015, as a Function of Antecedent Precipitation



$$(r^2 = 0.70, p < 0.0001)$$

$$(r^2 = 0.62 \text{ when not averaged})$$

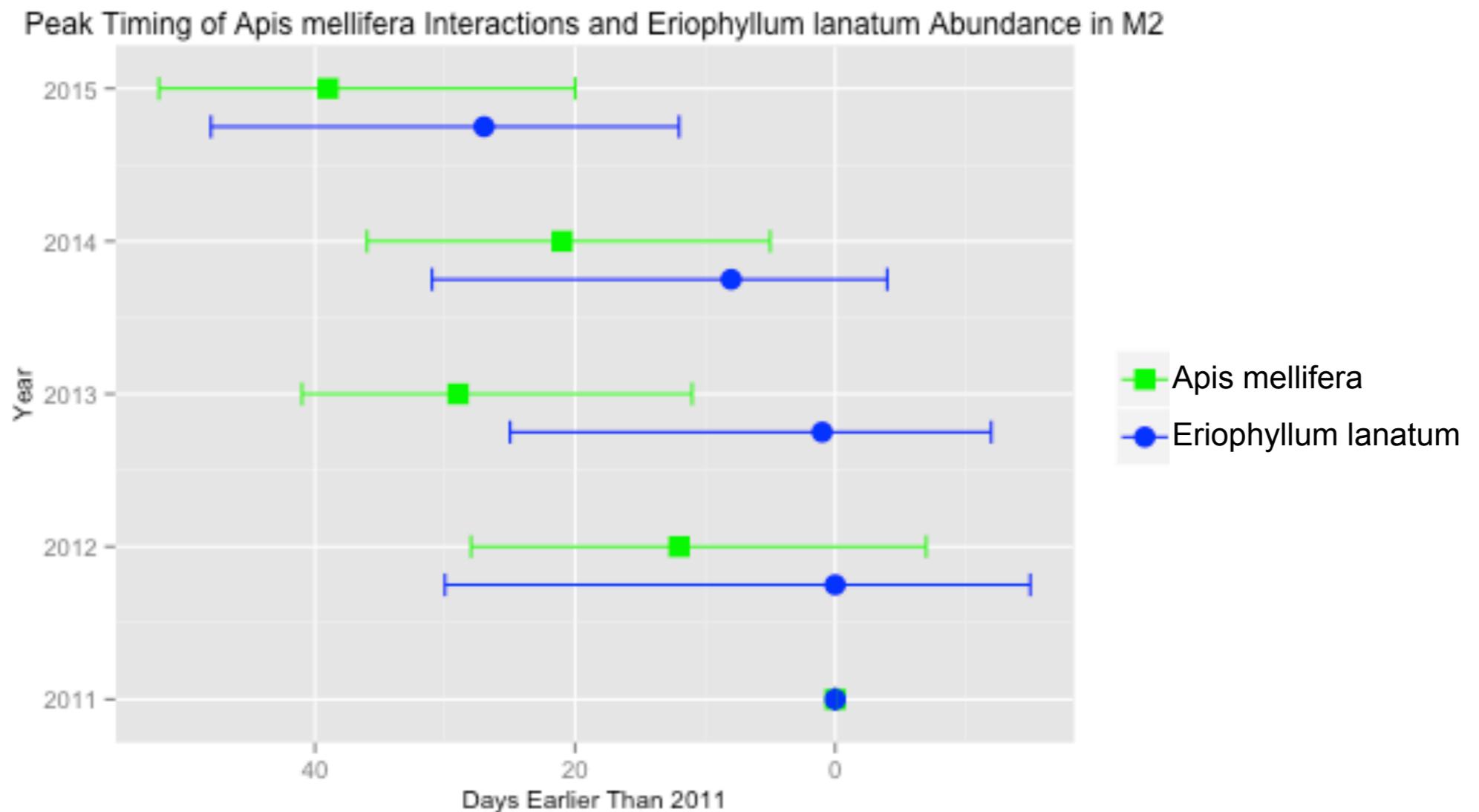
# Results

## 3) Flower visitations by *Apis mellifera* shifted in response to changes in timing of flowering of *Eriophyllum lanatum*

Timing of peak flowering in 2015 was 27 days earlier than 2011

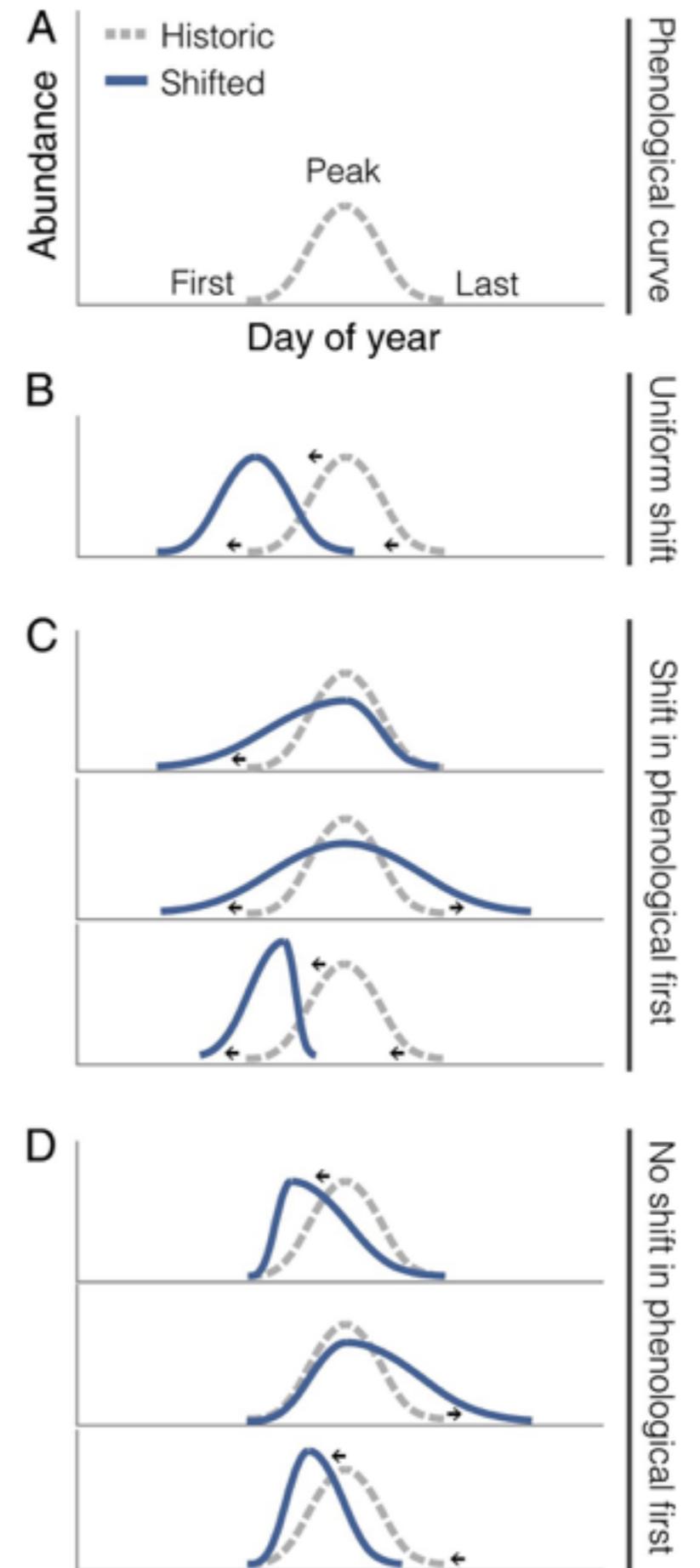
Timing of peak interactions was 39 days earlier than 2011

(uncertainty range: 12 to 48 days for flowering, 20 to 52 for interactions)



# Discussion

- Timing of flowering did shift earlier over time, but first, peak, and last flowering did not shift uniformly or consistently from year to year
- Snowmelt and cumulative degree days are the most significant explanatory variables and are probably highly correlated with each other
- *Apis mellifera* interactions have shifted earlier over time. But in response to changes in flower timing or to changes in climate, or both?
- Room for improvement:
  - Only five years of data
  - Fewer estimates for 2015 first flowering
  - Uncertainty intervals for flower timing were at least a week (time between data collection dates)
  - Climate data not at study meadows



(Diagram from CaraDonna, 2014)

# Discussion

- Timing of flowering did shift earlier over time, but first, peak, and last flowering did not shift uniformly or consistently from year to year
- Snowmelt and cumulative degree days are the most significant explanatory variables, and snowmelt is probably dependent on cumulative degree days
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# Conclusion

Climate warming

Degree days

Timing of snowmelt

Soil moisture

Plants

Pollinators

Phenology

Phenology

Temporal mismatch in plant-pollinator interactions

Visitation numbers

Pollen deposition

Reproductive success

Population dynamics

Nectar/pollen amounts

Food availability

Reproductive success / survival

Population dynamics

(Adapted from Hegland, 2009)

# Future Work

- Compare different responses in plants depending on life cycle (annual vs perennial, bulb above ground vs under ground)
- Changes in health of pollinator individuals and populations
  - Because of changes in climate or flowering phenology?
- Changes in quality of pollination
- Are specialist pollinator species less able to adapt to changes in flowering?



# Implications

- Can help inform policy to preserve plant-pollinator networks
  - **Pollinator biodiversity** buffers networks against negative effects of climate change
    - Honeybees can fill in pollination gaps - broad diets, long flight ranges, long foraging seasons
    - Wild bees also important because of differential responses to environmental changes

(Gonzalez 2013,  
Brittain 2012)



# Acknowledgements

- \* Eco-Informatics Summer Institute (OSU)

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- \* HJ Andrews Experimental Forest

- \* Natural Resources Conservation Service for data on snow depth

# Questions?

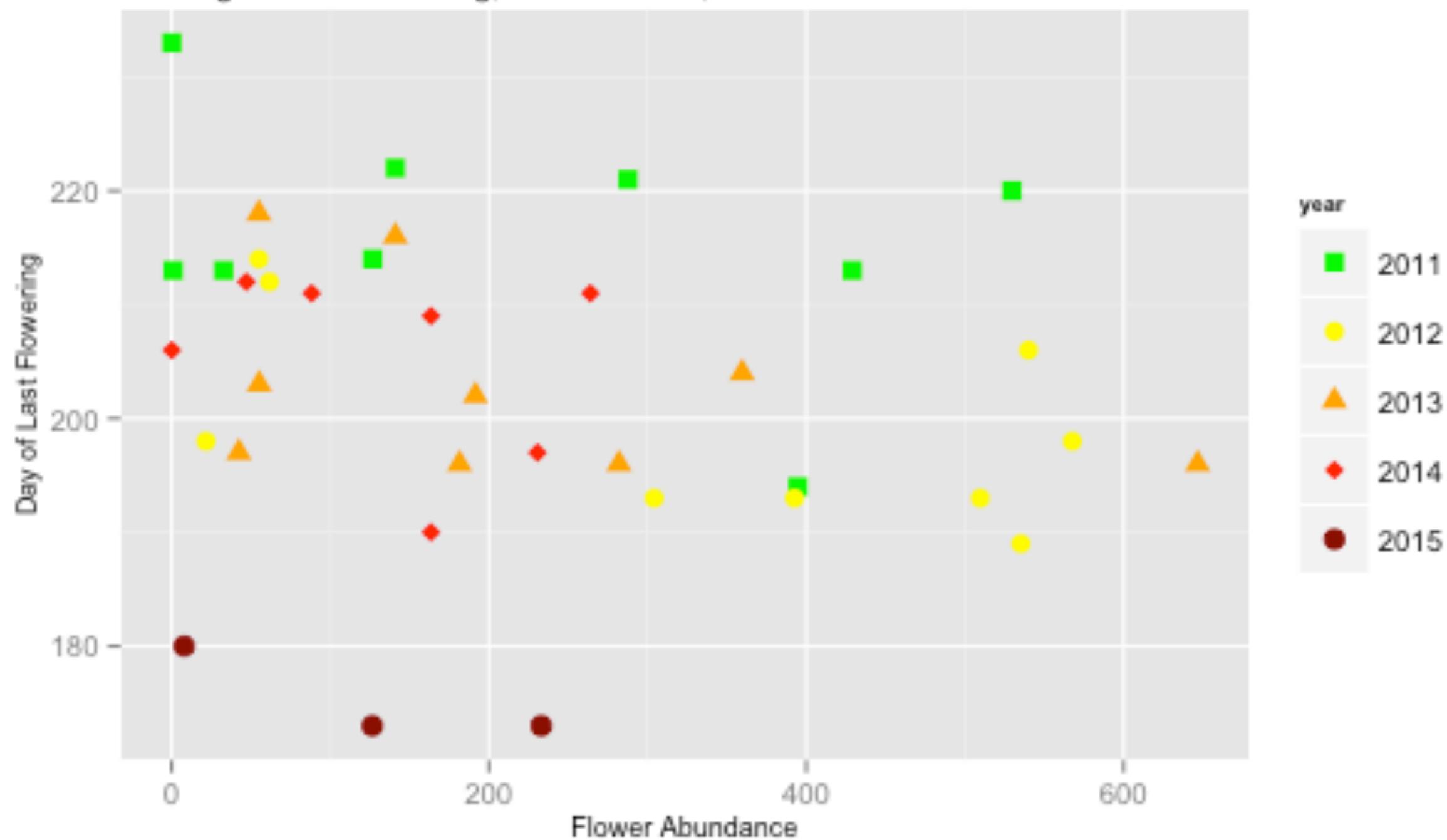


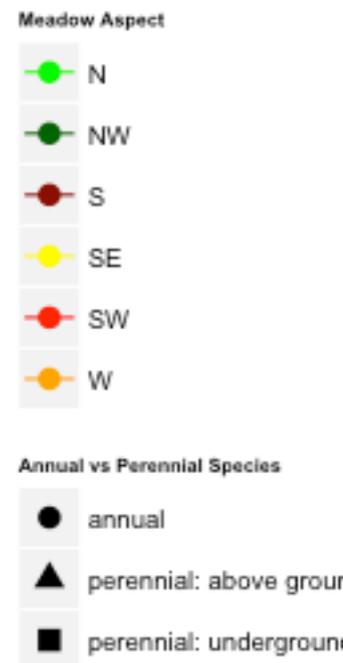
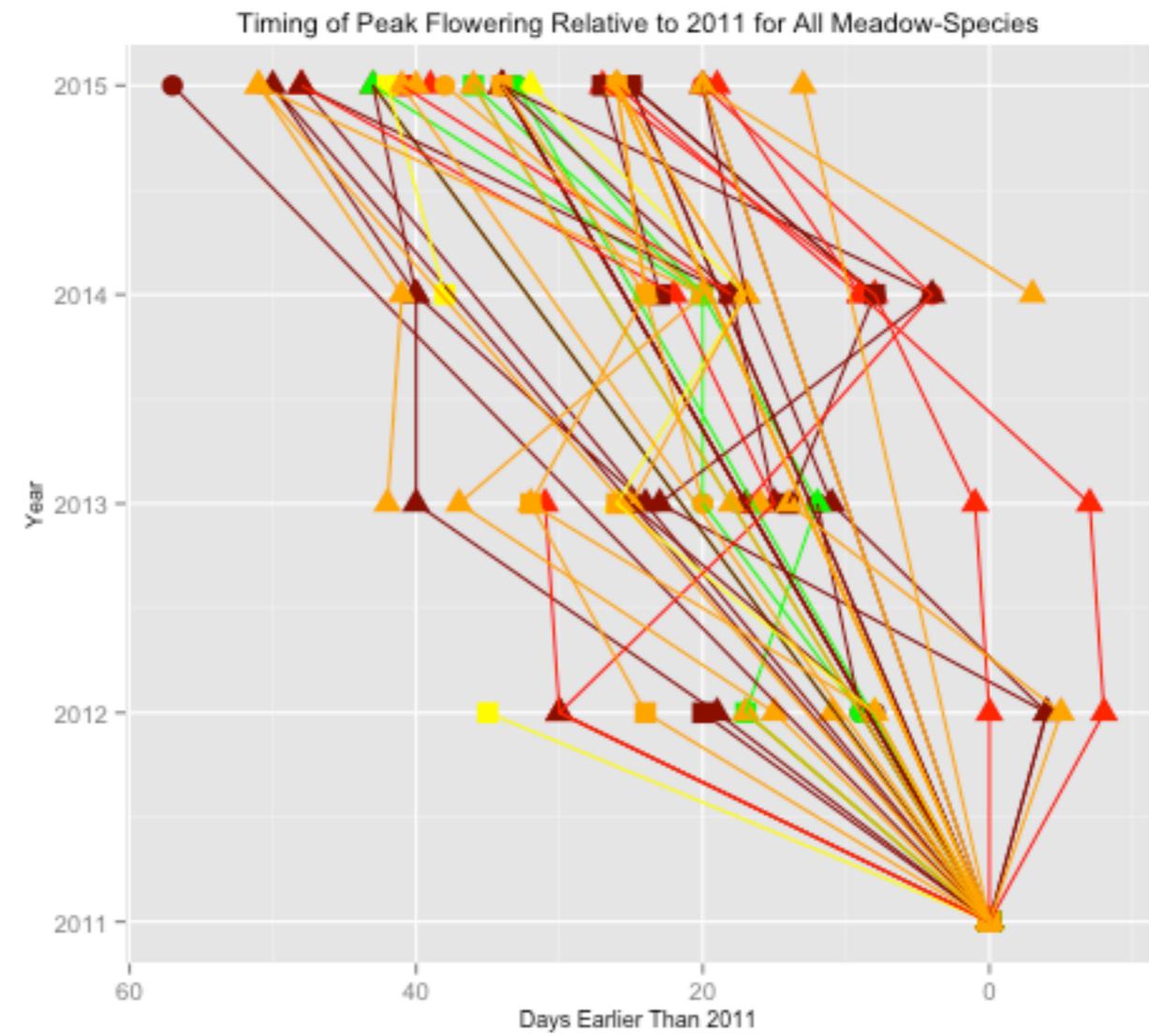
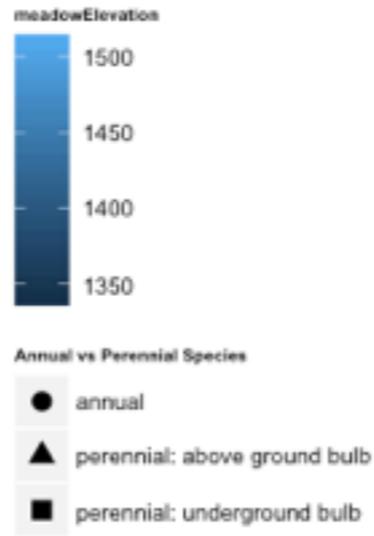
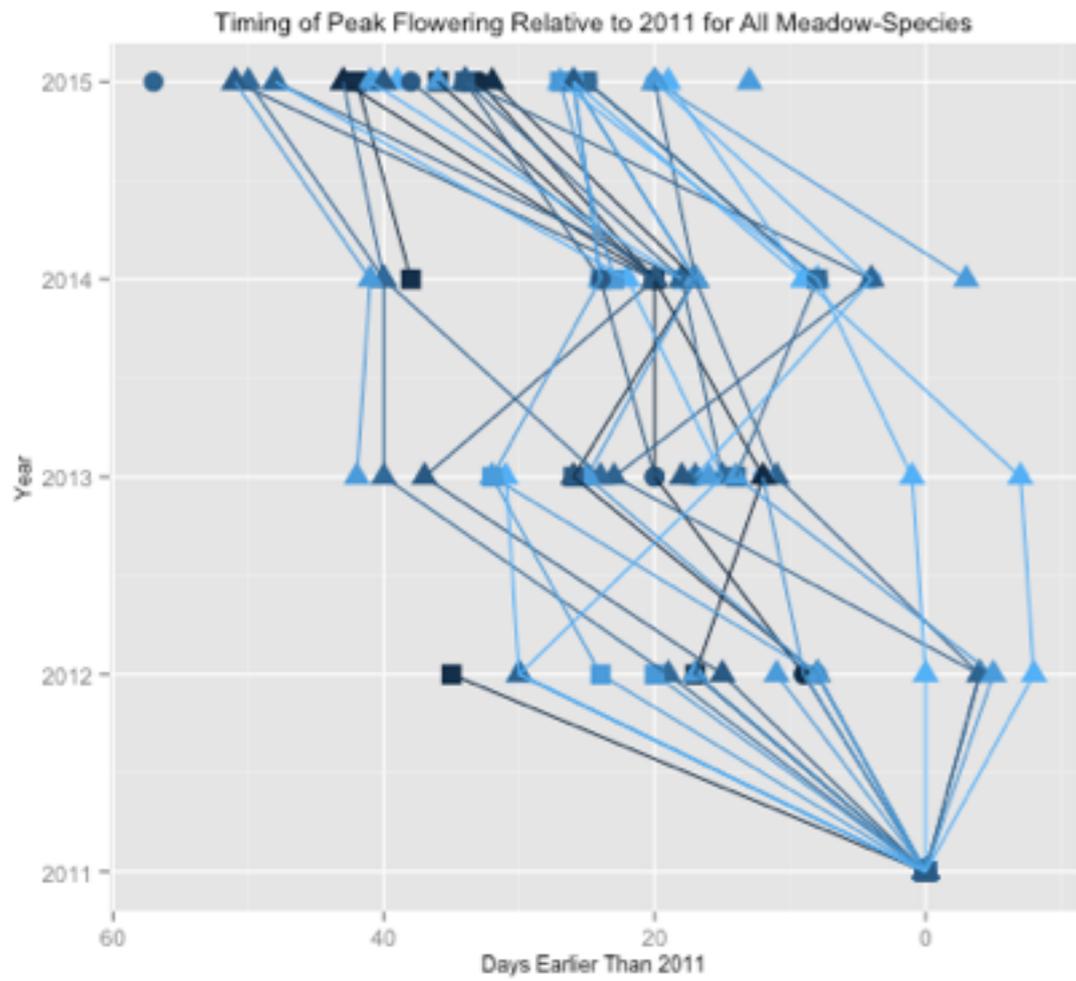
(Photo from Emelie)

# Supplementary Materials

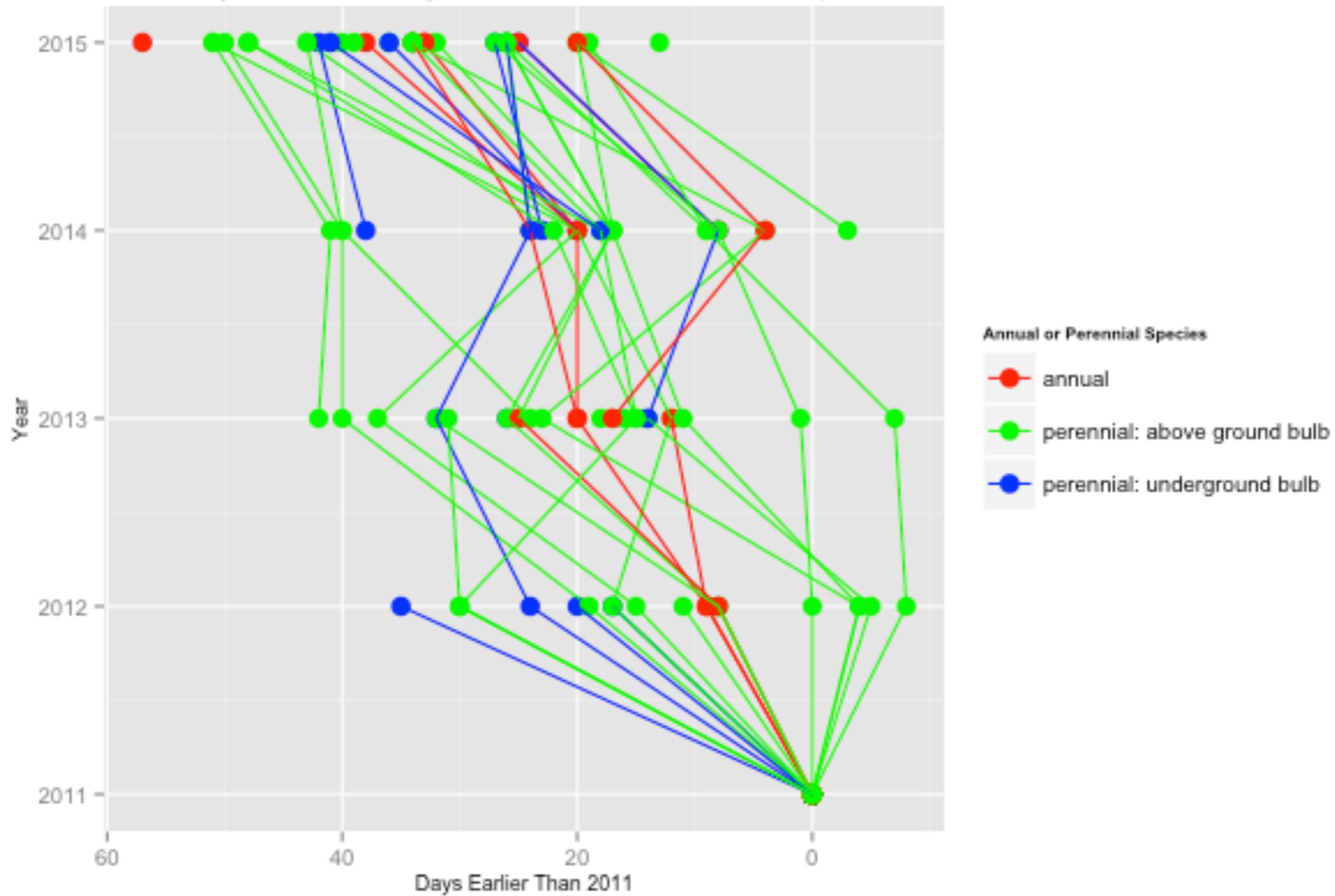
- **First flowering**
  - **7 meadow-species, 4 plant species**
    - *Eriogonum nudum*, *Erigeron foliosus*, *Hypericum perforatum*, *Eriogonum compositum*
- **Peak flowering**
  - **29 meadow-species, 12 plant species**
    - *Achillea millefolium*, *Eriophyllum lanatum*, *Orthocarpus imbricatus*, *Erigeron foliosus*, *Potentilla gracilis*, *Eriogonum compositum*, *Eriogonum nudum*, *Rumex acetosella*, *Vicia americana*, *Montia parvifolia*, *Lupinus laxiflorus*, *Eriogonum umbellatum*
- **Last flowering**
  - **52 meadow-species, 20 plant species**
    - *Gilia capitata*, *Castilleja hispida*, *Phlox gracilis*, *Delphinium nuttallianum*, *Ligusticum grayi*, *Rumex acetosella*, *Vicia americana*, *Potentilla gracilis*, *Erysimum asperum*, *Eriophyllum lanatum*, *Lupinus laxiflorus*, *Eriogonum compositum*, *Calochortus subalpinus*, *Collinsia parviflora*, *Montia parvifolia*, *Achillea millefolium*, *Erigeron foliosus*, *Sedum oreganum*, *Penstemon procerus*, *Mimulus guttatus*

Timing of Last Flowering, 2011 to 2015, as a Function of Flower Abundance

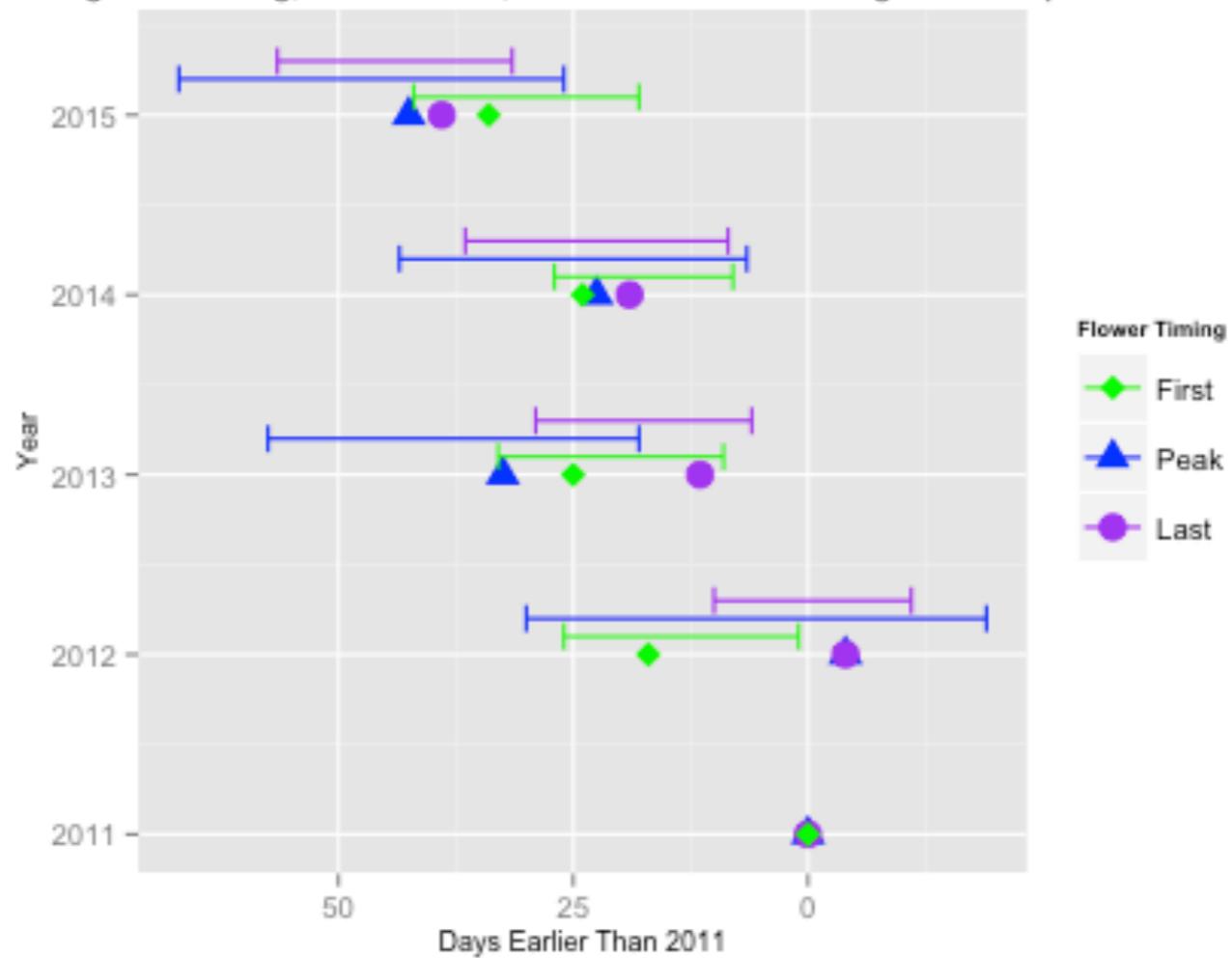




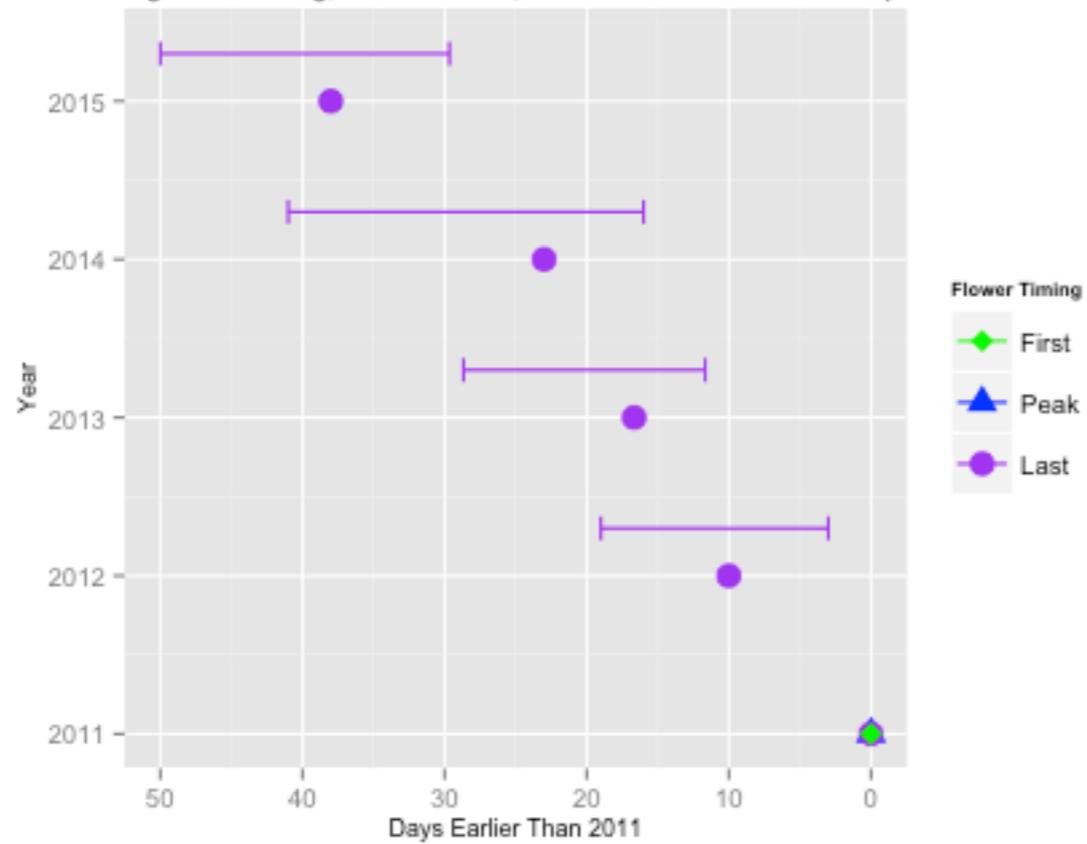
Timing of Peak Flowering Relative to 2011 for All Meadow-Species



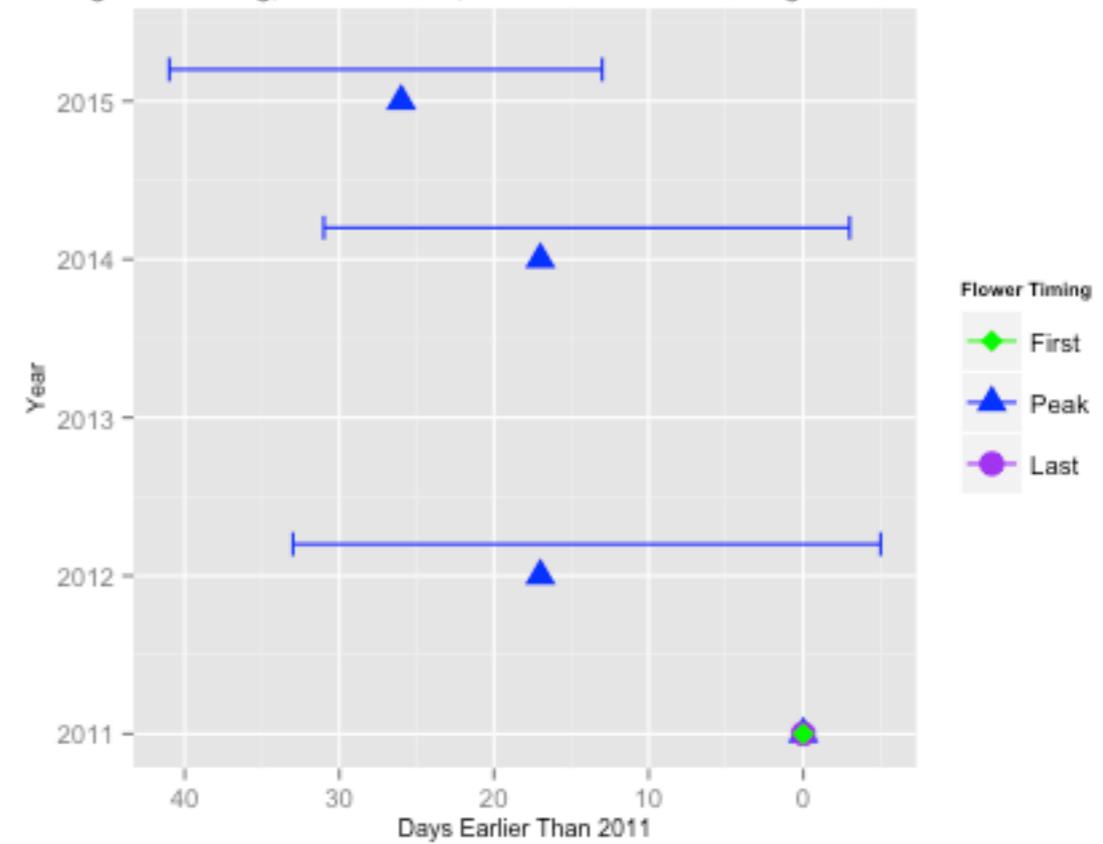
Timing of Flowering, 2011 to 2015, Relative to 2011 for *Eriogonum compositum*



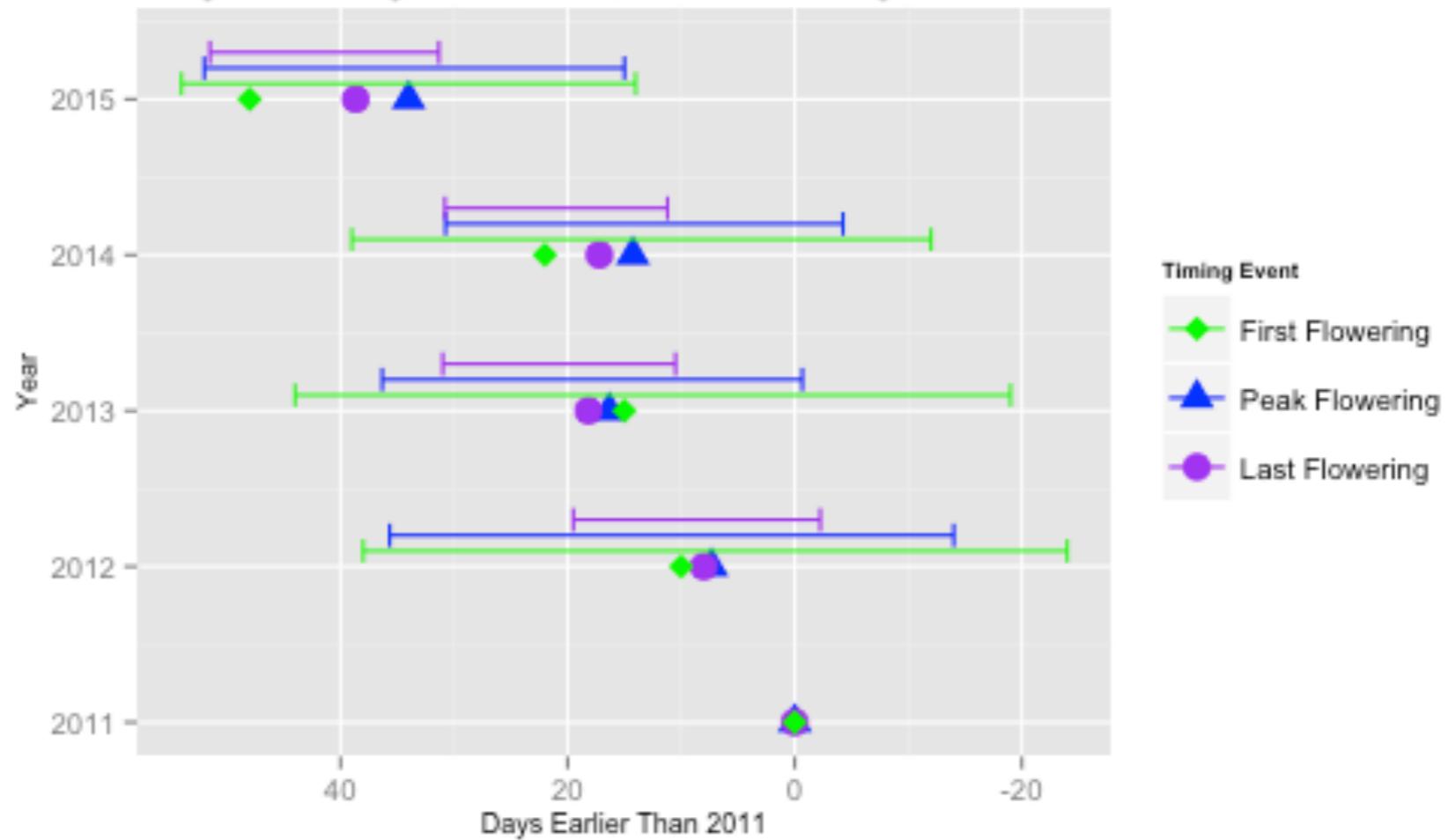
Timing of Flowering, 2011 to 2015, Relative to 2011 for *Gilia capitata*



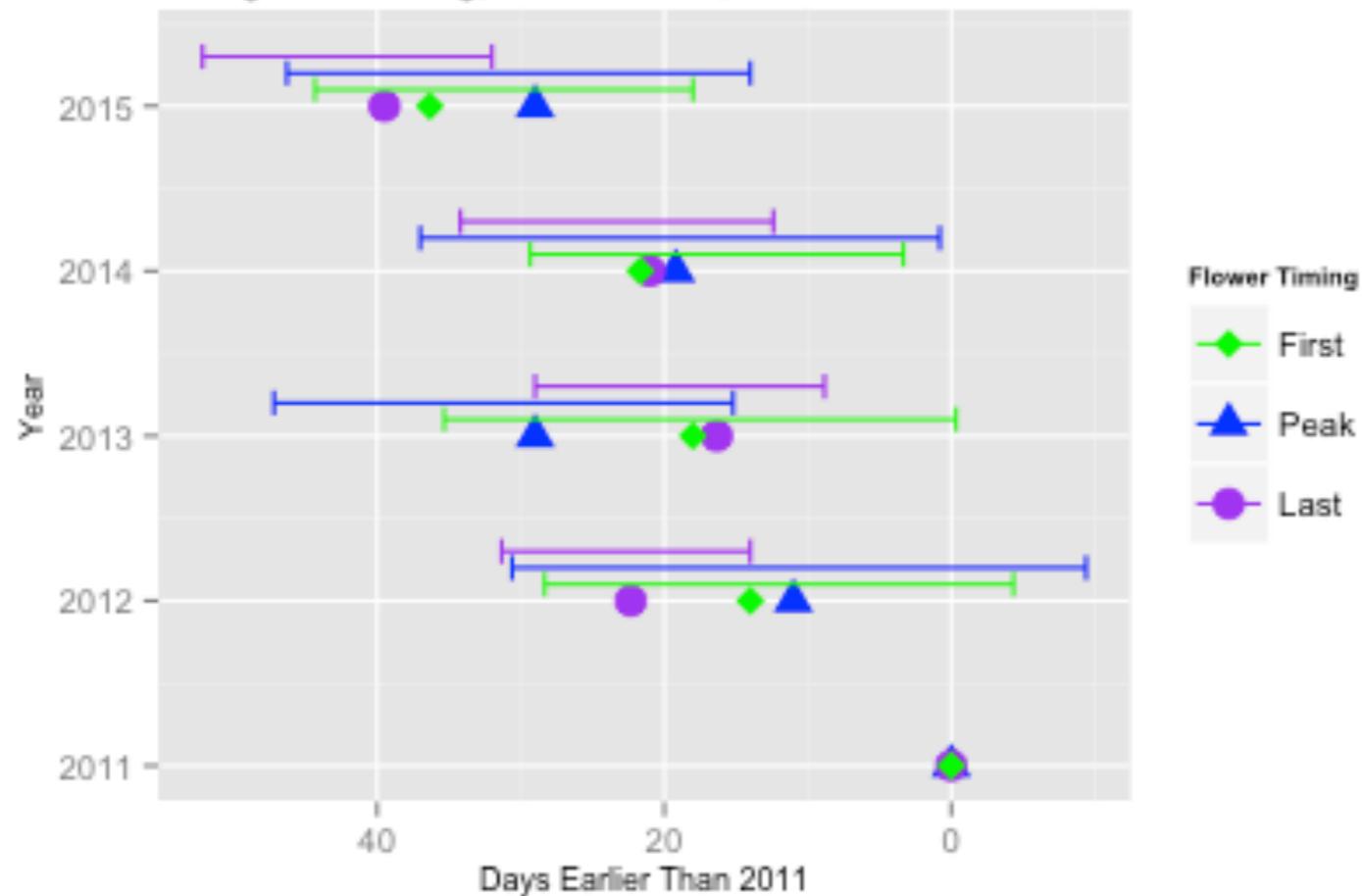
Timing of Flowering, 2011 to 2015, Relative to 2011 for *Eriogonum umbellatum*



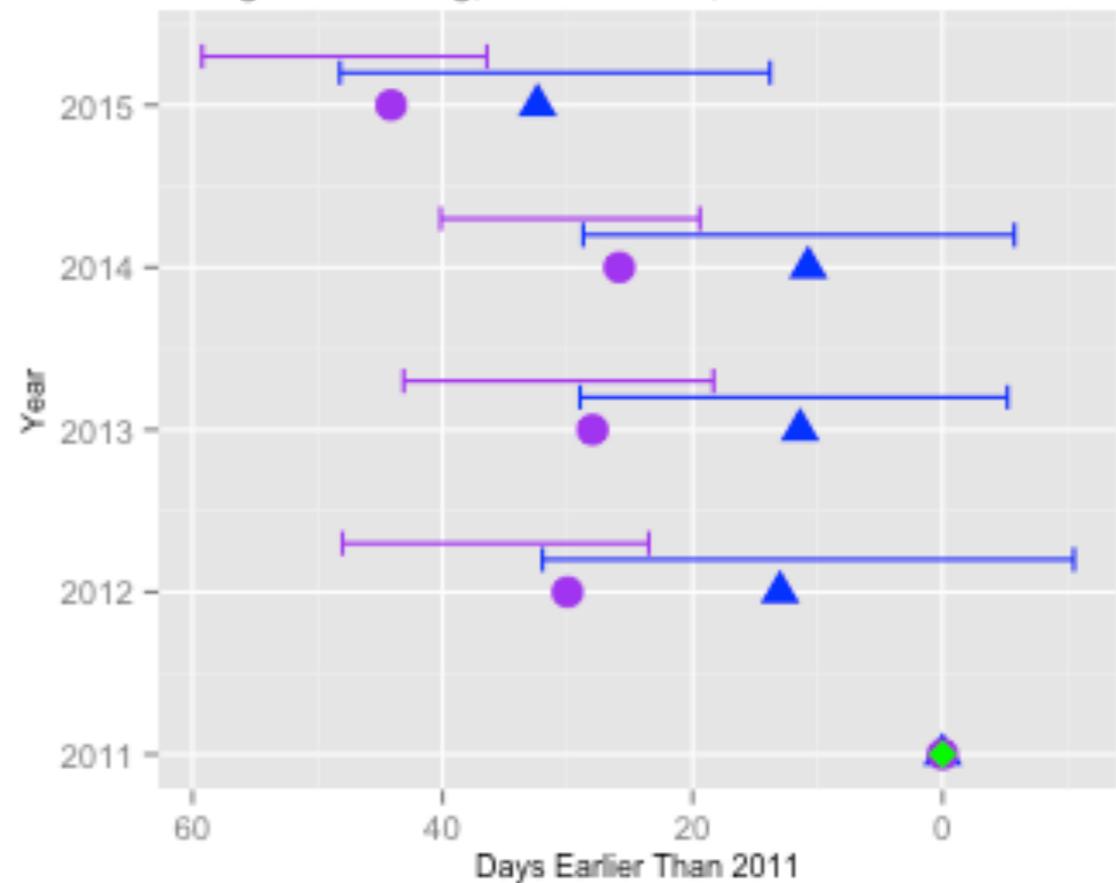
Timing of Flowering, 2011 to 2015, Relative to Timing in 2011 for RP1



Timing of Flowering, 2011 to 2015, Relative to 2011 for LO-

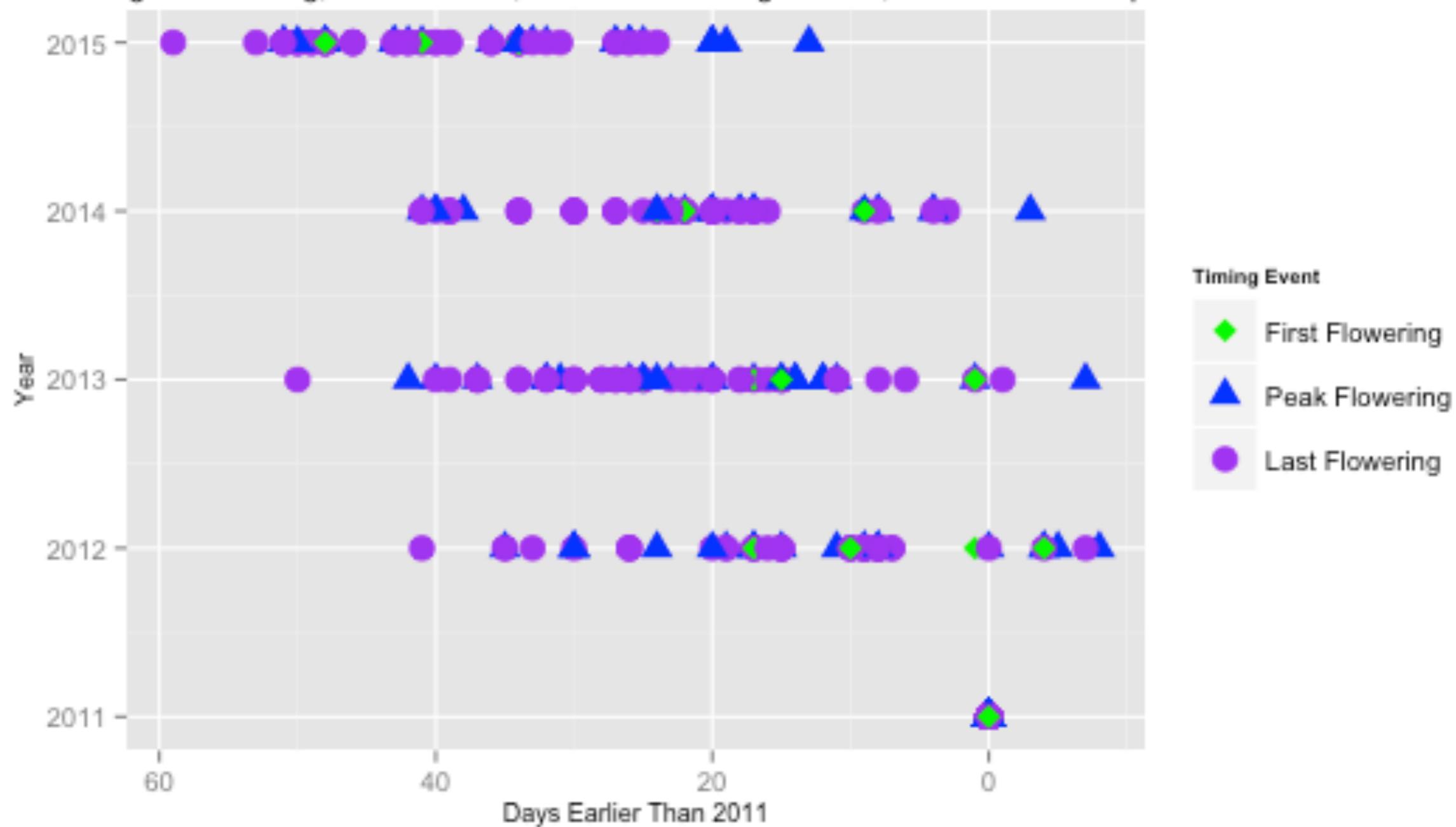


Timing of Flowering, 2011 to 2015, Relative to 2011 for M2-

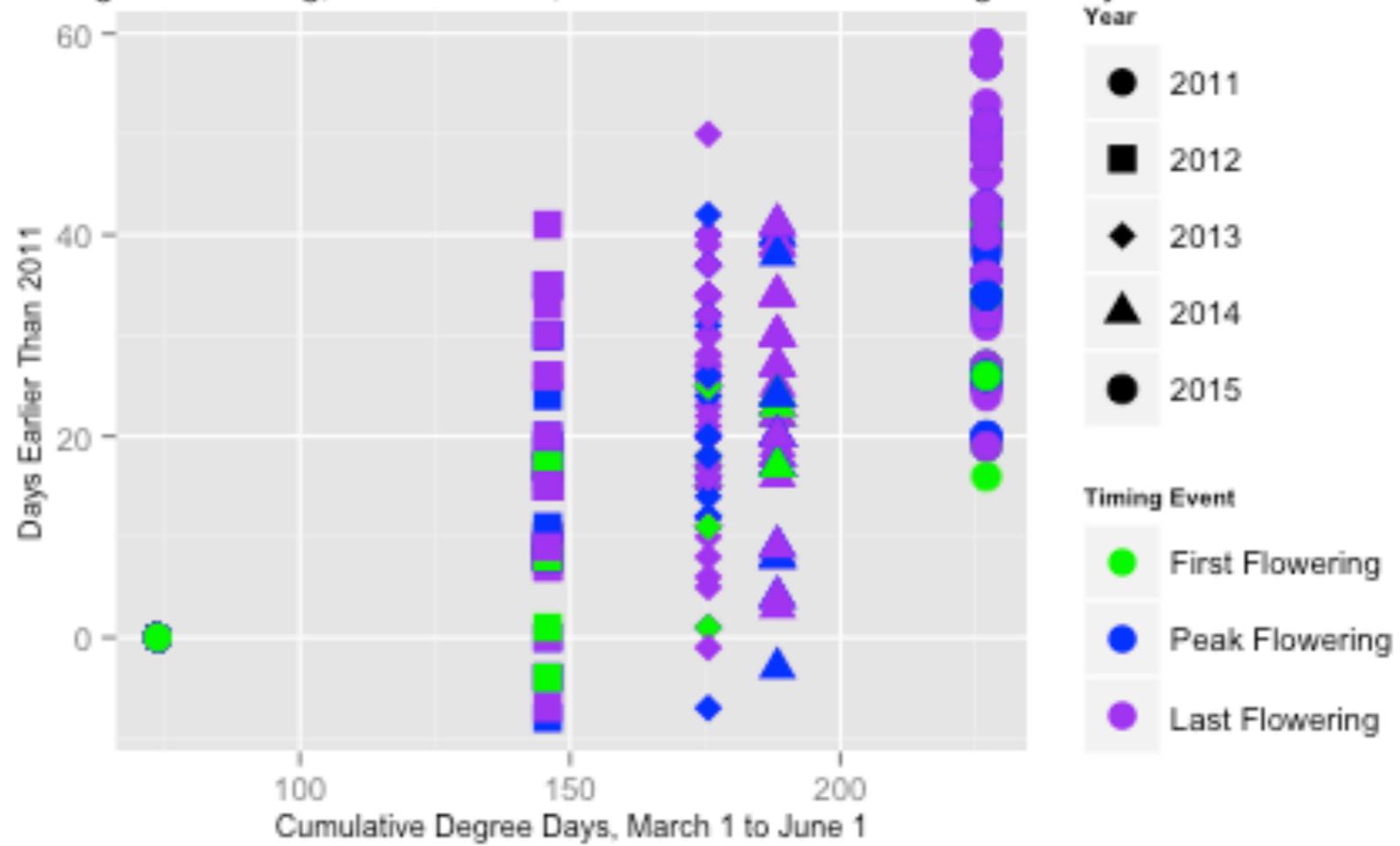




Timing of Flowering, 2011 to 2015, Relative to Timing in 2011, for All Meadow-Species



Timing of Flowering, 2011 to 2015, as a Function of Cum Degree Days



Timing of Flowering, 2011 to 2015, as a Function of Last Day of Snowpack for All Meadow-Species

