Invasive plants, native plants, and pollinators in a changing environment

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Bonanza Creek LTER Symposium

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Melilotus and *Vaccinium* species: interactions via pollinators?

Sweetclover
(Melilotus officinalis / albus)

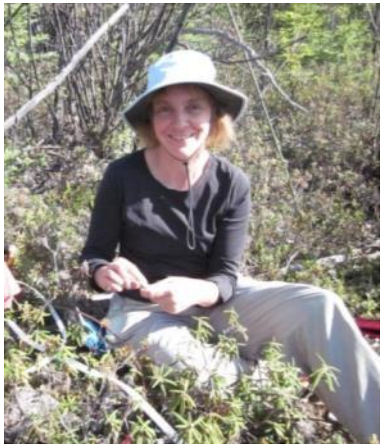
Arrived in Alaska in 1913
Invasiveness ranking: 81 (scale: 0-100)
Likely dispersed by moose

Bog cranberry *(Vaccinium vitis-idaea)*

Bog blueberry (*Vaccinium uliginosum*)

The Melibee Project

UAF (plants)



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UAA (pollinators)

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USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Melilotus and *Vaccinium*: shared habitat and pollinators

- Habitat preferences: recently burned forest; high light for reproduction
- Primary pollinators:
    - Cranberry: bumblebees (*Bombus* species) and syrphid flies (Syrphidae)
    - Blueberry: bumblebees, solitary bees, wasps, flies
    - *Melilotus*: many species including bumblebees and solitary bees.

Bee on cranberry. Photo: L. Schneller

Syrphid fly on willow
Photo: M. Carlson

Bombus on sweetclover. Photo: L. Schneller

How could *Melilotus* affect pollination?

1. Attraction of shared pollinators to an area

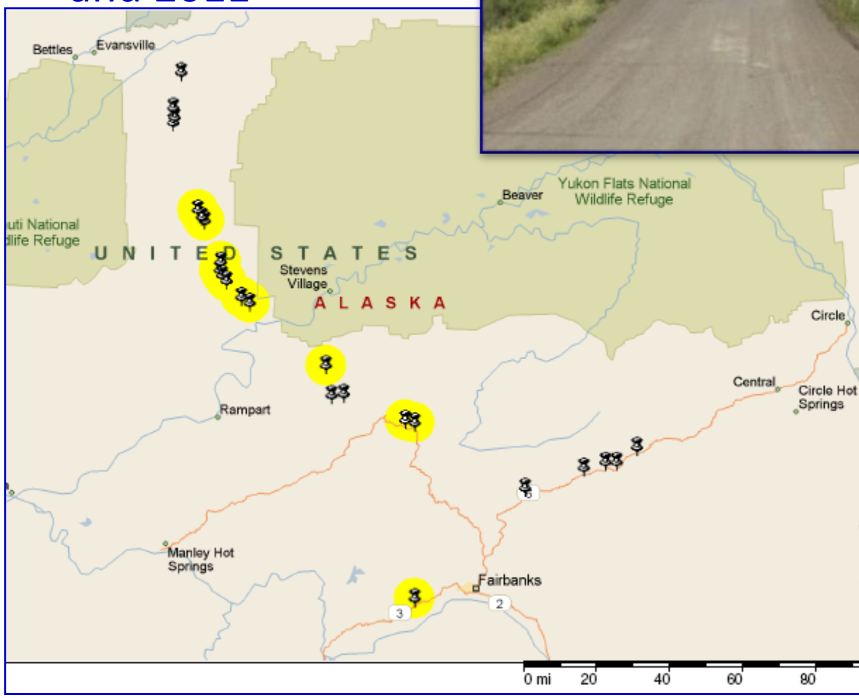
- *Melilotus* is very attractive to pollinators
  - High nectar production and strong scent
  - Up to 350,000 seeds per plant

2. Diversion of shared pollinators within a site

- Could distract pollinators from visiting native flowers because *Melilotus* is more attractive
- Could result in more mixed pollen loads (reduction in quality)

Two approaches

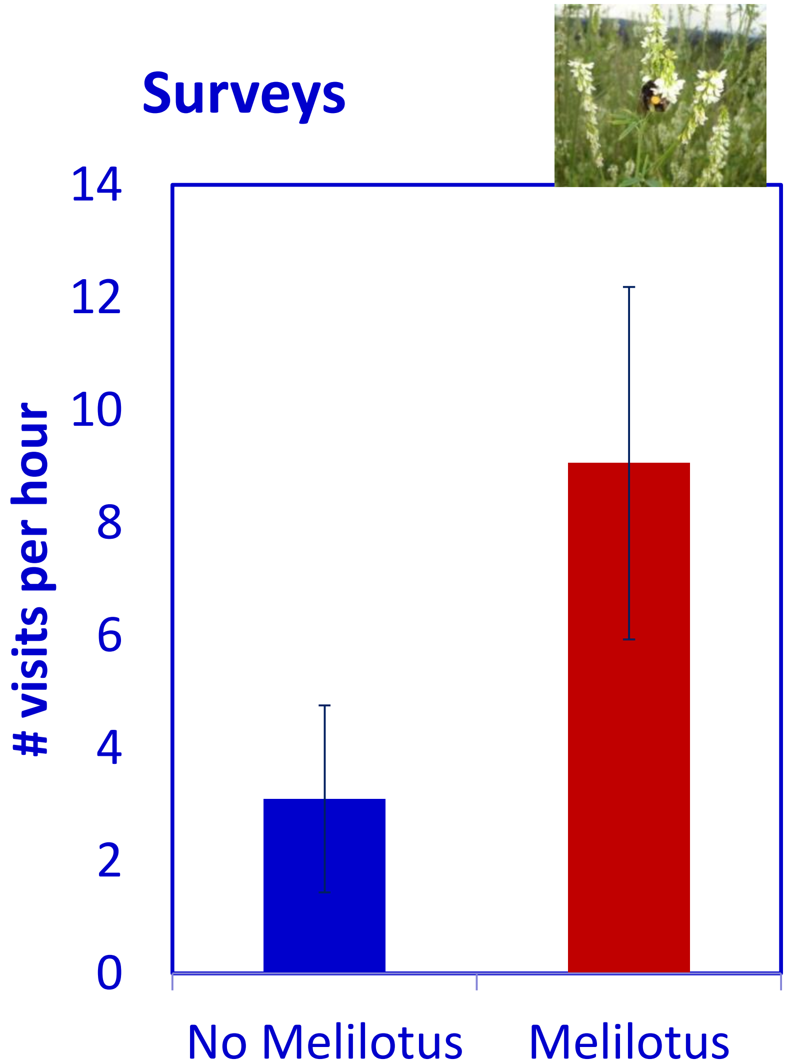
1. Surveys along the Steese, Elliot and Dalton highways in 2010 and 2011



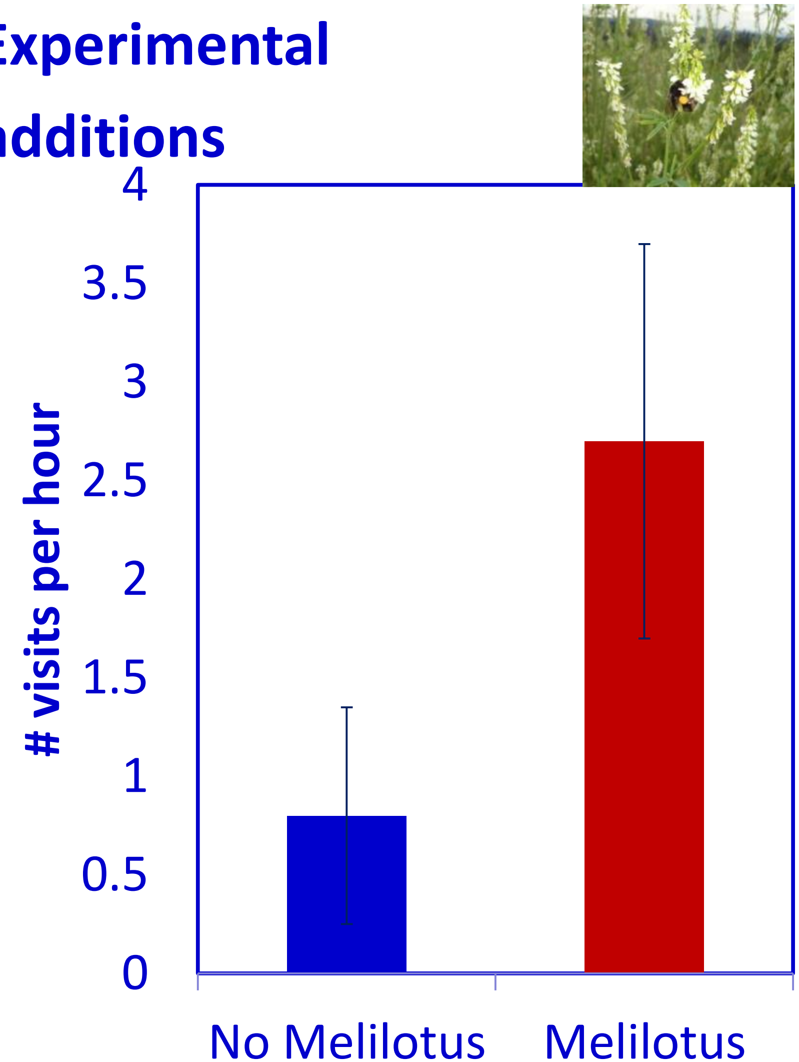
Survey sites
Yellow= sites with *Melilotus*
Pins only= sites without Melilotus

2. Experimental additions of *Melilotus* to sites at BNZ and CPCRW in 2011 and 2012 (18 sites total)

Presence of *Melilotus* increases local pollinator visitation rates

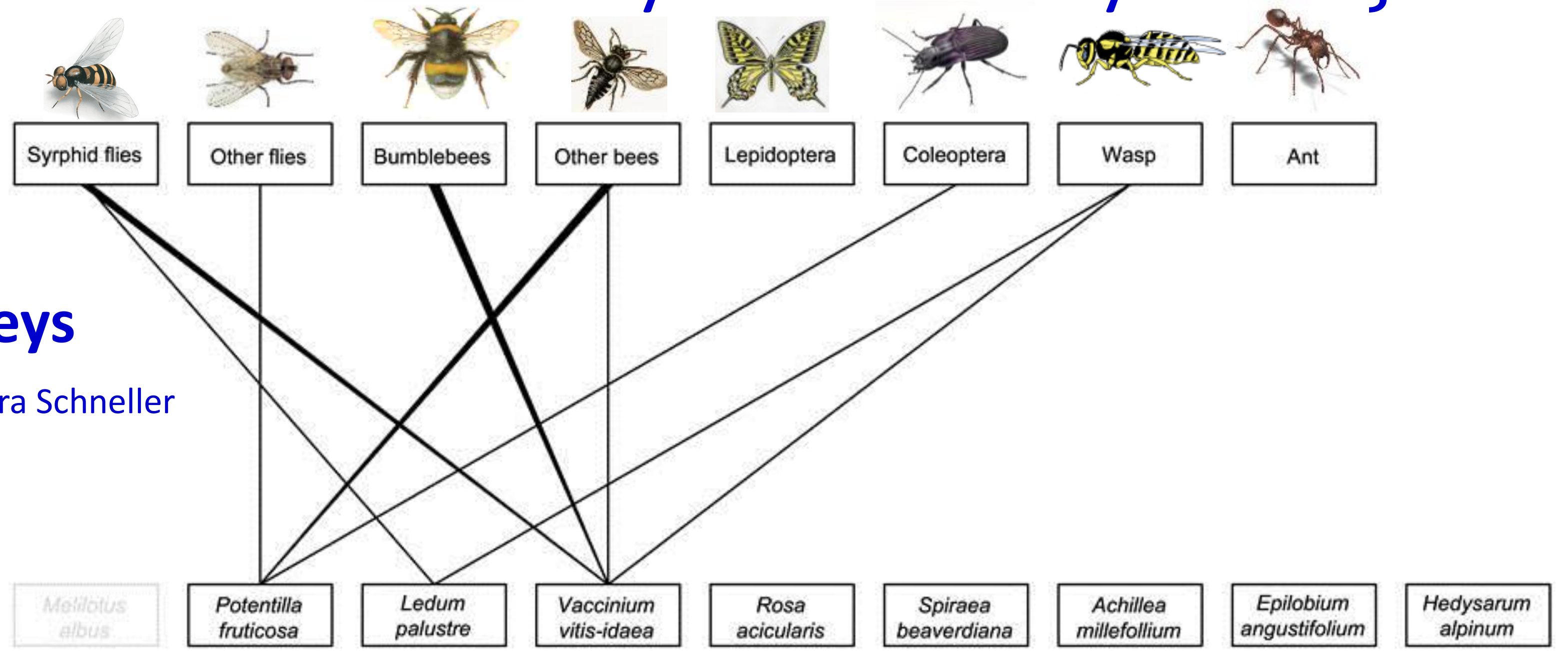


Data: Laura Schneller



Data: Laura Schneller

Pollinator activity and diversity are higher

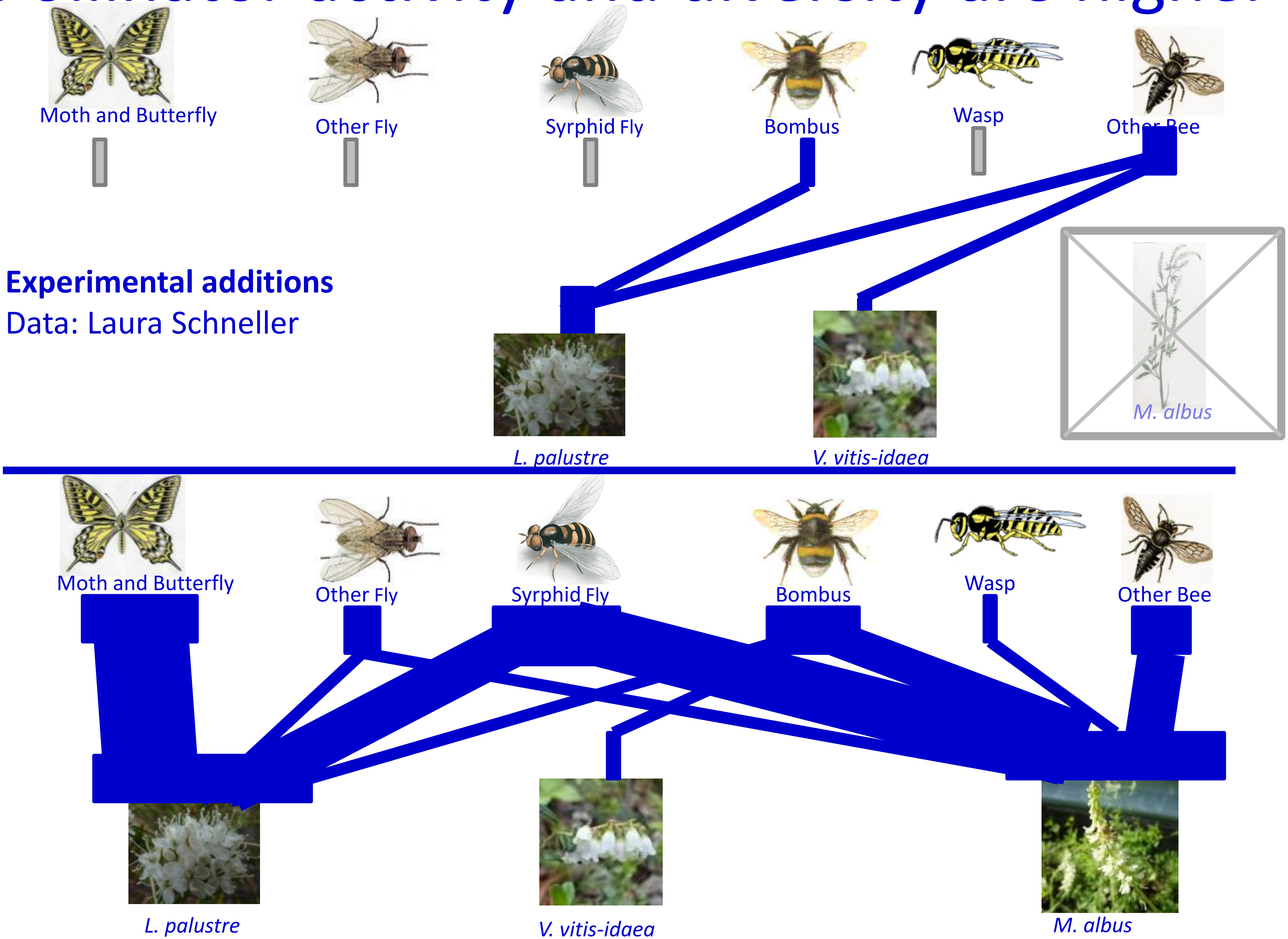


Surveys

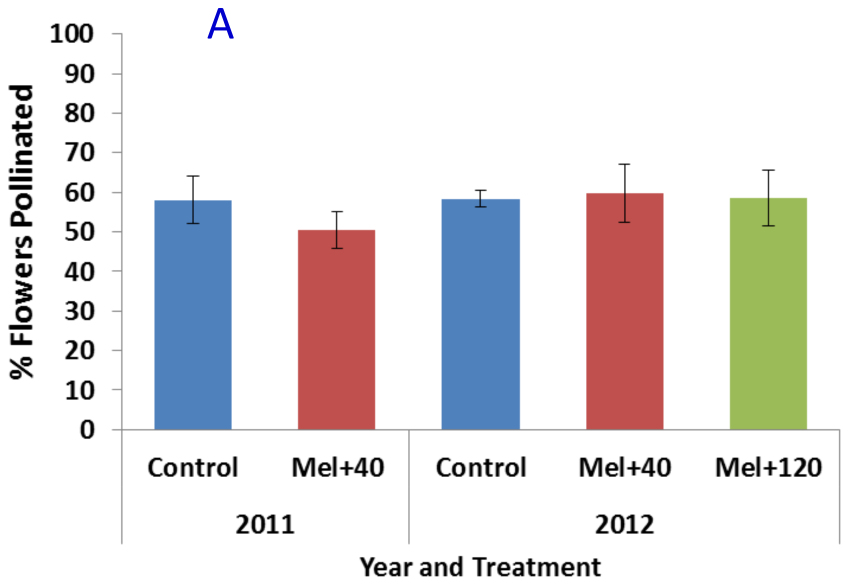
Data: Laura Schneller

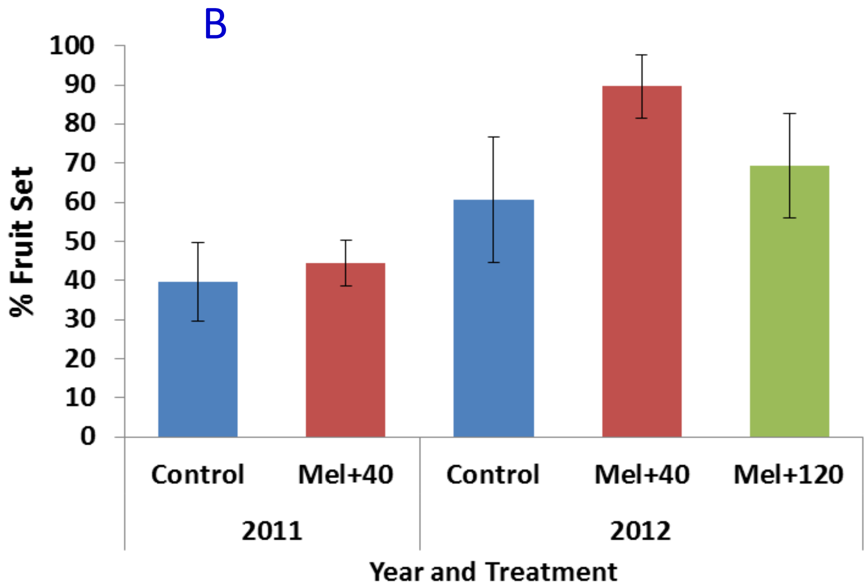
Pollinator activity and diversity are higher

Experimental additions
Data: Laura Schneller



Melilotus addition does not result in a large increase in pollination or fruit set





Cranberries, experimental data for 2011 and 2012

Data: Katie Spellman

Table 1. Average Akaike's Information Criterion parameter estimates (b) and cumulative parameter weights ($\sum \omega i$) for candidate variables explaining differences in % *Vaccinium vitis-idaea* flowers pollinated, total pollen deposited on stigmas, and % pollinated flowers setting fruit in sites with and without invasive *Melilotus albus*. Average parameter values were taken over models with a difference in AICc < 5. Bold values indicate well-supported parameters ($\sum \omega i > 0.5$).

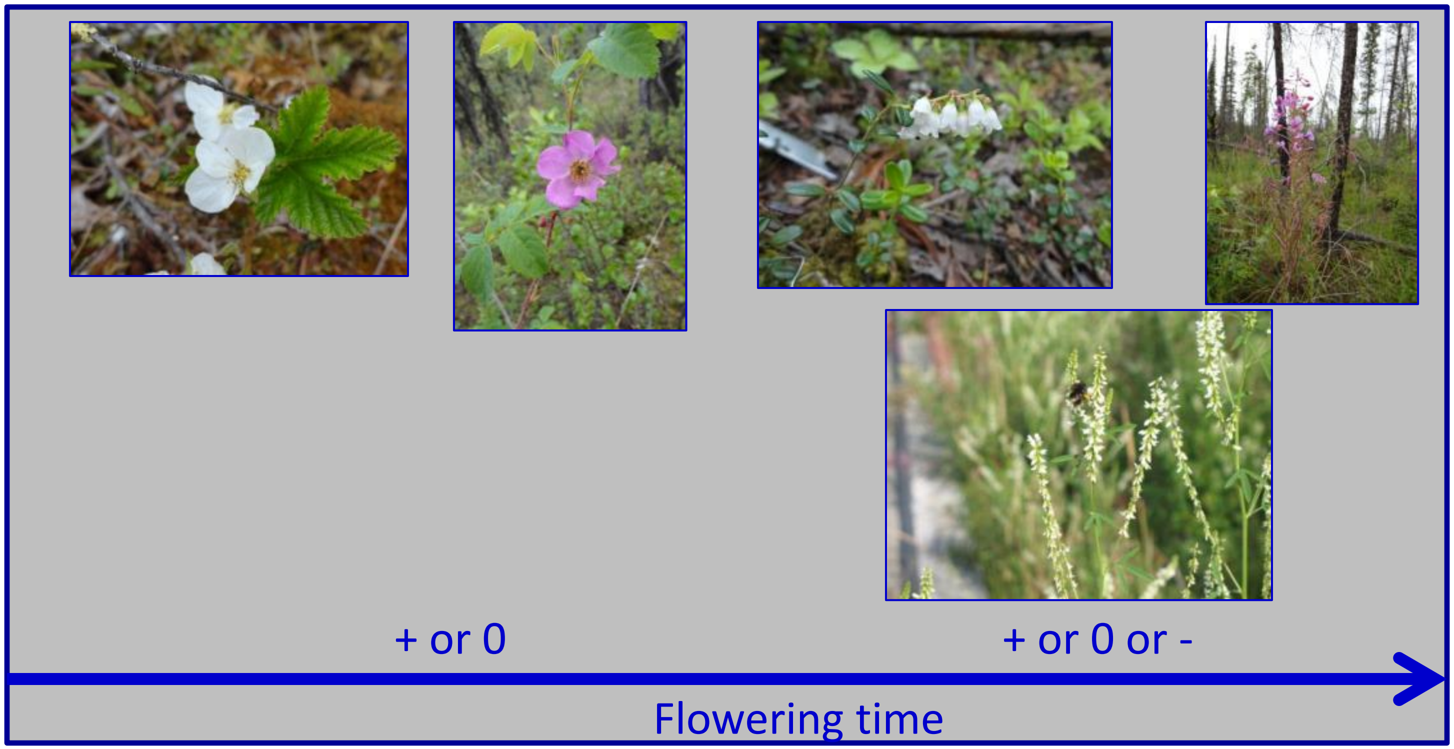
	Response Variables					
	% flowers pollinated		**total pollen**		**% fruit set**	
Explanatory Variables	$\bar{b}$	$\sum \omega_i$	$\bar{b}$	$\sum \omega_i$	$\bar{b}$	$\sum \omega_i$
# *M. albus* inflorescences at site	**-8.0E-05**	**0.576**	-0.001	0.235	3.6E-07	0.184
canopy cover (%)	**0.003**	**0.863**	**0.136**	**0.799**	0.002	0.233
shrub cover (%)	-0.028	0.33	-1.071	0.299	0.081	0.243
# *V. vitis-idaea* flowers	0.001	0.389	0.024	0.262	**0.042**	**0.894**
# all flowers	0.002	0.404	0.038	0.264	**-0.043**	**0.916**
flower richness	**0.094**	**0.675**	2.783	0.330	**0.341**	**0.911**
avg. temperature	**0.056**	**0.667**	-1.016	0.288	-0.025	0.204
hours of rain	-4.2E-05	0.222	0.024	0.375	**-0.002**	**0.805**

Conclusions, Part I

1. *Melilotus* acts as a pollinator attractor, altering pollination webs
2. Whether this results in altered pollination or fruit set for cranberries depends on the year and the distance from the *Melilotus*
3. Overall, more *Melilotus* results in lower pollination (but not fruit set)in cranberries

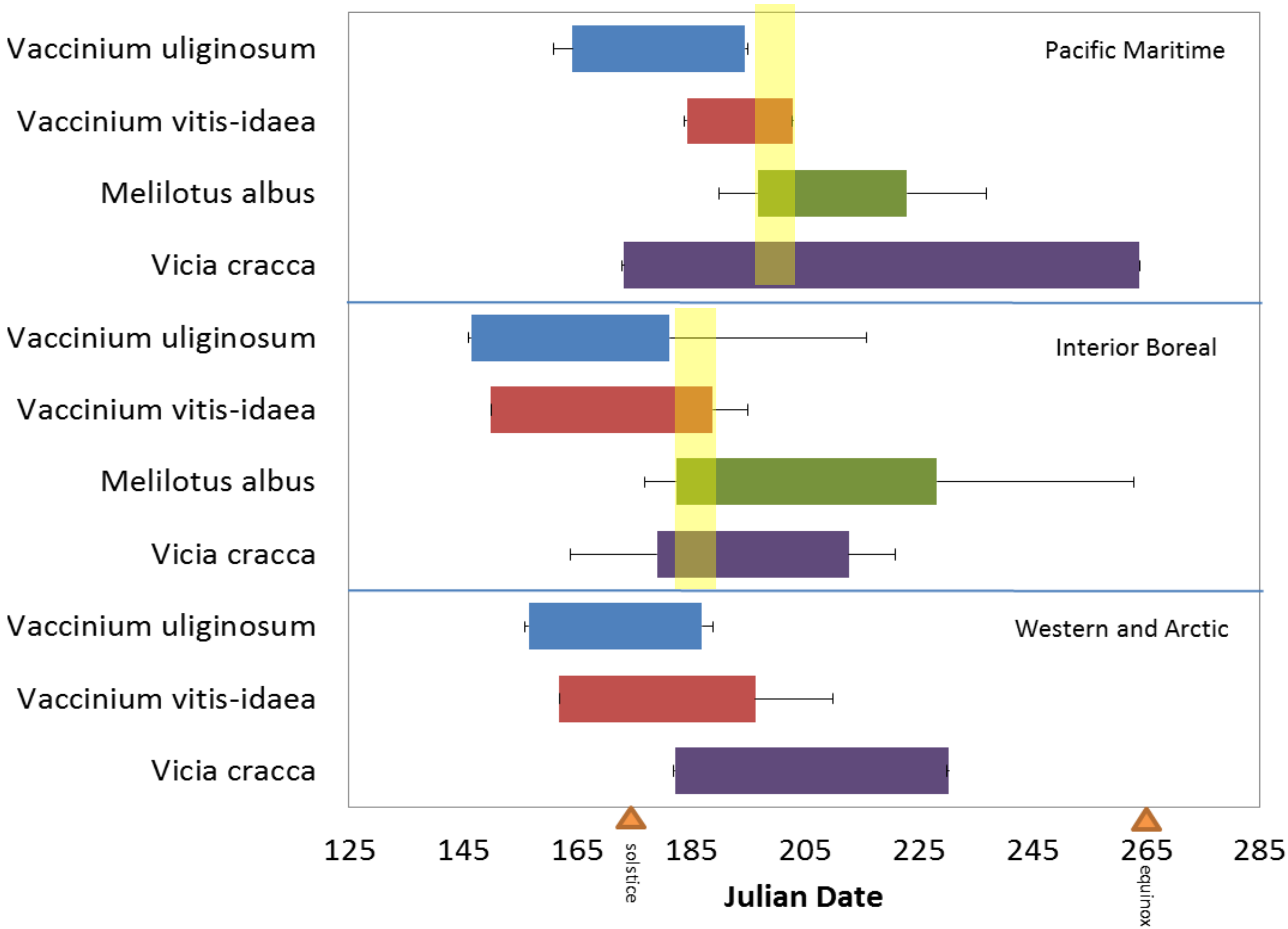
Phenology: a geographic mosaic of interactions?

- Overlap: potential for competition or facilitation
- "sequential mutualism": when two species do not overlap in flowering periods but the presence of one increases the pollinator availability for the other



Why might this shift over space?

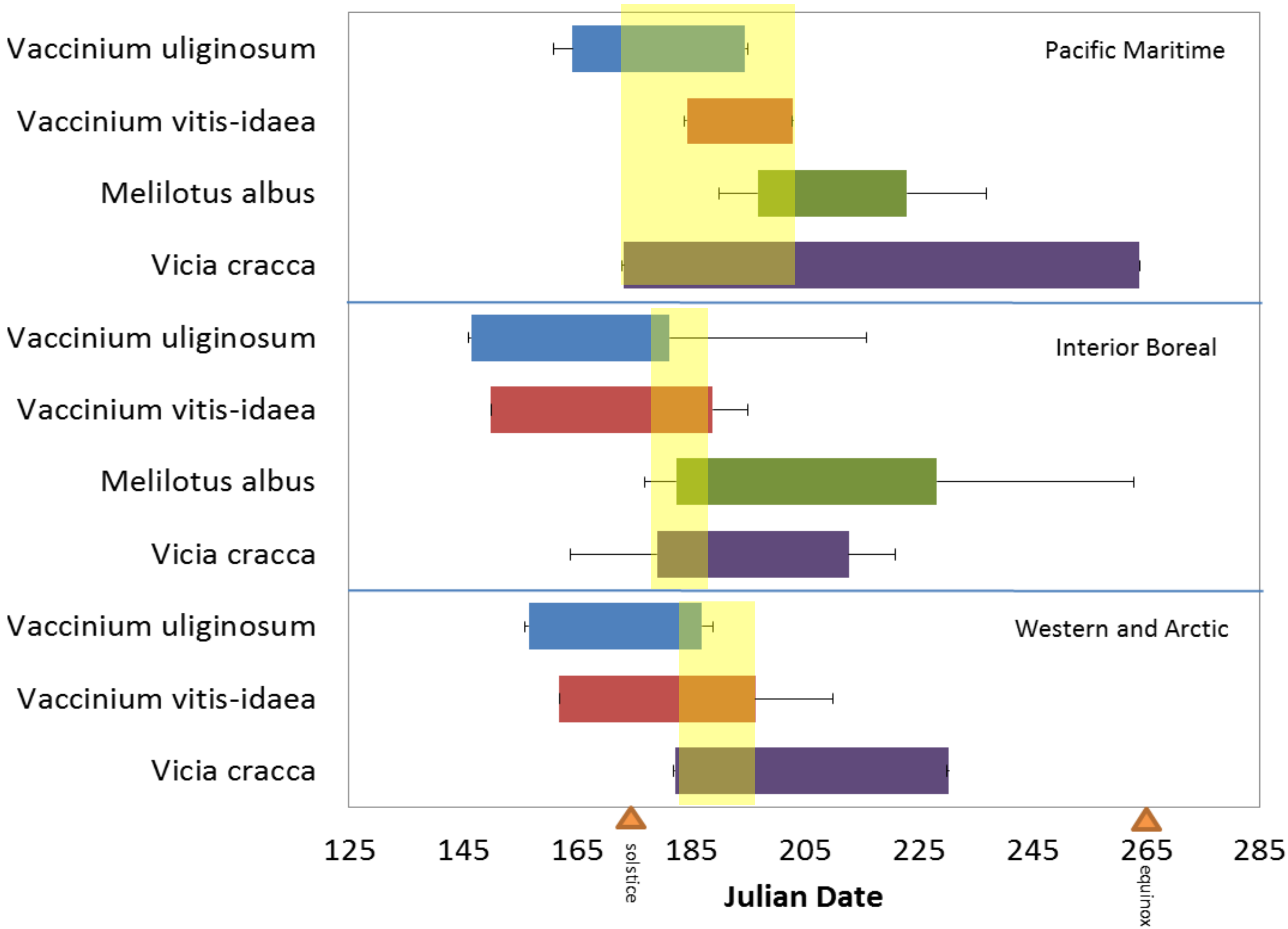
1. Differences in which environmental variables species respond to
2. Differences in strength of response
3. Local adaptations NOT explained by environmental conditions



Peak flowering dates (score of 1.1 to 2.9) for focal species in the three ecoregions of Alaska based on two years of citizen science monitoring data (2012-2013). Boxes are average start and end dates from regressions and the whiskers are the earliest and latest observed dates.

Data: Katie Spellman and the Melibee citizen scientists

Figure 1. Ecogeographic regions of Alaska (Nowacki et al. 2001).



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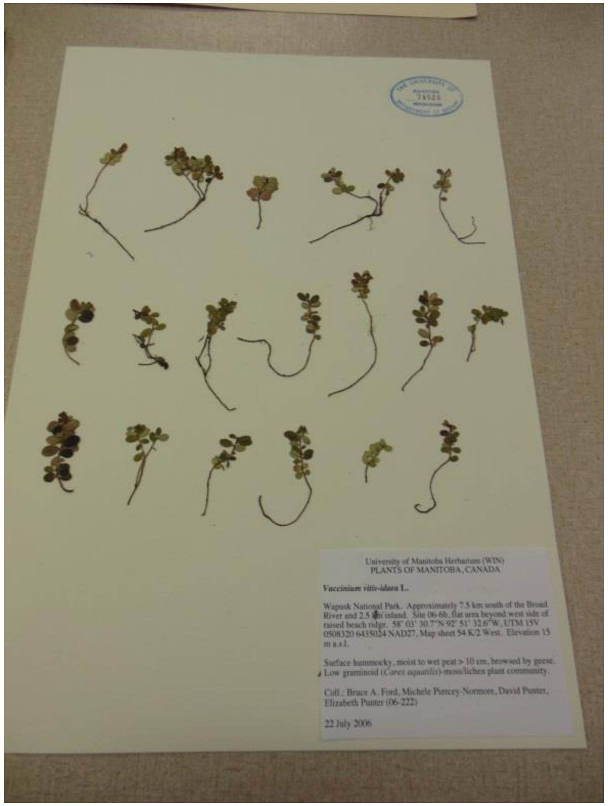
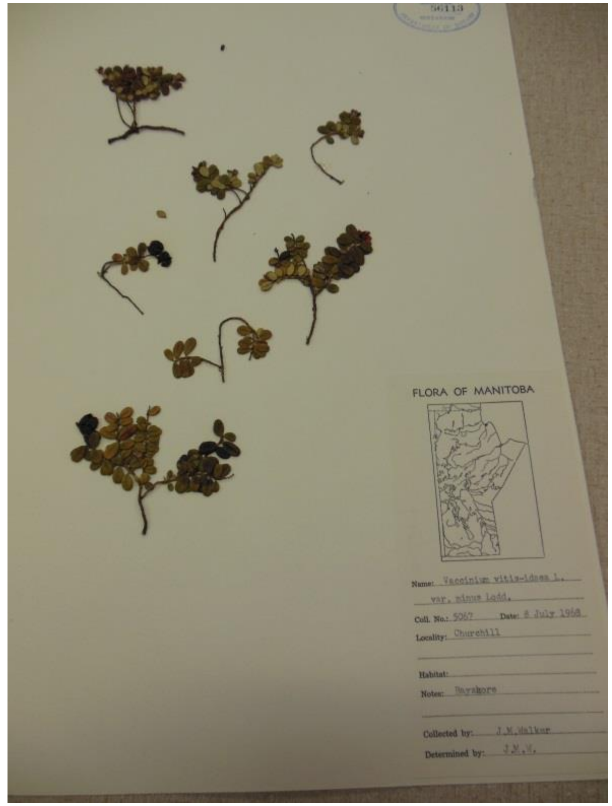
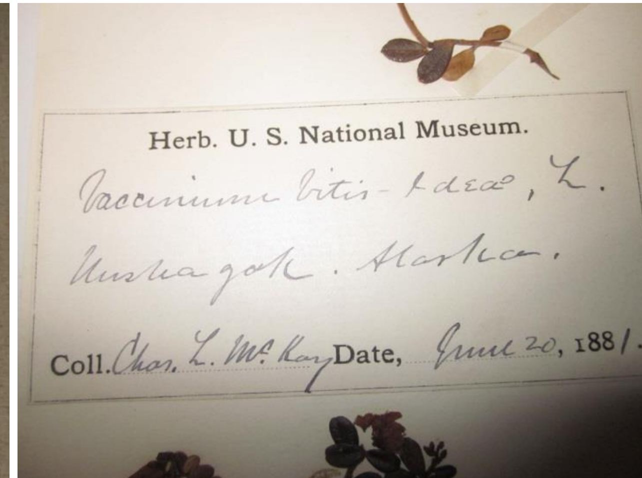
Herbarium specimens



V. vitis-idaea specimen, modern (2006)



V. vitis-idaea specimen, older (1968)



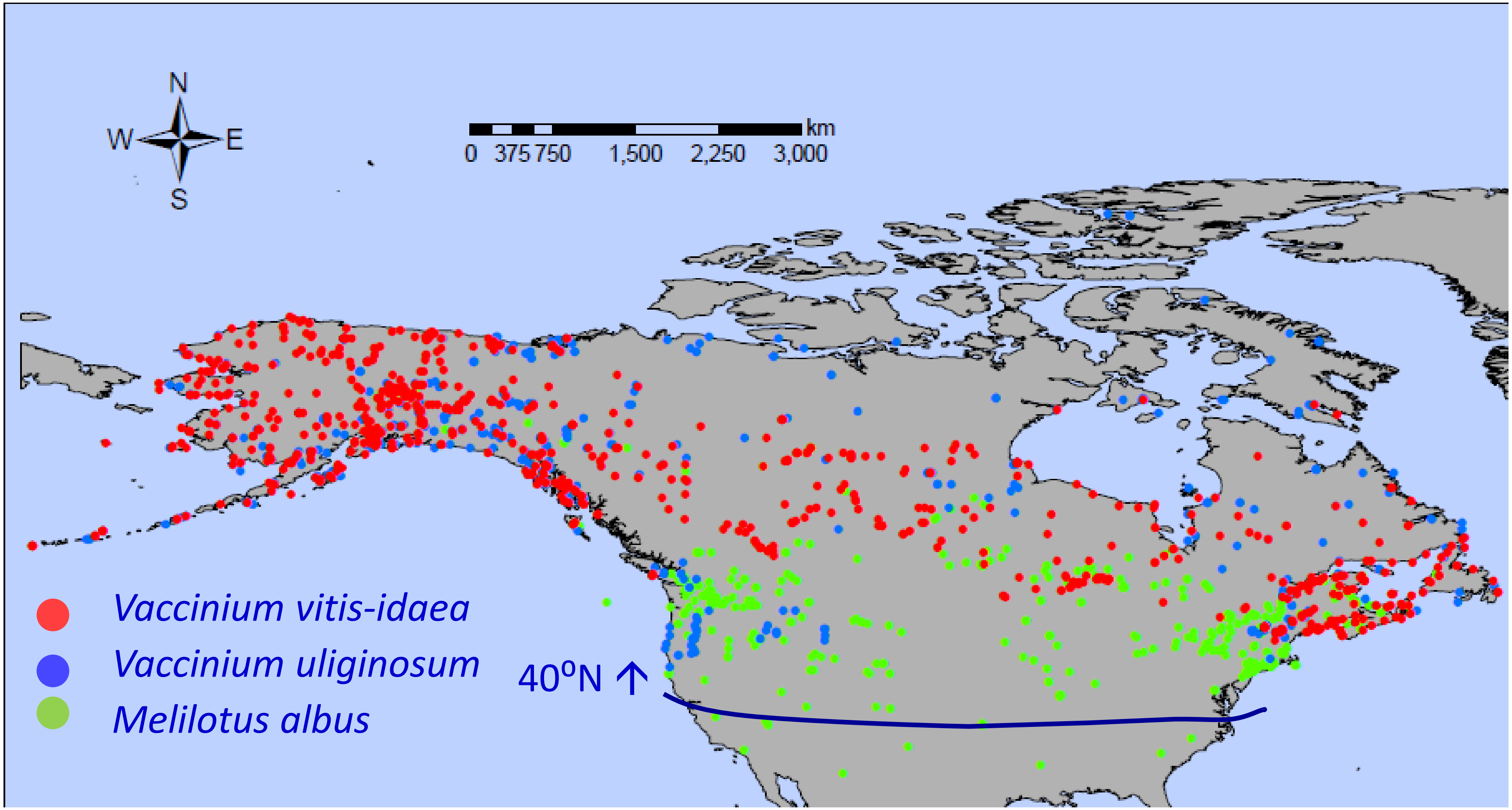
V. vitis-idaea specimen label, very old (1881)

Use any specimen that meets the following criteria:

1) A date
2) A location
3) At least one reproductive structure

Note: sweetclover has been in New England since 1785 and in Alaska since 1916

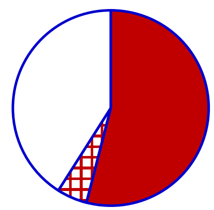
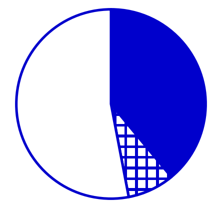
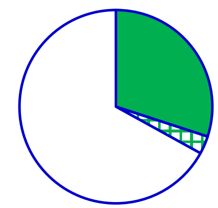
Sample Distribution



Approx. 900 *V. vitis-idaea* specimens
Approx. 870 *V. uliginosum* specimens
Approx. 460 *M. albus* specimens

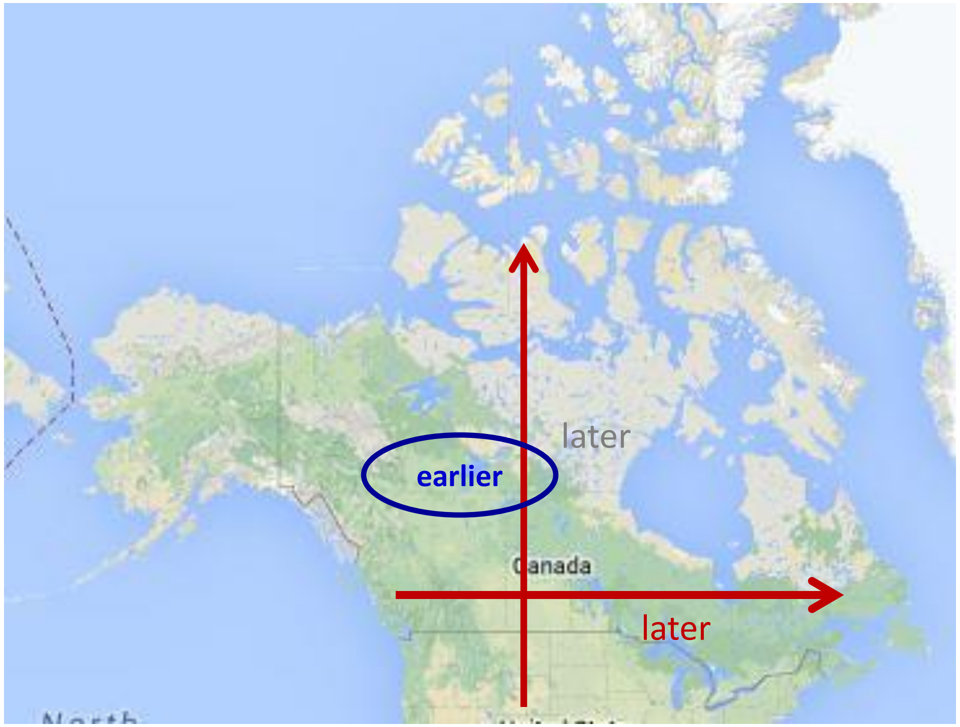


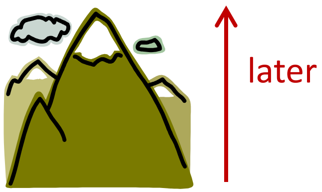
Source		*V. vitis- idaea*	*V. uliginosum*	*M. alba*
Julian date (all data)	Total explained	54% (903)	41% (883)	29% (457)
Julian + geographic (using means per location)	Total explained	59% (647)	47% (578)	33% (228)
geographic	Unique	6%	8%	3%

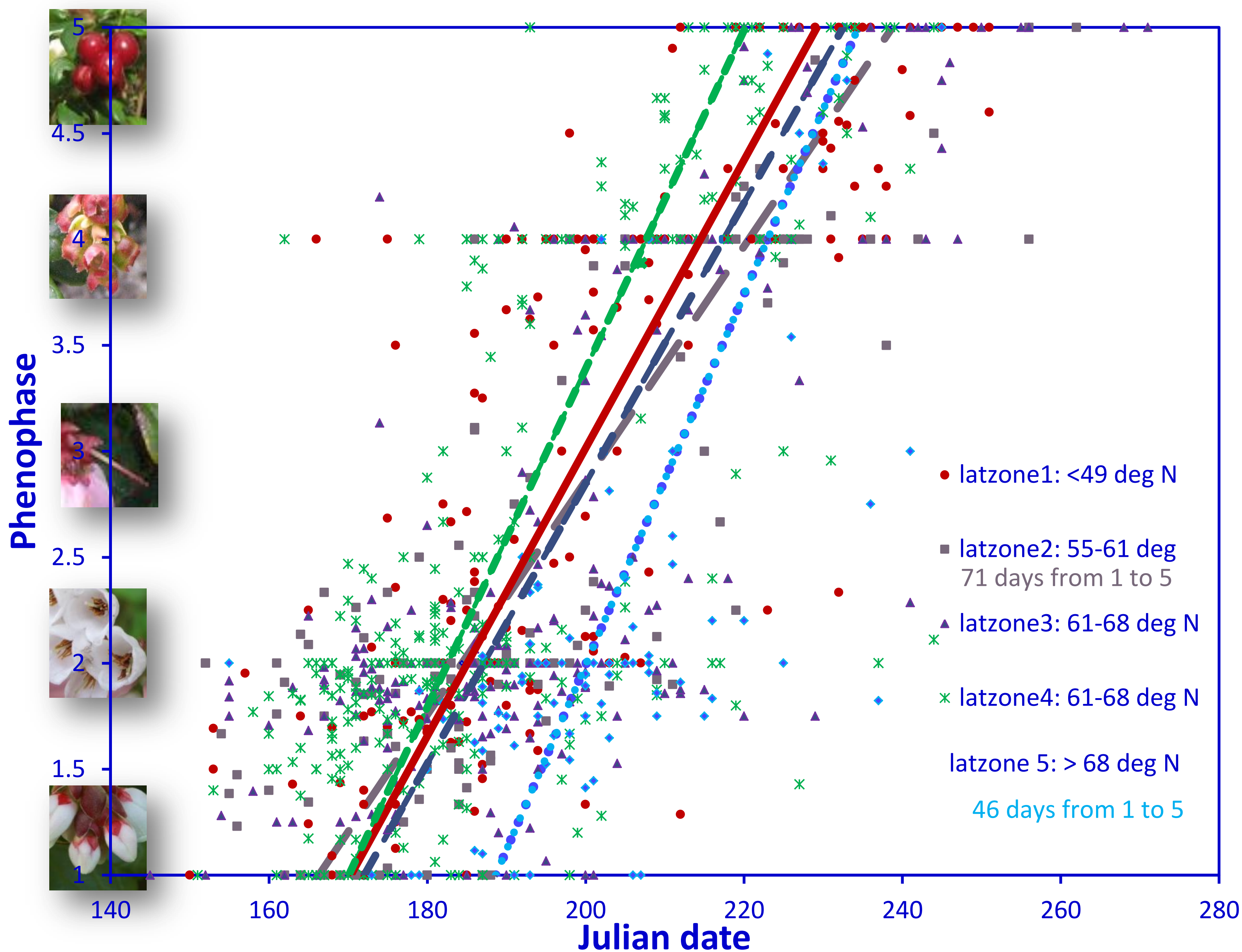




Testing geographic predictions: blueberry and cranberry

- ↑ latitude (further north): delayed
- ↑ longitude: (further east) delayed
- ↑ elevation: delayed
- ↑ distance from water: advanced
- latitude * Julian: strong interaction







Phenophase
5
4.5
4
3.5
3
2.5
2
1.5
1
140
160
180
200
220
240
260
280
Julian date
latzone1: <49 deg N
latzone2: 55-61 deg
71 days from 1 to 5
latzone3: 61-68 deg N
latzone4: 61-68 deg N
latzone 5: > 68 deg N
46 days from 1 to 5

Testing geographic predictions: Sweetclover

↑ Latitude (further north): delayed*

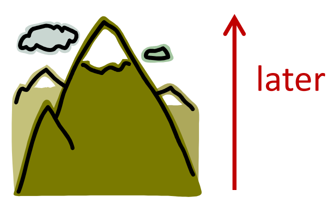
↑ elevation: delayed*

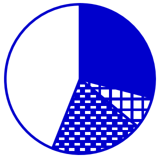
longitude: (further west): no effect

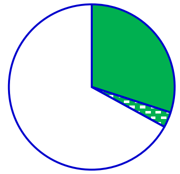
distance from water: no effect

on an island: no effect

latitude * Julian: no effect







Source		*V. vitis- idaea*	*V. uliginosum*	*M. alba*
Julian date (all data)	Total explained	54% (903)	41% (883)	29% (457)
Julian + geographic (means per location)	Total explained	59% (647)	47% (578)	33% (228)
geographic	Unique	6%	8%	3%
Julian + geographic + climate	Total explained	[not run]	56% (417)	33% (227)
climate	Unique		7%	3%
geography	Unique		20%	0%

+ temp in March
+ temp in June
- temp in July
- precipitation in March
+ precipitation in July
-precipitation in August

-latitude
-elevation
+distance to water

This is driven by the change in developmental rate

-temp in April
+ temp in June
+ temp in August

What about inter-annual variation?

- Best model for blueberry included both climate (long-term average) and weather (that year) variables:

  + Julian date

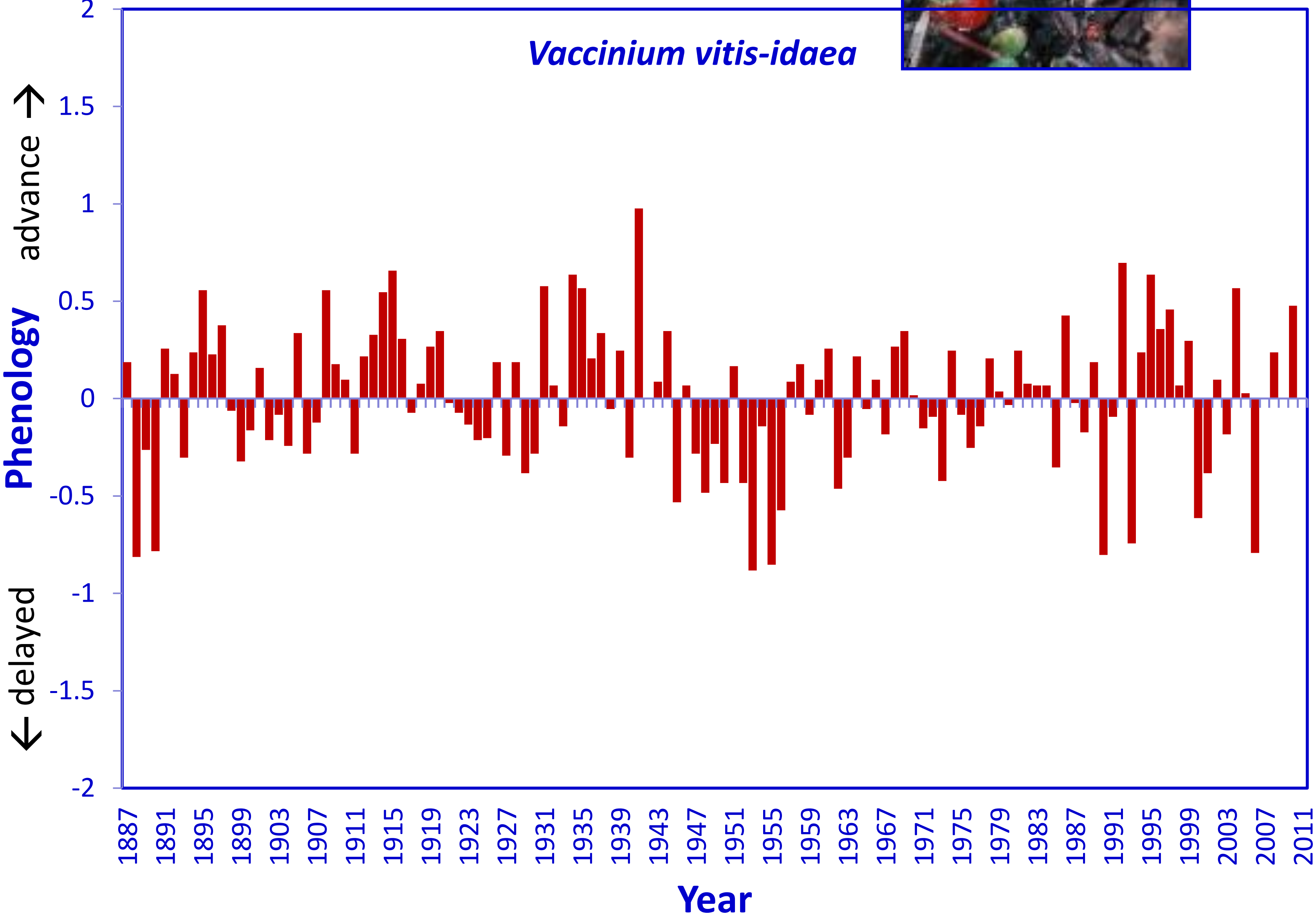
  + latitude

  - snowfall (weather) in previous winter

  - temperature (weather) in March

  + temperature (climate) in April

- Would expect a smaller role for climate and a larger one for weather for *Melilotus*



Vaccinium vitis-idaea
Phenology
advance
delayed
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1887
1891
1895
1899
1903
1907
1911
1915
1919
1923
1927
1931
1935
1939
1943
1947
1951
1955
1959
1963
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1971
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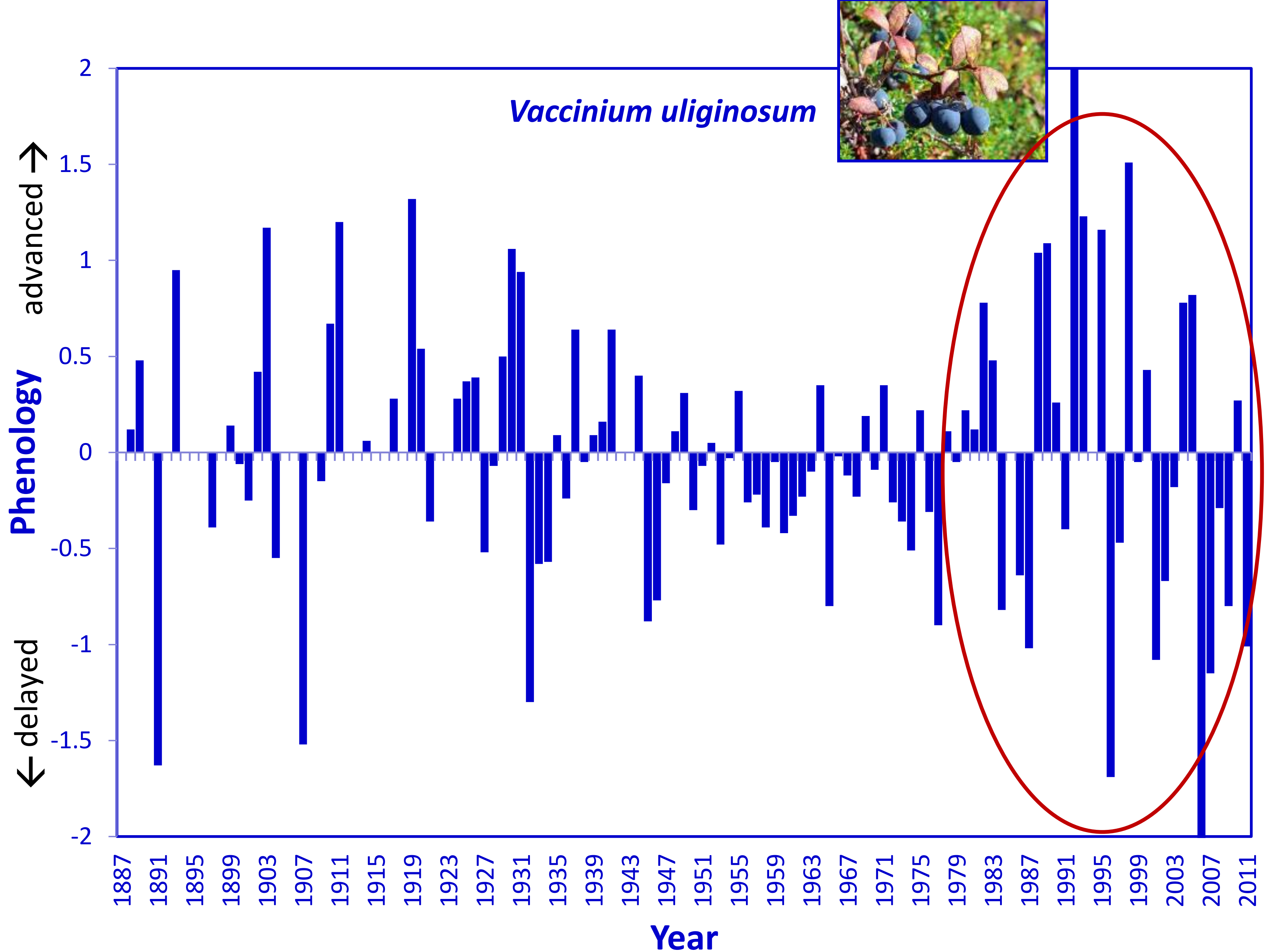
1995
1999
2003
2007
2011
Year

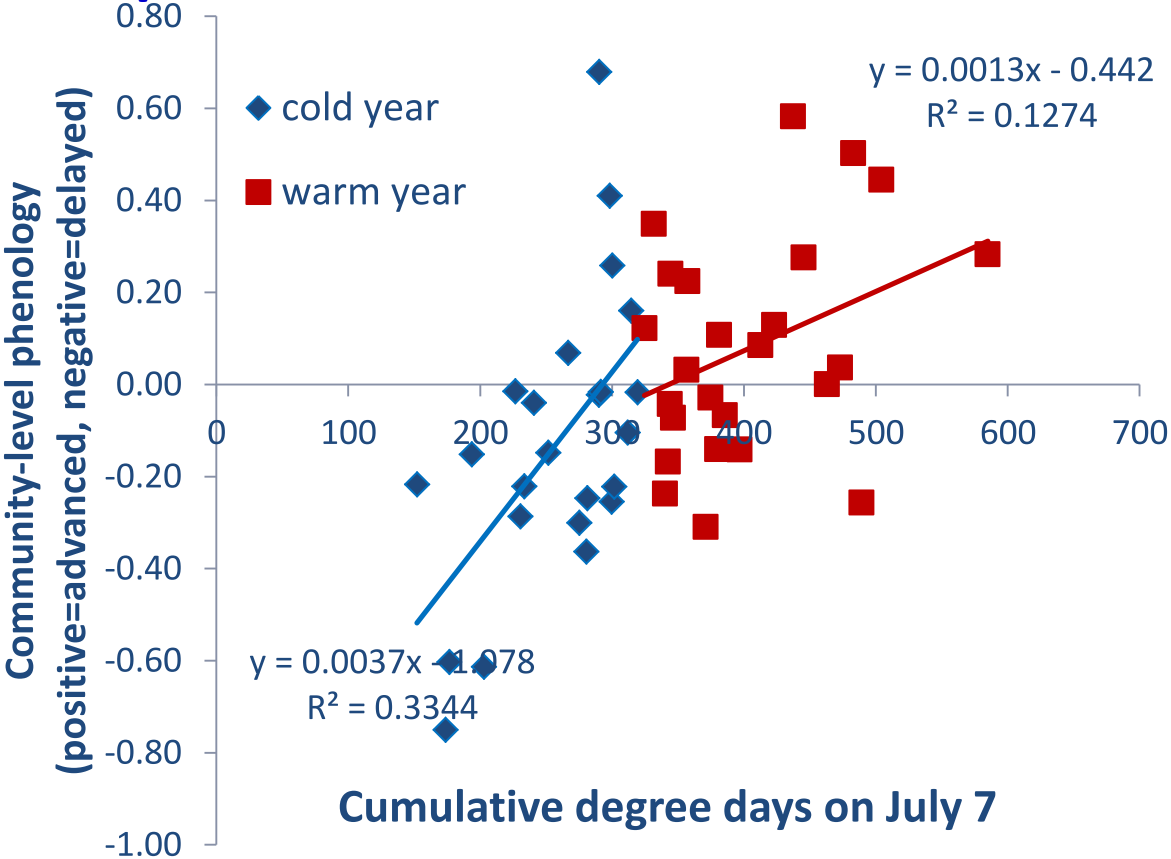


Vaccinium uliginosum
advanced
Phenology
delayed
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1887
1891
1895
1899
1903
1907
1911
1915
1919
1923
1927
1931
1935
1939
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
2007
2011
Year

Plants may be asymmetrical in phenological responses to temperature

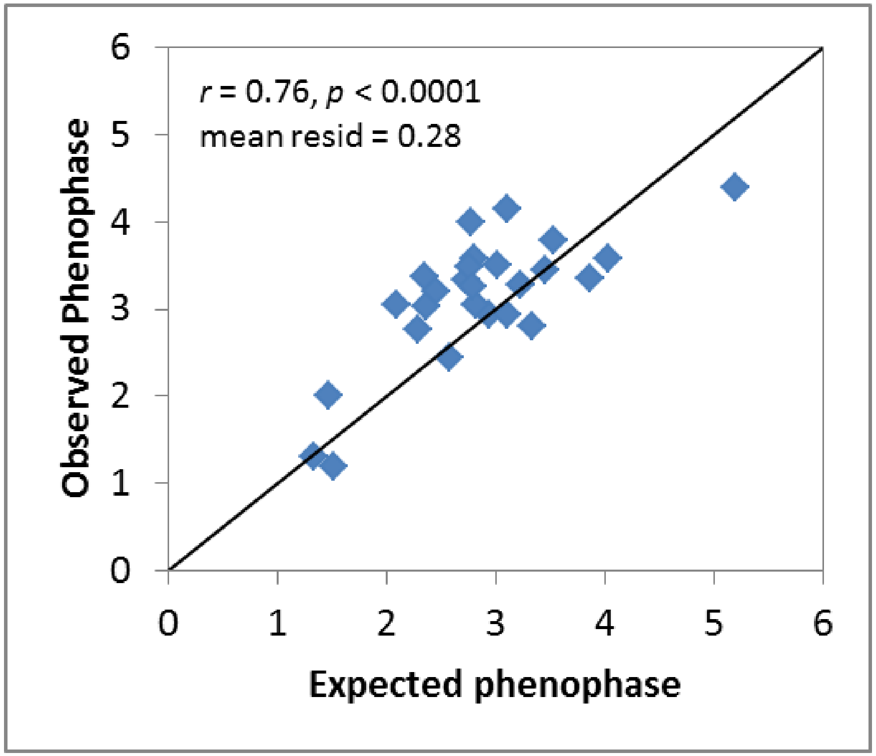
- On the Cape Churchill Peninsula (Hudson Bay), temperature mean and variance are increasing, and plant phenology is advanced in warmer years
- Despite this, there is no advance over time…the slope is actually negative. Why?
- Phenology is delayed more in “bad” years than it is advanced in “good” years
- Prediction: if both mean and variance for temperature keep increasing, on average the plant community will be more <u>delayed</u> over time!!

- This is consistent with the results for blueberry

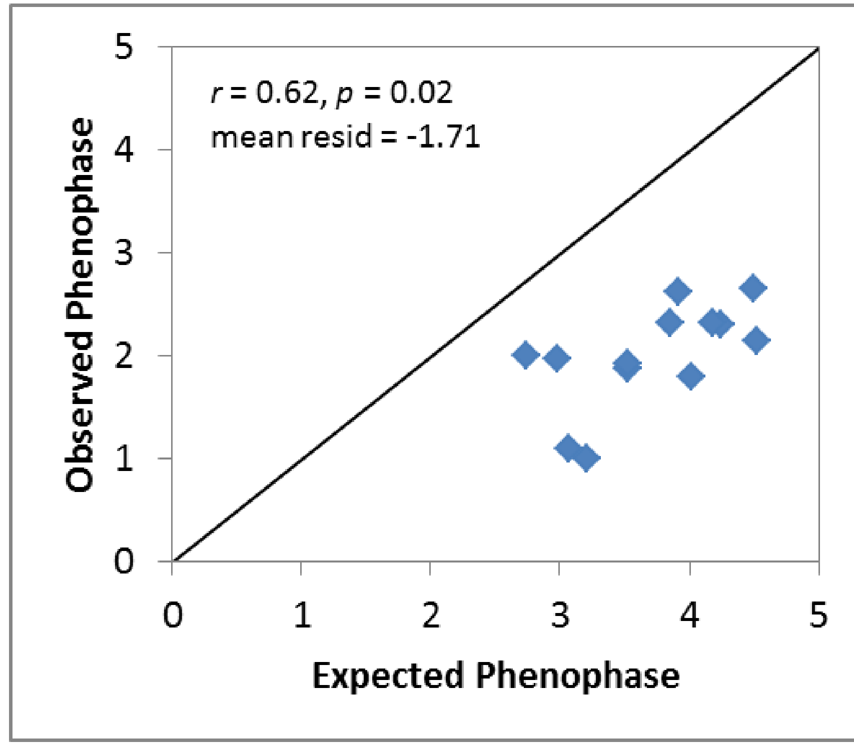


Model validation using citizen science data

Blueberries



Melilotus



Very good fit
Observed slightly higher than predicted – 2013 was a very warm year

Much poorer fit
Observed consistently below expected

Conclusions, Part II

1. Overall, phenology of blueberries and cranberries can be better predicted than that of *Melilotus*
2. Geographical location matters independent of climate for berries (but not *Melilotus*): affects developmental rate in both
3. No evidence for a consistent change in phenology over 125 years
   - But: flowering in blueberries is becoming more variable
   - Blueberries show greater inter-annual variation than cranberries, with spring conditions being most important

→ Results suggest that blueberries and cranberries are adapted to local climate…. Can they take advantage of earlier springs and later falls?

Are non-native plants more able to take advantage of extended seasons than non-native plants?

Fairbanks area:

- Expansion of growing seasons (days >0 ^{o}C) from 85 to 123 days
- Reduced maximum snow depth in January and February
- Few sub-freezing days in April
- Greater variability in snow depth in May and temperature in October

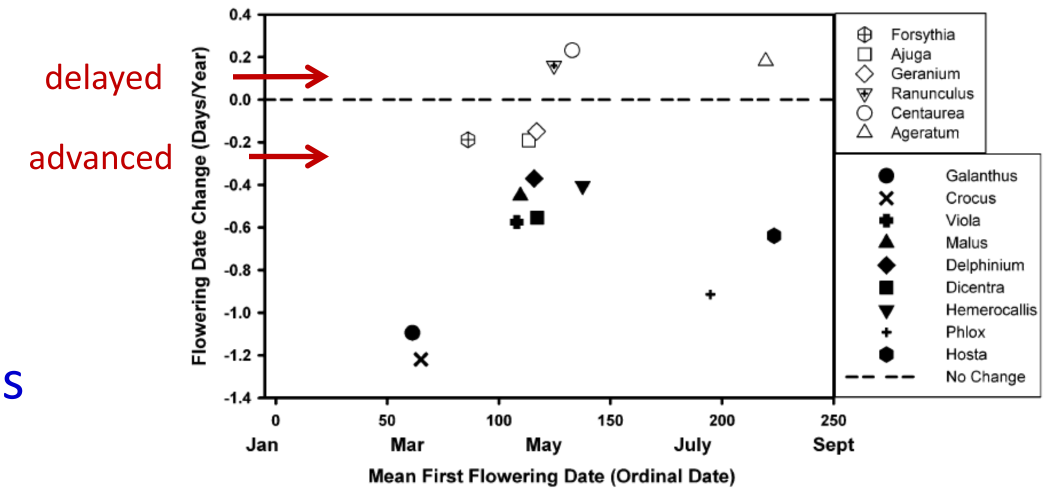
Fall 2013:

- Third warmest fall on record
- Tracked phenology of 11 non-native and 28 native insect-pollinated species

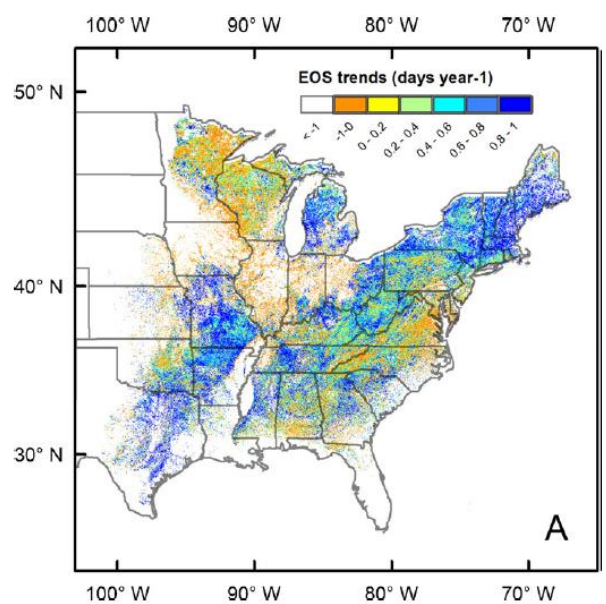
Global Impact of Climate Change on Plant Phenology

- Globally plants are showing <u>advanced</u> leaf-out and flowering
- Globally, plants are showing <u>delayed</u> leaf senescence
- Fall responses are generally smaller than spring responses
- However, although whole communities show an advance, species differ in their response
- Often, only a minority respond strongly, while the rest show little or no response

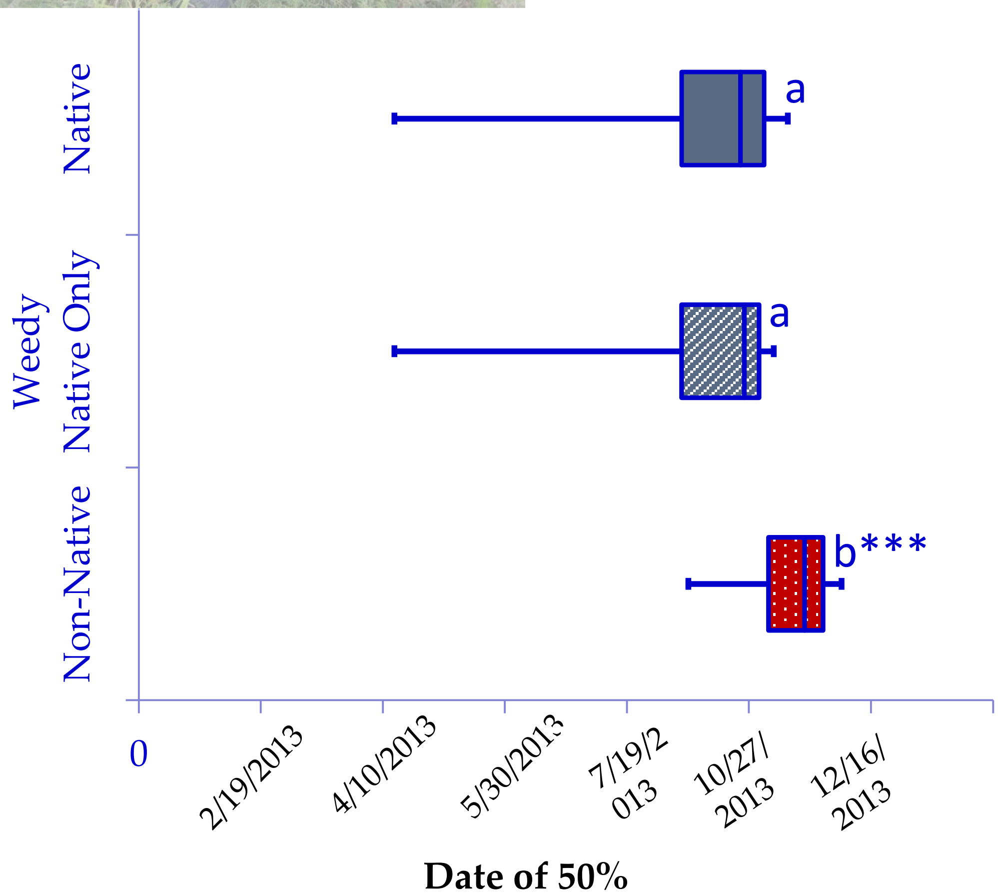
McEwan et al. 2011: Ohio, USA, 1976-2003

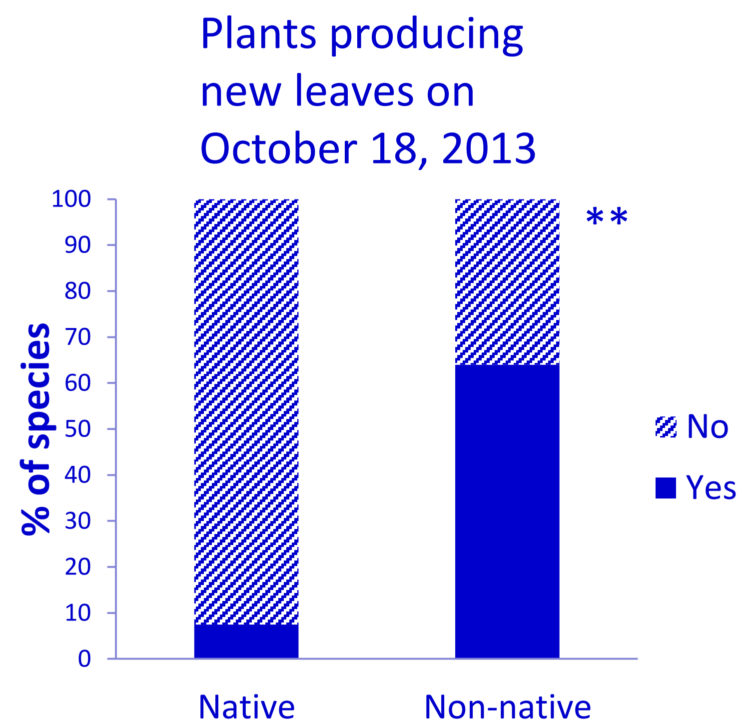


Dragoni and Rahman 2012: deciduous forest 1989-2008



Do native plants senesce earlier in a late fall than non-native plants?





Does this mean native plants will outcompete non-natives?

- This comparison did not include graminoids
- We do not know how evergreen and wintergreen species respond to extended seasons
- We do not know responses to <u>negative</u> impacts of extended climate (increased variability, increased freeze-thaw cycles)

Evergreen (top) and wintergreen (bottom) species showing winter reddening

Increased temperatures and increased variability pose new problems to plants

In spring:

- Warmer temperatures can prevent plants from maintaining freeze tolerance
- Snow is a good insulator; early melt can result in more freeze-thaw cycles, exposure to very cold conditions, and dessication
- Extreme winter warming can result in ice encasement, with severe shoot damage

In fall:

- continued warm temperatures can prevent nutrient resorption
- It can also result in reduced cold acclimation, leading to frost damage once the temperatures do drop

Leaves killed by a late spring frost

Ice encasement makes branches vulnerable to breakage

Birch broken by ice build-up

Images: Missouri Botanical Garden, http://www.missouribotanicalgarden.org/

Conclusions

1) Overlap in flowering time between Vaccinium and Melilotus likely varies across the North due to
   - differences in responses to environmental conditions
   - differences in developmental rates for *Vaccinium* but not *Melilotus*

2) Invasive plants may be more able to take advantage of extended falls than native species
   - Developmental rates of native plants may be relatively inflexible
   - Very few deciduous native plants continue leaf activity in a late fall

   What consequences could shifts in resources have for pollinators and herbivores?

3) Models based on herbarium data for native plants have the potential to
   - identify environmental variables to which plants respond
   - predict flowering phenology

Next Steps

Next steps:

1) **Project Brown-Down**: an expansion of the citizen science network to include leaf senescence

2) Identification of traits that predict ability of native and non-native plants to benefit from early springs and late falls

3) Evaluation of whether this will result in consistent shifts at the next trophic levels (herbivores and detritivores)

Special thanks to all the herbarium staff:

- UA Museum of the North (Steffi Ickert-Bond, Jordan Metzgar)
- U of Washington Burke Herbarium (David Giblin)
- New York Botanical Gardens
- U of Connecticut Torrey Herbarium (Bob Capers)
- Canadian Museum of Nature (Jennifer Doubt)
- Royal Ontario Museum (Tim Dickinsen, Deb Metsger)
- U of Manitoba Herbarium (Diana Sawatsky)
- Churchill Northern Studies Center (LeeAnn Fishback)

…and Rocky Rockwell and Kit Schnaars-Uvino for help with data collection

AND TO ALL THE INTREPID EXPLORERS WHO RISKED LIFE AND LIMB TO PICK FLOWERS!!!

Thank you!!!