

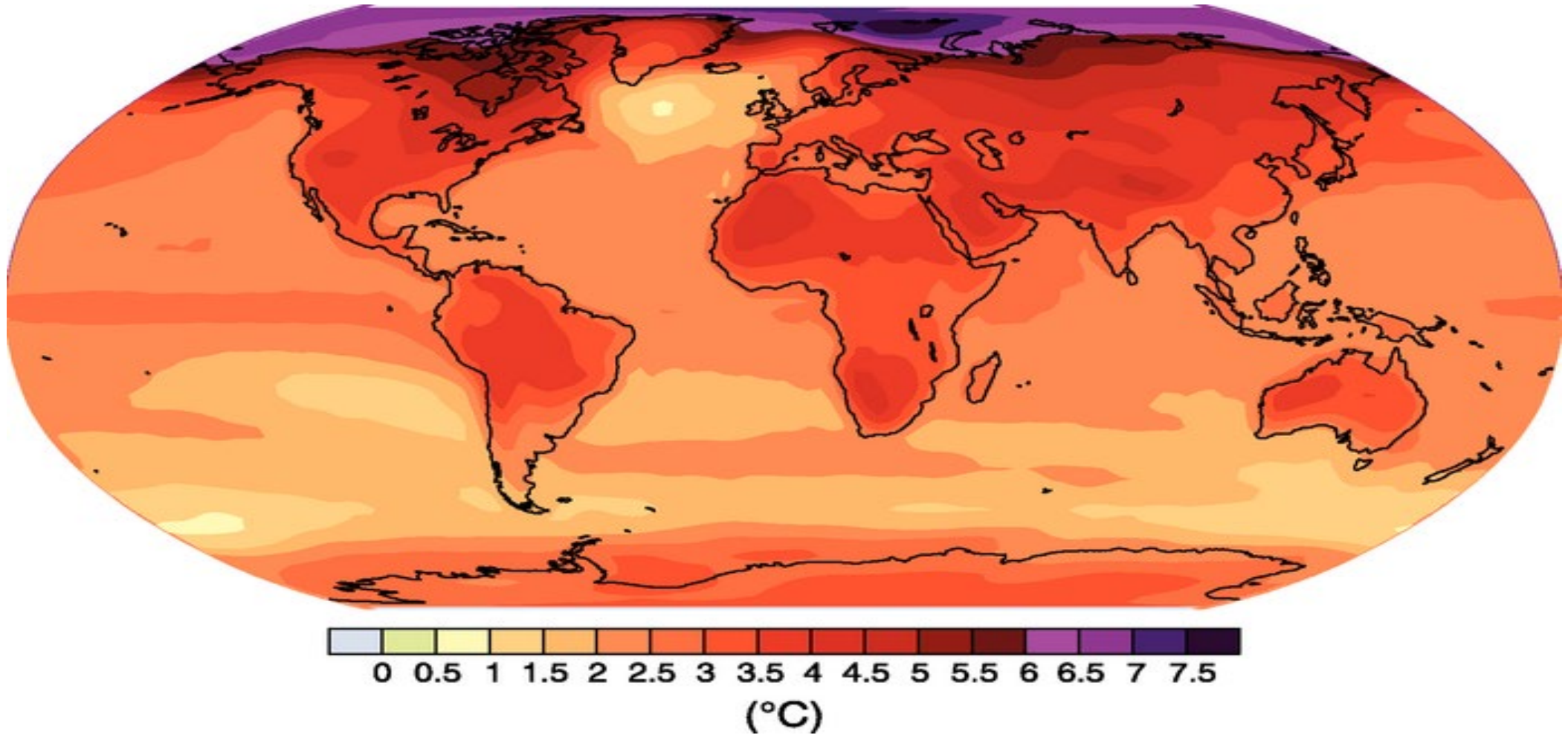
# Failure to shift phenology may be associated with local extinction

MEREDITH A. ZETTEMAYER\* &  
KATARINA RENALDI

KELLOGG BIOLOGICAL STATION,  
MICHIGAN STATE UNIVERSITY

10 JUNE 2019, DIGITAL DATA IN  
BIODIVERSITY RESEARCH CONFERENCE



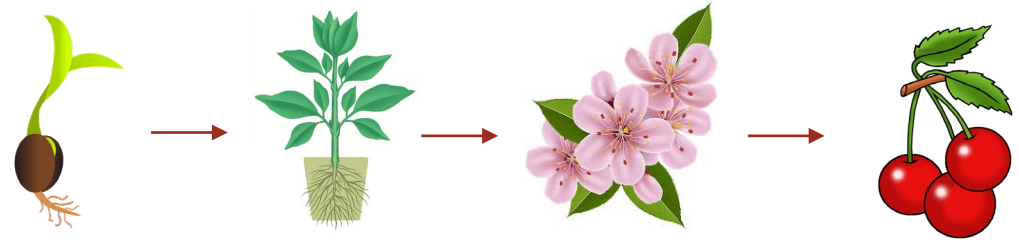


Predicted temperature increases of 2.0-6.2°C by the end of the 21<sup>st</sup> century in the US Midwest (National Climate Assessment)

# Shifts in phenology in response to warming

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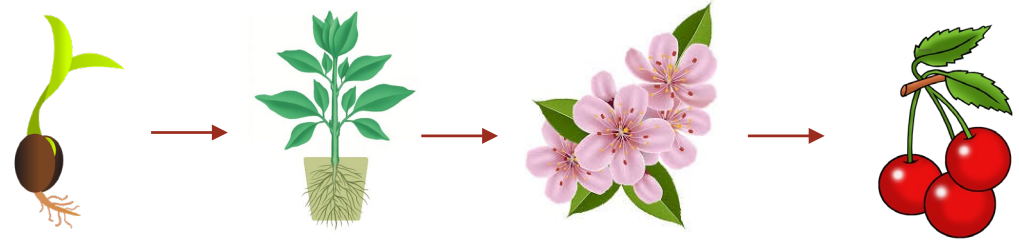
Timing of life history events



# Shifts in phenology in response to warming

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Timing of life history events



Sensitive to local environmental conditions



Native species likely adapted to local conditions

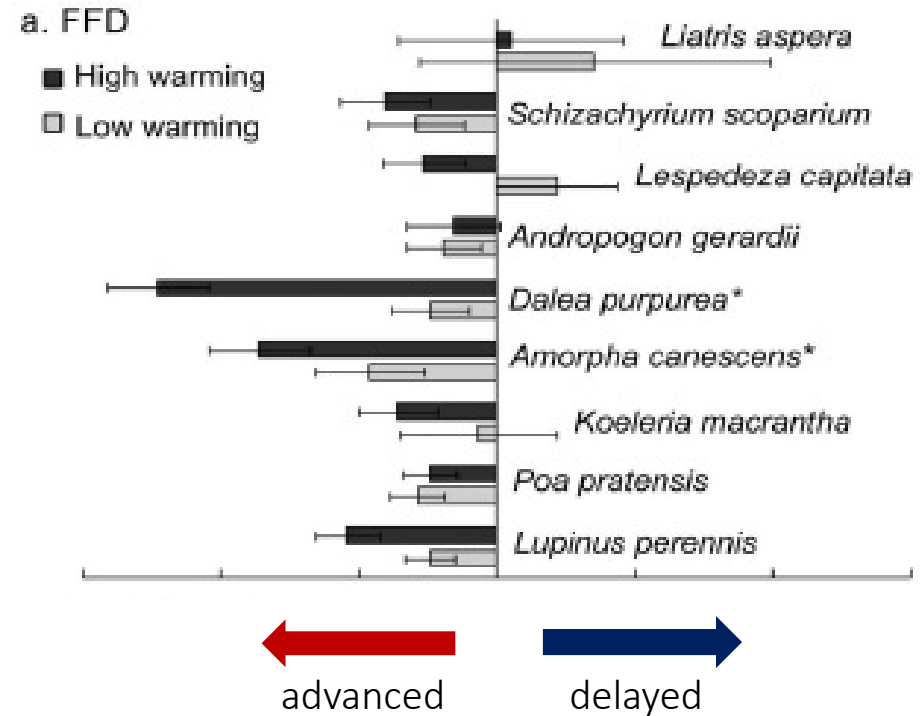
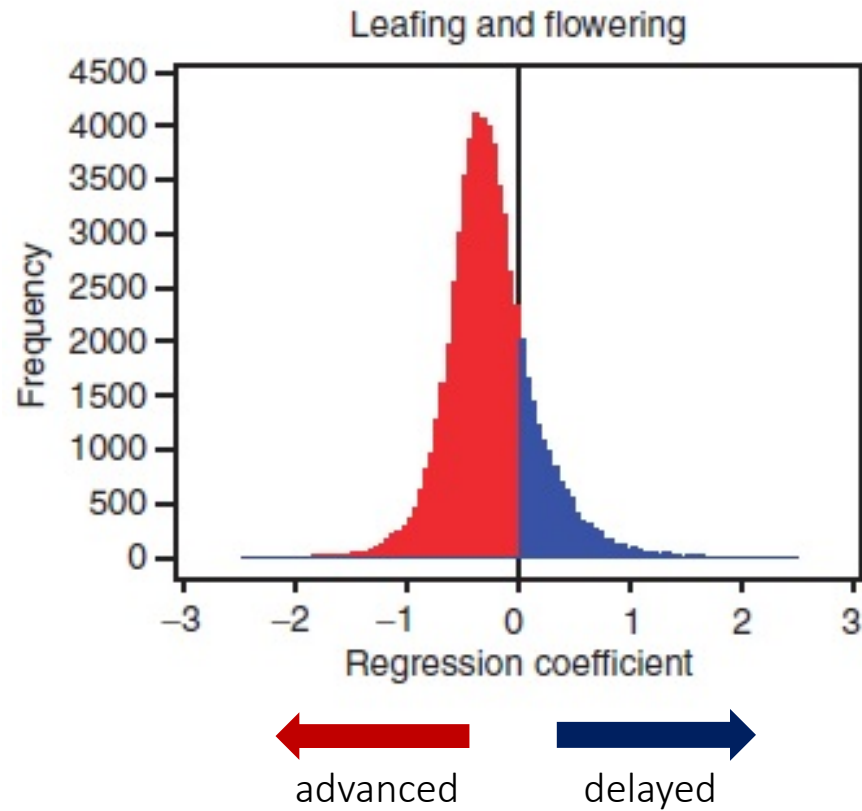
Climate change may cause a mismatch

# Potential impacts of shifting phenology

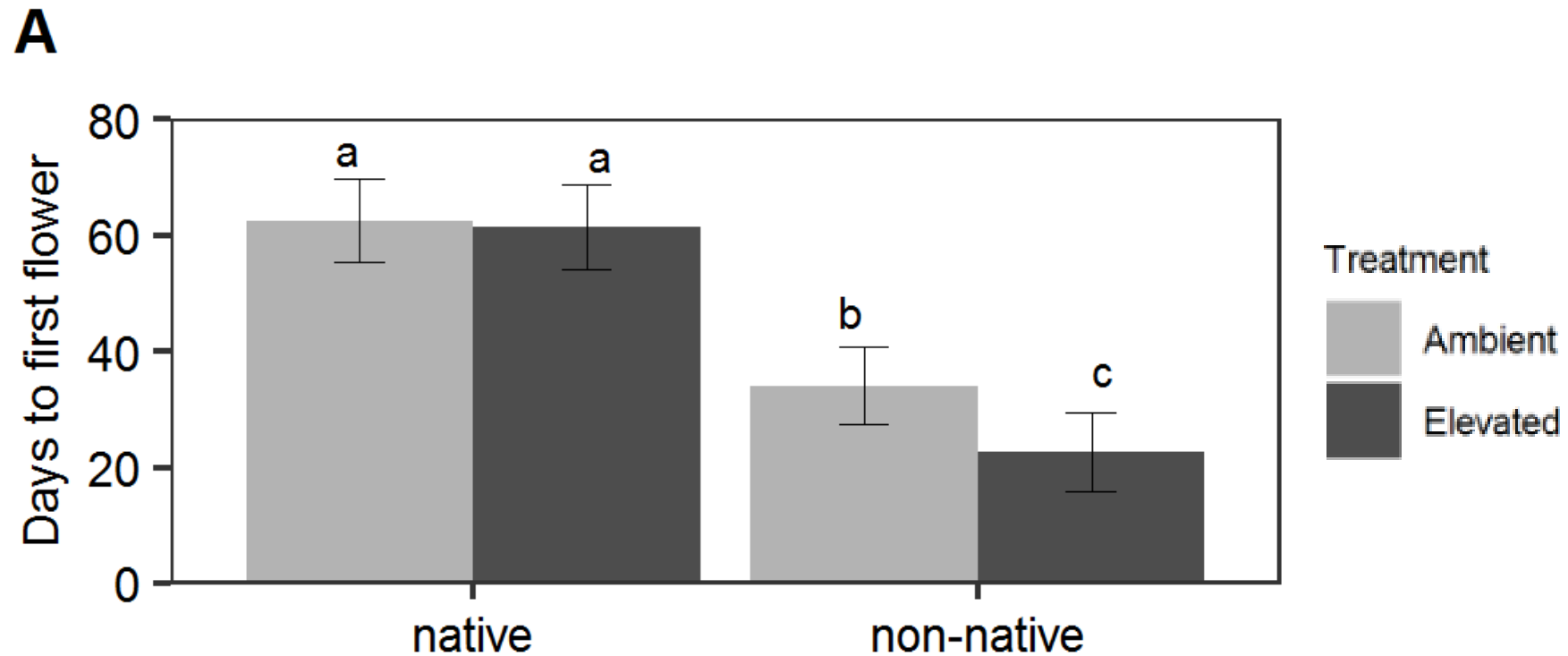
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- Plant pollinator interactions
- Resource access
- Competition with other species
- Species fitness and population dynamics

# Advancing (but variable) phenology under warming climates

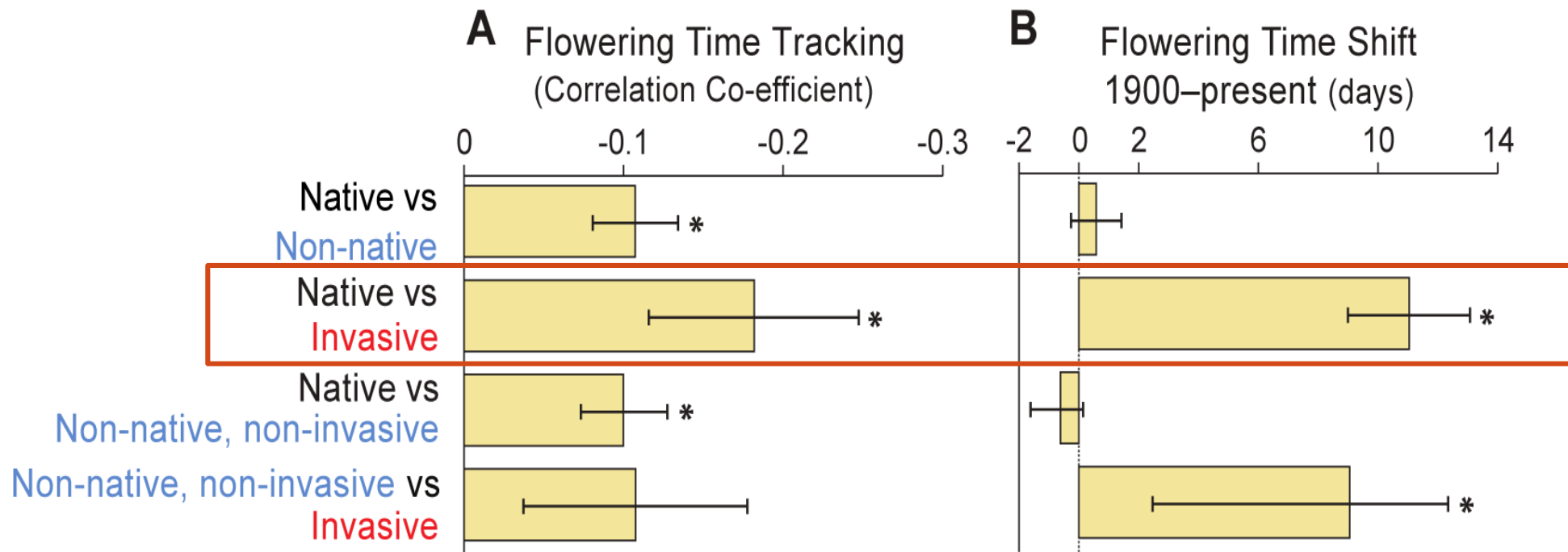


# Native species are less responsive to warming temperatures



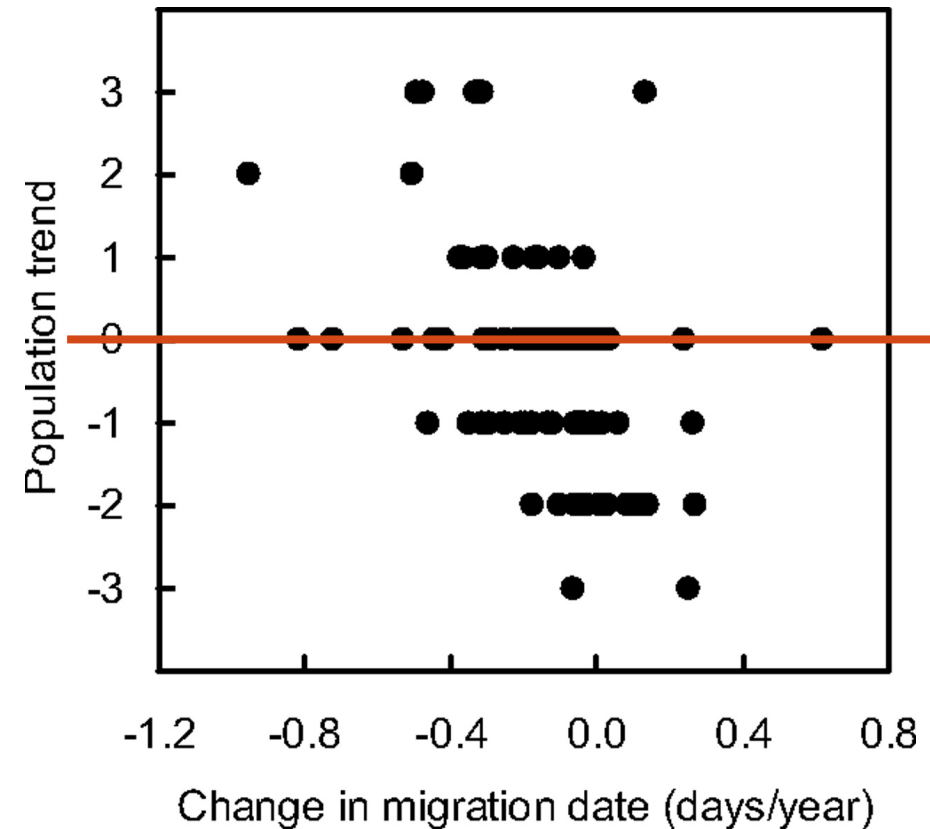
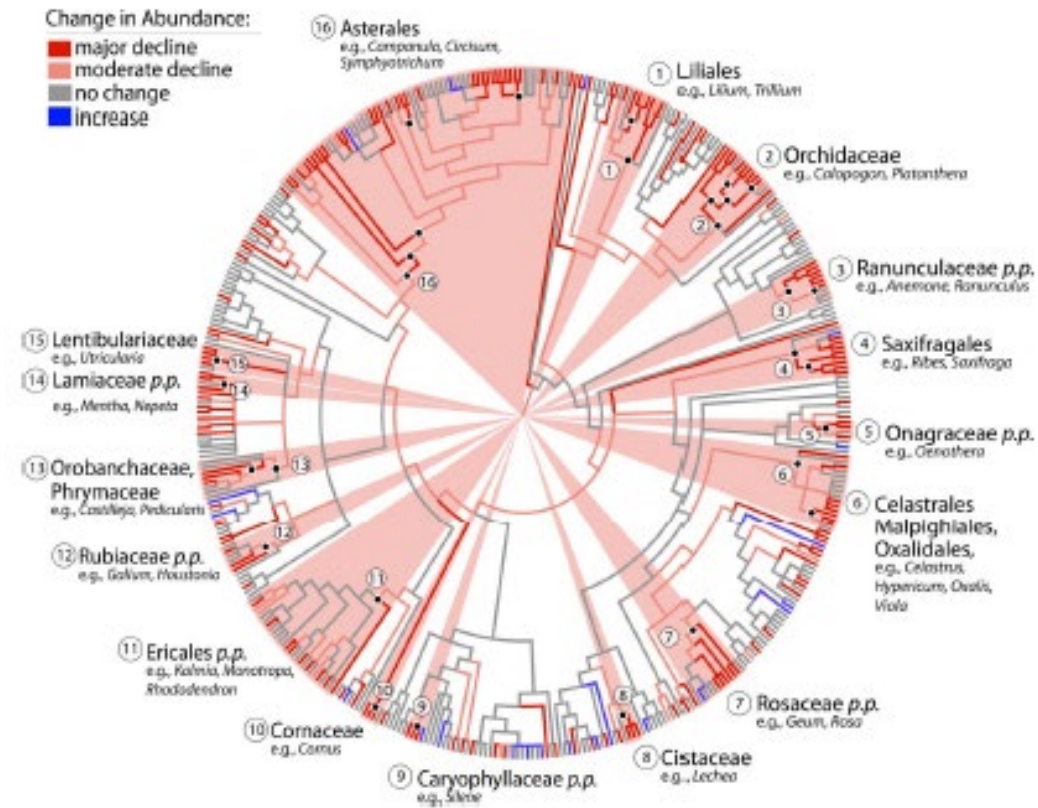
# Native species are less responsive to warming temperatures

## Climate Change Response Traits





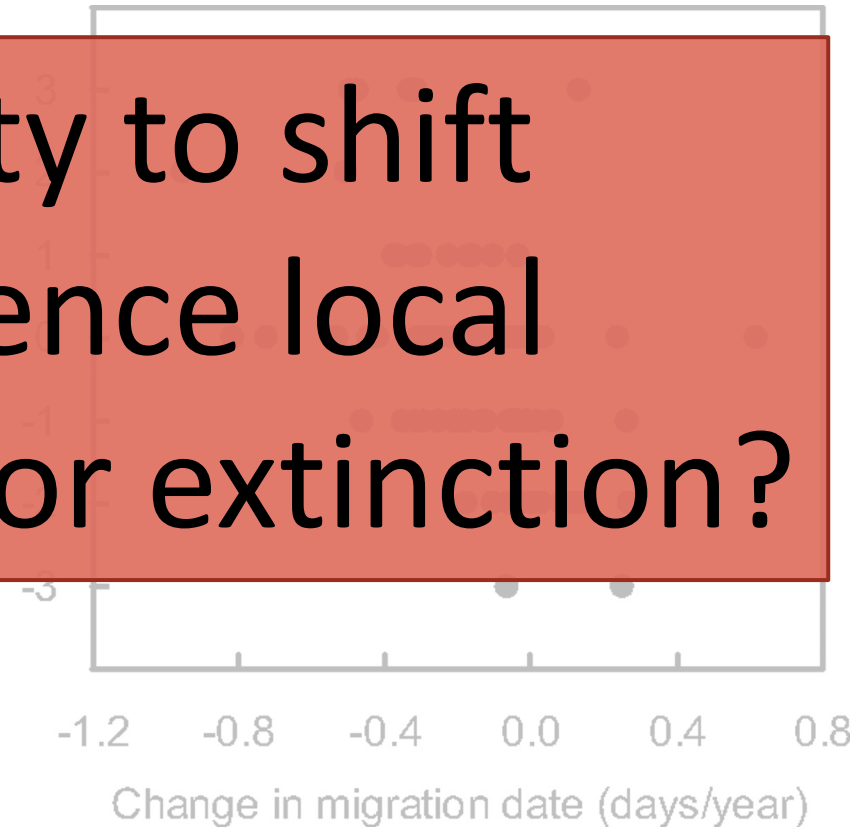
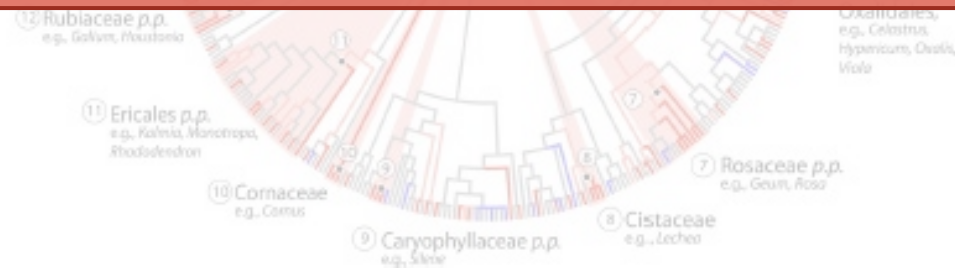
# Non-responding species are more likely to exhibit population declines



Willis et al. (2008) *PNAS*  
Møller et al. (2008). *PNAS*

Non-responding species are more likely to exhibit population declines

Does the inability to shift phenology influence local population declines or extinction?



# Research Questions

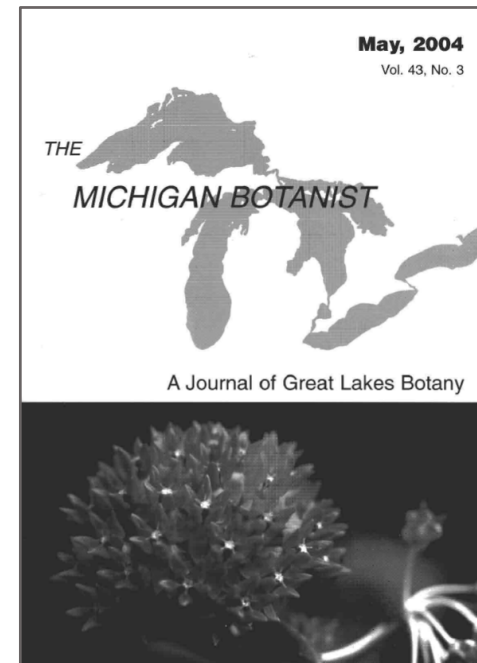
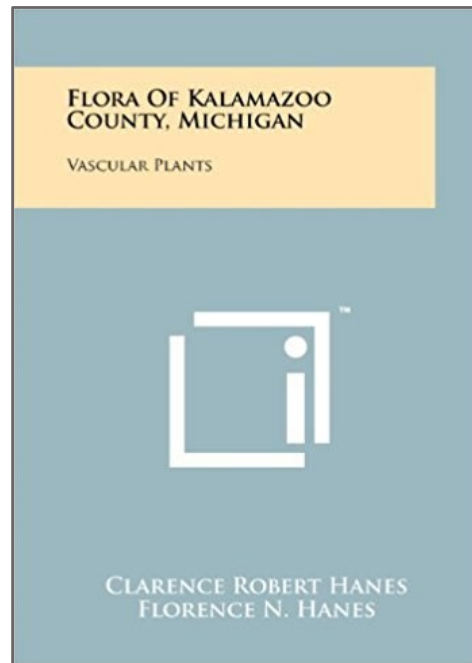
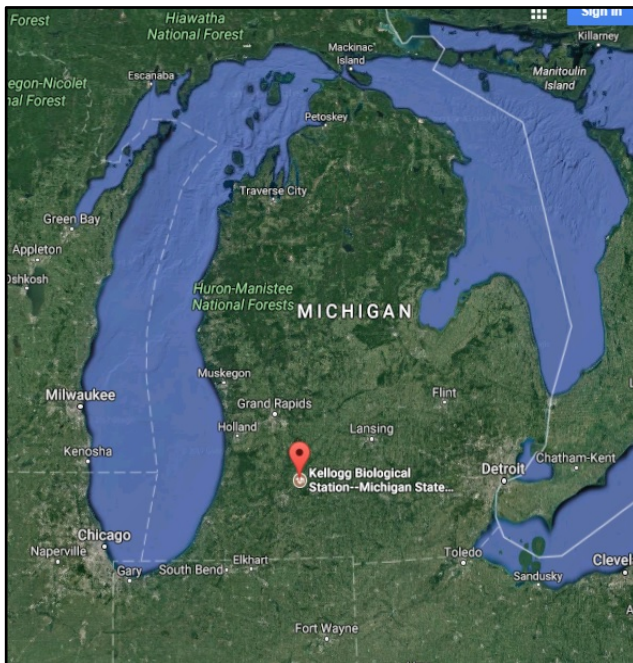
---

1. Does the phenology of locally extinct and extant species differ?
2. Has the phenology of locally extinct and extant species shifted over time?
3. Has the phenology of locally extinct and extant species shifted in response to temperature?

# Extinction in Kalamazoo County, MI

Area surveyed in 1947, 1990

Historical records provide presence-absence and habitat data



Hanes & Hanes (1947).  
McKenna (2004). *MI Bot.*  
Map: MI Natural Features Inventory

# Species loss in Kalamazoo County, MI

*4% species lost, mostly specialist prairie forbs*





\* Locally extinct species



\* *Locally extinct species*



*Eryngium yuccifolium*



*Thaspium trifoliatum\**



*Penstemon digitalis*



*Penstemon hirsutus\**



*Penstemon pallidus\**

*\* Locally extinct species*



# Leveraging herbarium records

- Local, species-specific
- Span centuries
- Large sample size
- Likely replace changes that have recently driven species to local extinction



Plotnick, R. et al. (2016). *Ecol. Lett.*  
Primack, D. et al. (2004). *Am. J. Bot.*

JAN 5 1981



WIEGAND HERBARIUM OF CORNELL UNIVERSITY  
FLORA OF THE ALLEGHENY MOUNTAINS  
OF PENNSYLVANIA  
LAUREL HILL, Somerset COUNTY  
PLANTS COLLECTED BY STANWYN G. SHETLER  
ALT. 610 METERS  
COLL. No. 56  
PLANT No. 7681

*Baptisia tinctoria* (L.) R. Br.  
(var. *tinctoria*)  
flowers yellow  
Well drained, stony, loamy sand; open  
at edge of dry oak woods near  
northwest

APR 20 1978







































U. S. Geol

Bapti  
Fla  
sl  
Me  
J

Counted buds, flowers, fruits

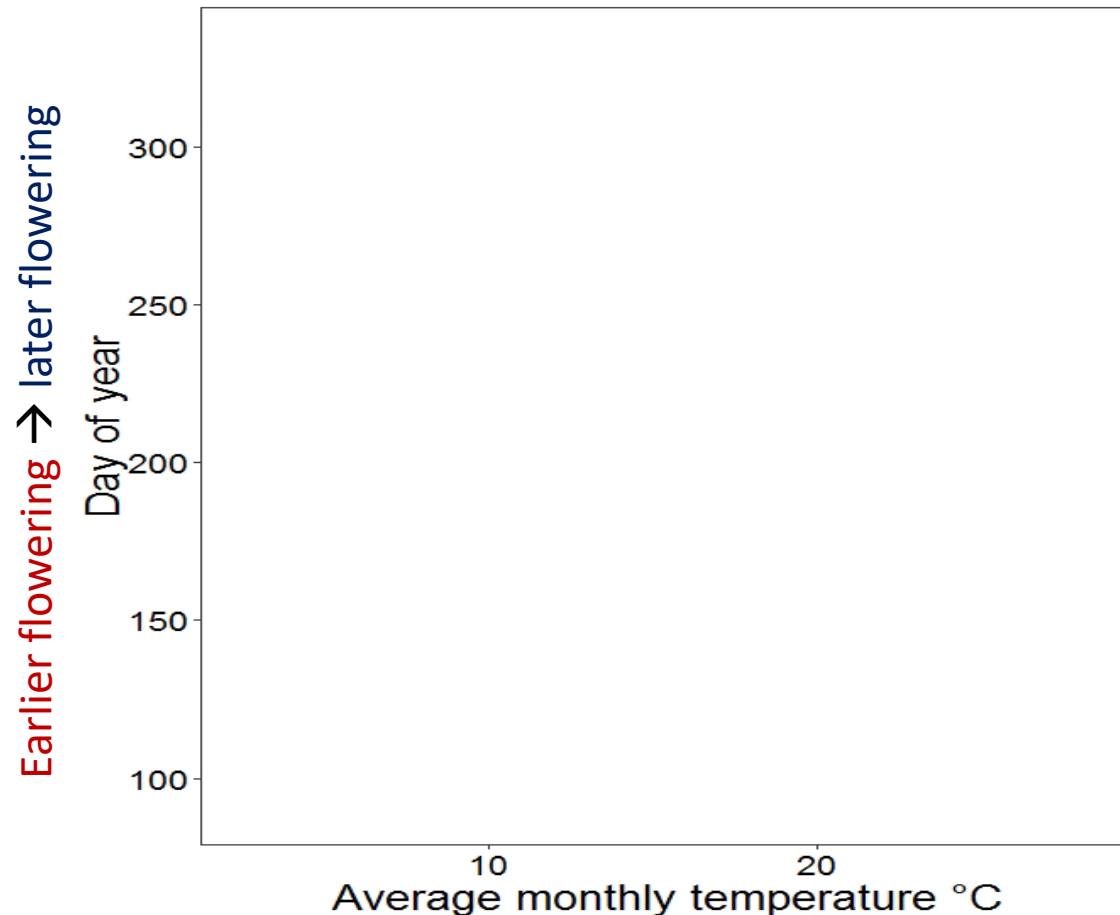
# Using the Consortium of Midwest Herbaria

-   Amway Herbarium (AMWH) [more info...](#)
-   Albion College (ALBC) [more info...](#)
-   Augustana College (AUGIE) [more info...](#)
-   Butler University, Friener Herbarium (BUT) [more info...](#)
-   Butler University, Friener Herbarium, Indiana Plant Atlas (BUT-IPA) [more info...](#)
-   Calvin College (CALVIN) [more info...](#)
-   Central Michigan University (CMC) [more info...](#)
-   Chicago Botanic Garden (CHIC) [more info...](#)
-   Eastern Michigan University Herbarium (EMC) [more info...](#)
-   Field Museum of Natural History (F-Sotany) [more info...](#)
-   Grand Valley State University (GVSC) [more info...](#)
-   Hilledale College Herbarium (HLSD) [more info...](#)
-   Hope College (HCHM) [more info...](#)
-   Huntington University Herbarium (HUNT) [more info...](#)
-   Illinois Natural History Survey (ILLS) [more info...](#)
-   Indiana University Herbarium (Deam Herbarium) (IND) [more info...](#)
-   Indiana University Southeast Herbarium (JEF) [more info...](#)
-   J. F. Bell Museum of Natural History Herbarium (MIN) [more info...](#)
-   Kent State University Herbarium (KE) [more info...](#)
-   Miami University, Willard Sherman Turrell Herbarium (MU) [more info...](#)
-   Michigan State University (MSC) [more info...](#)
-   Morton Arboretum (MOR) [more info...](#)
-   Northern Illinois University Herbarium (DEK) [more info...](#)
-   Northland College (NC) [more info...](#)
-   Ohio State University Herbarium (OS) [more info...](#)
-   Ohio University, Bartley Herbarium (BHO) [more info...](#)
-   Purdue University, Kriebel Herbarium (PUL) [more info...](#)
-   Seney National Wildlife Refuge (SENEY) [more info...](#)
-   Stover-Eblinger Herbarium (Eastern Illinois University) (EIU) [more info...](#)
-   University of Cincinnati, Margaret H. Fulford Herbarium (CINC) [more info...](#)
-   University of Illinois Herbarium (ILL) [more info...](#)
-   University of Michigan Herbarium (MICH) [more info...](#)
-   University of Notre Dame, Green/Nieuwland Herbarium (ND) [more info...](#)
-   University of Wisconsin-LaCrosse (UWL) [more info...](#)
-   University of Wisconsin-Madison, Wisconsin State Herbarium (WIS) [more info...](#)
-   University of Wisconsin-Milwaukee (UWM) [more info...](#)
-   University of Wisconsin-Stevens Point, Robert W. Freckmann Herbarium (UWSP) [more info...](#)
-   Western Illinois University, R. M. Myers Herbarium (MWW) [more info...](#)
-   Western Michigan University (WUW) [more info...](#)



# Collection day as a proxy for flowering

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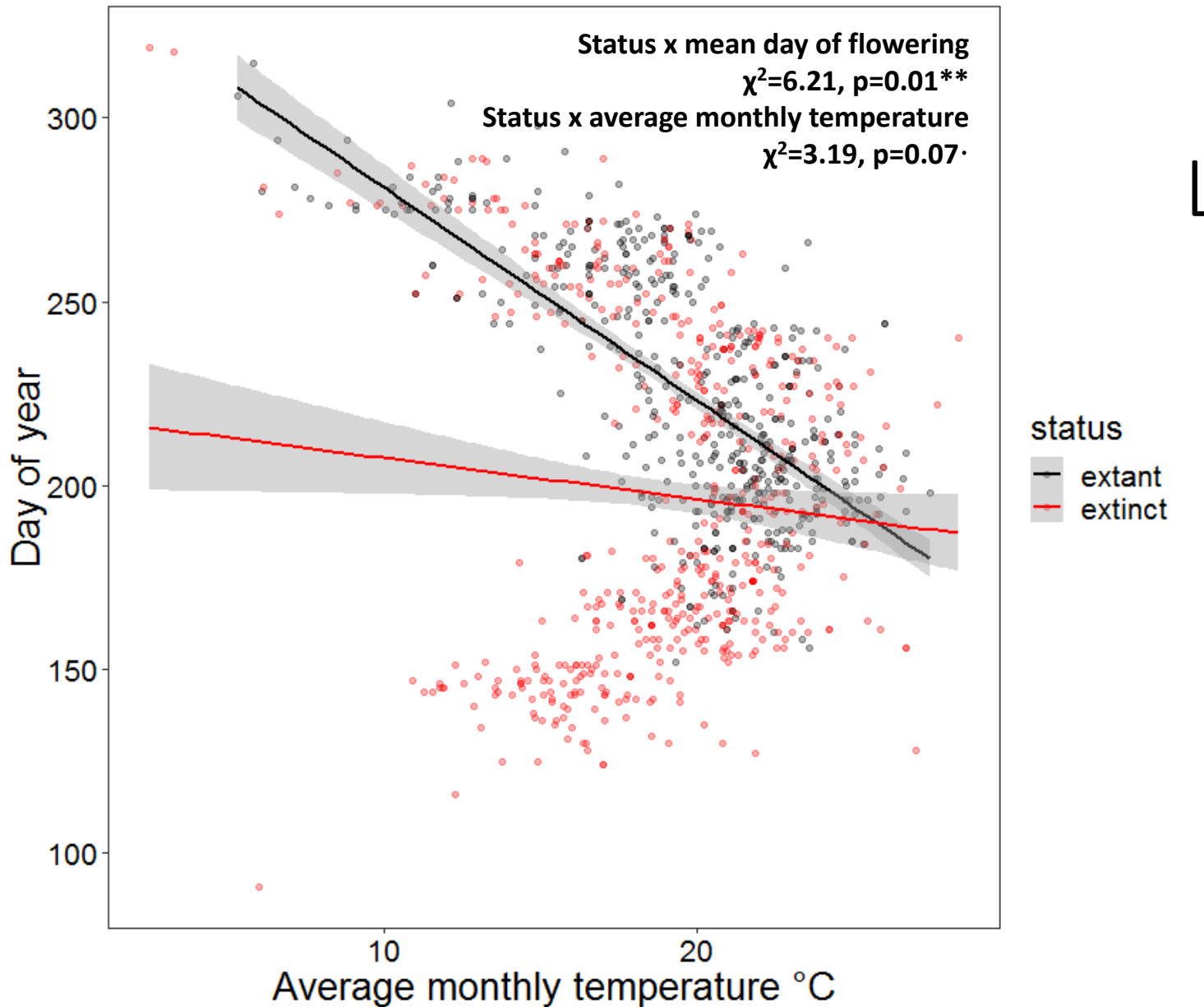


- Compared to a continuous phenological variable
- Compared to growing season temperature
- Controlled for latitude and mean day of flowering

# Research Questions

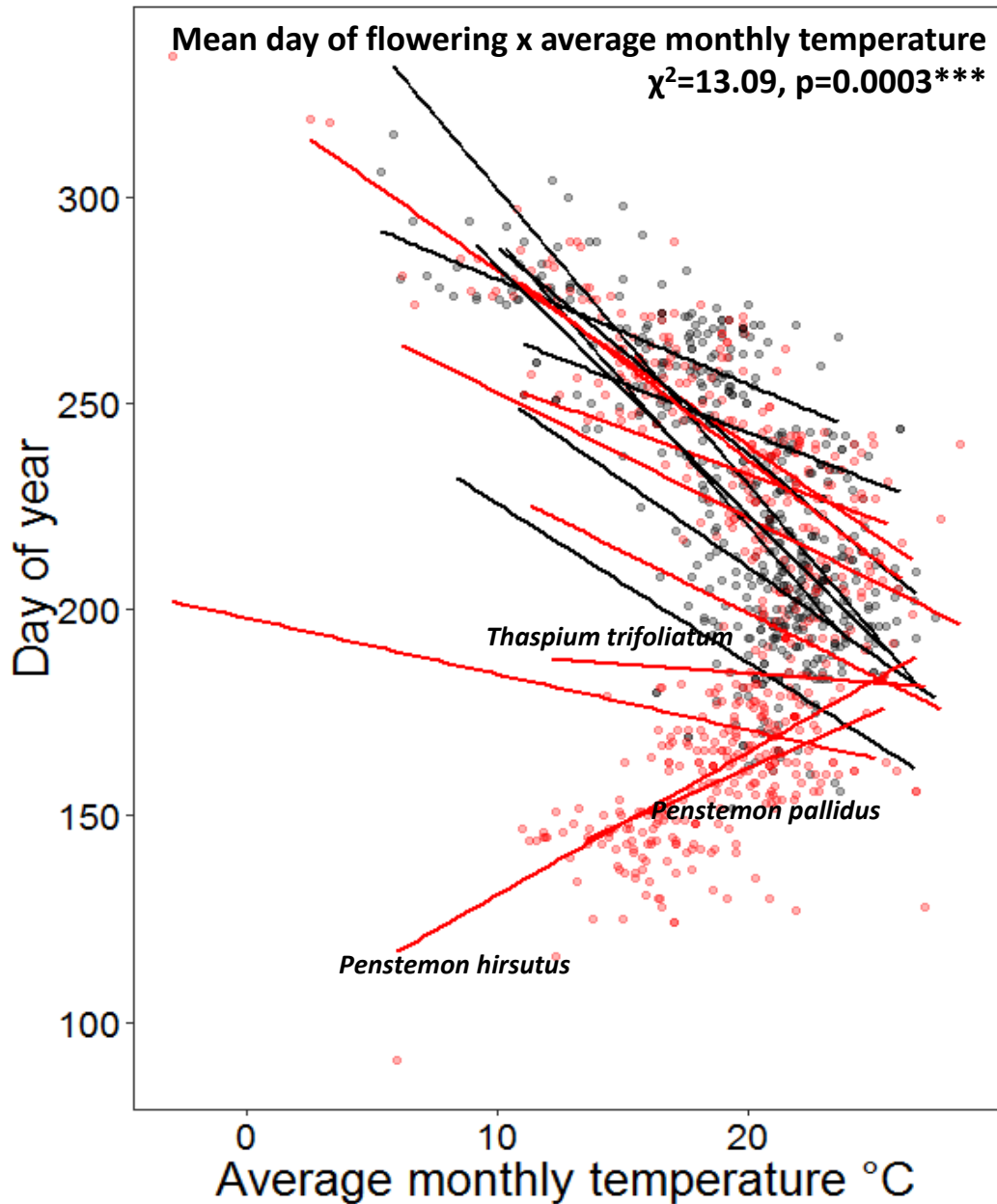
---

1. Does the phenology of locally extinct and extant species differ?
2. Has the phenology of locally extinct and extant species shifted over time?
3. Has the phenology of locally extinct and extant species shifted in response to temperature?



## Locally extinct species:

- Flower earlier than extant species
- Tend to be less responsive to temperature than extant species



species

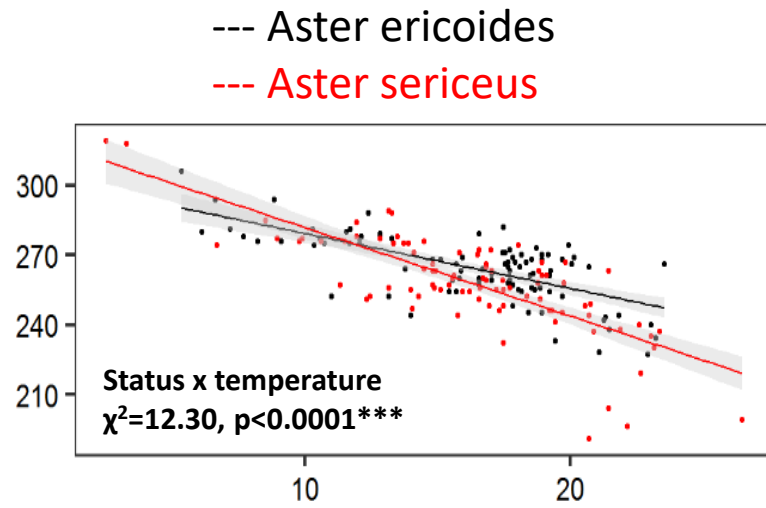
- Aster ericoides
- Aster sericeus
- Baptisia bracteata
- Baptisia tinctoria
- Eryngium yuccifolium
- Liatris aspera
- Liatris punctata
- Monarda fistulosa
- Penstemon digitalis
- Penstemon hirsutus
- Penstemon pallidus
- Pycnanthemum tenuifolium
- Ratibida columnifera
- Ratibida pinnata
- Silphium perfoliatum
- Silphium terebinthinaceum
- Thaspium trifoliatum

--- Extinct

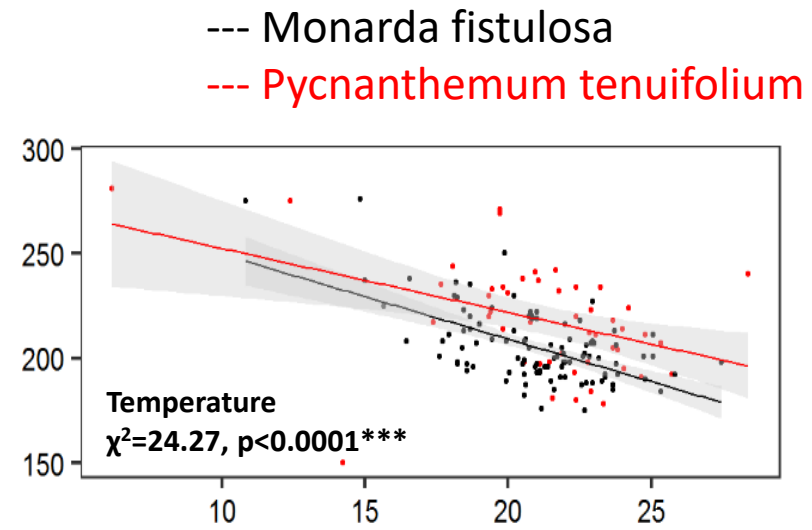
--- Extant

Earlier-  
 flowering  
 (extinct) species  
 shift flowering  
 later at warmer  
 temperatures

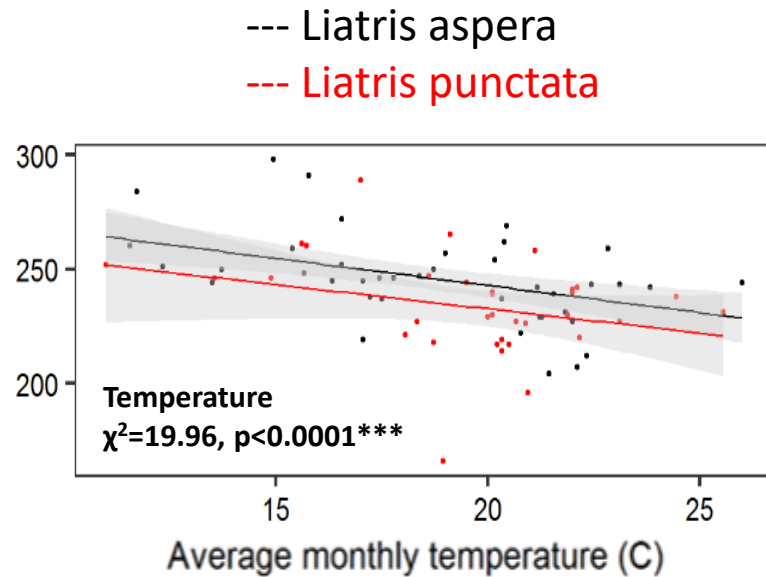
A



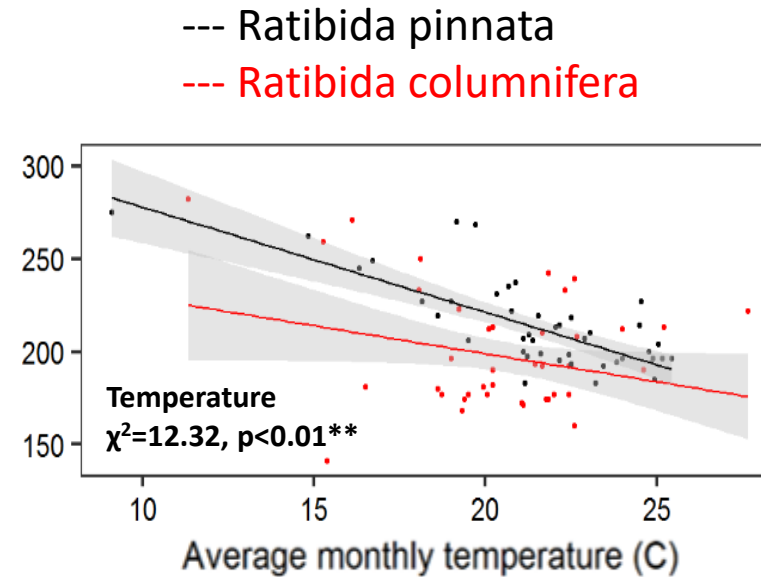
B



C



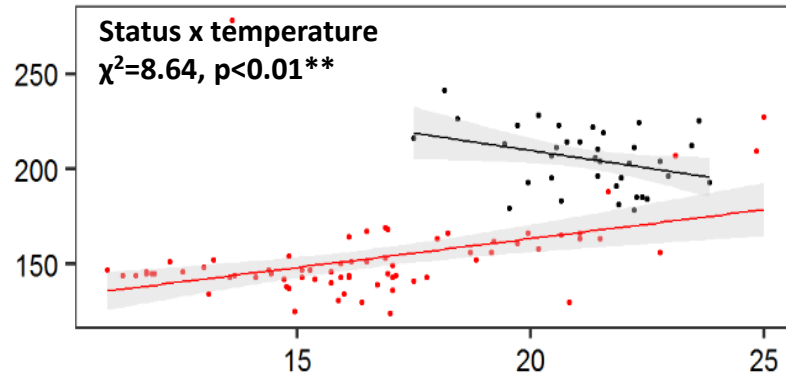
D





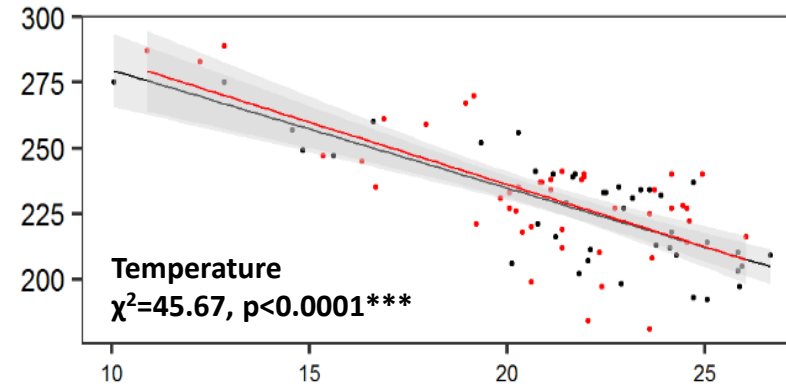
E

--- *Baptisia tinctoria*  
 --- *Baptisia bracteata*



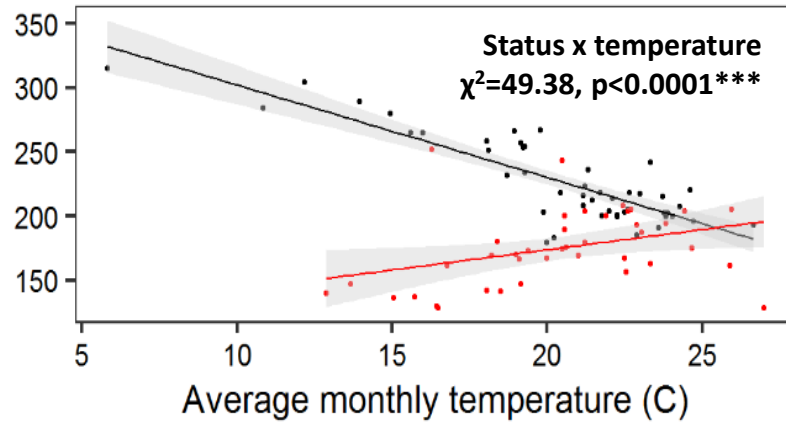
F

--- *Silphium perfoliatum*  
 --- *Silphium terebinthinaceum*



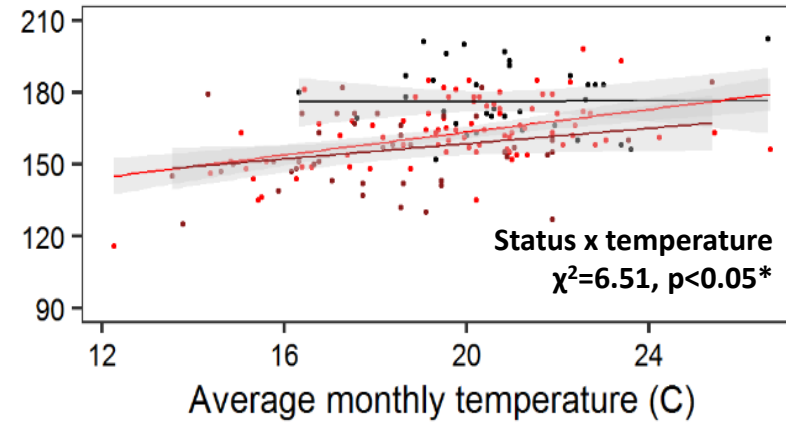
G

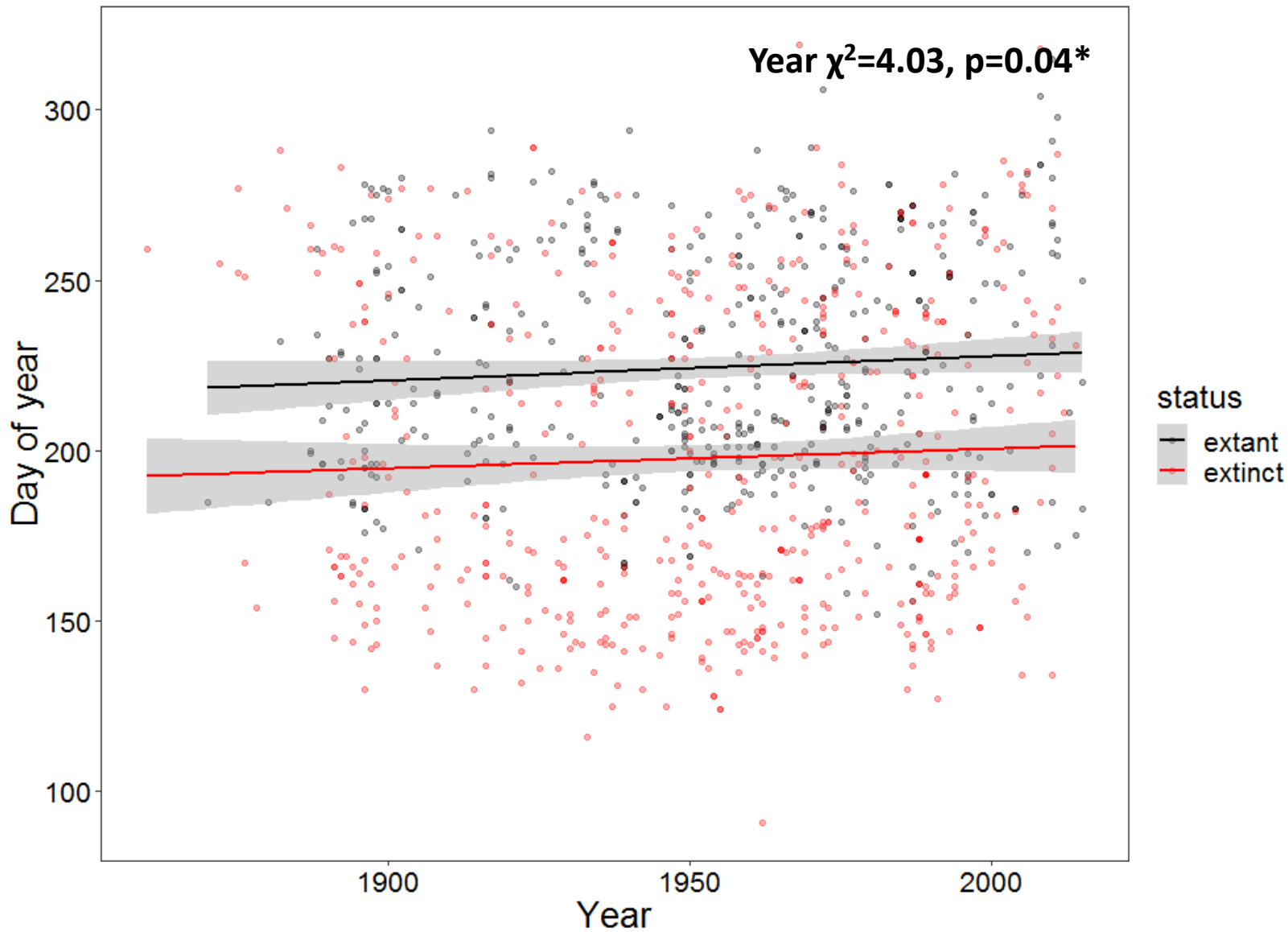
--- *Eryngium yuccifolium*  
 --- *Thaspium trifoliatum*



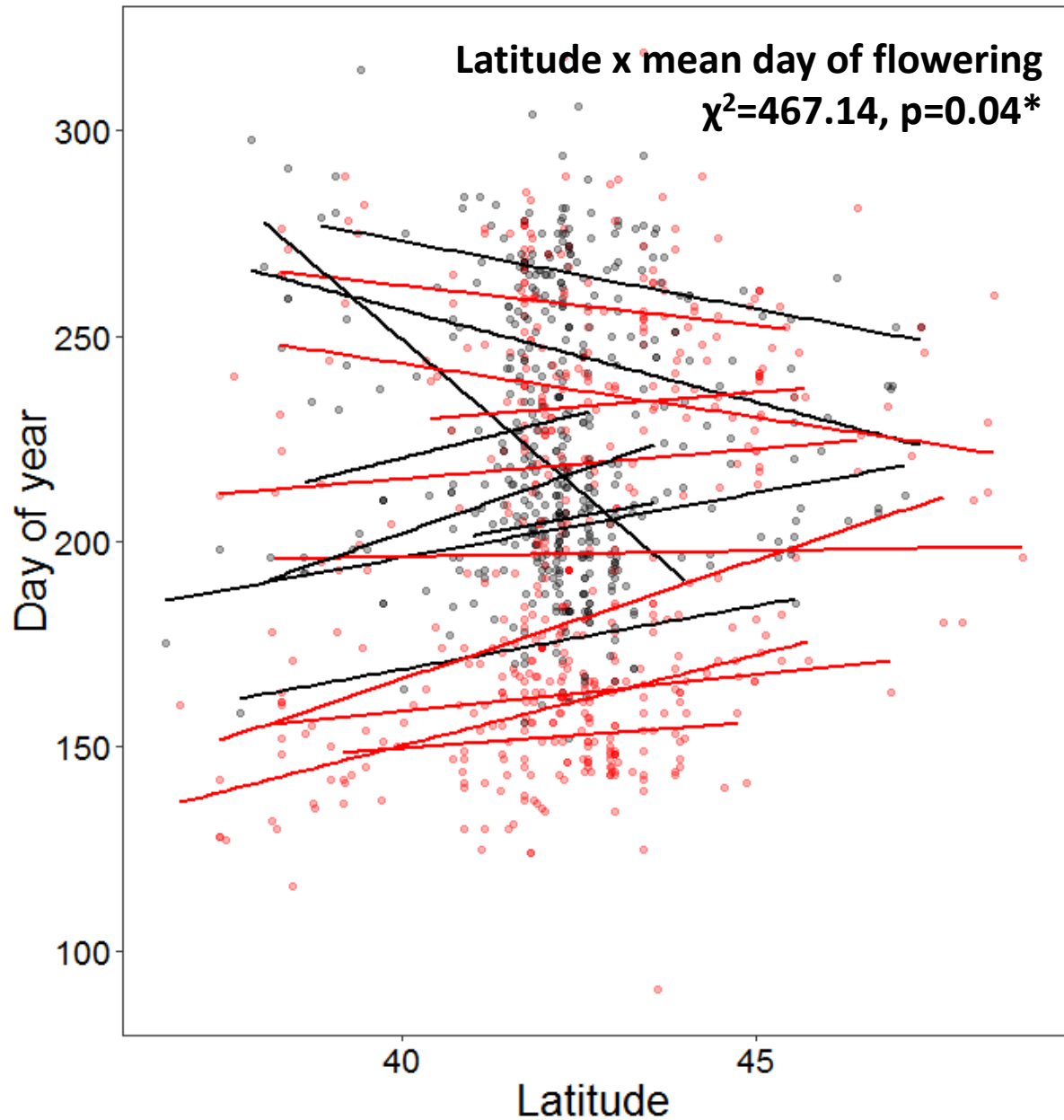
H

--- *Penstemon digitalis*  
 --- *Penstemon hirsutus*  
 --- *Penstemon pallidus*





Flowering has shifted later over time in these native species



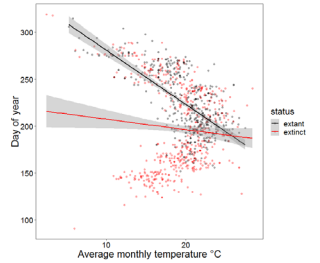
Flowering occurs later at northern latitudes, esp. in early-flowering species

# Research Questions

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1. Does the phenology of locally extinct and extant species differ?

Yes – extinct species flower earlier than extant species.

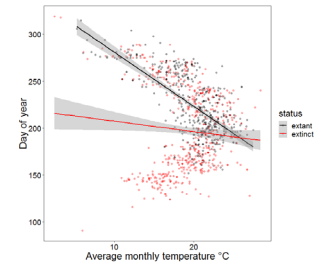


# Research Questions

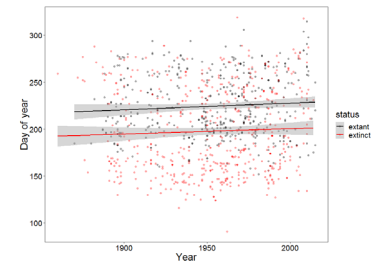
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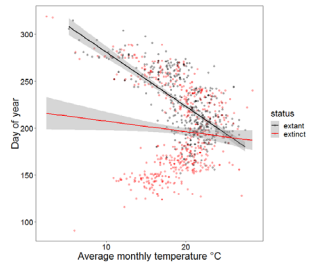
2. Has the phenology of locally extinct and extant species shifted over time? Yes – flowering has shifted later over time.



# Research Questions

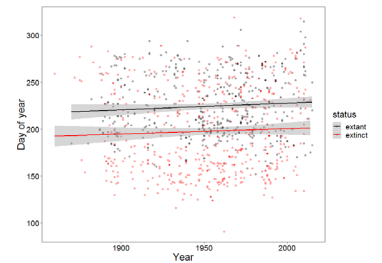
1. Does the phenology of locally extinct and extant species differ?

Yes – extinct species flower earlier than extant species.



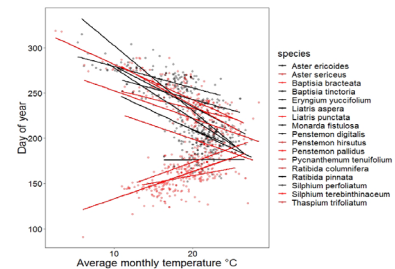
2. Has the phenology of locally extinct and extant species shifted over time?

Yes – flowering has shifted later over time.



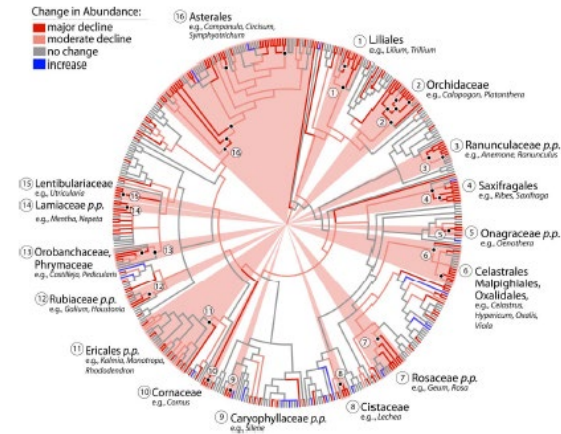
3. Has the phenology of locally extinct and extant species shifted in response to temperature?

Yes – locally extinct species flower later and extant species flower earlier at warmer temperatures.



# Ineffective responses to climate change may increase extinction risk

- Previous evidence suggests that native species that do not respond to climate decline in abundance
- Future work should focus on how temperature and phenology impacts population declines



# Acknowledgements

Dr. Jennifer Lau

Lau Lab

NSF REU Program

Kellogg Biological Station

Michigan State University



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