CLIMATE CHANGE TRACKING USING A CENTURY OF HERBARIUM DATA IN COLORADO

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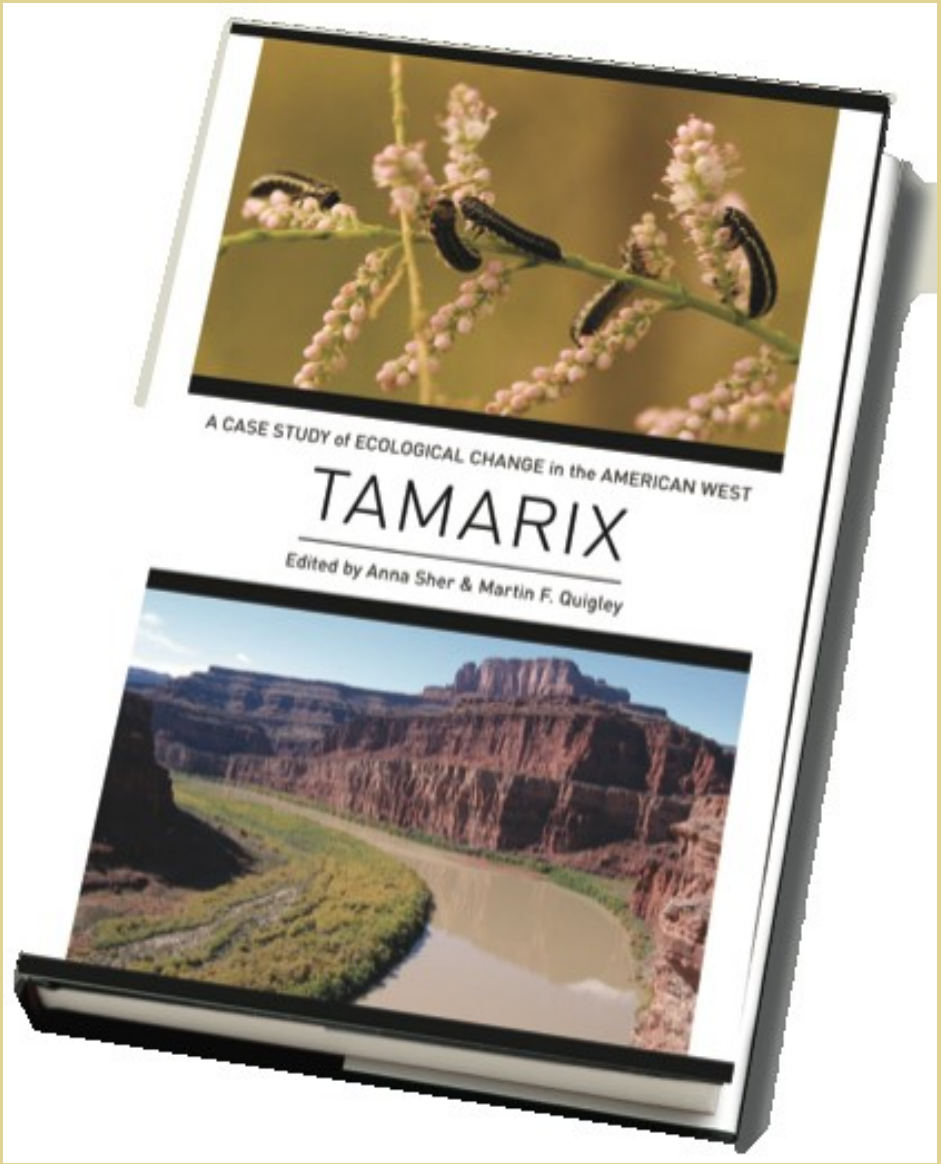
UNIVERSITY of DENVER

DENVER BOTANIC GARDENS

CO Native Plant Society Conference 2015

FIRST, A STORY…



OXFORD UNIVERSITY PRESS

DRAGGED KICKING AND SCREAMING

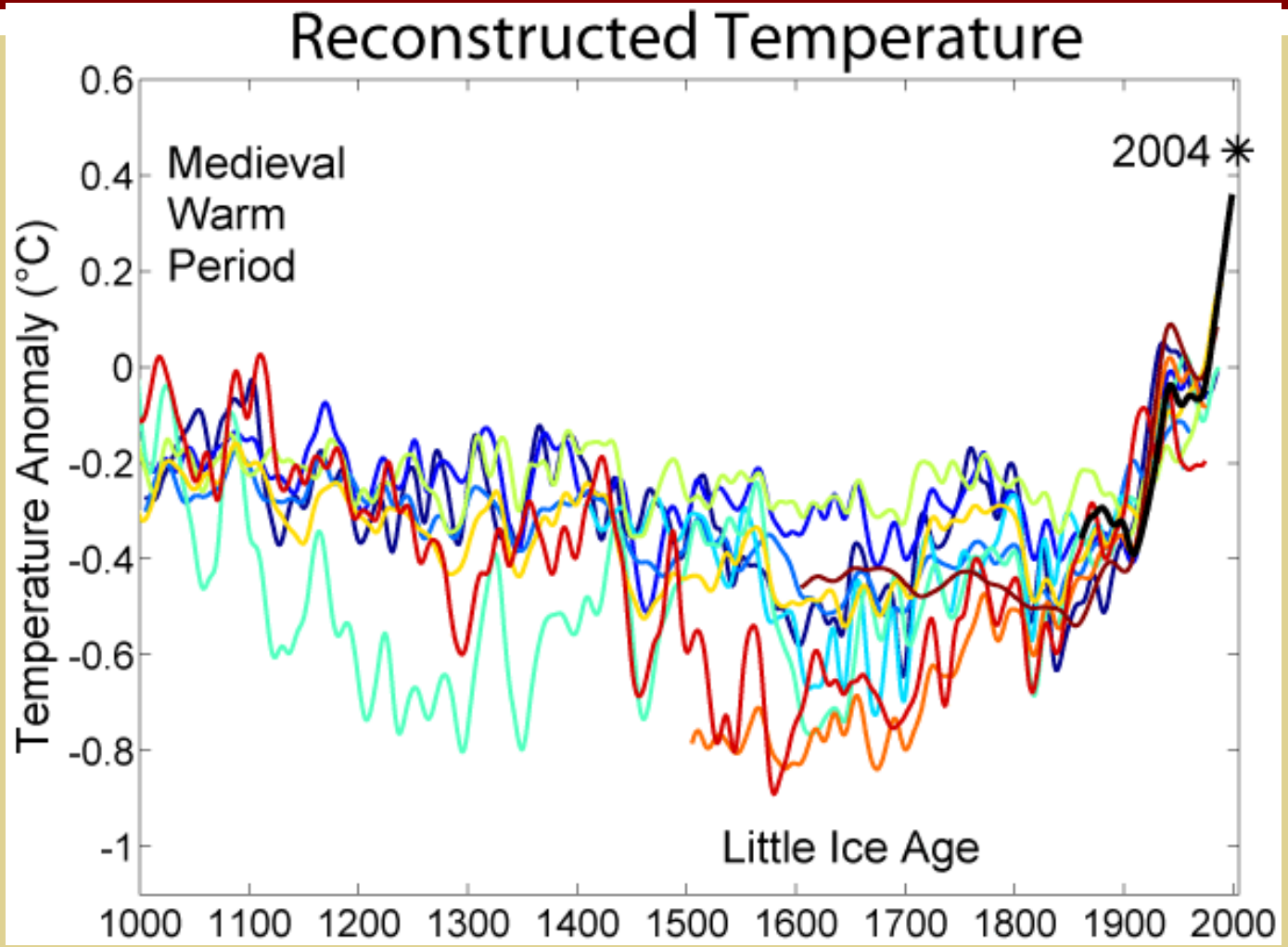
Or "I was a restoration ecologist…"

CLIMATE IS CHANGING

… but there is a lot of noise

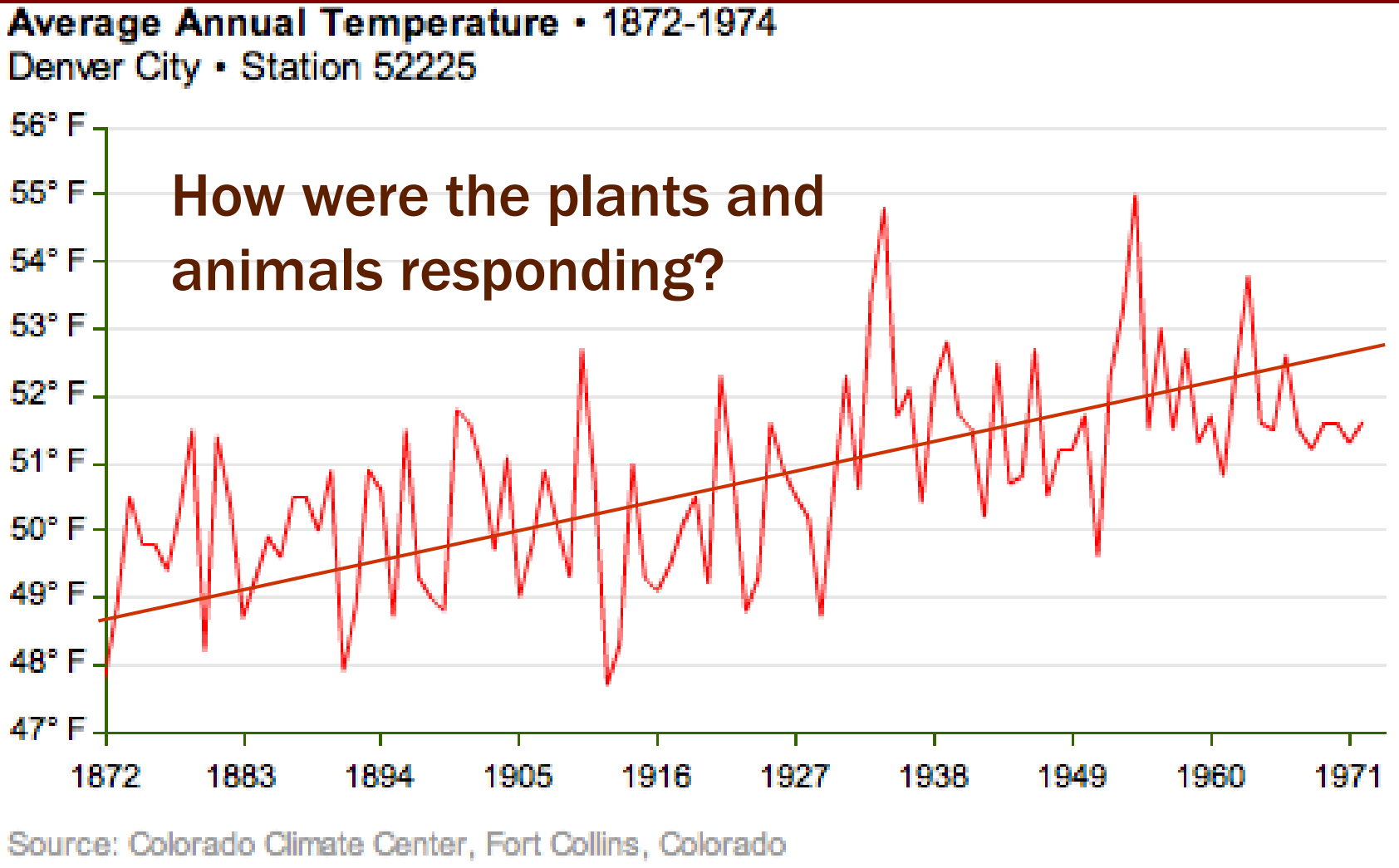
"How do we know that changes we are observing represent long-term trends?"

PLANTS AND POLLINATORS ARE EXPERIENCING NEW TEMPS



By Robert A. Rohde, in Global Warming Art Project

DENVER TEMPERATURES FLUCTUATE YEAR TO YEAR



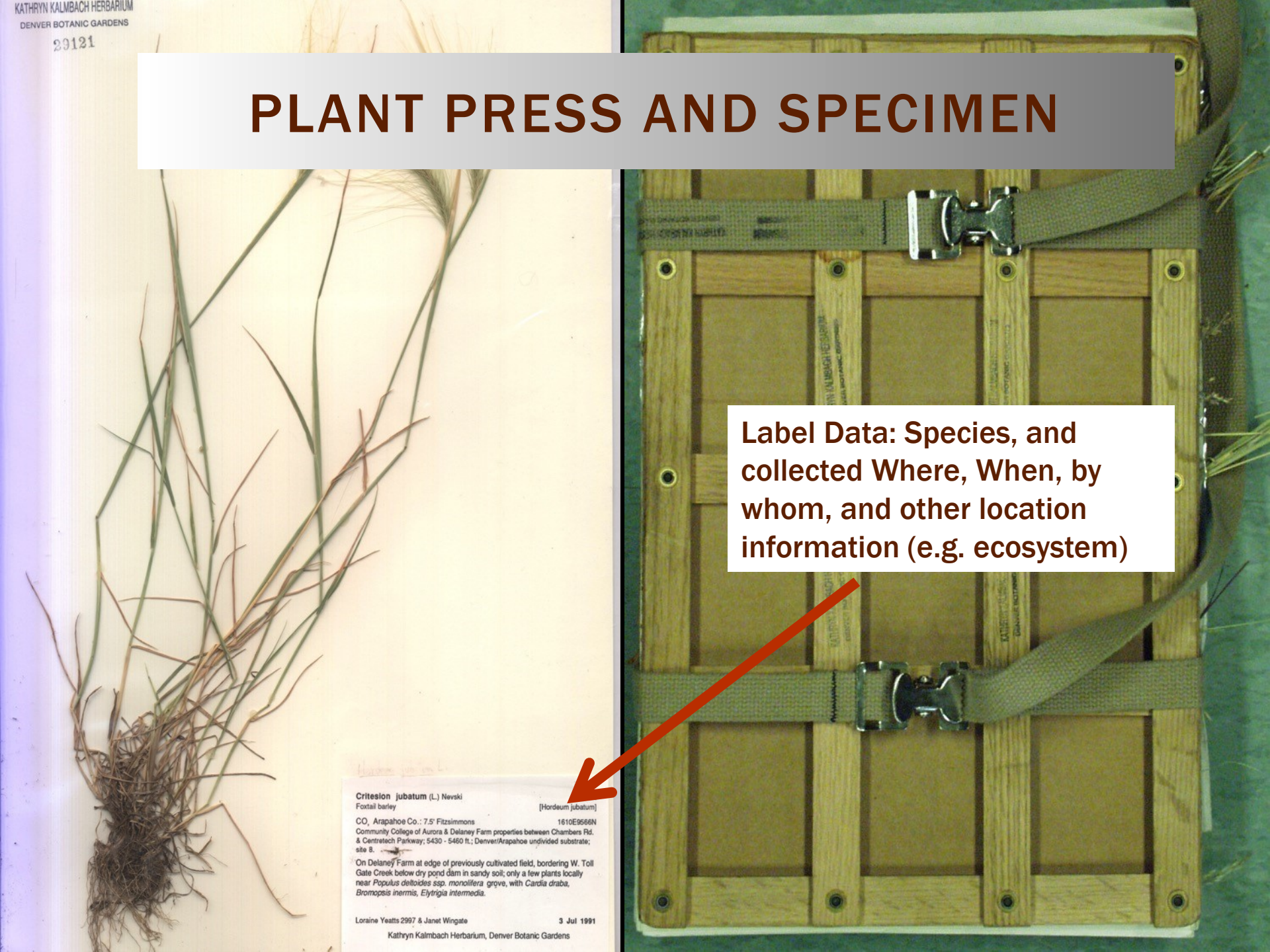
NEED LONG-TERM DATA

Borchert 1996, Primack et al 2004

Our Time machine!

USING HERBARIUM DATA TO TRACK HISTORIC PHENOLOGY

PLANT PRESS AND SPECIMEN



COLLECTION DATE AS PROXY FOR FLOWERING TIMES

- Most plant ID's are based primarily on reproductive parts
- Plants are collected and pressed when in flower
- An herbarium specimen is proof that a particular species was flowering (or not) at a specific place at a specific time

PHENOLOGY IS OFTEN CUED BY ENVIRONMENT

Temp and/or moisture often indicates “safe to flower/hatch/germinate/etc”

THE QUESTIONS WE ASK:

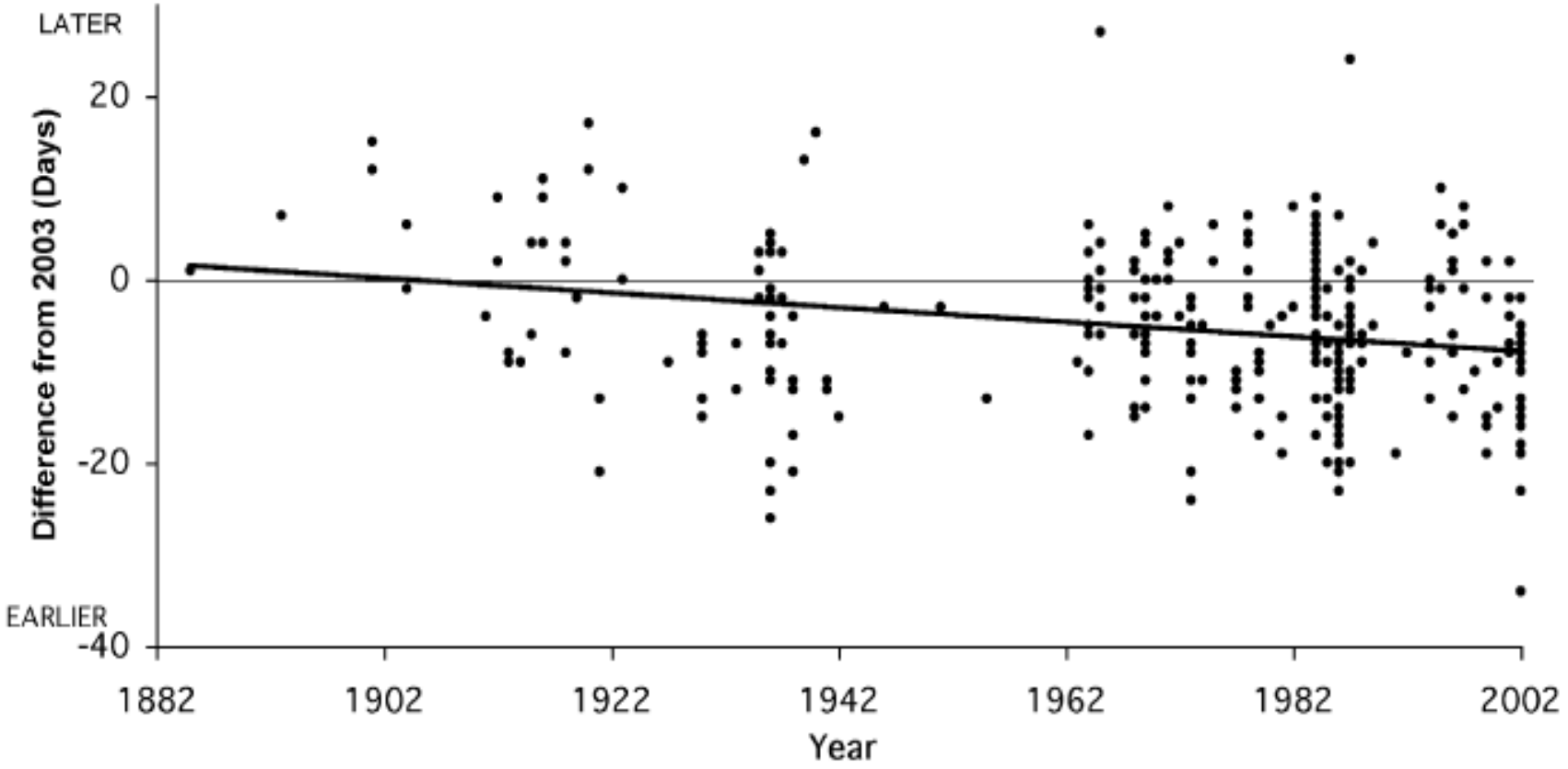
- Are native plants responding to climate change?
- What might this mean for pollination?

SOURCES OF NOISE

- Inter-year variability in climate
- Collection relative to flowering window
- Inter-species variability
- Geographic variability (incl. altitude)

PLANTS IN BOSTON ARE FLOWERING 8 D EARLIER THAN 100 YRS AGO

Primack et al 2004 American Journal of Botany 91(8): 1260–1264.



ges in flowering times of plants at the Arnold Arboretum over time: number of days plants flowered earlier or later in the past than
ed as the Julian date the herbarium specimen was collected subtracted from the peak flowering date in 2003. Negative values indic
n an earlier date than that it did in 2003. The line is the best fit line for the series.

TEMPERATURE IN CONCORD, MA
1852-2006
(MILLER-RUSHING & PRIMACK 2008)

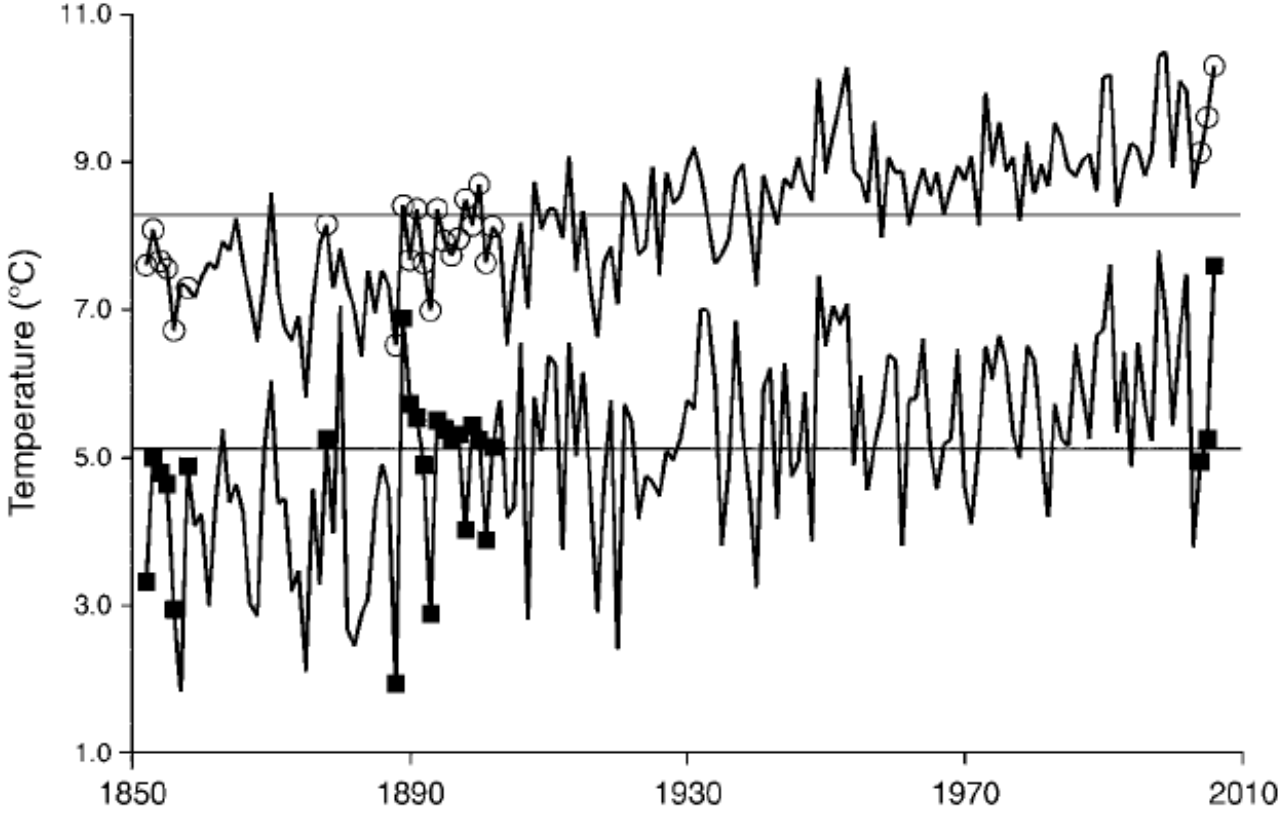
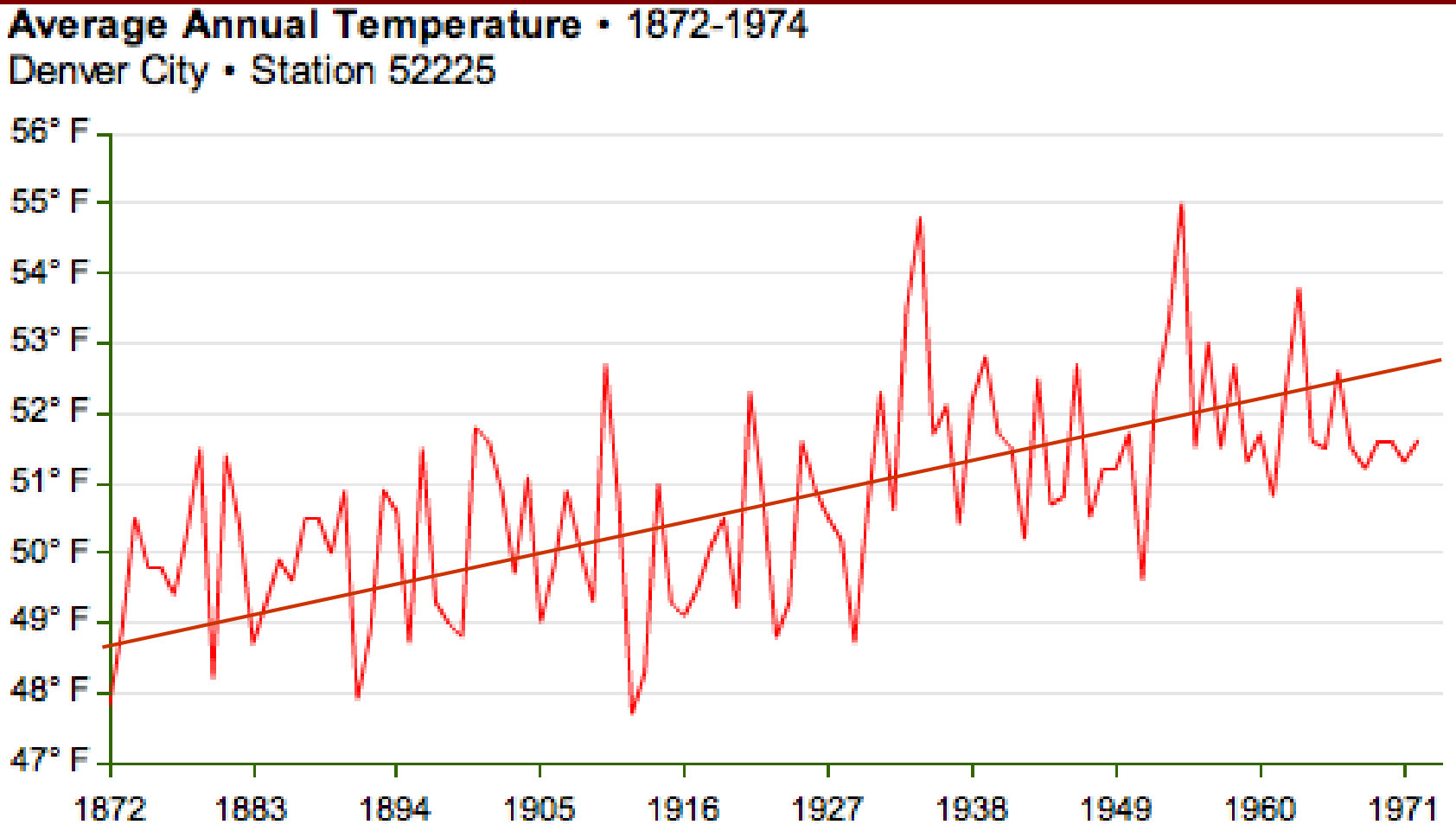


FIG. 1. Temperatures at Blue Hill Meteorological Observatory (33 km southeast of Concord, Massachusetts, USA) from 1852 to 2006. The upper line and open circles represent mean annual temperatures. The lower line and solid squares represent mean monthly temperatures in January, April, and May, temperatures that were highly correlated with flowering times for many species. Horizontal lines show long-term means for each (annual = 8.3°C; Jan, Apr, May = 5.1°C). Circles and squares show years with flowering data.

WHAT ABOUT COLORADO?

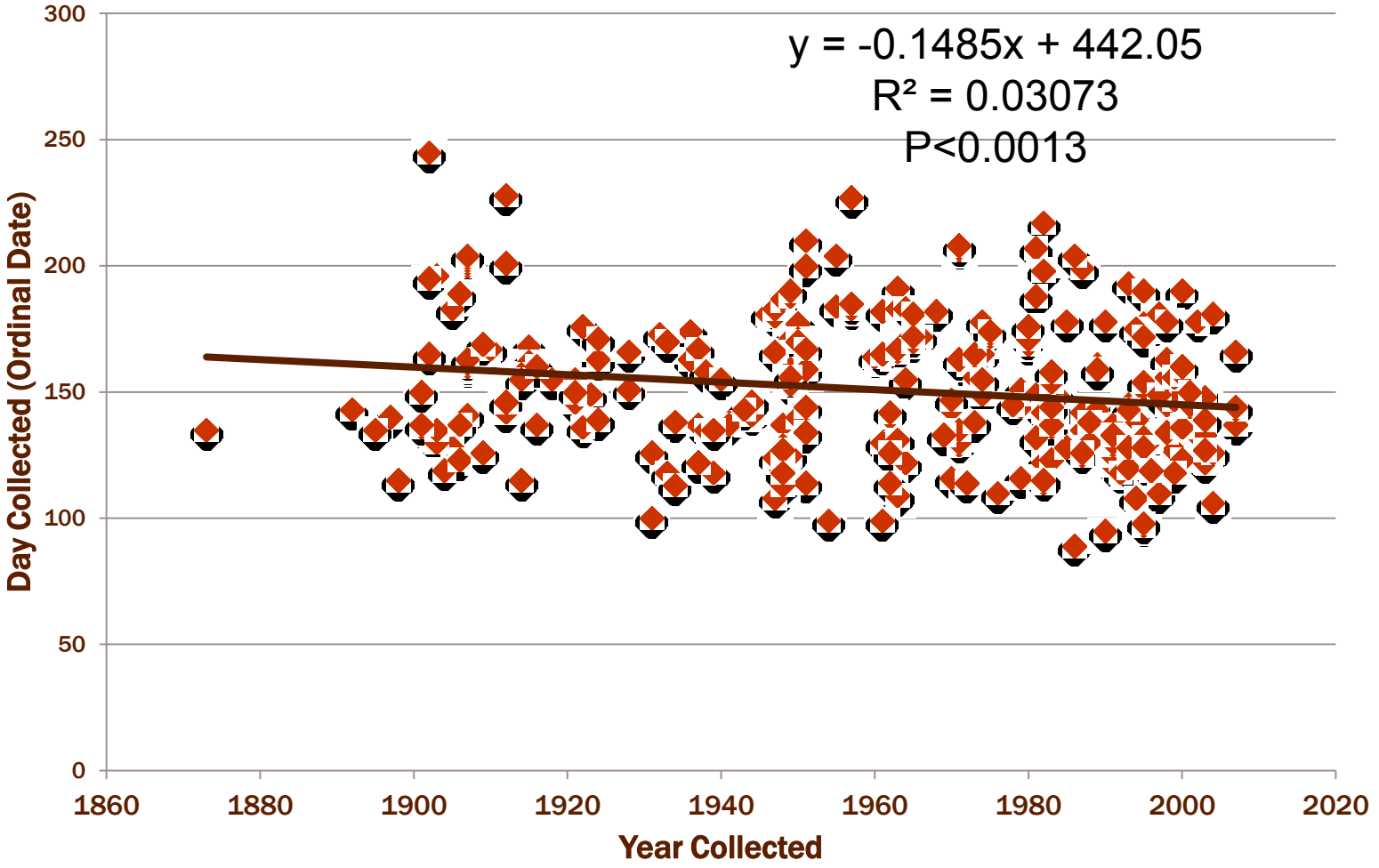
IS THERE EVIDENCE OF EARLIER FLOWERING TIMES HERE?

DENVER TEMPERATURES



Source: Colorado Climate Center, Fort Collins, Colorado

COMMON SPRING SPECIES: 15 DAYS/100 YRS



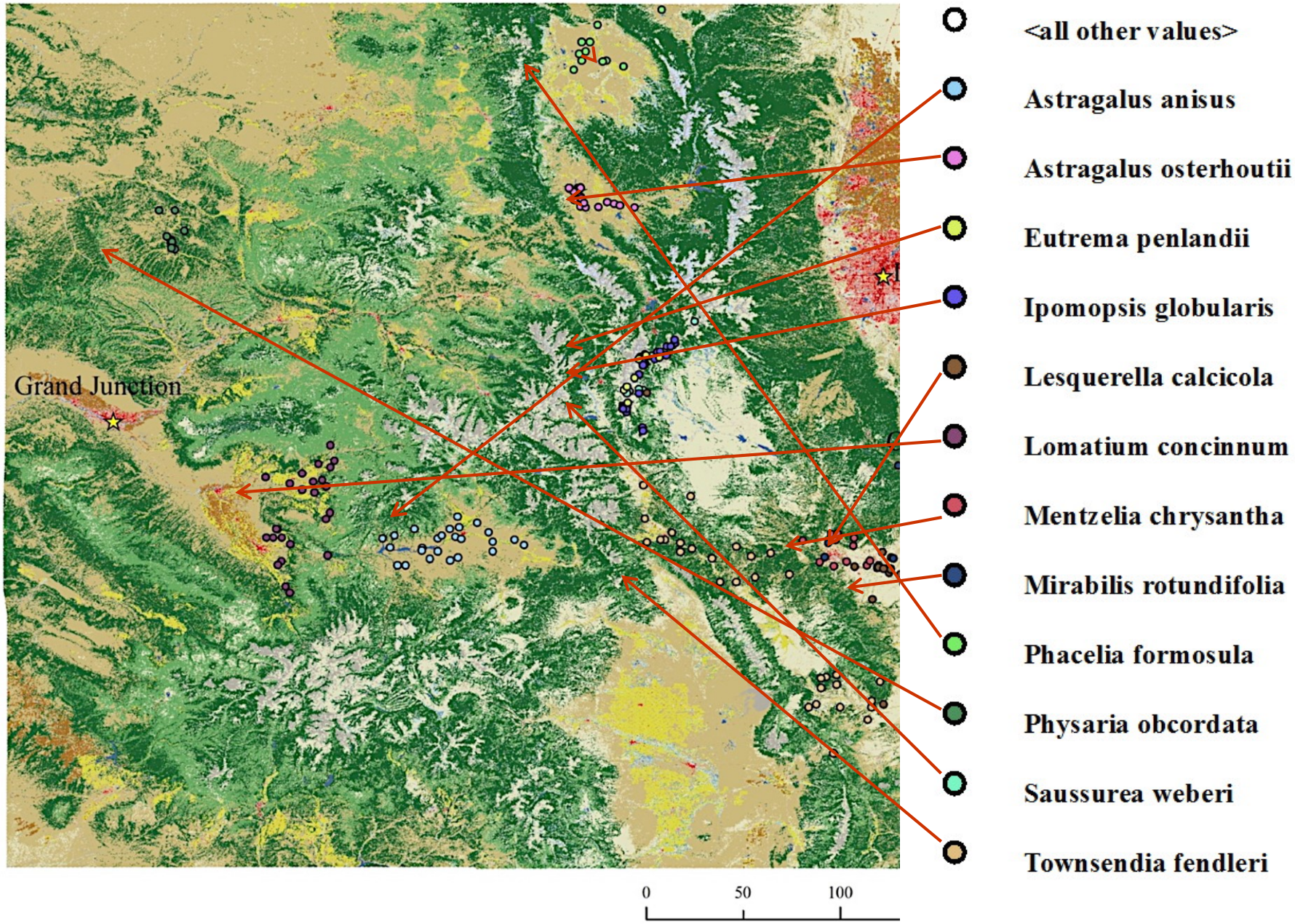
HOW DOES THIS COMPARE TO RARE SPECIES?

CRITERA: species must be federally listed, at least 10 specimens & 1 specimen >100 yrs old

• *Astragalus anisus*	• *Astragalus osterhoutii (*syn. *Lonchophaca osterhoutii)*
• *Physaria obcordata*	• *Eutrema penlandii (*syn. *Eutrema edwardsii ssp. penlandii)*
• *Phacelia formosula*	• *Lesquerella calcicola (*syn. *Physaria calcicola*)
• *Saussurea weberi*	• *Mirabilis rotundifolia (*syn. *Oxybaphus rotundifolius, Allionia rotundifolia)*
• *Townsendia fendleri*	• *Ipomopsis globularis (*syn .*Gilia globularis*)
• *Mentzelia chrysantha*	• *Lomatium concinnum*

12 NATIVE, RARE SPECIES

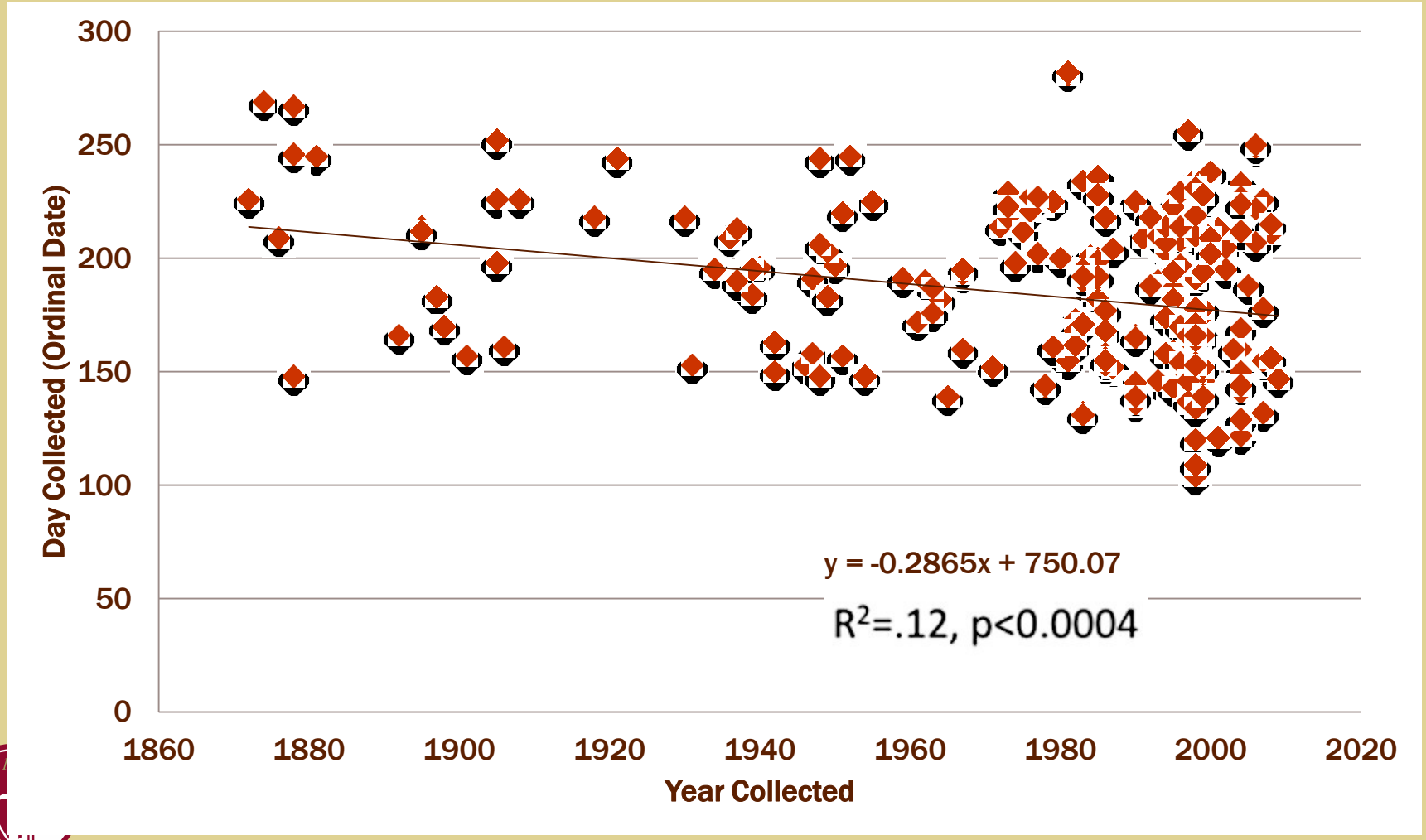
Species	Elevation - ft (in collection)	Common Name	Occurrence	Lifespan	Conservation Status
Ipomopsis globularis	10520 - 10600	Globe gillia	Mosquito Range (CO endemic)	Biennial	G2
Eutrema penlandii	11950-13790	Mosquitto range mustard	Mosquito Range (CO endemic)	Perennial	G1
Saussurea weberi	10499-12914	Alpine Meadow	Middle Rockies (CO, WY, MT)	Perennial	not listed (rare)
Astragalus osterhoutii	7359-9831	Kremmling Osterhout milkvetch	Middle Park, near Kremmling (CO endemic)	Perennial	G1
Astragalus anisus	7400-8950	Gunnison milkvetch	Gunnison Basin (CO endemic)	Perennial	G2
Lomatium concinnum	5000-7520	CO desert-parsley	Tri-River Area (CO endemic)	Perennial	G2
Physaria obcordata	5950-9076	Twin pod	Piceance Basin (CO endemic)	Perennial	G1
Phacelia formosola	7896-8202	North Park phacelia	North Park (CO endemic)	Biennial	G1
Mentzelia chrysantha	4910-7445		Arkansas River Valley (CO endemic)	Biennial	G2
Mirabilis rotundifolia	4898-6762	Blazing star	Arkansas River Valley (CO endemic)	Perennial	G2
Lesquerella calcicola	4800-8340		Arkansas River Valley (CO, NM)	Perennial	G2
Townsendia fendleri	4950-9010	Townsendia daisy	Arkansas River Valley (CO, NM)	Annual	not listed (rare)


Legend
<all other values>
Astragalus anisus
Astragalus osterhoutii
Eutrema penlandii
Ipomopsis globularis
Lesquerella calcicola
Lomatium concinnum
Mentzelia chrysantha
Mirabilis rotundifolia
Phacelia formosula
Physaria obcordata
Saussurea weberi
Townsendia fendleri
Grand Junction
0
50
100

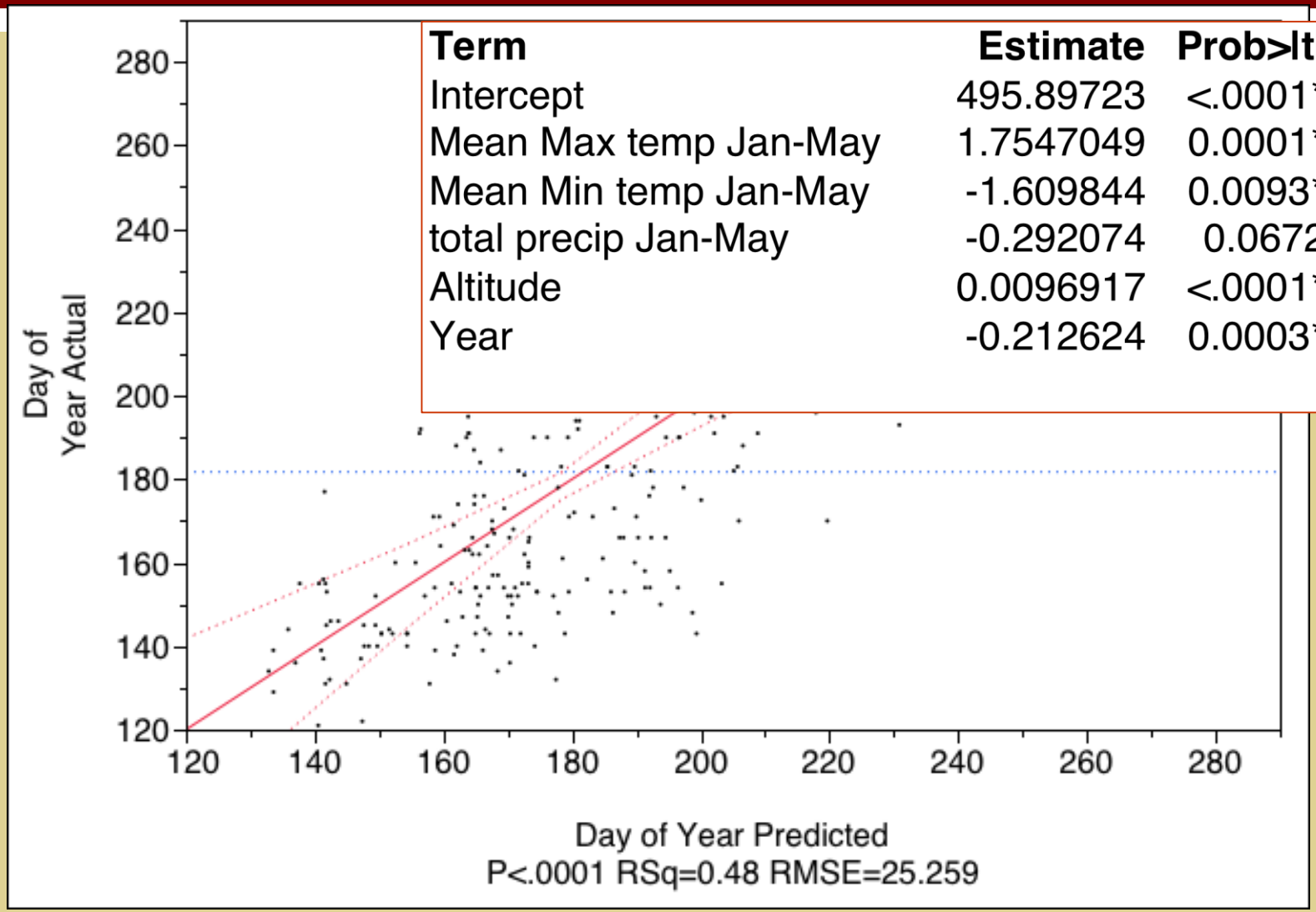
METHODS

- 8 on-line herbaria used
- Label data checked
  - Inter-herbaria duplicates removed
  - Names verified
- Non-flowering specimens excluded
- Geo-referencing

RARE PLANTS IN COLORADO: 35 DAYS EARLIER



FLOWERING WAS RELATED TO CLIMATE (MULTIPLE REGRESSION)



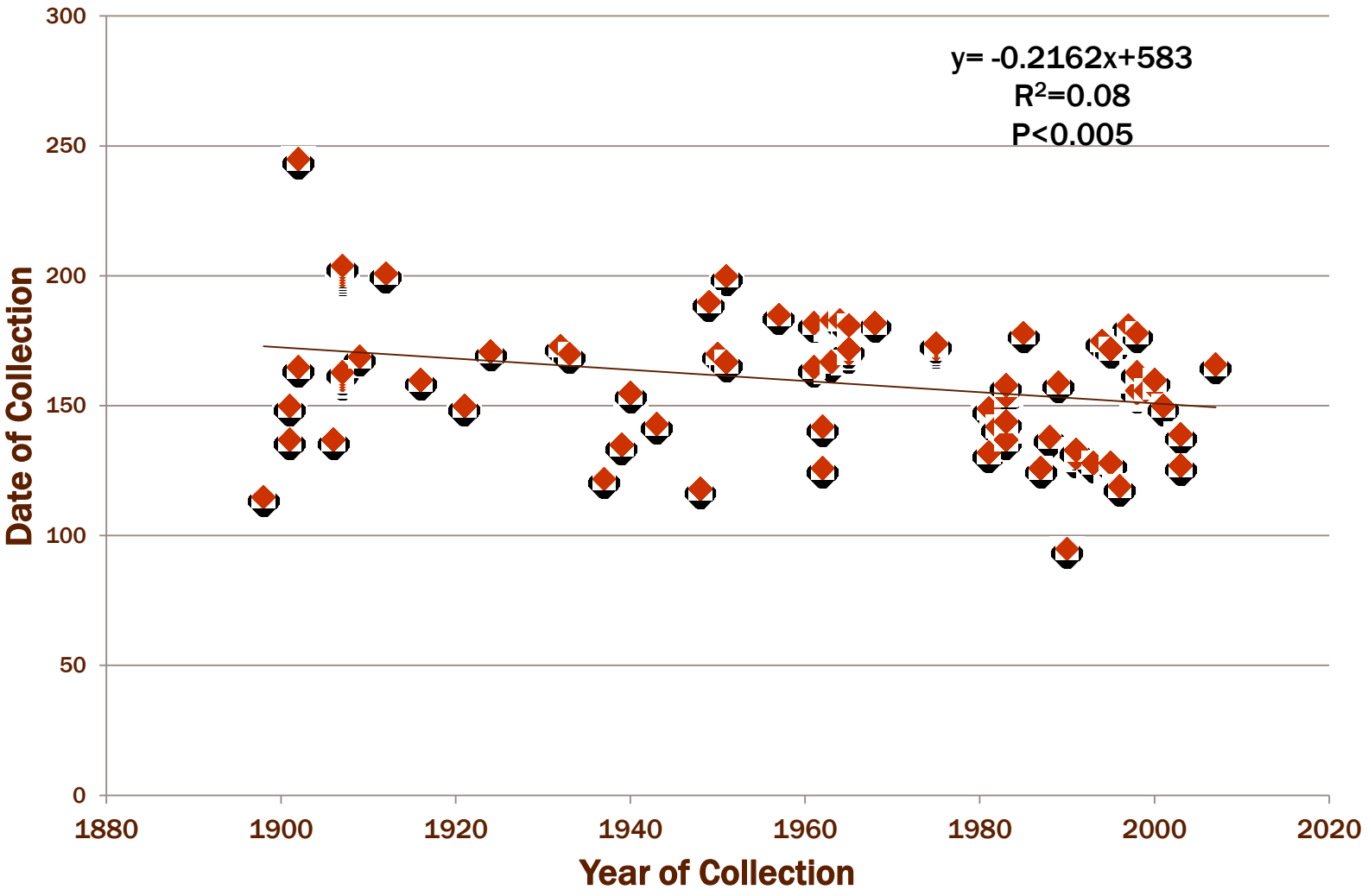
Term	Estimate	Prob>|t|
Intercept	495.89723	<.0001*
Mean Max temp Jan-May	1.7547049	0.0001*
Mean Min temp Jan-May	-1.609844	0.0093*
total precip Jan-May	-0.292074	0.0672
Altitude	0.0096917	<.0001*
Year	-0.212624	0.0003*


Pasque Flower
Spring Crocus
Pulsatilla patens
photo by M. Hopson


KATHRYN KALMBACH HERBARIUM
DENVER BOTANIC GARDENS
3298
May 30th, 1921
Pulsatilla patens (L.) Mill.
P. hirsutissima, Britton.
Rock Grouse, Prairie Flower.
"Easter Lily" in Colorado.
Lookout Mt., Jefferson Co., Colo.
May 30, 1921.
Alt. 7500'.
DENVER BOTANIC GARDENS
KHD00038166

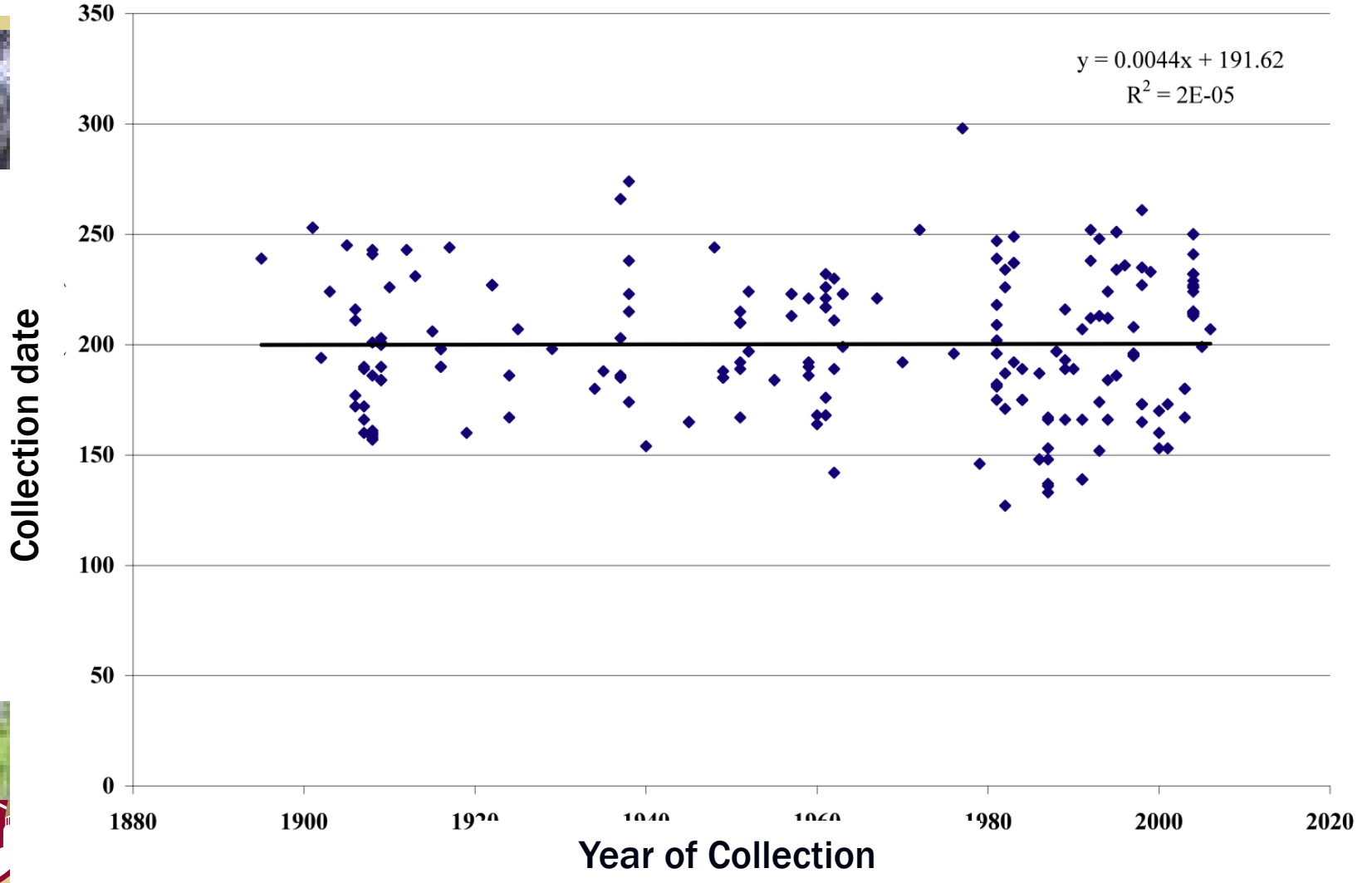

KATHRYN KALMBACH HERBARIUM
DENVER BOTANIC GARDENS
29956
April 28th, 1981
POISONOUS PLANTS
RAN
Pulsatilla patens (L.) Miller
ssp. multifida (Fritzel) Zamels
Growing on north facing hillside: Soil was gravely organic: Growing in clumps of 3-5 plants: Corolla blue-purple.
Larimer Co: Found 1.7 miles up Rist Canyon road from Bellvue on south side of road.
Collector: M. Yeatts
Alt.: 1885 m.
Date: Apr. 28, 1981
Type of Poisoning: Mechanical
Plant #15
DENVER BOTANIC GARDENS
KHD00038187

PULSATILLA PATENS: 22 DAYS



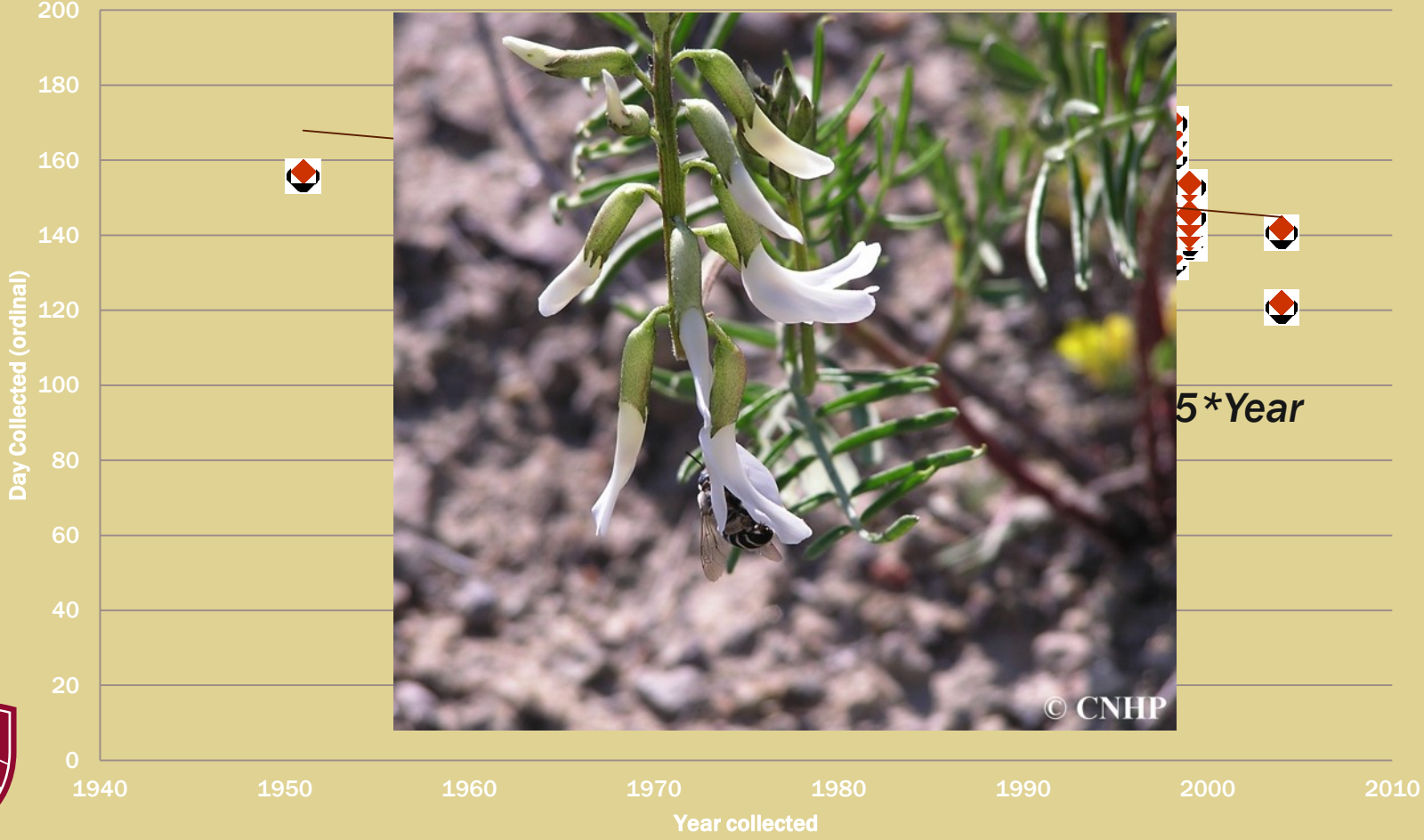
DO ALL PLANTS HAVE THIS PATTERN?

CYSTOMPTERIS FRAGILIS
NO CHANGE



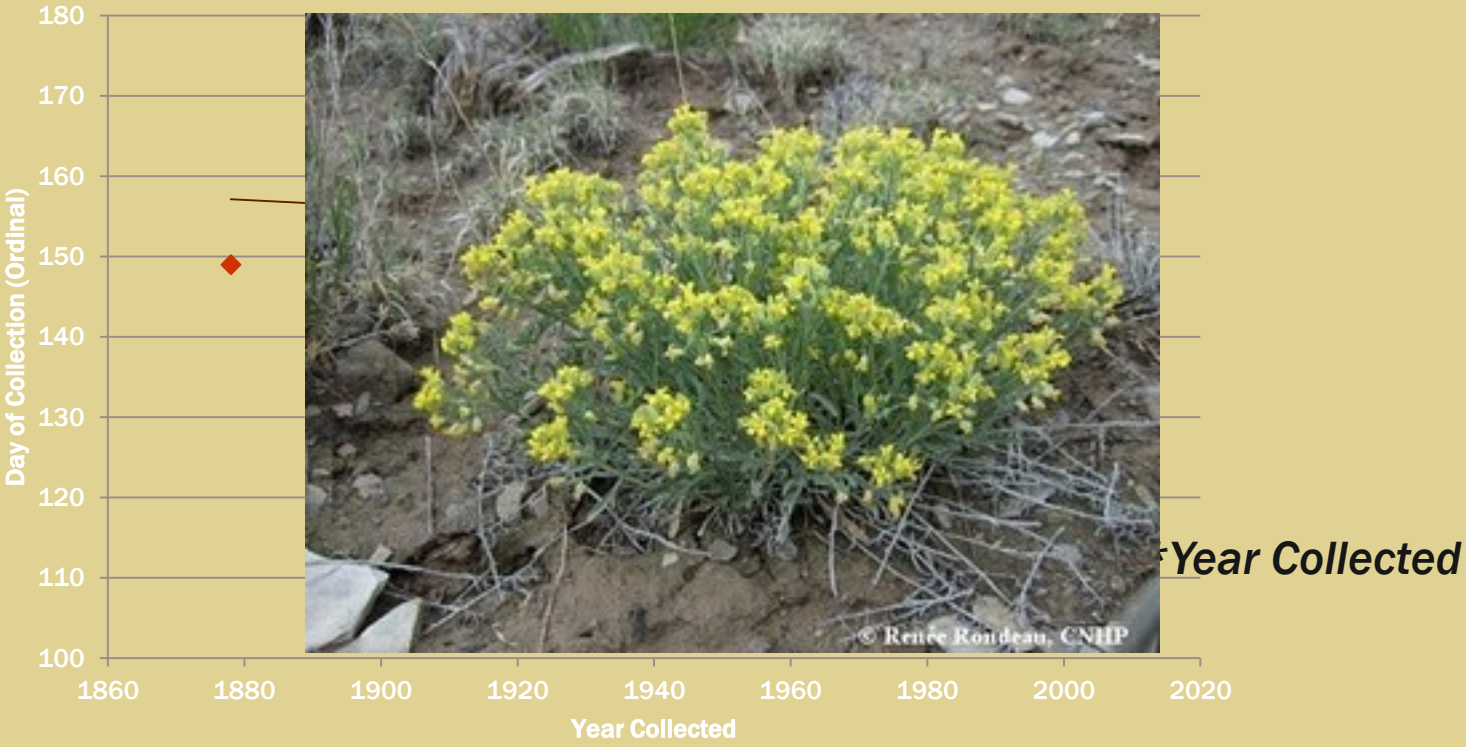
GUNNISON MILK-VETCH:
45 DAYS EARLIER

Astragalus anisus



ROCKY MOUNTAIN BLADDERPOD; 19 DAYS EARLIER

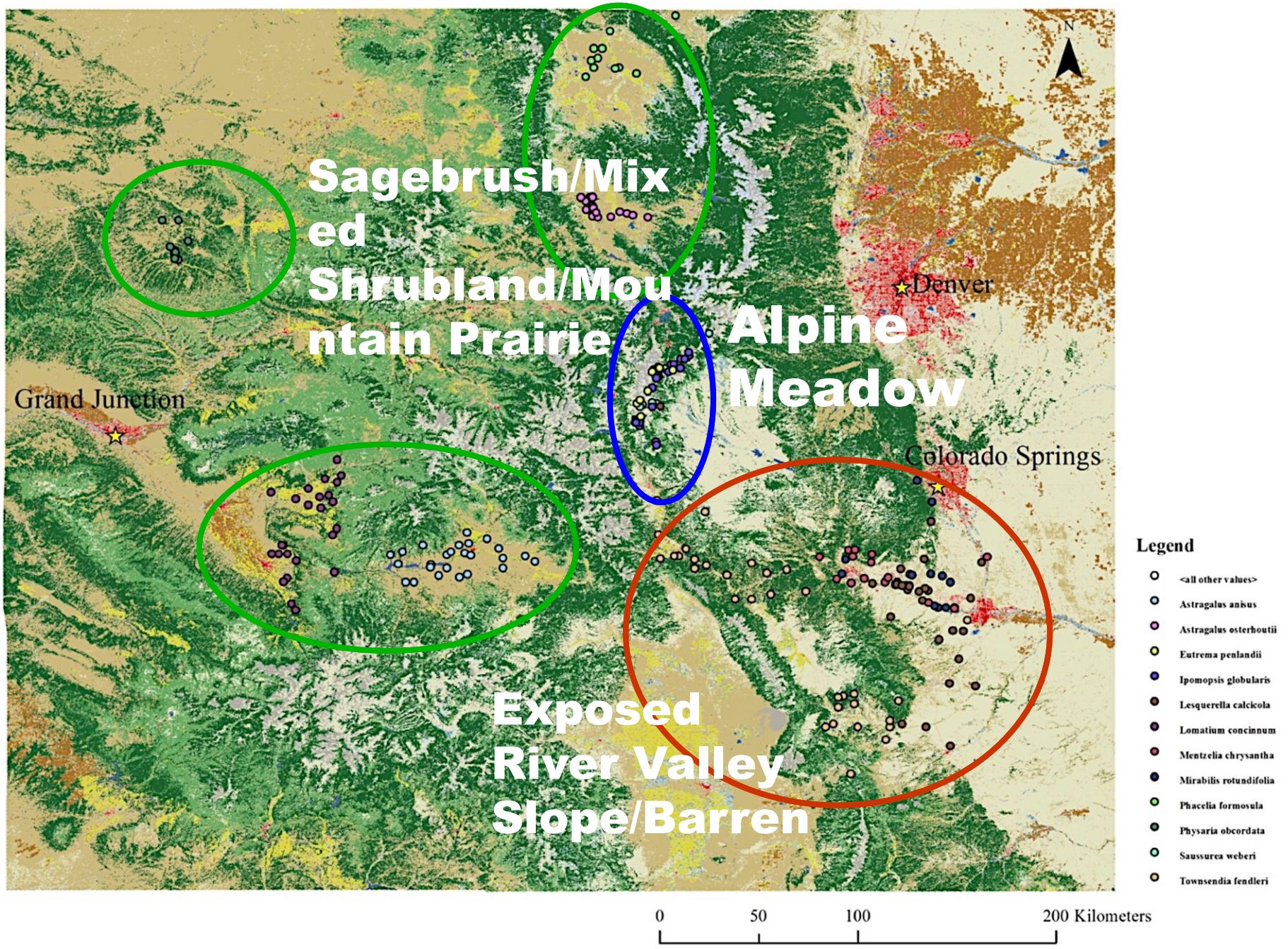
Lesquerella calcicola



Year Collected

GOLD BLAZING STAR: CHANGE NOT SIGNIFICANT

Mentzelia chrysantha


Sagebrush/Mixed Shrubland/Mountain Prairie
Alpine Meadow
Exposed River Valley Slope/Barren
Denver
Grand Junction
Colorado Springs
N
Legend
<all other values>
Astragalus anisus
Astragalus osterhoutii
Eutrema penlandii
Ipomopsis globularis
Lesquerella calcicola
Lomatium concinnum
Mentzelia chrysantha
Mirabilis rotundifolia
Phacelia formosula
Physaria obcordata
Saussurea weberi
Townsendia fendleri
0
50
100
200 Kilometers

THREE HABITATS

Species	Elevation - ft (in collection)	Habitat	Occurrence	Lifespan	Conservation Status
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Phacelia formosola	7896-8202	Exposed River Valley Slope/Barren	North Park (CO endemic)	Biennial	G1
Mentzelia chrysantha	4910-7445	Exposed River Valley Slope/Barren	Arkansas River Valley (CO endemic)	Biennial	G2
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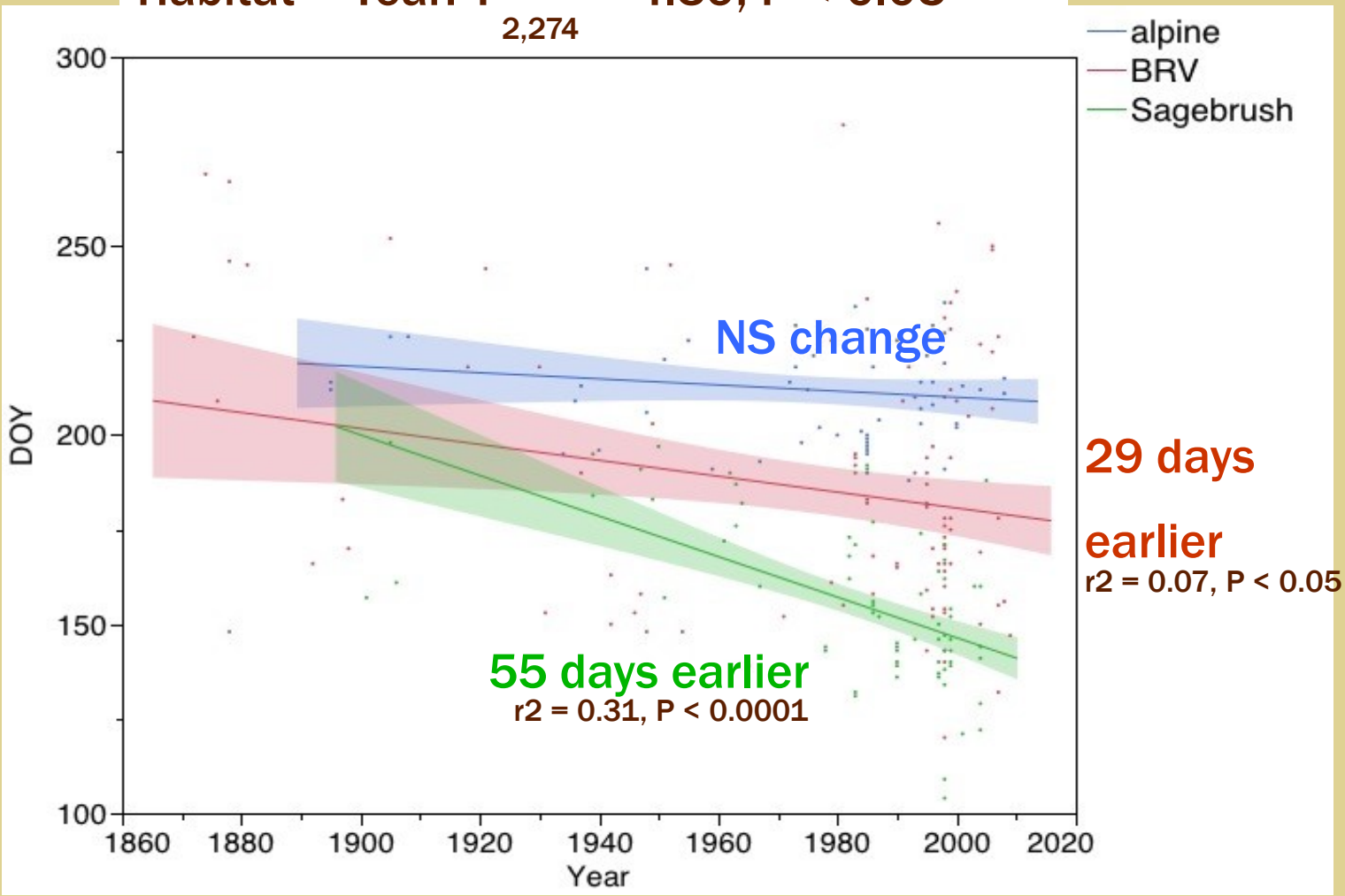
SLOPE DEPENDENT ON HABITAT

Habitat * Year: $F_{2,274} = 4.39, P < 0.05$



DIFFERENCES BETWEEN HABITATS

- Rare alpine plants showed least change in flowering over time
- Biggest changes were observed for rare plants in sagebrush/mountain prairie habitat

2-4 WEEKS/100 YRS IN COLORADO

- both common and rare species
- Various areas and habitats

MAJOR ECOLOGICAL IMPLICATIONS

CHANGE COULD MEAN ADAPTATION TO CLIMATE CHANGE (I.E. GOOD) OR…

PROBLEM 1: INCREASED RISK OF FROST

- David Inouye's work at Rocky Mountain Biological Labs
- Earlier spring ≠ earlier last frost

PROBLEM 2: POTENTIAL DISCONNECTS WITH POLLINATORS

- If pollinators are cued by something different than the flowers…
- Many are cued by temperature (Bartomeus et al. 2011)
- Bad news for alpine plants?

FUTURE WORK

- NSF REU program topic
- Is there evidence of disconnects with pollinators at high altitudes for species with altered phenology?

TAKE HOME MESSAGES

- Rocky Mountains showing dramatic changes
- Phenology should be a component of rare plant conservation planning
- Get involved with NPN

and Project Budburst

Acknowledgements:

National Fish & Wildlife Foundation
The Nature Conservancy
Denver Botanic Gardens
Colorado Natural Areas
Kathryn Kalmbach Herbarium
CU Herbarium
Rocky Mountain Herbarium
Missouri Botanical Garden Herbarium
Chicago Botanic Gardens Herbarium
Amelia Bowman, Ryan Whittney, Eliot Jackson, Rob Robinson, and Francesca Aguirre-Wong, and Seth Munson

Photos by Anna Sher or Scott Dressel-Martin (Denver Botanic Gardens)

THANK YOU

www.anna-sher.com