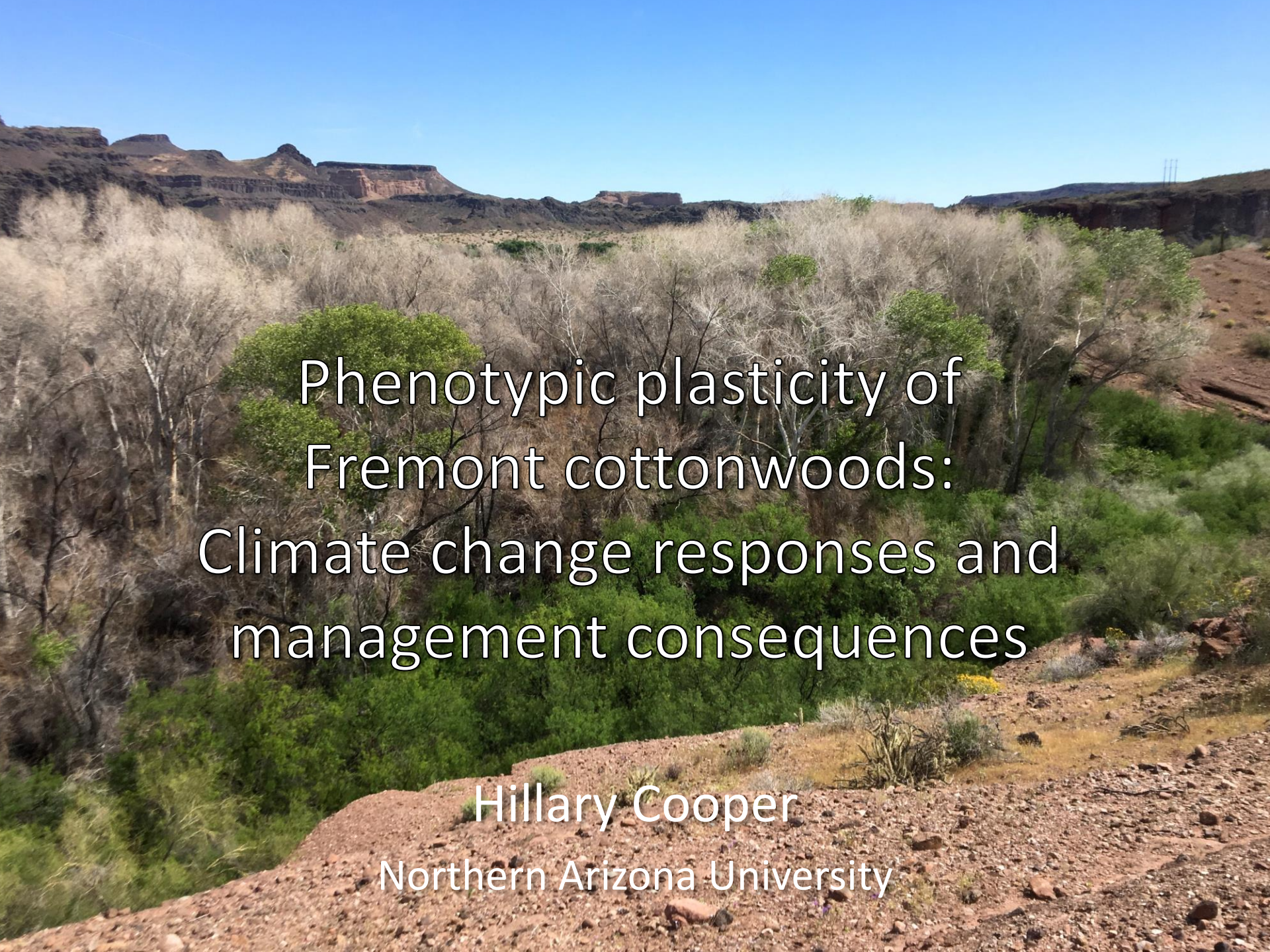


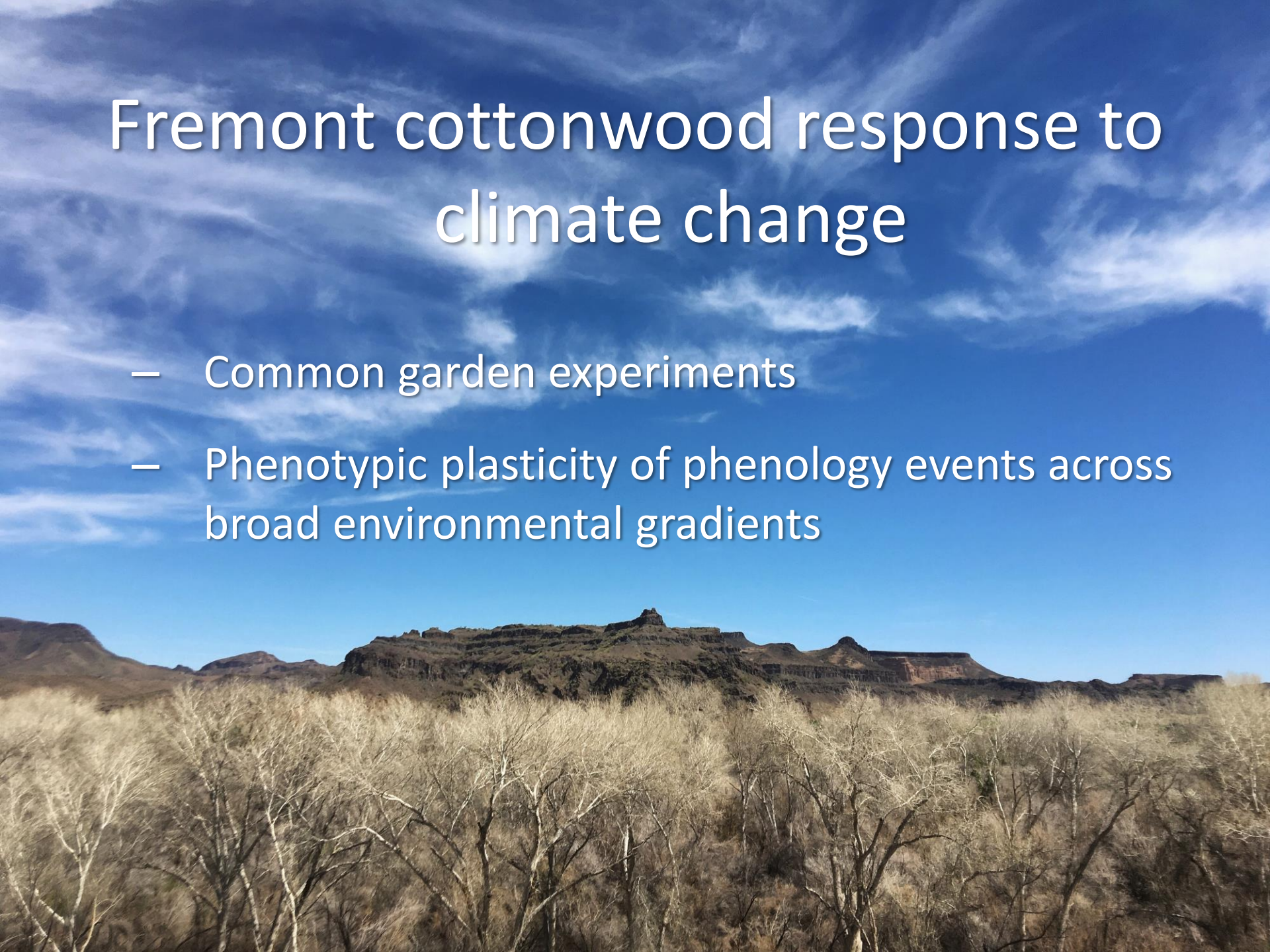
Phenotypic plasticity of Fremont cottonwoods: Climate change responses and management consequences

Hillary Cooper

Northern Arizona University

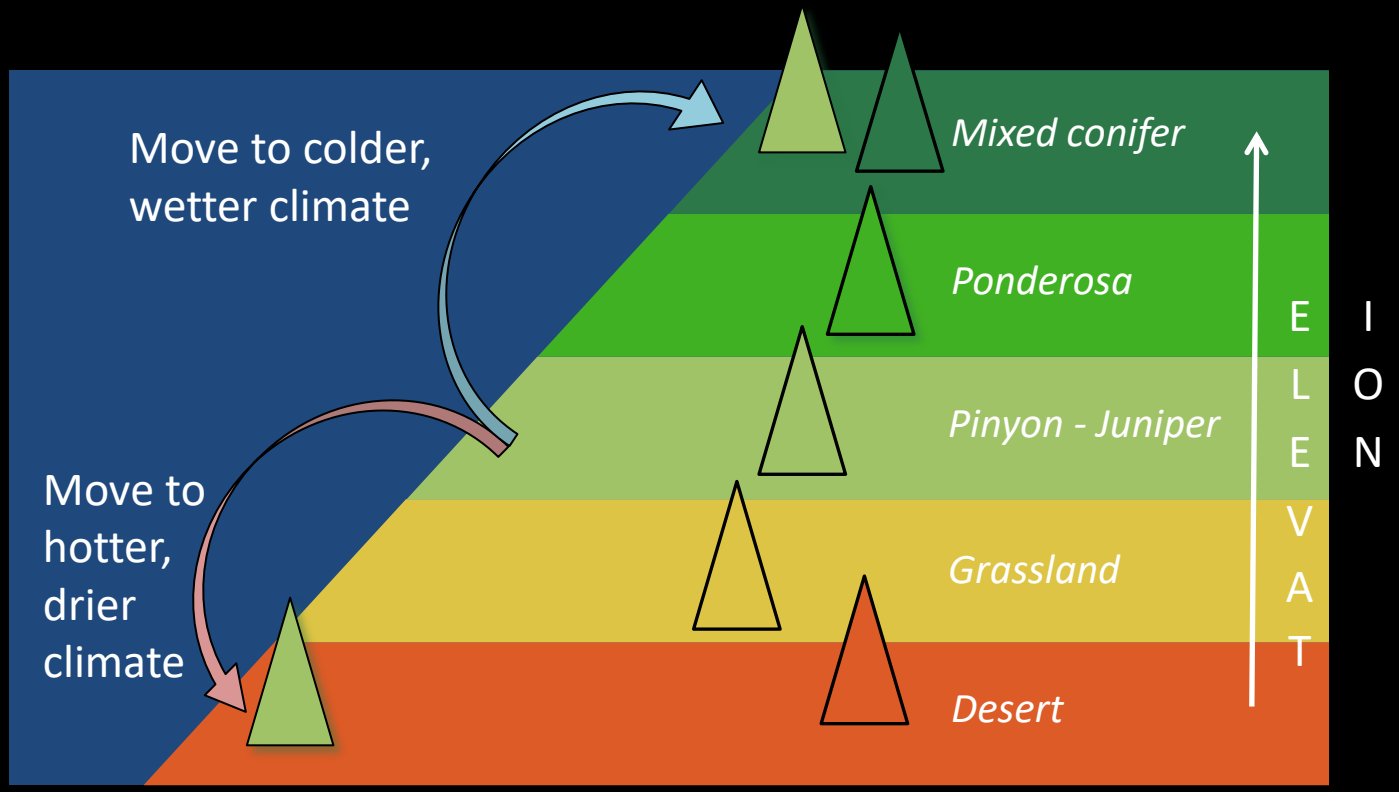
Fremont cottonwood response to climate change

- Common garden experiments
- Phenotypic plasticity of phenology events across broad environmental gradients



Experimental Common Gardens

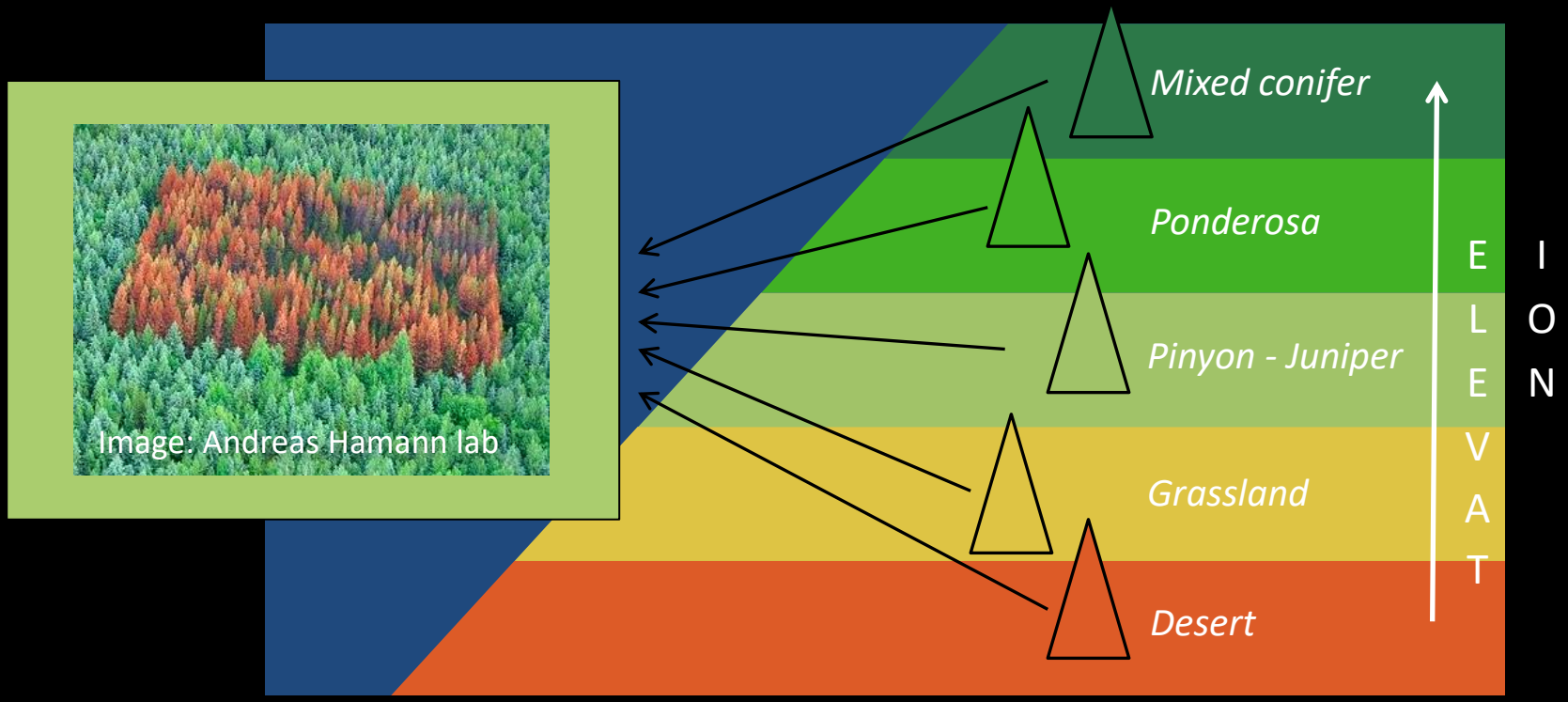
- Proxy for climate change



Experimental Common Gardens

- Reveal genetic effects

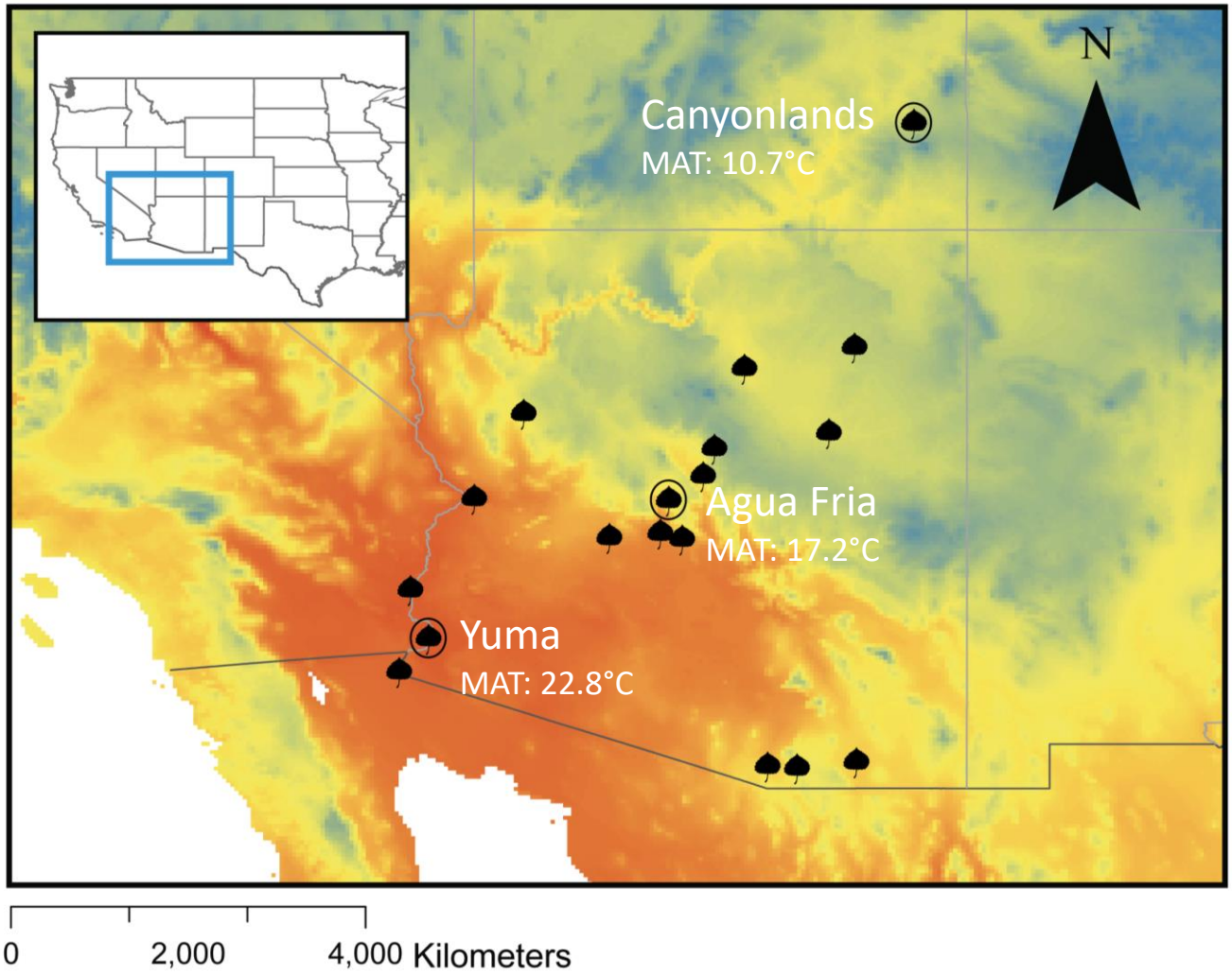
  Uniform ("common") environment reveals phenotypic differences due to genetics



Common garden design

16 populations,
12 genotypes per population

4096 trees from 192 genotypes replicated in each common garden!



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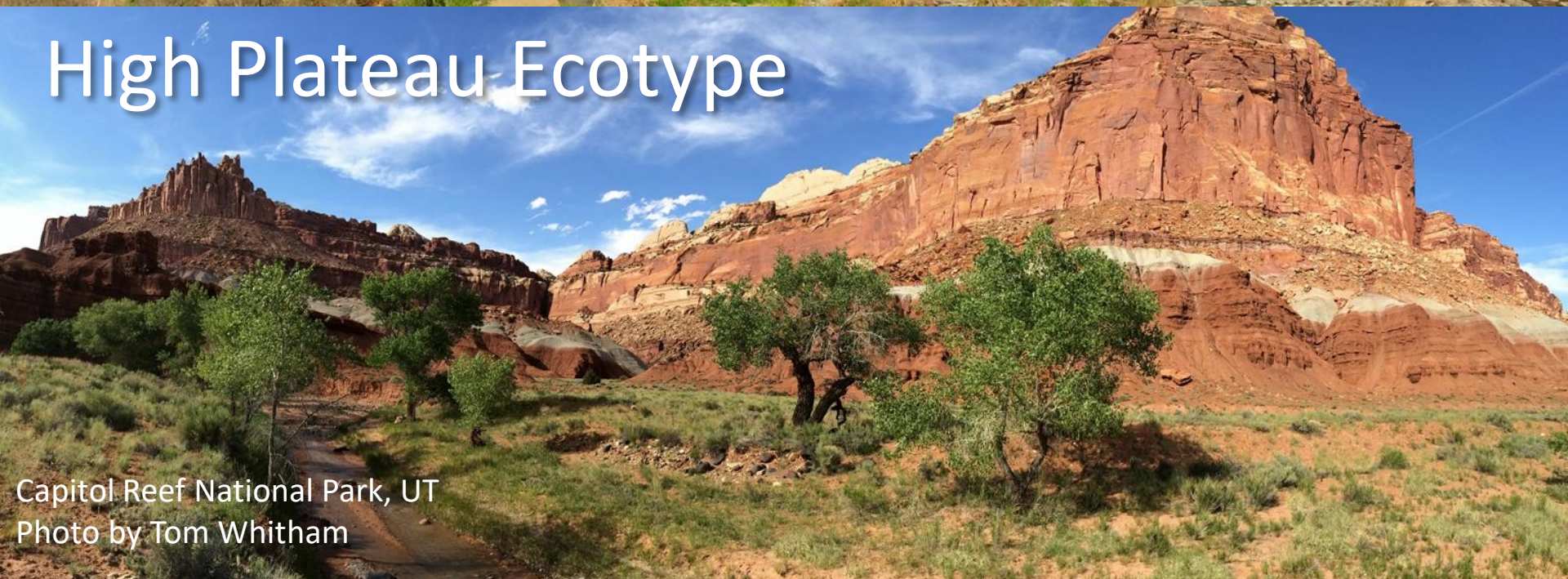
Sonoran Desert Ecotype
Cave Creek, AZ
Photo by Tom Whitham


High Plateau Ecotype
Capitol Reef National Park, UT
Photo by Tom Whitham

Yuma, AZ

Elevation 49m

MAT 22.8°C

MAP 93mm

2015

2017

Agua Fria, AZ

Elevation 988m
MAT 17.2°C
MAP 440mm

Photos: Tom Whitham

Canyonlands, UT

Elevation 1581m
MAT 10.7°C
MAP 226mm

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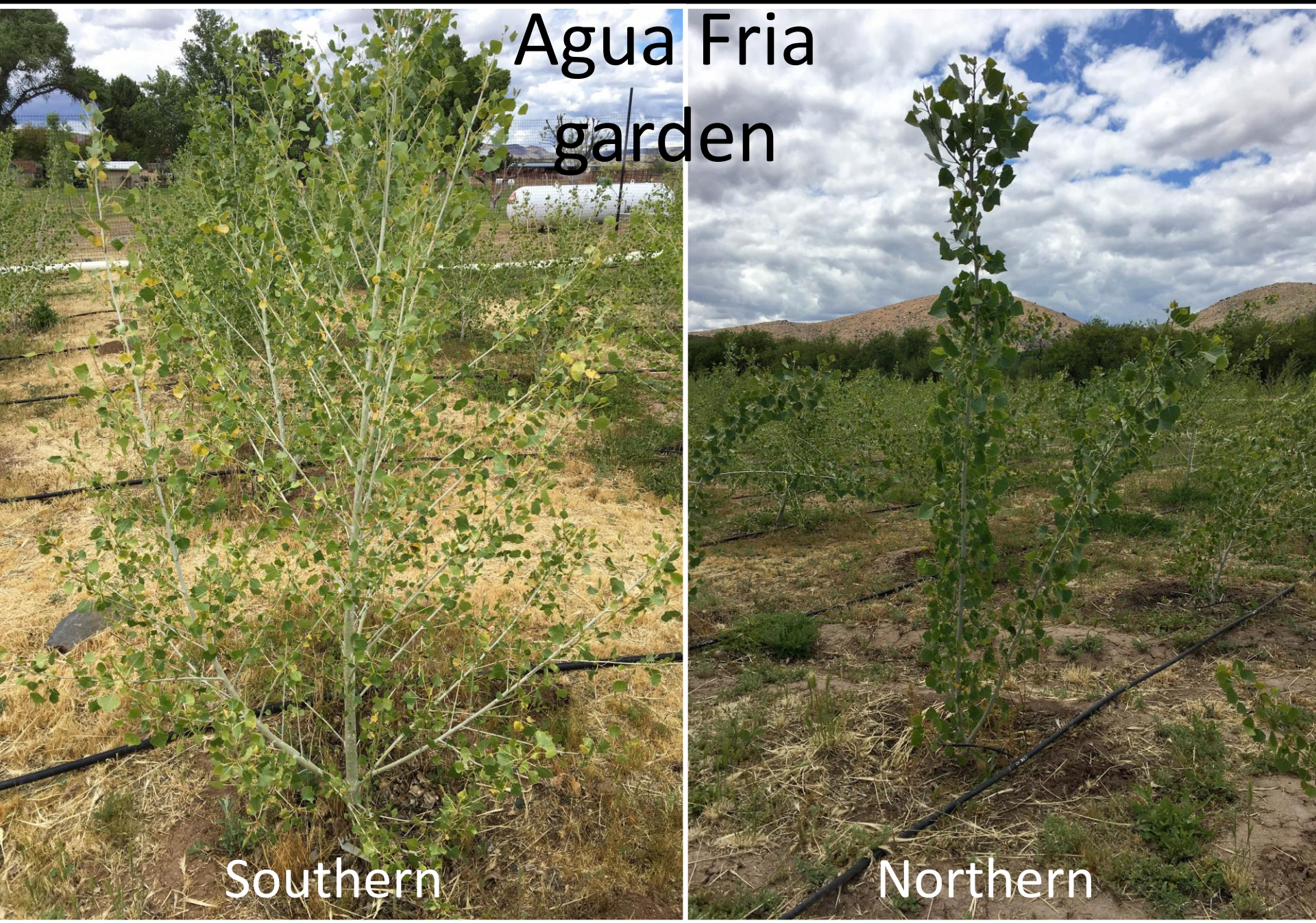

Agua Fria
garden
Southern
Northern

Genetic variation shapes traditional and extended phenotypes

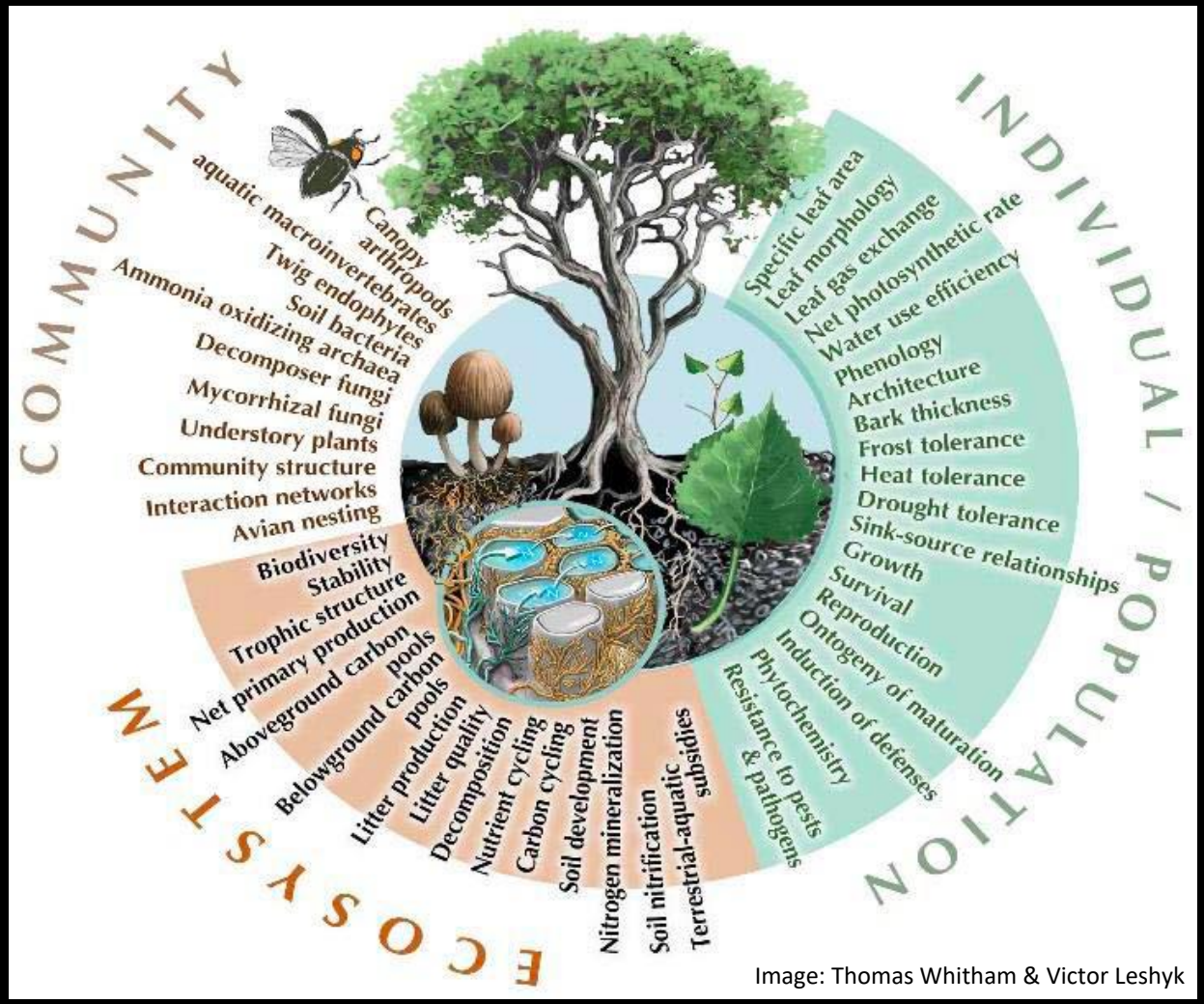


Image: Thomas Whitham & Victor Leshyk

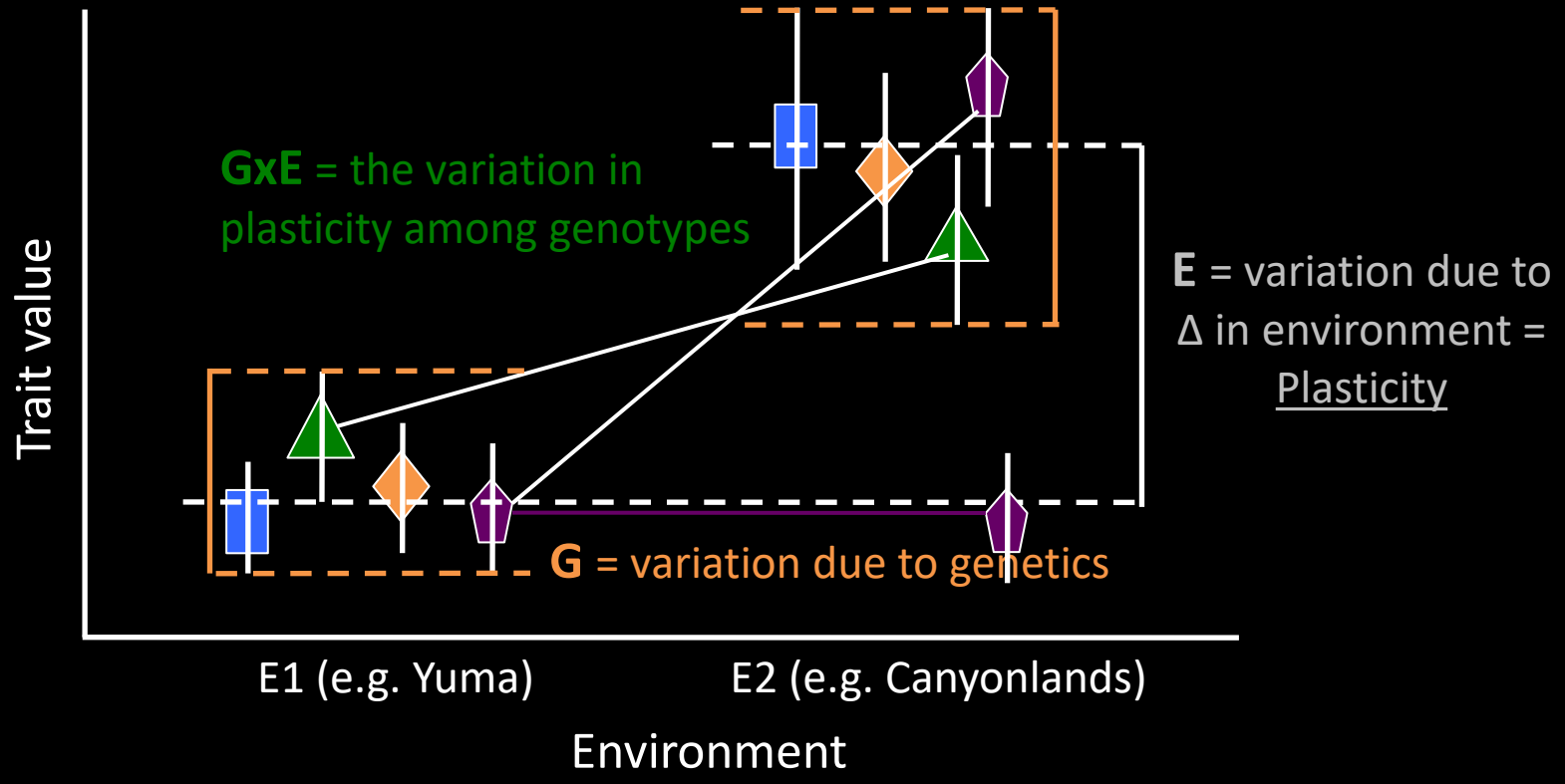
Usually only tested in a single common garden

Phenotypic plasticity

The capacity of a single genotype to exhibit a range of phenotypes in response to variation in the environment (Fordyce 2006)

Phenotypic plasticity

The capacity of a single genotype to exhibit a range of phenotypes in response to variation in the environment (Fordyce 2006)

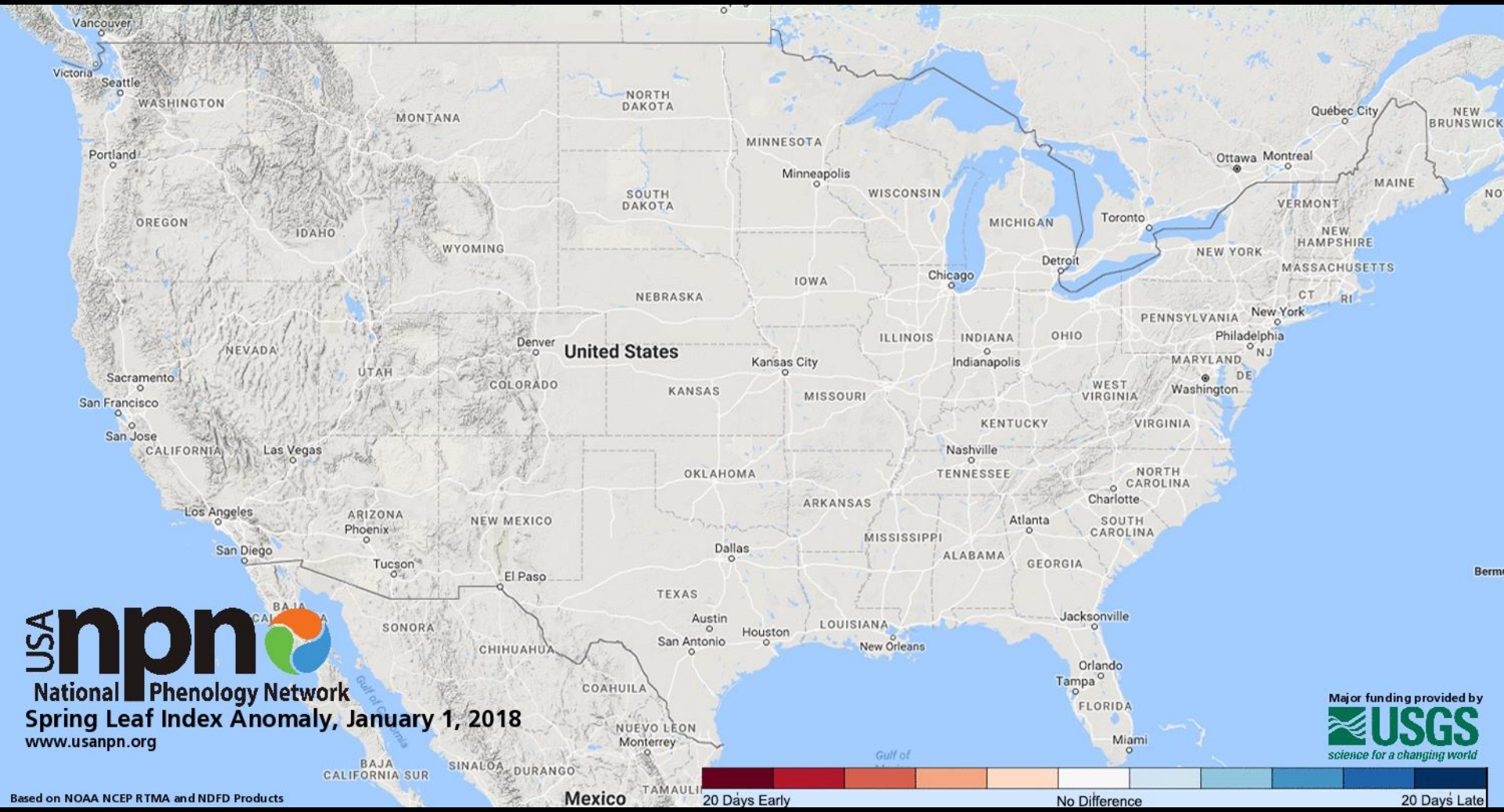


Phenology

The study of seasonal phenomena, particularly of plant and animal life in relation to climate.

Phenology “is perhaps the simplest process in which to track changes in the ecology of species in response to climate change” – IPCC Fourth Assessment Report (2007)

Spring leaf flush



Phenotypic plasticity

H1: Spring bud flush will be more plastic than fall bud set

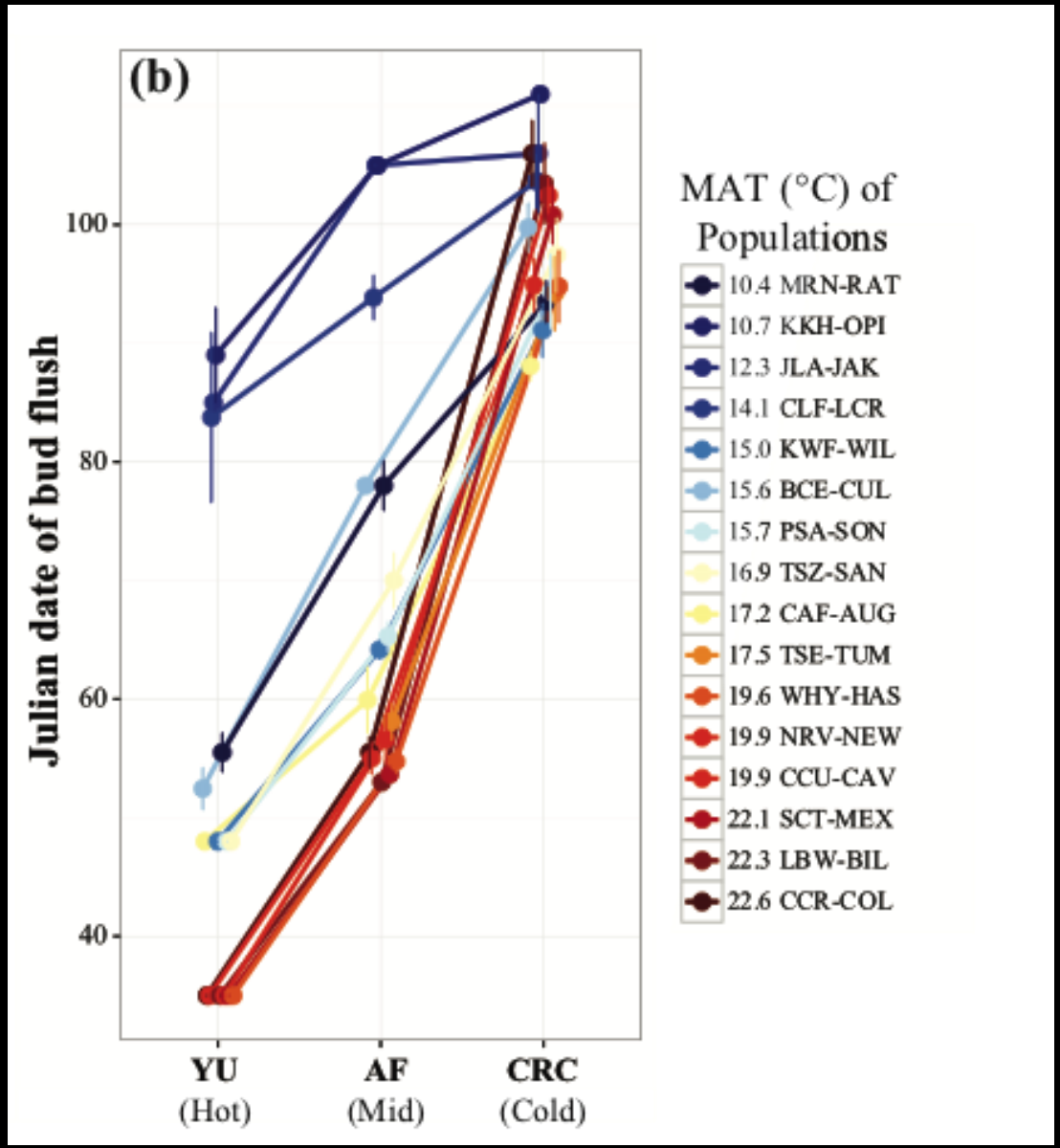
H2: Provenance climate will predict the magnitude of plasticity

H3: More plastic genotypes will have greater fitness compared to less plastic genotypes

SPRING BUD FLUSH

Adaptive plasticity:
A change in trait value in the direction of local optimum

Both directions of transfer show genotypes exhibiting adaptive plasticity

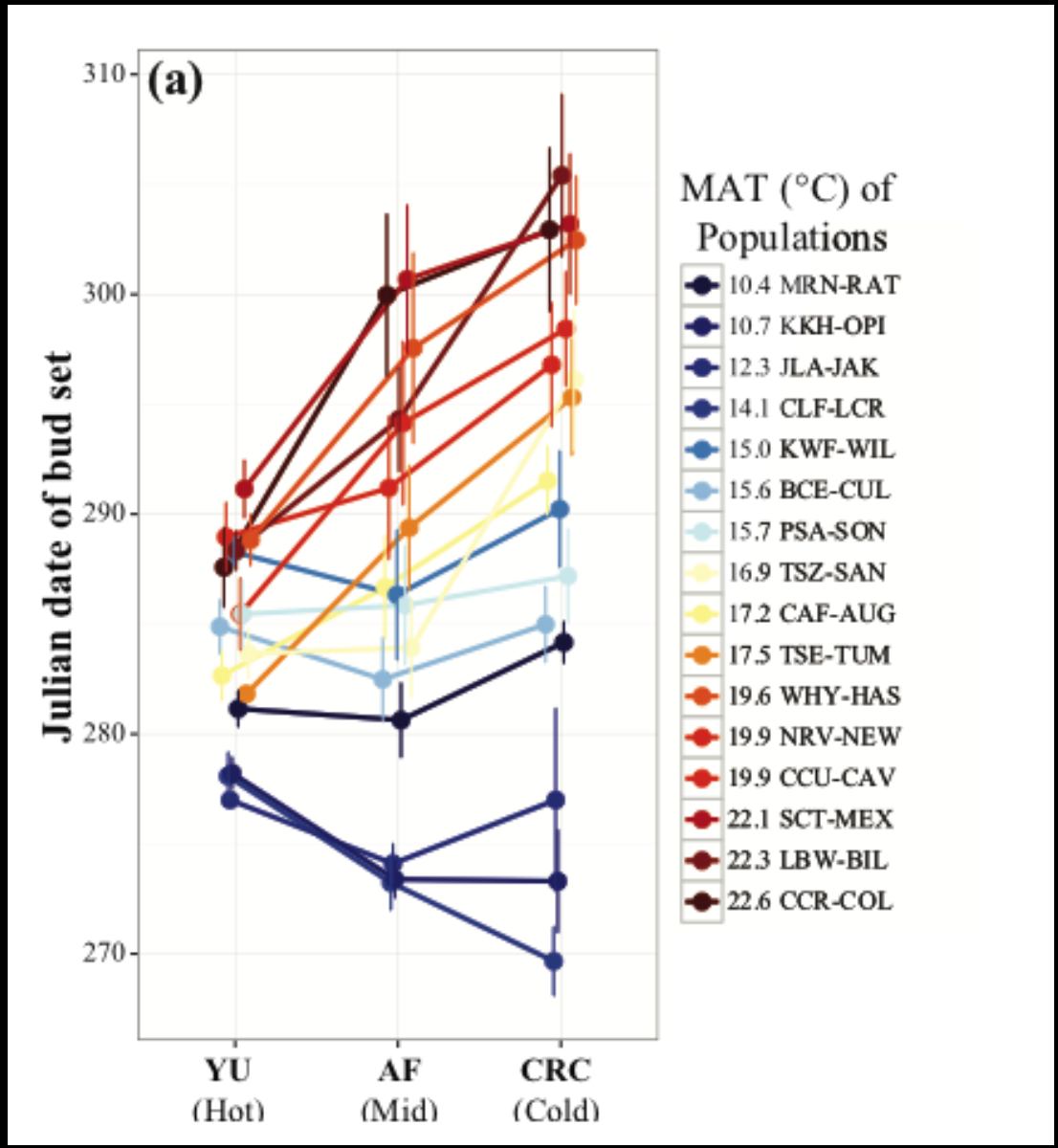


Cooper et al. 2019,
Global Change Biology

FALL BUD SET

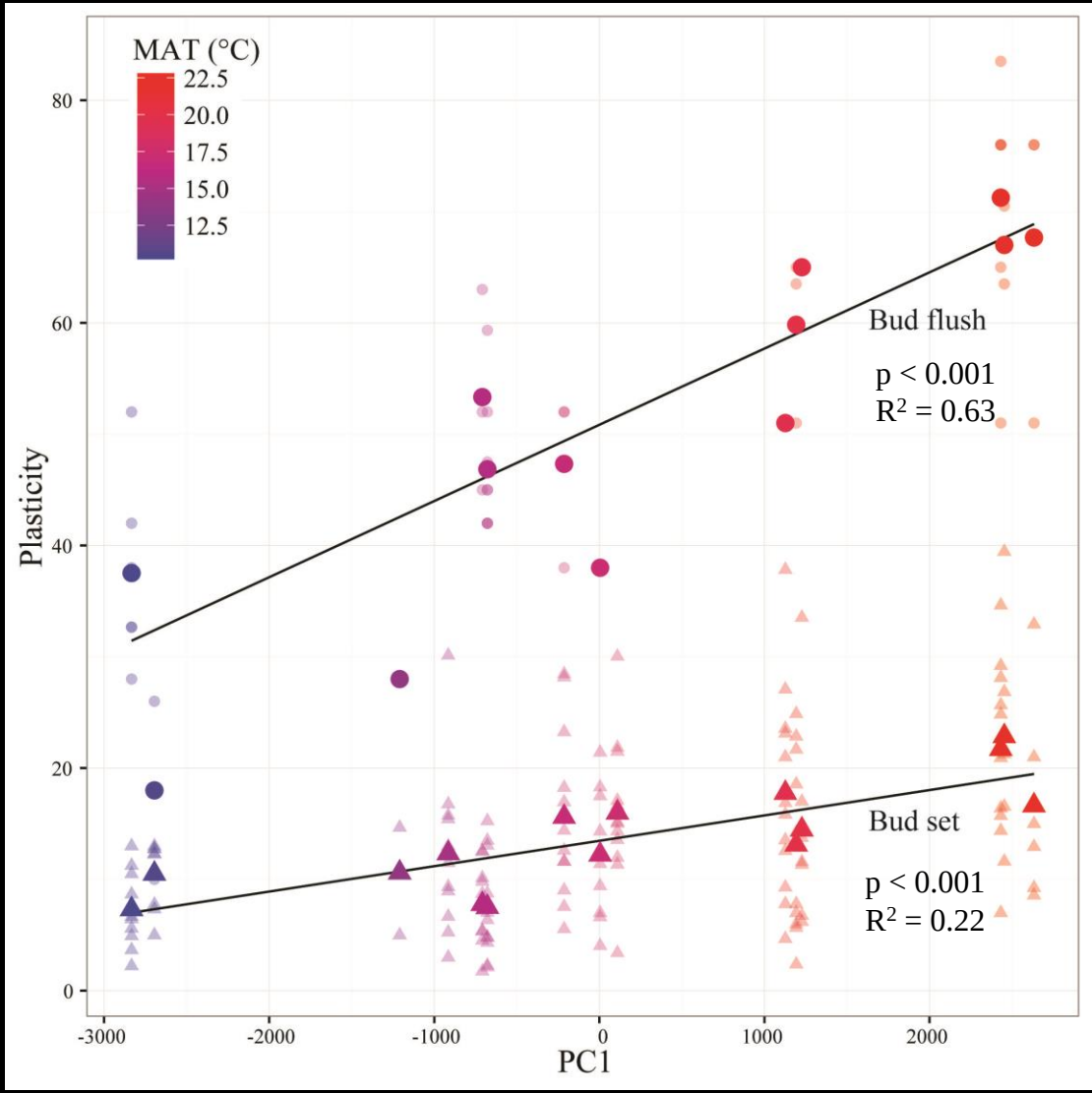
Hot-adapted populations show non-adaptive plasticity

Cold-adapted populations show adaptive and non-adaptive plasticity



Cooper et al. 2019,
Global Change Biology

Plasticity – climate correlations



DD < 18°C ← → DD > 5°C

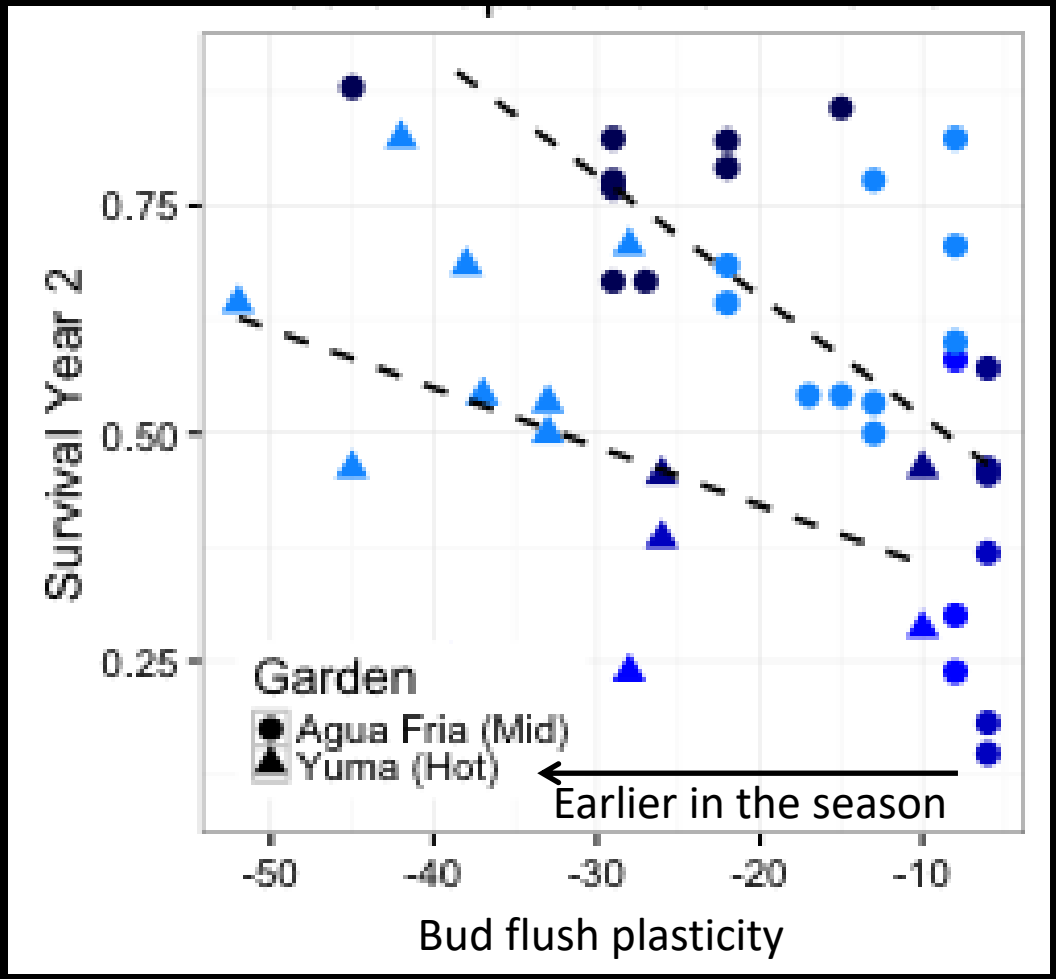
elevation ← → DD > 18°C

→ summer heat:moisture

Cooper et al. 2019,
Global Change Biology

Cold genotypes to Hot garden:

Spring bud flush plasticity in the right direction correlated with higher fitness



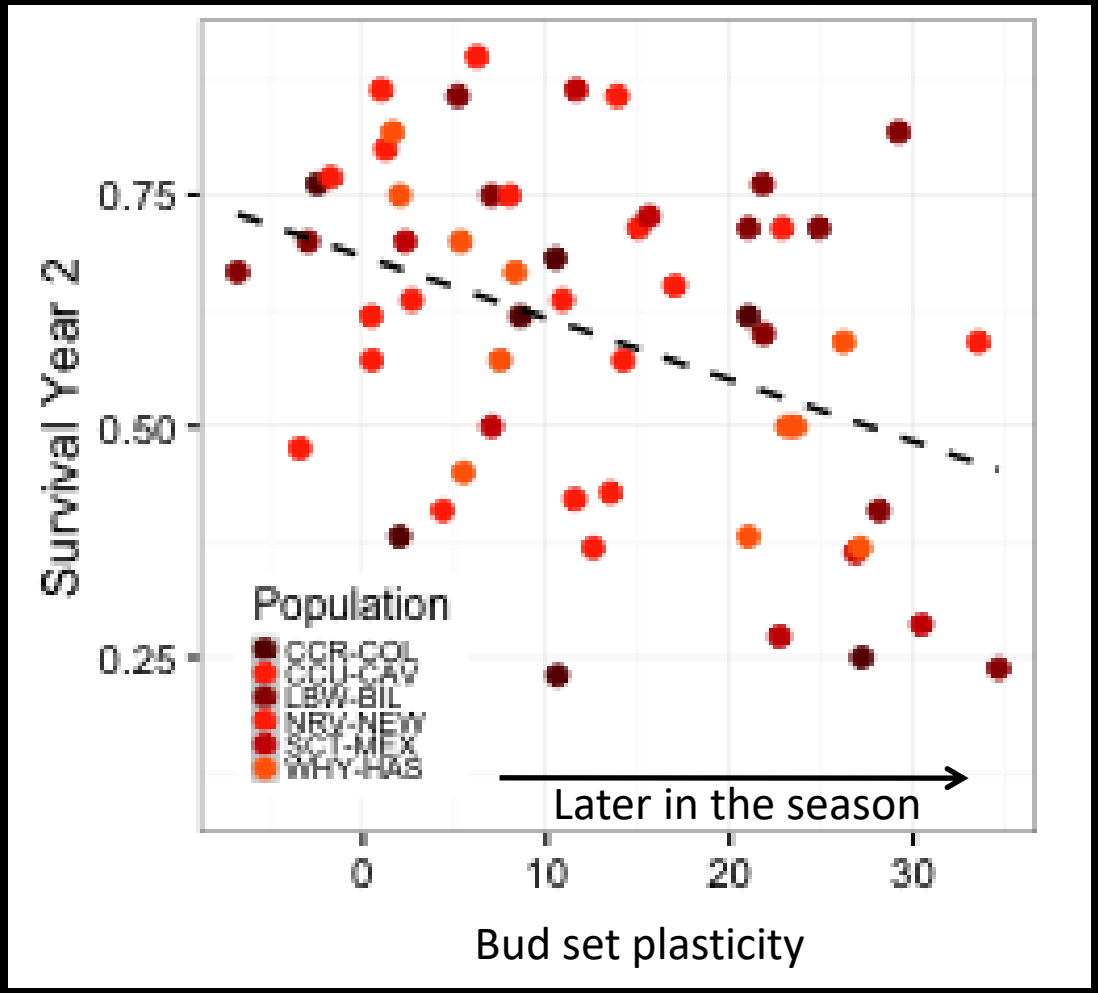
✓ *Adaptive:*
- Trait change in the correct direction
- Increased fitness

✓ Hopeful result for climate warming

Cooper et al. 2019, *Global Change Biology*

Hot genotypes to Cold garden:

Fall bud set plasticity in the wrong direction correlated with higher mortality



✗ *Non-adaptive:*

- Trait change in the wrong direction
- Decreased fitness

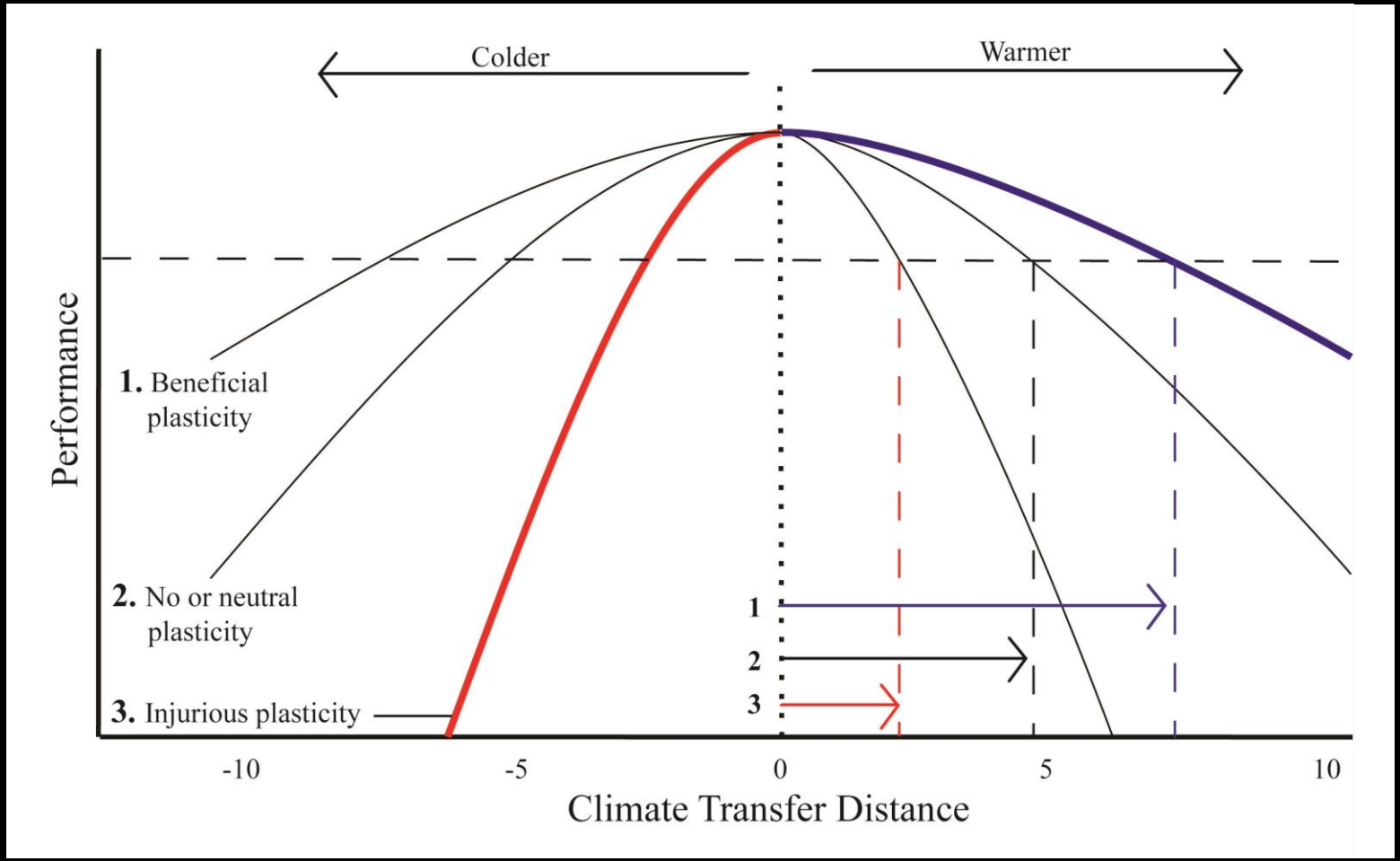
✗ Not great for assisted migration into colder climates

Cooper et al. 2019, *Global Change Biology*

Plasticity conclusions

1. Bud flush is more plastic than bud set
2. Plasticity – climate relationships
   - Hot populations > cold populations
3. Adaptive and non-adaptive responses
   - Moving cold populations to hotter, drier climates => moderately adaptive
   - Moving hot populations to colder, wetter climates => non-adaptive response
     - Southern populations cannot anticipate freezing

Potential consequences of plasticity



Management implications

1. Arizona populations are poised for maladaptation with abrupt environmental change
2. Climate warming: moderately adaptive phenology responses
3. Assisted migration
   - Transfer distances depend on the target environment: greater range into mid and cold gardens

Management implications

1. Arizona populations are poised for maladaptation with abrupt environmental change
2. Climate warming: moderately adaptive phenology responses
3. Assisted migration
   - Transfer distances depend on the target environment: greater range into mid and cold gardens
   - Hot-adapted populations moved north suffer high mortality: Recommend small transfer distances.

Thank you

Tom Whitham, Gery Allan, Rebecca Best, Kevin Grady, Jackie Parker, Michelle Bem, Jacob Cowan, Zack Ventrella, Chris Updike, The Cottonwood Ecology Group

NORTHERN ARIZONA UNIVERSITY

The Nature Conservancy

ARIZONA GAME & FISH

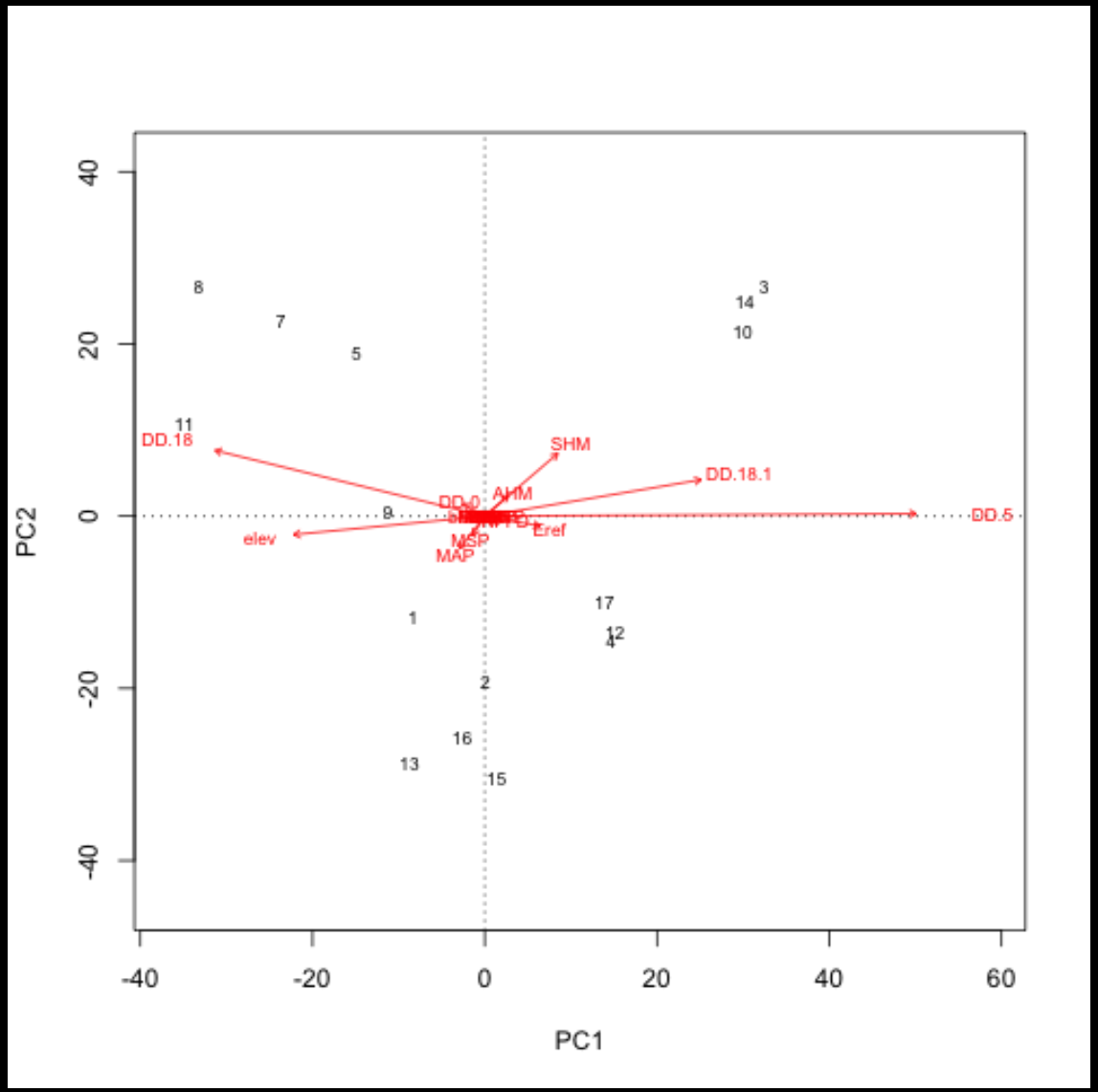
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

CANYONLANDS RESEARCH CENTER

NSF

SEGA
Southwest Experimental Garden Array

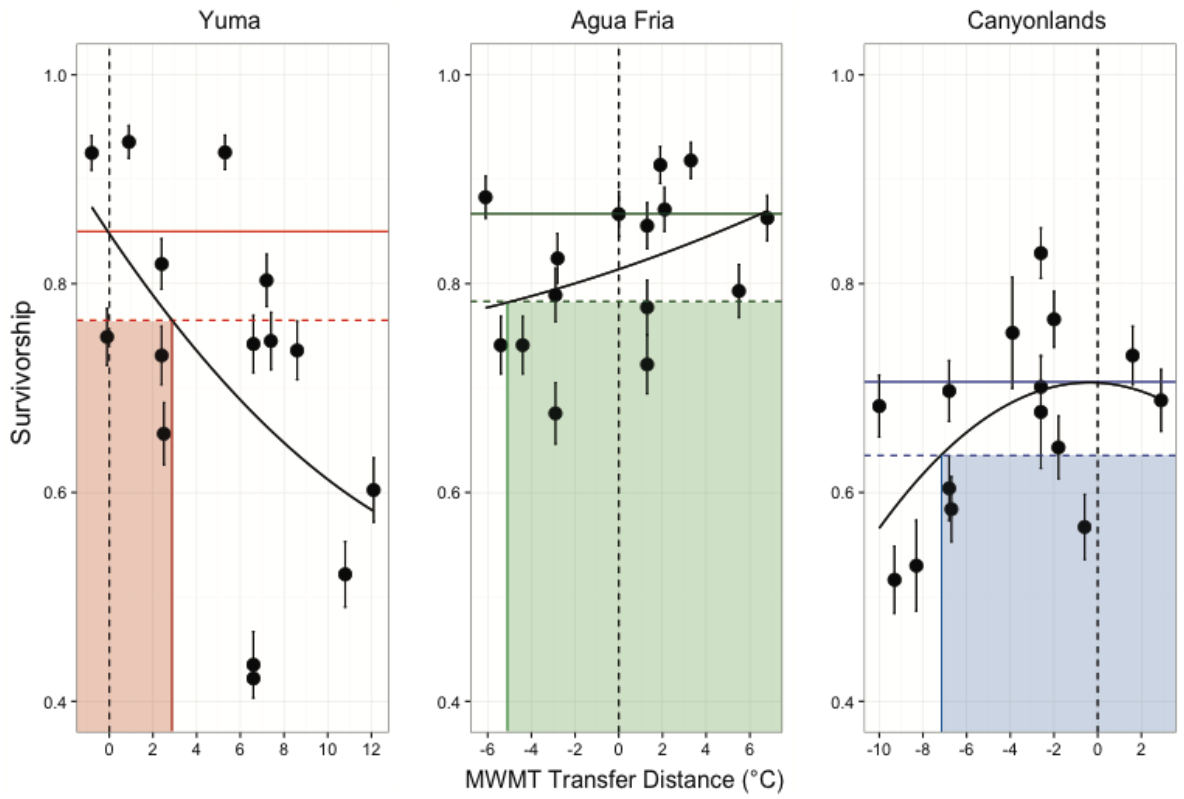
Provenance climates



PCA of 21 annual variables (1961-1990 averages) + elevation, latitude, longitude for each population

Temperature-driven climate differences among populations

- Degree days
- Summer heat:moisture index
- Elevation


Yuma
Agua Fria
Canyonlands
Survivorship
1.0
0.8
0.6
0.4
0
2
4
6
8
10
12
-6
-4
-2
0
2
4
6
-10
-8
-6
-4
-2
0
2
MWMT Transfer Distance (°C)