Plant transfer experiments along a distance/elevation gradient show limits to supporting home site communities
“If you build it will they come?”

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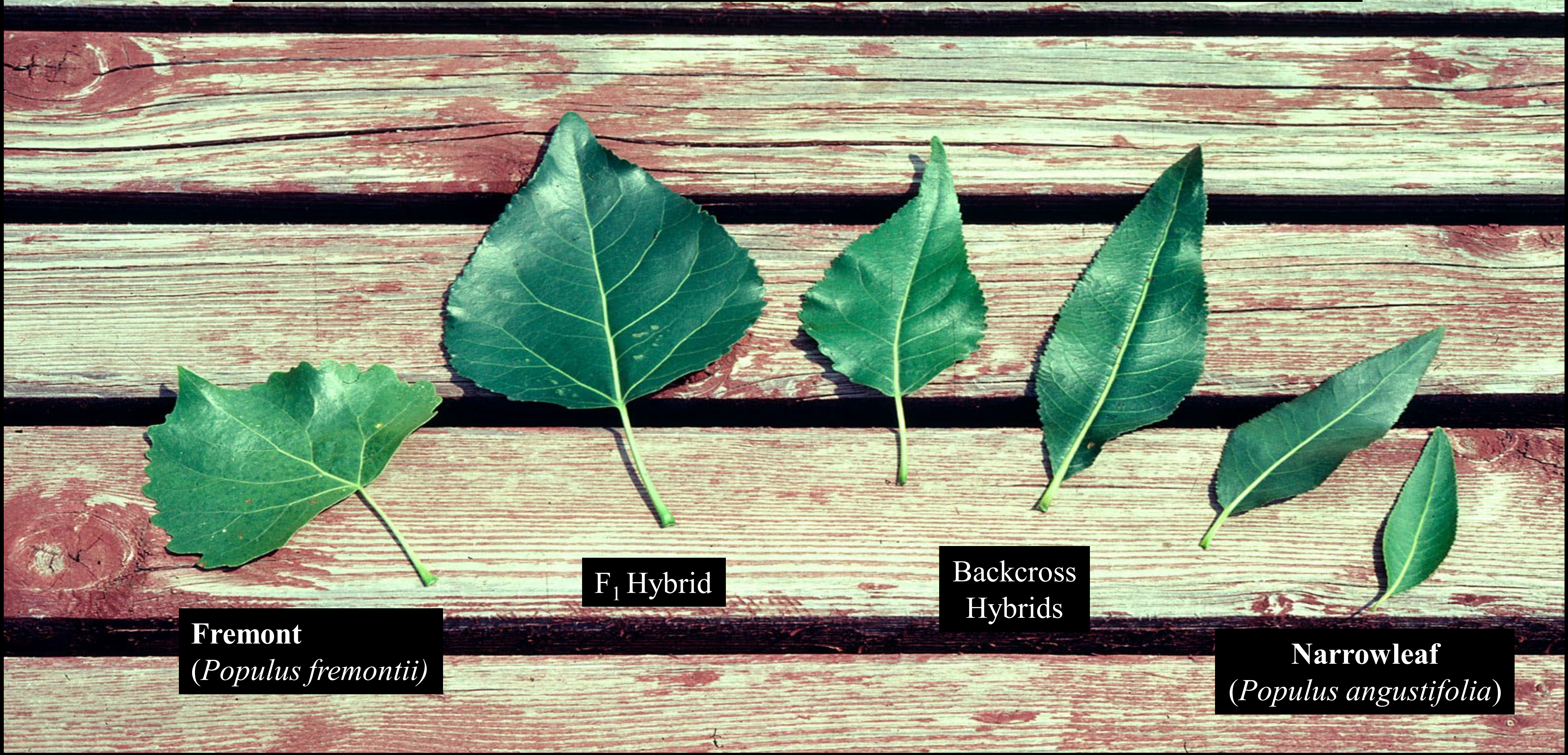
Cottonwood (*Populus*) in the desert southwest

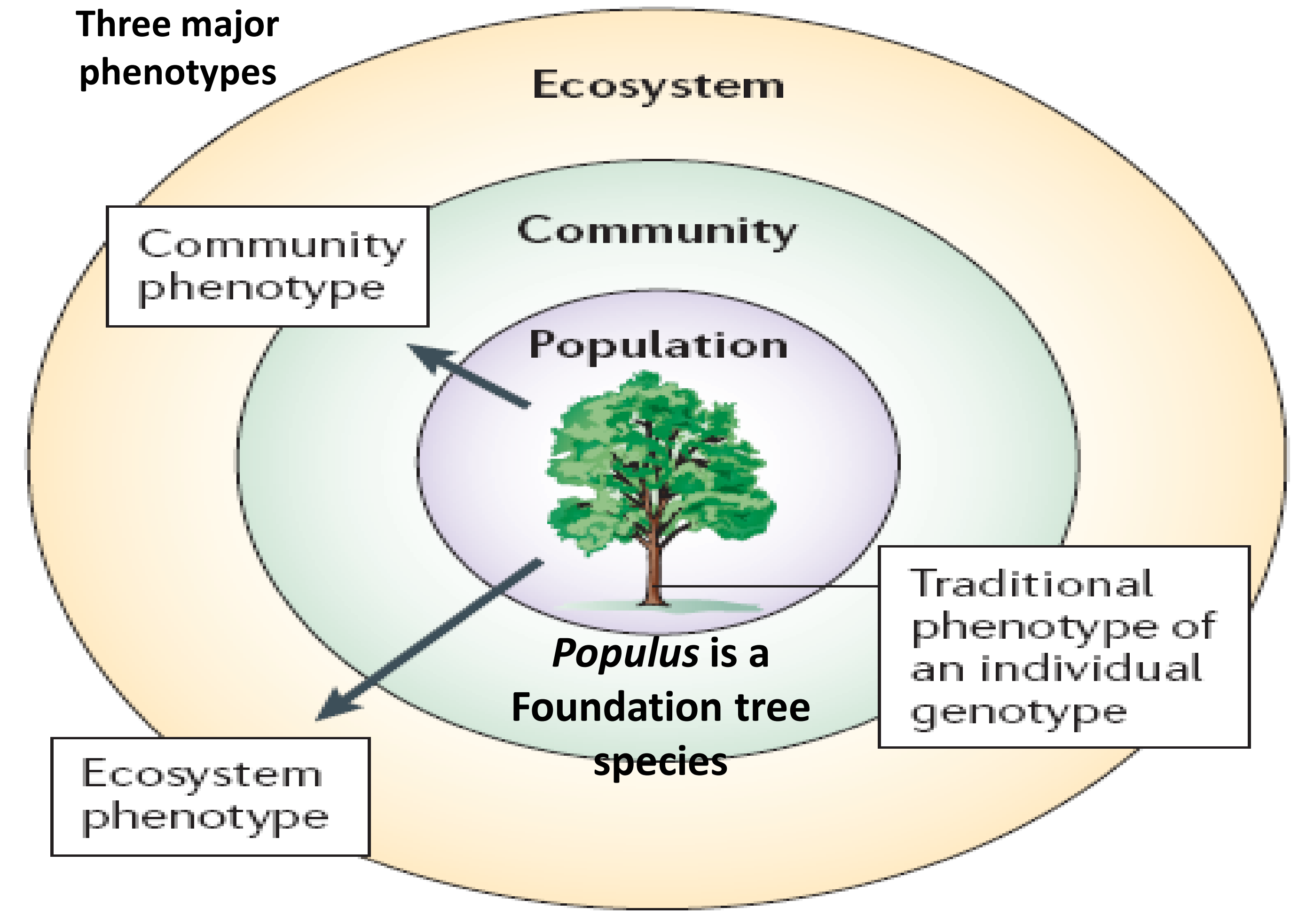


Unidirectional Introgression in Cottonwoods

Importance of Freemont and Narrowleaf cottonwood in the southwestern US:

- Fast growing (recolonization)
- Shade (evaporation, temps)
- Bank stabilization (stream channel morphology)
- Aquatic inputs (water quality, runoff, macroinvertebrates)
- Resistance to invasives (Tamarix, Russian Olive, understory grasses)
- Sacred and useful to indigenous peoples (Kachinas, baskets, medicinal)
- Support endangered/threatened species (Willow Flycatcher, Yllw. Billed Cuckoo)
- Ecologically a "Foundation" riparian tree species
- Support of biodiversity (estimated 75-85%)
- Approximately 3% of pre-19th century distribution remains!

Foundation Species and Community Phenotypes

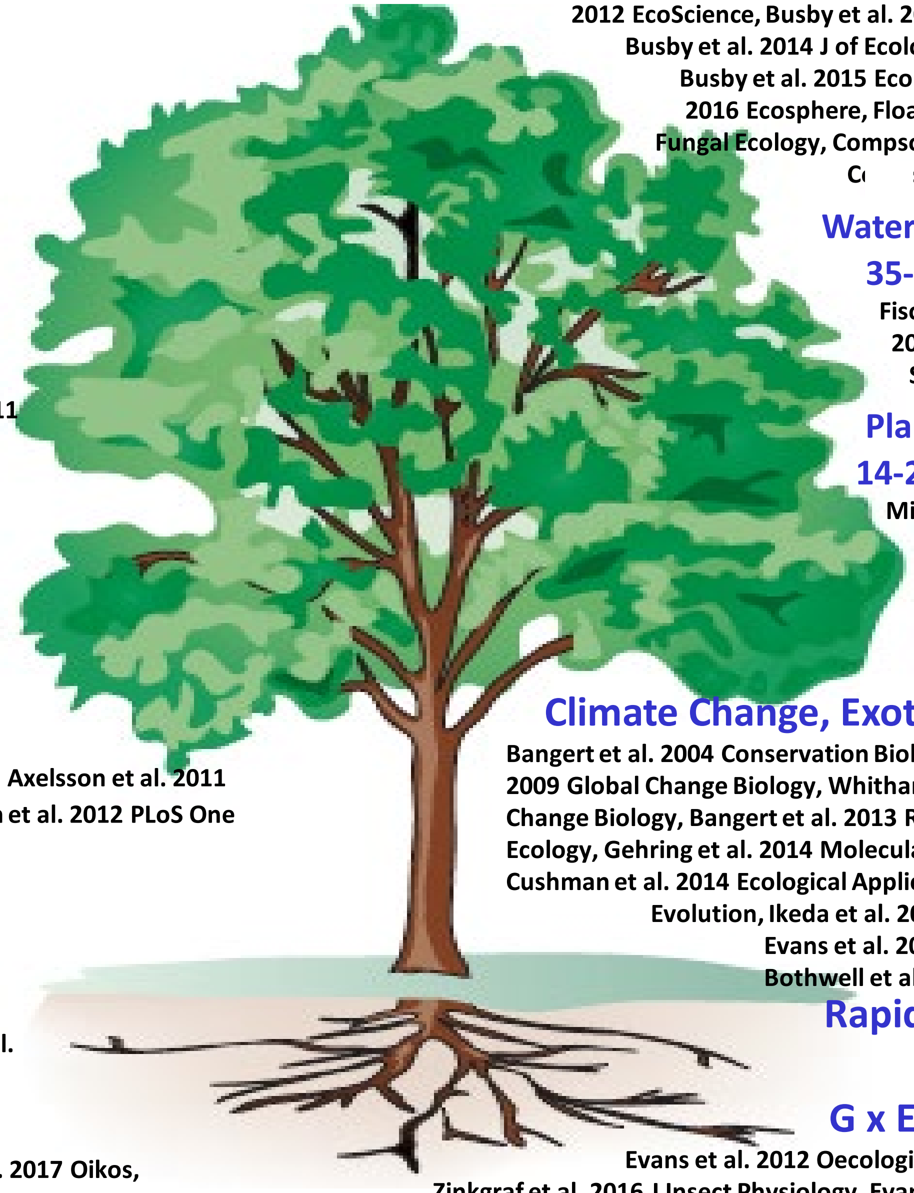


Three major phenotypes

Populus is a Foundation tree species

Definition of a foundation species: species that structure their ecosystems by creating locally stable conditions and provide specific resources for diverse organisms (Ellison et al. 2005)

Published studies of genetic variation in *Populus* traits affecting community and ecosystem phenotypes



Plant Growth 25-72%

(architecture) Bailey et al. 2004 Evolution, (productivity) Lojewski et al. 2009 Tree Physiology, Grady et al. 2011 Global Change Biology, (sink-source) Compson et al. 2011 Oecologia, (leaf economic traits) Grady et al. 2013 Functional Ecology, Kaluthota et al. 2015 Tree Physiology, Fischer et al. 2017 Functional Ecology

Trophic Structure & Networks 80%

(tree-insects-birds) Bailey et al. 2006 Ecology Letters, Smith et al. 2011 J of Evolutionary Biology, (aquatic) Marks et al. 2009 Freshwater Biology, Compson et al. 2014 Ecosystems, (terrestrial) Lamit et al. 2015 J of Ecology, Smith et al. 2015 Acta Oecologica, Wymore et al. 2015 Freshwater Ecology, Lau et al. 2016 Ecology

Nutrient Cycles 34-65%

Schweitzer et al. 2004 Ecology Letters, 2005 Ecology, 2005 Oikos, 2011 Population Ecology, Classen et al. 2007 J of Ecology, Fischer et al. 2010 Plant & Soil, Schweitzer et al. 2011 Pop. Ecology, Classen et al. 2013 Ecosphere, Wymore et al. 2016 Microbial Ecology

Soil & Microbial Feedbacks 20%

Pregitzer et al. 2010 Evolutionary Ecology, Smith et al. 2011 Plant & Soil, Gehring et al. 2014 Botany, Schweitzer et al. 2012, Gehring et al. 2017 PNAS

Community Stability 32%

Keith et al. 2010 Ecology , Keith et al. 2017 Proc. R. Soc. B

GMO Effects on Communities 25-33%

Axelsson et al. 2011 J. Appl. Ecology, Axelsson et al. 2011 Chemoecology, Hjältén et al. 2012 PLoS One

Review and Meta-Analysis

Whitham et al. 2003 Ecology, Whitham et al. 2006 Nature Reviews Genetics, Whitham et al. 2008 Science, Bailey et al. 2009 Phil. Trans. R. Soc. B., Wymore et al. 2011 New Phytologist, Allan et al. 2012, Whitham et al. 2012 Trends in Plant Science, Fischer et al. 2014 Plant & Soil, Hultine et al. 2016 Nature Plants

Evolution of Associated Species

Evans et al. 2008 Evolution, Evans et al. 2012 Conservation Genetics, Evans et al. 2013 Evolutionary Ecology, Grady et al. 2017 Oikos, Jarvis et al. 2017 Ecology & Evolution

Biodiversity 39-78%

(Bacteria, Insects, Spiders, Birds, Mammals, Lichens, Endophytes, Pathogens, Mycorrhizae) Wimp et al. 2004 Ecology Letters, Wimp et al. 2007 Molecular Ecology, Shuster et al. 2006 Evolution, Bangert et al. 2006a,b Molecular Ecology, Schweitzer et al. 2008 Ecology, Bangert et al. 2008 Heredity, Sthultz et al. 2009 New Phytologist, Barbour et al. 2009, Lamit et al. 2011 Fungal Ecology, Ferrier et al. 2012 Arthropod-Plant Interactions, Meneses et al. 2012 EcoScience, Busby et al. 2013 J of Ecology, Lamit et al. 2014 Am J Botany, Busby et al. 2014 J of Ecology, Gehring et al. 2014 Frontiers in Microbiology, Busby et al. 2015 Ecology, Axelsson et al. 2015 PLoS One, Compson et al. 2016 Ecosphere, Floate et al. 2016 New Phytologist, Lamit et al. 2016 Fungal Ecology, Compson et al. 2016 Ecosphere, Co son et al. 2017 Ecology

Water Cycles & Terrestrial-Aquatic Interface 35-40%

fluxes from soil to plant to atmosphere – Fischer et al. 2004 Oecologia; aquatic relationships – LeRoy et al. 2006 Ecology, LeRoy et al. 2007 J. N. American Benthological Soc., Wymore et al. 2015 Freshwater Science

Plant Community Composition & Biomass 14-20%

Lamit et al. 2011 Botany, Adams et al. 2011 American Journal of Botany, Michalet et al. 2011 Ecology Letters

Belowground Carbon Storage & Root Production 77%

Fischer et al. 2006 Oecologia, Fischer et al. 2007 New Phytologist, Lojewski et al. 2012 New Phytologist

Climate Change, Exotics, Conservation & Modeling

Bangert et al. 2004 Conservation Biology, Bangert & Whitham 2007 Evolutionary Ecology, Sthultz et al. 2009 Global Change Biology, Whitham et al. 2010, Grady et al. 2011 Global Change Biology, Bangert et al. 2013 Restoration Ecology, Grady et al. 2013 Functional Ecology, Gehring et al. 2014 Molecular Ecology, Ikeda et al. 2014 Functional Ecology, Cushman et al. 2014 Ecological Applications, Woolbright et al. 2014 Trends in Ecology & Evolution, Ikeda et al. 2014 PLoS One, Grady et al. 2015 Restoration Ecology, Evans et al. 2015 Heredity, Ikeda et al. 2017 Global Change Biology, Bothwell et al. 2017 Molecular Ecology

Rapid Evolution in Plants Redefines Communities

Sthultz et al. 2009 Global Change Biology, Gehring et al. 2014 Molecular Ecology, Smith et al. 2015 Oecologia

G x E Interactions & Gene Discovery

Evans et al. 2012 Oecologia, Busby et al. 2014 J of Ecology, Lamit et al. 2015 Ecology, Zinkgraf et al. 2016 J Insect Physiology, Evans et al. 2016 Ecology & Evolution

Genetics based traits affect community structure on an elevation/distance gradient and in a common garden

25yo common garden 10trees/site, 10 genotypes/origin in comm. garden

Distance/elevation gradient of 90km and 530m, temp 1.5 °C

Elev.=1300m

1720m, 48km

1400m, 18km

1830m, 98km

Weber River, Wasatch mountains in Northern Utah

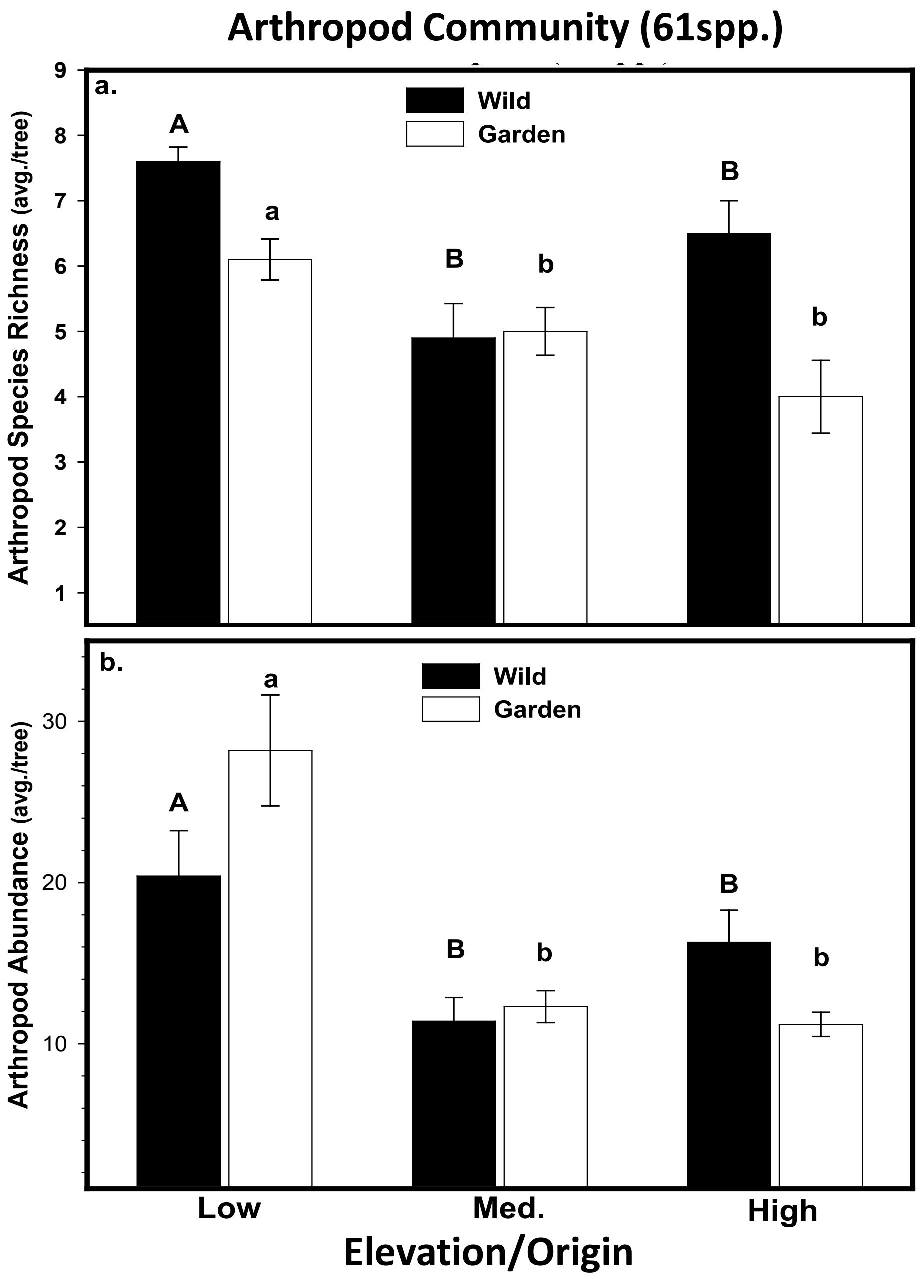
Evolutionary response to elevation drives diversity patterns in arthropod communities on *Populus*

Common Garden (Ogden UT)

Initial Findings:

- 25yrs after relocation trees still supported similar patterns of arthropod species richness and abundance.
- Trees from lower/warmer sites support greater species richness and abundance.

Keith (2023 PlosClimate)



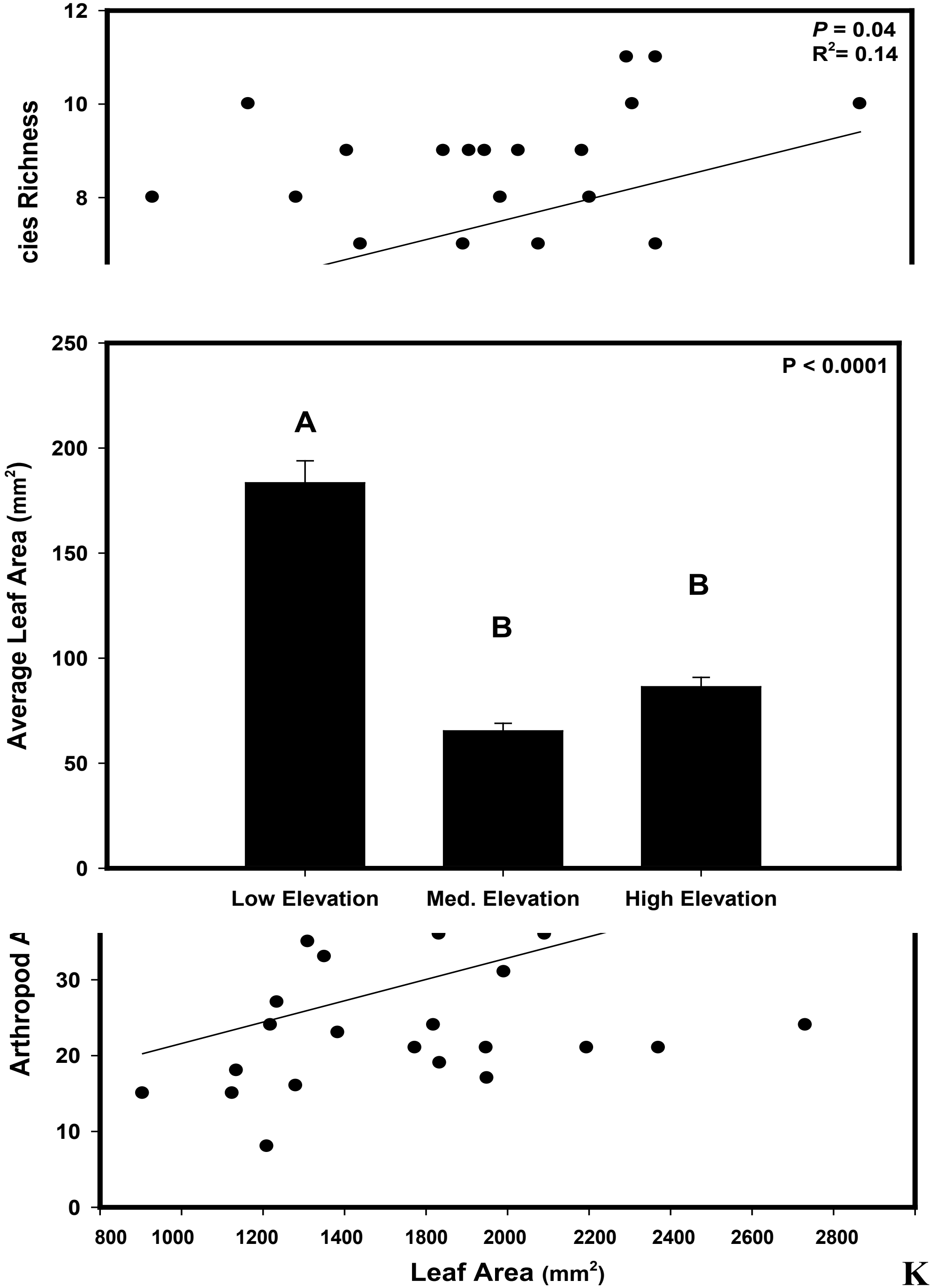
Arthropod Community (61spp.)

Potential Mechanisms

Common Garden

We examined five plant traits:
N content
Tannins (%dw cond.)
Salicortin
Growth rate (ANPP)
Leaf area *

- A trait known to be under genetic control varies along a elevation gradient and affects community structure.
- Because genetically based traits structure communities and also vary across landscapes, then moving plants too far (dist/elev.) may disrupt their associated communities.



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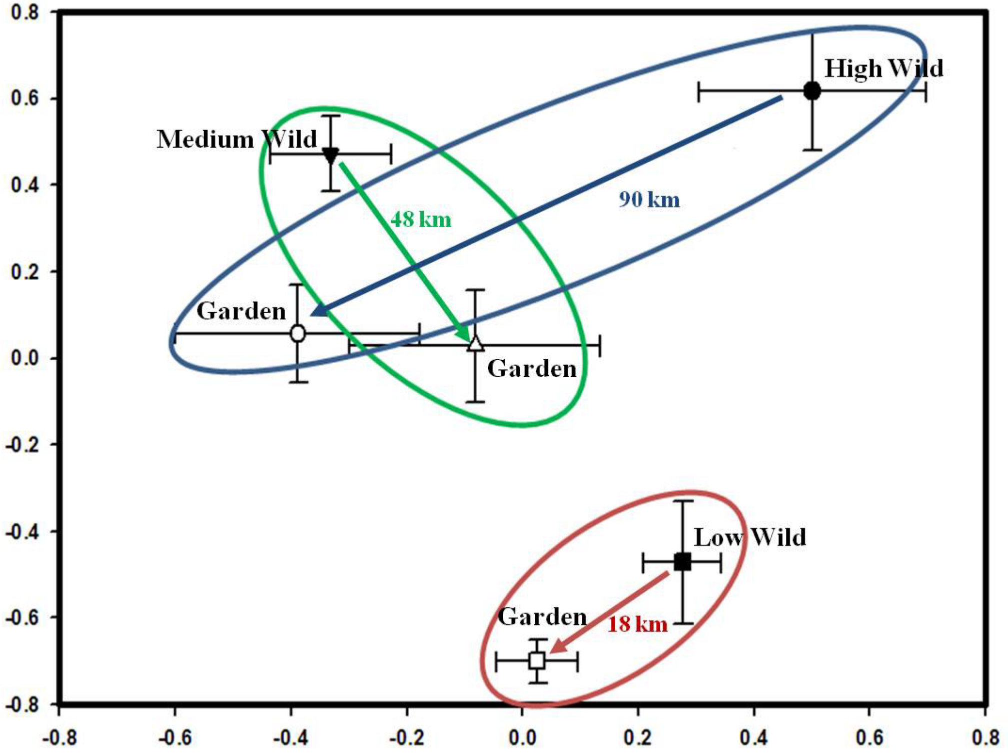
As trees are moved farther, their communities become more dissimilar

Nonmetric Multidimensional Scaling (NMDS)



(Anosim-R: Low = 0.319, Med. = 0.681, High = 0.804)

With Transfers of 18km and 48km, garden and wild trees support similar communities, but at 90km/530m they are quite different.

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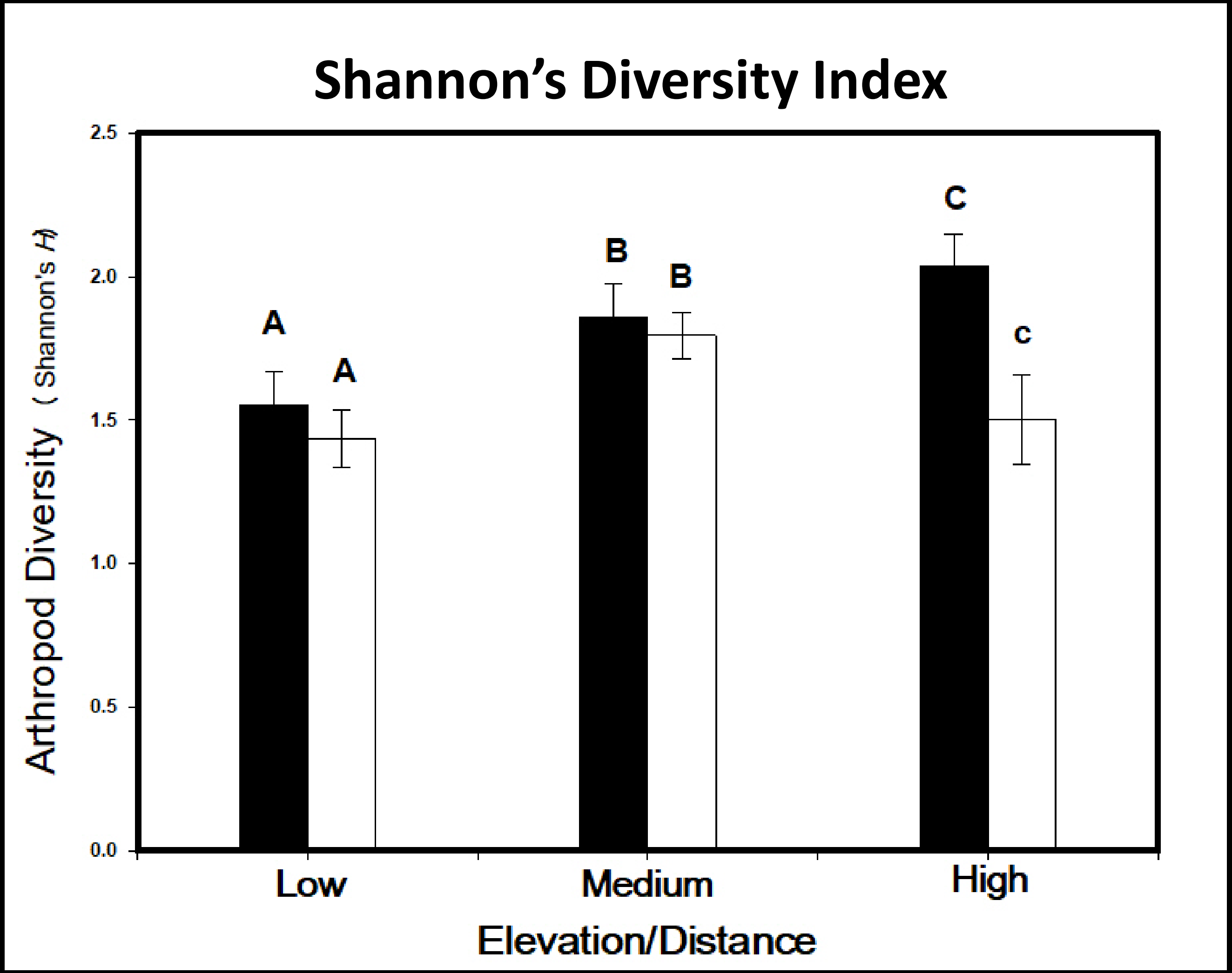
Moving trees can result in loss of arthropod diversity



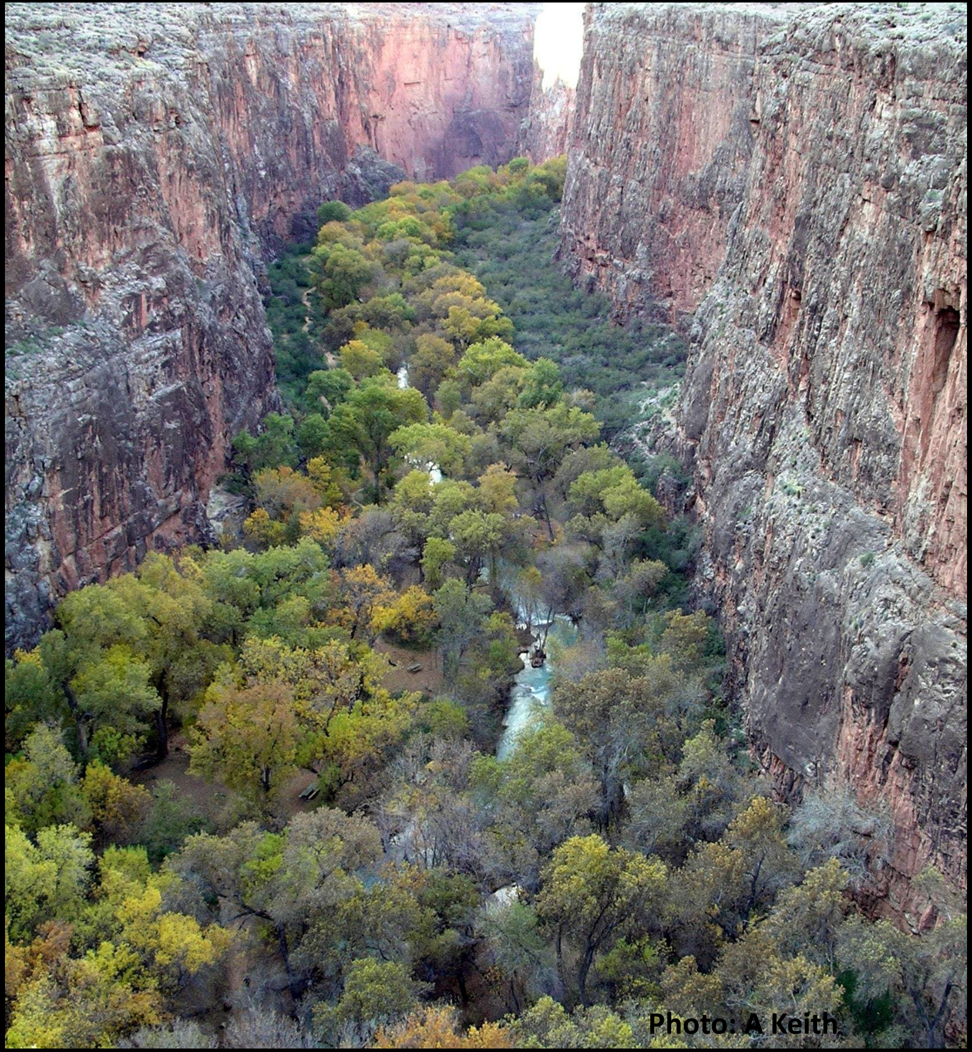


Photo: A Keith

Summary

- Variation in genetically based plant traits along a elevation/distance gradient affects arthropod species richness and abundance.
- When trees are moved, genetically based differences in community richness and abundance can be conserved (25yrs).
- As *Populus* trees are moved farther from their home sites, their associated arthropod communities become **less similar** and **less diverse.**


7 months later

A 10,000 tree restoration/science experiment

If you build it they may come, up to a certain point.

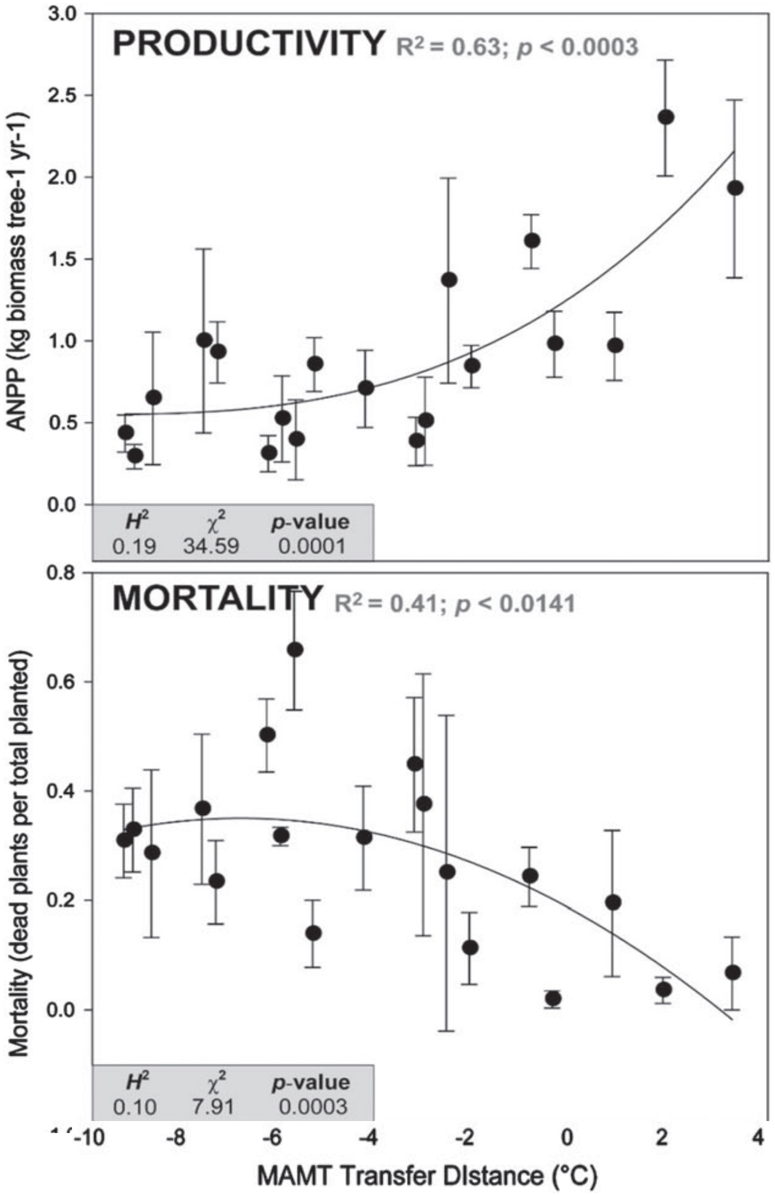
“Assisted Migration” of foundation species currently a “hot topic”

- **Many studies now focusing on how far species can be moved and used for restoration.**
- **Few studies examining how far species can be moved and keep their associated communities intact.**

A Big Question:

How far can we move a foundation species and expect its communities (assoc. biodiversity) to also move?

Grady et al. 2015 Restoration Ecology

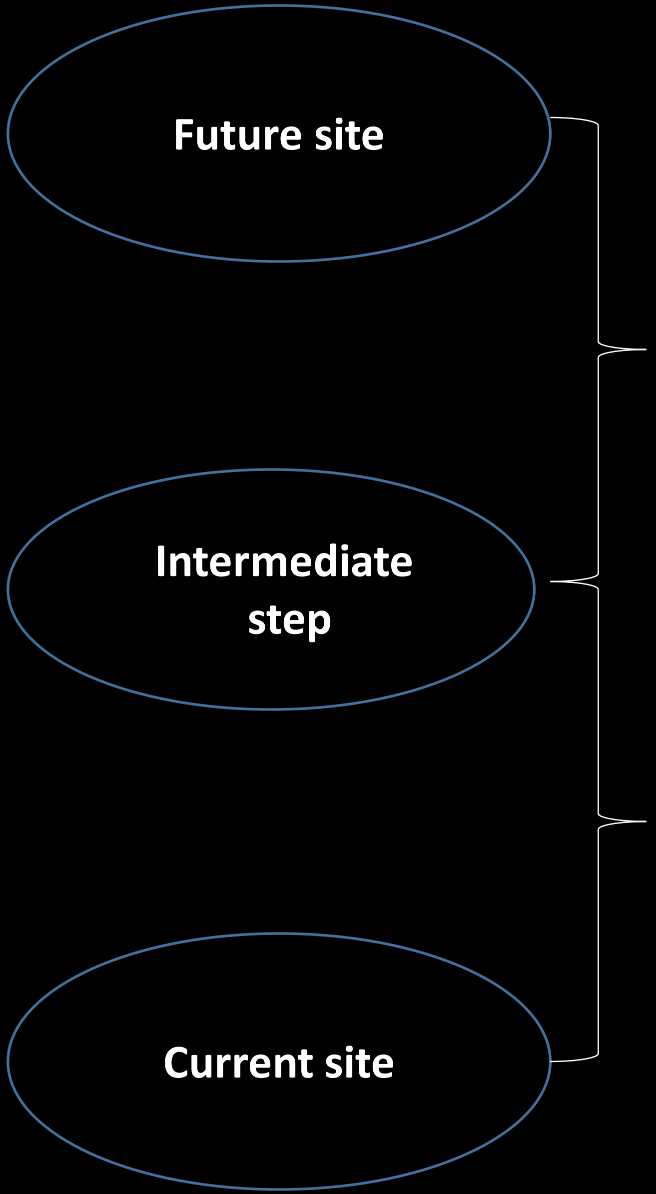


Populus fremontii

Applied Research Findings:

Plant Transfer experiment affects future restoration by showing:

1. How genetically based plant traits can affect arthropod community structure.
2. How moving a foundation tree species too far may result in loss of biodiversity.
3. The limits of successful transfers of foundation plants is likely different than their associated communities.



Future site

Intermediate step

Current site

For Fremont cottonwood
Optimal Transfer distance
MAMT = 3 ^{o}C
(Grady et al. 2013, 2015)

Associated communities may not be supported if moved more than 1.5 ^{o}C
(Keith 2023 PlosClimate)

Restoration efforts may need to incorporate intermediate distances to keep communities intact.

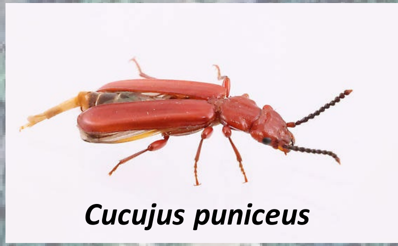
NAU’s Southwest Experimental Garden Array (SEGA)

Bear Springs AZ: Elevation: 2688m, MWMT : 14.0C

Walnut Creek AZ: Elevation: 988m, MWMT : 25.5C

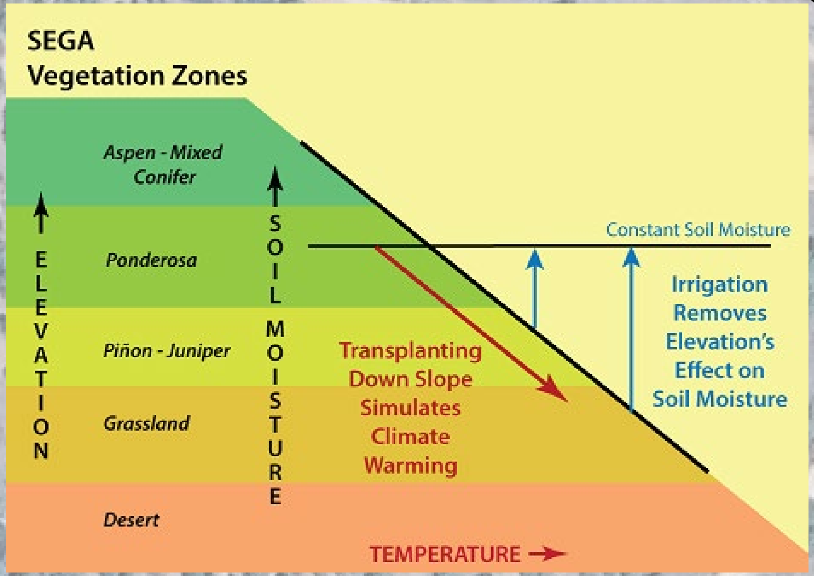
Yuma AZ: Elevation: 49m, MWMT : 33.8C

Approx. 800-1000 species collected at WC so far!



Cucujus puniceus

Dorytomus marginatus



- a 1615m/1000km elevation/distance gradient
- mean annual temperatures ranging from 2.4 - 14.5°C

Newest Garden/Current Study:
Walnut Creek Center for Education and Research
6 Populations/River systems
Populus parental species (*fremontii* & *angustifolia*) and their hybrids
Drought tolerance and arthropod community assembly

https://www.sega.nau.edu/

Questions?

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