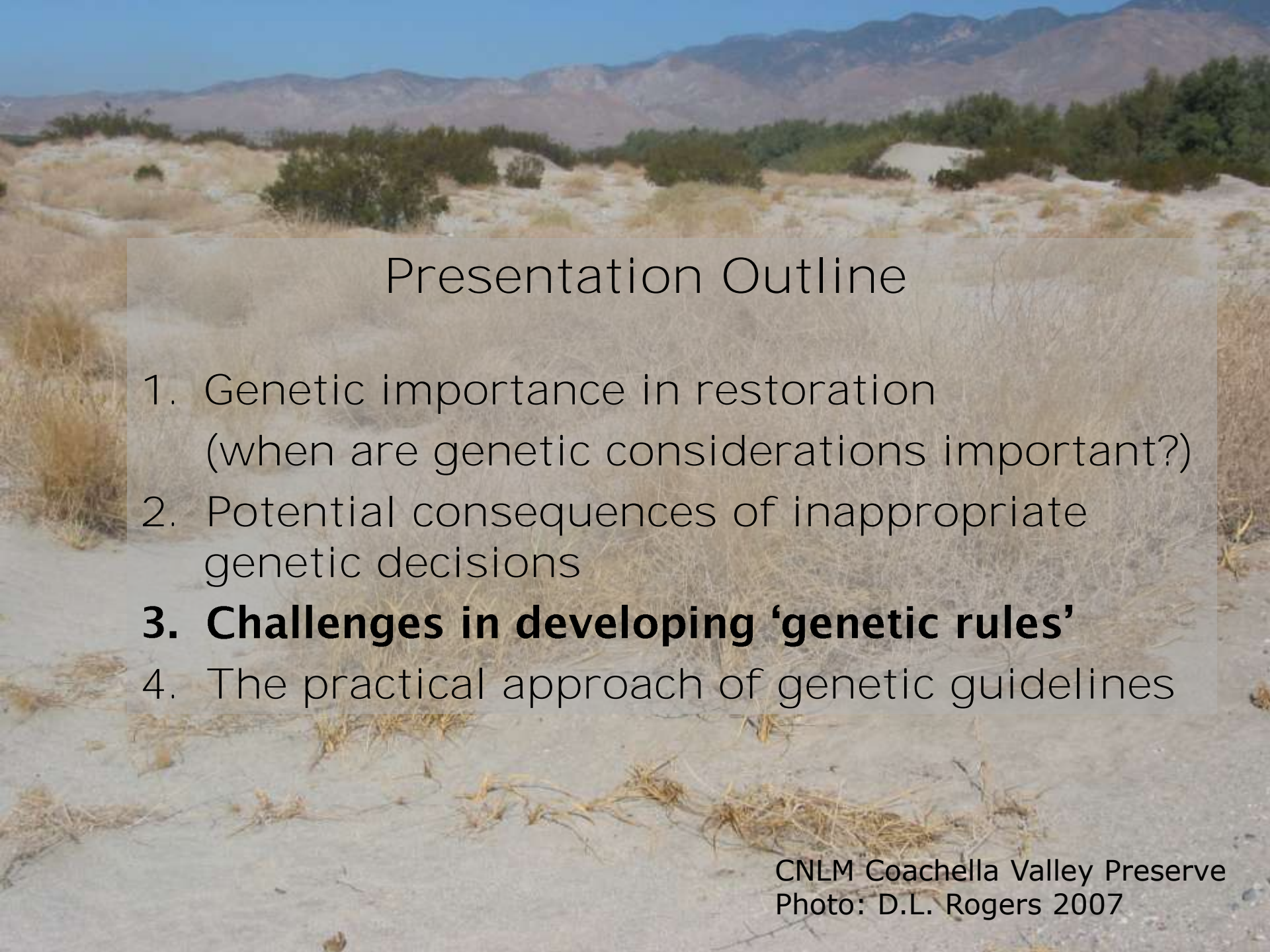


# Restoration Success: the certainty of genetic roles, the uncertainty of genetic rules

Dana Point Preserve,  
Orange County, CA

Deborah L. Rogers  
Center for Natural Lands Management  
[www.cnlm.org](http://www.cnlm.org)  
and University of California, Davis

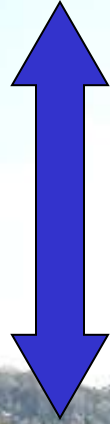




## Presentation Outline

1. Genetic importance in restoration  
(when are genetic considerations important?)
2. Potential consequences of inappropriate genetic decisions
- 3. Challenges in developing 'genetic rules'**
4. The practical approach of genetic guidelines

# Restoration Genetics



- Collections
- Propagation
- Deployment
- Monitoring
- Germplasm storage

*Pinus radiata*  
Central coastal California



CNLM Warm Springs Preserve  
Riverside County, CA

## 1. Genetic Importance in Restoration

- Success of initial restoration project
- Sustainability of initial project through natural regeneration
- Genetic impacts on local native plant populations

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Genetic considerations:  
When *don't* they matter?



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## 2. Potential consequences of inappropriate genetic decisions

### i. Too little diversity:

- i. Insufficient diversity for adaptation
- ii. Selfing ( $\rightarrow$  inbreeding depression)
- iii. Genetic swamping, dilution, or erosion of native genetic diversity.

### ii. Inappropriate diversity:

- i. Maladaptation of restored population
- ii. Outcrossing depression, or undermining local adaptations.

# Cascading effects throughout the ecological community



(Photo from G. Allan)

“Conserving genetic diversity is more than a species issue ... it is an important **community issue** ... nearly 60% of arthropod diversity could be accounted for by genetic diversity in cottonwood **stands** ...

MVP concept may be inadequate for describing the genetic diversity needed in a producer to maintain species **diversity in the dependent community** ... conserving genetic diversity in dominant plant species may be just as important as conserving genetic diversity in rare **and endangered species.**”

Whitham et al. 2003, Wimp et al. 2004.



Johnson Ranch Preserve  
Riverside County, CA

### 3. Challenges in developing genetic rules for restoration

### 3. Challenges in developing genetic rules

- i. Rarely sufficient information (esp. for long-lived species or long generation time)
- ii. Genetic information is often based on neutral genetic markers
- iii. Context dependent
- iv. Different spatial scales of adaptation for different traits
- v. **Adaptation to past environments: is 'locally adapted' a sufficient criterion in the face of rapid environmental change?**
- vi. **Difficulty of determining 'adaptive genetic variation' for threatened/endangered species**

i) Cryptic

## ii) Quick vs. biologically meaningful studies: the 'Great Divide'

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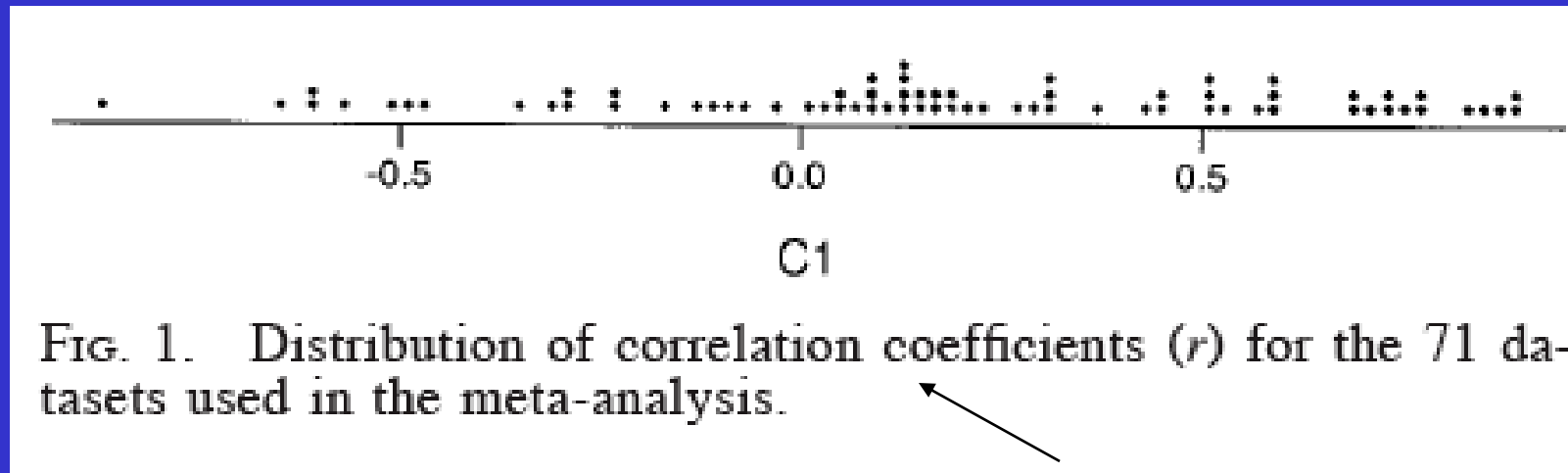
### *Molecular/allozyme*

- Traits expressed as **'presence/absence'** or different alleles
- Measured in allele frequencies and distributions
- Single-locus (typically)
- Typically reflect neutral genetic variation

### *Quantitative genetics*

- Traits that have a continuous distribution of values or phenotypes
- Influenced by several or many genes
- Experimental design and analysis separates **'environmental' effects from 'genetic' effects**
- May reflect adaptive genetic variation

## Relationship between molecular and genetically based phenotypic variation



between molecular and phenotypic variation

### iii) Varying spatial scales of genetic diversity

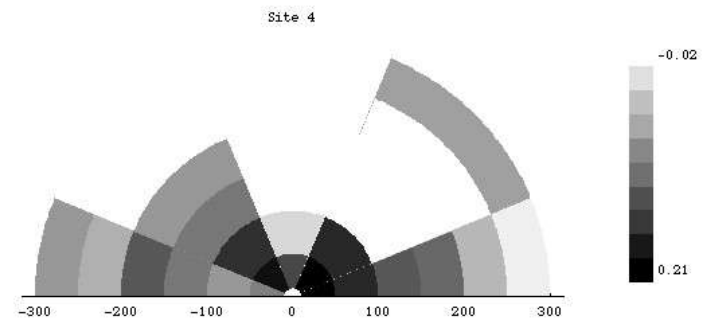
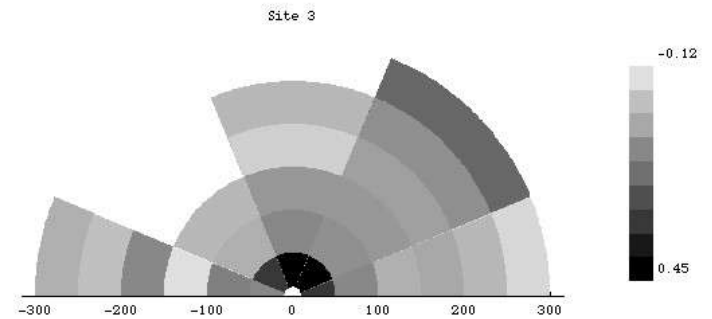
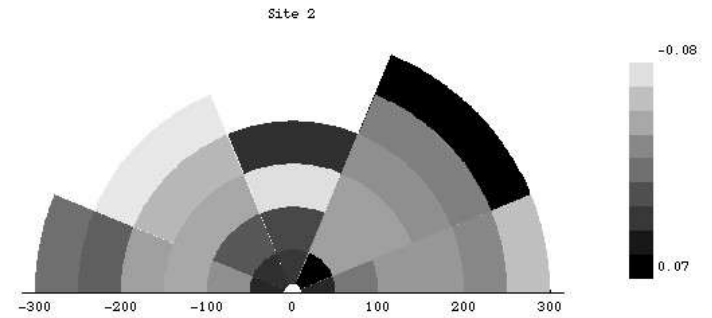
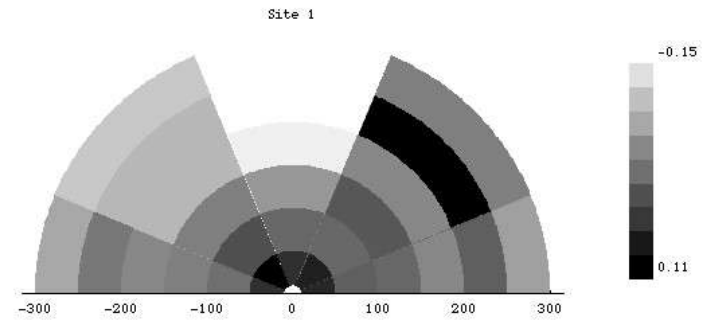
Species

Trait

Site (population)



Westfall and Rogers





Genetic restoration or  
contamination?

*Atriplex joaquiniana*  
Northern California

Common-garden study (2008-09)

- **4 'populations'**
- 100 m, 1 km, 100 km

No differences

- Days to first flower

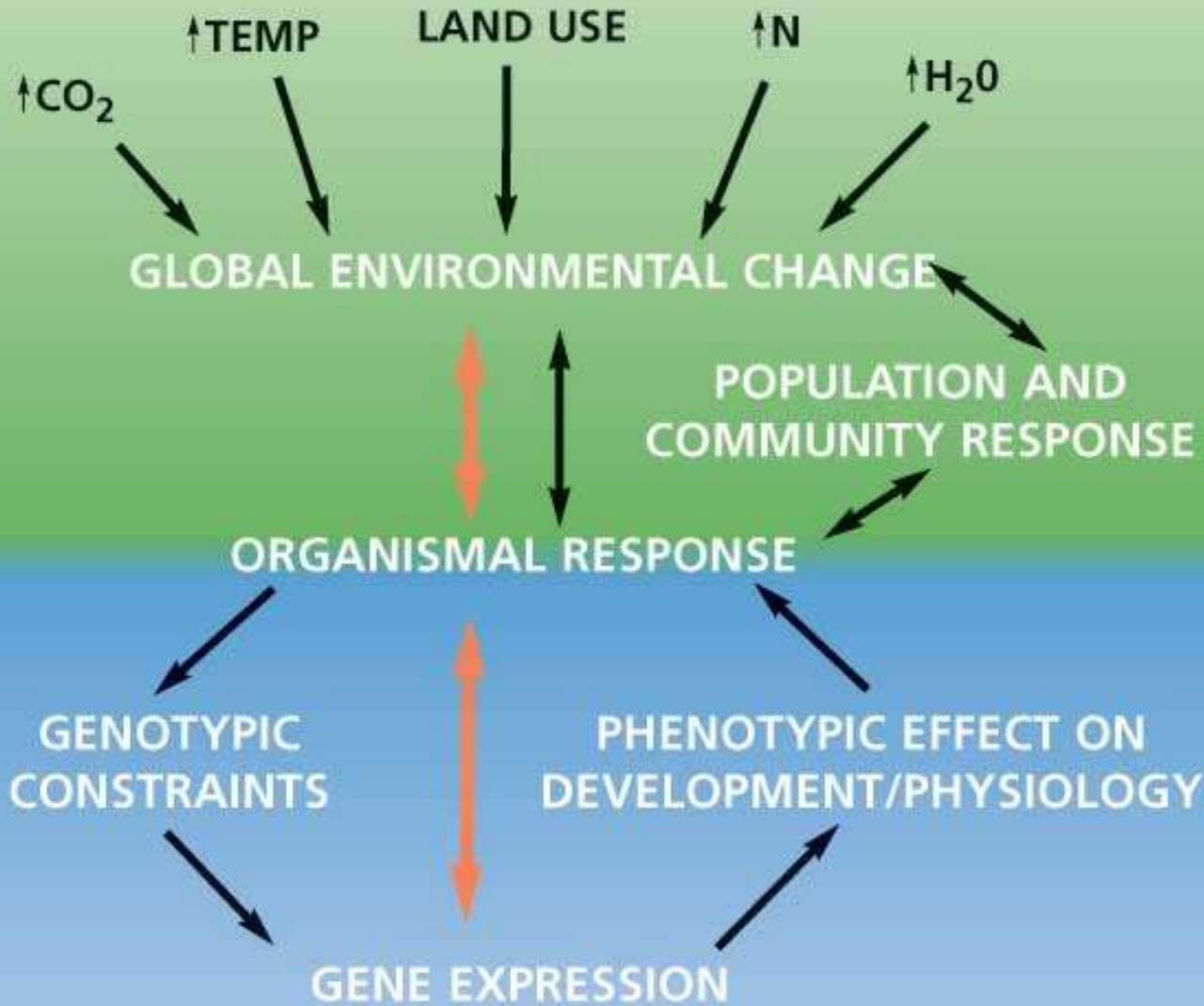
Differences

- Days to first germination
- Total height
- Total above-ground biomass

## iv) Uncertain response to climate change



GENETICS ECOLOGY



ECOLOGICAL GENOMICS

# Summary of Genetic Considerations for Sampling

- Match sampling site to deployment/restoration site, if known
- As a proxy for genetic information, use environmental information and species biology
- Ensure donor plants are natural (not planted)
- Sample in more than one year (providing there is reasonable shelf life)
- Sample throughout the season of seed ripening
- Avoid large collections from single plants or clusters
- Adjust sample size for mating system (e.g., higher for selfing than outcrossing) (Lawrence et al. 1995)
- If plants are clonal, be mindful of collecting from same individual

# Genetic Considerations for Propagation

- Maintain identity of donor plants (location)
- Allow for variable germination times
- Avoid over-culling (contract issues)
- Determine growing conditions with input from restoration managers
- If clonal, limit number of propagules per donor plant

Photo credit: J. Kitzmiller



# Genetic guidelines are practical **alternatives to 'rules'**

Every restoration project is unique

- For each restoration project, important to consider management objective(s) and ecological context to determine relative importance of genetic considerations
- Decisions are species-specific, site-specific
- Information/guidelines are available from:
  - Life-history, ecological proxies for genetic information
  - Information from congeners
  - Some species-specific genetic information
  - Emerging information from invasion biology, maternal effects, etc.
- Ecological genomics advances
- Genetics 'support groups'!

Photo: Peter Knapp

Restoration Success:  
the certainty of genetic roles,  
the uncertainty of genetic rules



Burrowing owl, CNLM Johnson Ranch Preserve Photo: G. Short



# 1. Climate Change: A new selective pressure?

- Rate of change
- Direction of change
- New vegetative communities, genetic relationships, and abiotic/biotic relationships
- Indirect effects (invasives)

# Limits of Migration

- Reproductive rate and distance
- Species competition
- Fragmentation, edge effects
- Availability of suitable habitat
- Barriers
- Loss of essential pollinators, seed dispersers
- Contradictory influences (latitude/elevation, day length/temperature)

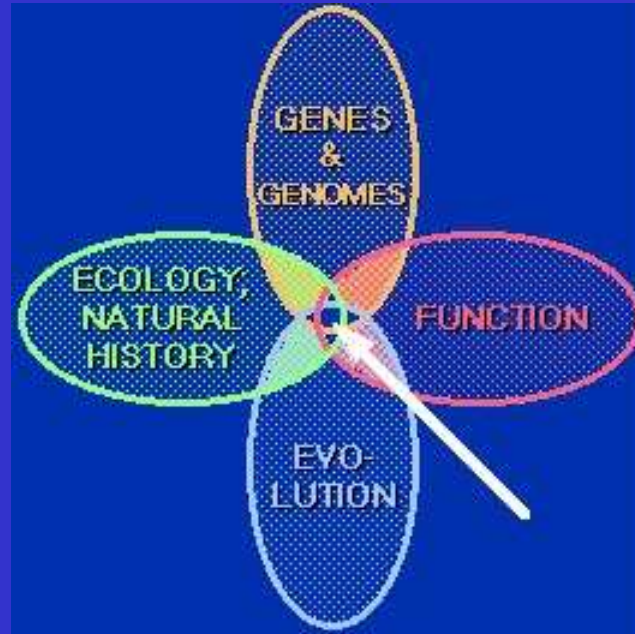
# Serendipitous hybridizations



Hybridization with *Helianthus debilis* has contributed to increased adaptation and invasive behavior of *H. annuus*

- Whitney, Randell, and Rieseberg 2007

# Evolutionary and Ecological Functional Genomics



# Guiding Principles for Managing Genetic Diversity of Native Plants in a Rapidly Changing Environment

- Genetic diversity is more important than ever: maintain
  - Planning is more important than ever
  - Revisit management objectives (natives, sustainability)
  - Increase vigilance towards detecting and managing invasives
  - Invest in seed storage: practice and technologies
  - Monitor for change (abiotic environment, invasives)

# Potential for responses to climate change

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## *Response*

- Phenotypic plasticity
- Migration
- Adaptation

## *Time-scale*

- Individual life-time
- Generations
- Generations

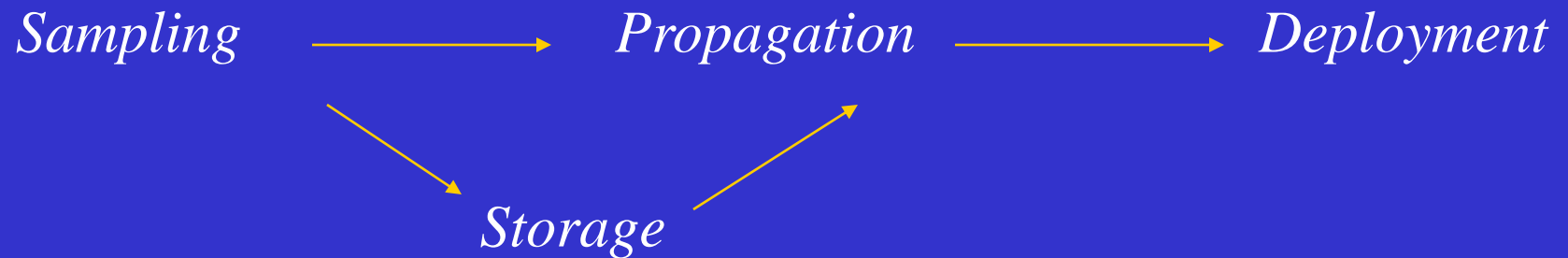
# Limits of Adaptation



Kern Mallow

- Genetic basis for trait(s) of interest (heritability)
- Genetic diversity (in population) in trait(s) of interest
- Reproduction (generations)
- Variable fitness related to trait(s) of interest

# 5. Genetic Considerations for Restoration





iv) Uncertain response to climate change

Whitebark pine (*Pinus albicaulis*) Eastern Sierra Nevada,  
Photo credit: D. Rogers

# Limits to Adaptation

'Gain' or response to selection varies according to three values:

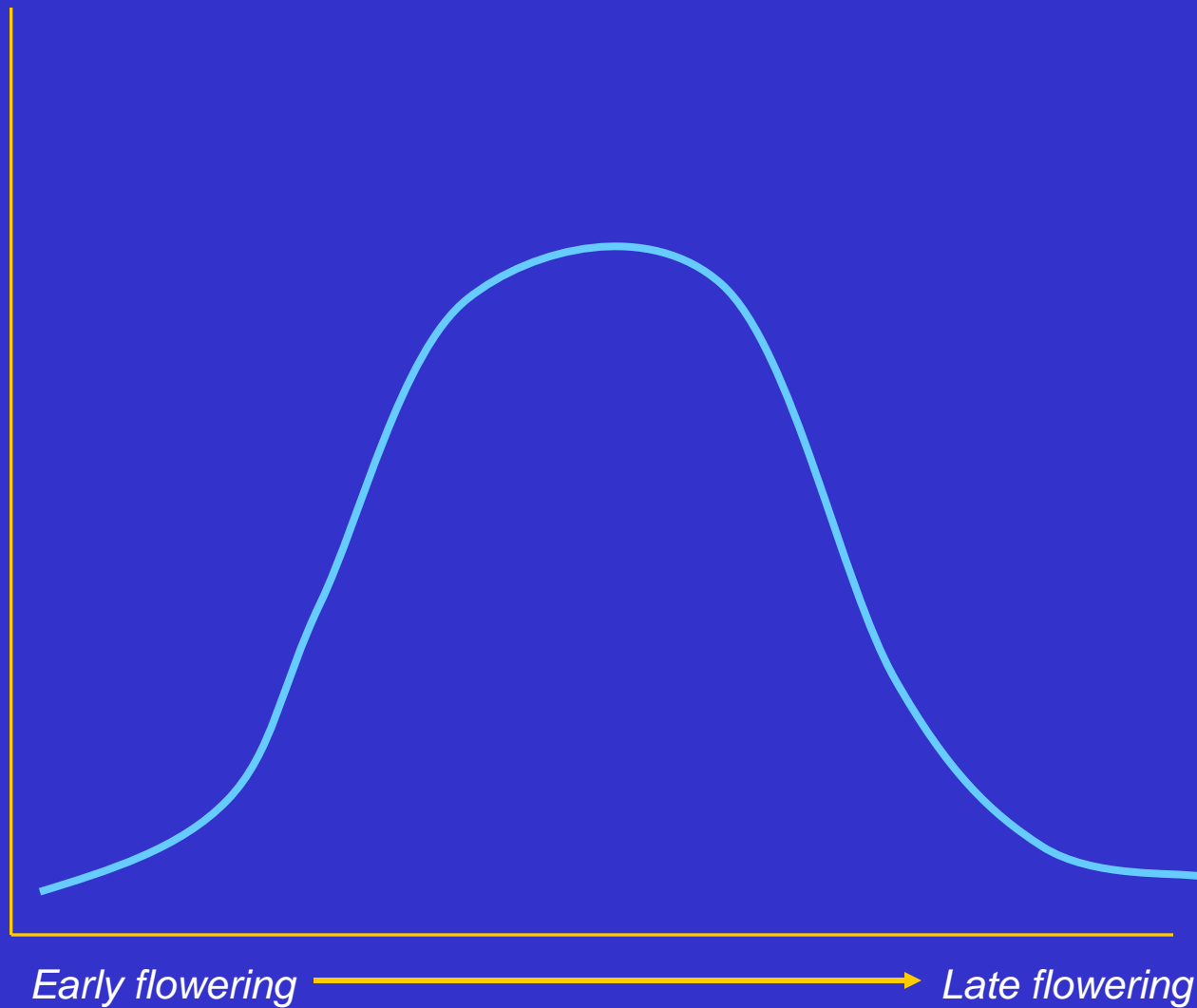
$$G = I h^2 \leftarrow p^2$$

1. Intensity of selection applied (i)
2. Heritability ( $h^2$ )
3. The amount of variation:  $\leftarrow p^2$

Example: In forestry, much research has been directed at determining  $h^2$  (and then response to selection) for traits such as height, stem straightness, and wood specific gravity.

Trait	Species	$h^2$
Height	Douglas-fir	0.10-0.30
Height	Yellow poplar	0.42-0.84
Wood specific gravity	Loblolly pine	0.76-0.87
Stem straightness	Loblolly	0.14-0.21

Frequency of a phenotype



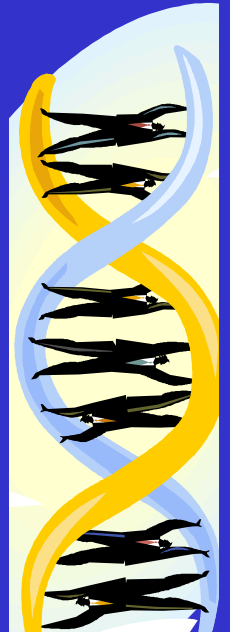
Array of phenotypes with different flowering times

# Mechanisms of Outbreeding Depression

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- Different chromosome structures or numbers (ploidy)
- Environmental dependent: loss of local adaptation in hybrids (only exhibits in some environments; GxE)
- Environmentally independent: disruption of favorable interactions among loci (coadaptation) in  $F_1$  or later generations

Can involve one or more mechanisms simultaneously



# Can Adaptation Occur Quickly Enough?

“Human activities are impacting evolutionary process and the scientific community has not adequately incorporated this into conservation planning. Evolution precipitated by human activities is occurring in years and decades rather than **centuries and has “disrupted”** evolutionary processes in recent times. Adaptation of species through evolution cannot keep pace with the rate **of change.**”

UCLA Evolutionary Change  
Conference 2007

Joshua Tree NP May 2006



# Resources

## Genetic factsheets

12 downloadable factsheets

UC/GRCP in collaboration with the USDA Forest Service's National Forest Genetics Lab (NFGEL)

[www.grcp.ucdavis.edu](http://www.grcp.ucdavis.edu)



Can genetic diversity be influenced  
by nursery practices?

Why We Care About Genetics Vol.10



Is Genetic Management Important  
in Urban Landscapes?

Why We Care About Genetics Vol. 12

# Resources

2006 Society for Conservation Biology  
Shortcourse on Restoration Genetics  
(Rogers, Rice, and McGuire)

List of articles, books, policies and links  
related to genetic restoration

<http://www.grcp.ucdavis.edu/projects>  
(conservation biology - restoration genetics  
shortcourse)