Guidelines for Propagule Source Selection: Ecology, Evolution and Pragmatics

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Why introduce?

Establish new plant communities with high native species component

Add extirpated or otherwise absent species to existing plant communities

Supplement existing populations to increase population size or increase genetic diversity

Where to Introduce?

Common situations:

1) No known occurrence on proposed introduction site or nearby

   Historically suitable but unoccupied, or changed to be suitable

2) Extirpated on site and not nearby

   Reasons for extirpation addressed

3) Not currently on introduction site but nearby

   Habitat suitable; must consider effects on nearby population(s)

4) Currently extant on introduction site

   Mitigate reductions in population size or genetic diversity

Potential benefits of introducing ex-situ plant population stock

Reduce inbreeding depression

Counteract genetic drift

Increase plant fitness and vigor via heterosis

Renew gene flow following reductions from historic levels

Increase adaptive genetic diversity in face of altered site conditions and rapid climate change

Cost-effectiveness

Sometimes the only option

Potential risks of introducing ex-situ plant population stock

Reduced success of introduced plants due to low fitness in new site*

Increased genetic load

Interspecific and intraspecific hybridization

Genetic swamping

Outbreeding depression (F1-F3)** via dilution or hybrid breakdown

Hufford & Mazer (2003):

* 11/15 reciprocal transplant studies of 13 species showed local adaptation

** 11 studies: 2 F1 outbreeding depression, 2 distance effects, 6 F1 heterosis,
1 mixed for F1 hybrids

F2/F3 hybrid breakdown in 3/4 cases

Cautionary issues to consider

- Pollen and seed dispersal are typically leptokurtic, dropping off steeply with distance:
  - Mitigating inbreeding depression, genetic drift and historic gene flow reductions are likely to take very little plant or pollen introduction and it can be counterproductive to add too much (swamping, genetic load of maladapted genotypes)
- Selection and local adaptation may be driven by extreme events:
  - Introduced genotypes could do well for 20-50 years until an extreme drought, winter, flood, etc.
  - During that time there could be substantial reduction in the frequency of alleles or genotypes adapted to such infrequent, extreme events, potentially resulting in a major population decline

Balance negative genetic load with capacity for adaptation (Rice & Emery 2003):

- Too much genetic diversity that is maladaptive can lead to a high genetic load and compromise population success.

- Low levels of genetic diversity particularly when adapted to some non-local or non-future selective optima will provide little ability to adapt.

Linking goals and approaches

Tu & Randall (2002). *Draft* TNC Guidelines for Selecting Native Plant Seeds and Stock for Restoration, Emergency Rehabilitation, Roadside and Horticultural Plantings: Issues of Translocating Foreign Genes into Native Systems.

Gordon(1994). Translocation of Species into Conservation Area: Key for Nat Resource Managers

Rogers & Montalvo (2004). Genetically appropriate choices for plant materials to maintain biological diversity.

McKay et al. (2005). "How local is local?" -- A review of the practical and conceptual issues in the genetics of restoration.

TNC: Soll & Alverson (2005). Conceptual Model for Plant Materials Selection In the Willamette Valley

Johnson & Roy (in prep). Decision-making protocols for propagation and introduction of native planting stock

General Guidelines for the Selection of Plant Stock (Tu & Randall 2002)

1. Collect native plant stock from on-site or from nearby sites with similar climatic, edaphic (soil) and biotic conditions.
2. If not possible to collect the plant material from immediate vicinity, then make every effort to collect the necessary material from nearest possible source, within same local climate and soils.
3. Use non-local native, or non-native plant materials ONLY when no other feasible alternative. Avoid non-local ecotypes, which may not be adapted to site conditions.
4. Locally-adapted plant stock should be gathered from many individual plants (or clones) within close-by population to obtain full complement of genetic variability.
5. Advocate the use of site-identified seed and stock

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Addresses whether or not to introduce plants

Addresses selection of plant introduction stock

Key steps in dichotomous key for species translocation decision-making (Gordon 1994)

I. Species status
II. Dispersal potential
III. Interspecific genetic risks
IV. Cause of threat or decline
V. Propagule source
VI. Competitive interactions
VII. Consumptive interactions
VIII. Contamination risks
IX. Site management

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Addresses whether or not to introduce plants (blue)

Addresses selection of plant introduction stock (yellow)

Steps for informing choices (Rogers and Montalvo 2004)

Identify project objective

↓

Determine project context

↓

Is natural regeneration sufficient to render introductions unnecessary?

↓

Is the species a state or federally listed species?

↓

Are there seed transfer rules?

↓

Is the species clonal?

↓

Is there evidence of genetic differentiation or local adaptation?

↓

Is the species polyploid?

↓

What is the main breeding system? Mating system?
Is there evidence of inbreeding or outbreeding depression?

↓

Site considerations

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Site considerations

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Addresses selection of plant introduction stock

Restoration genetics recommendations (McKay et al. 2005)

1) Collect locally if at all possible

2) Match climatic and environmental conditions between collection and restoration sites

3) Determine breeding systems of restoration species

4) Determine ploidy systems of restoration species

5) Minimize “unconscious” selection during seed increases

Restoration genetics recommendations (McKay et al. 2005)

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TNC: Alverson & Soll (unpublished)

6 x 3 contingency table:

- On-site, off-site, regional, out-of-region
- Single site v. multiple site
- Species present v. not on-site or nearby
- Outcomes: most suitable, adequate, less suitable, inappropriate

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Decision-making protocols for propagation and introduction of native planting stock

Bart Johnson and Bitty Roy

Acknowledgements:
Plant Introduction Subcommittee of the Friends of Buford Park - Mt. Pisgah Stewardship and Technical Advisory Committee (STAC), including Jason Blazar, Aryana Ferguson, Bruce Newhouse and Trevor Taylor, as well as the comments and insights of all parties who participated in discussions

Factors to be considered in selection of propagule source

- Life history traits
- Population characteristics
- Habitat conditions
- Landscape ecological relation of donor and recipient sites
- Collection and propagation protocols
- Genetic status of donor and recipient populations
- Population or species knowledge
- Goals and implications of restoration project
- Project parameters

Genetic Effects Rapid Assessment Matrix

To identify potential undesirable outcomes from introduction of off-site plant stock

Matrix logic: *all else being equal, effects of increasing distance* of propagule source from introduction site are such that:*

a) Distance is less likely to be a problem for success on site for outcrossers than for selfers

b) Distance is less likely to lead to undesirable genetic effects on site or nearby for selfers than for outcrossers

c) The consequences of undesirable genetic effects on site or nearby are greater for sensitive species and those which are more likely to hybridize

d) Species with small populations relative to the introduction are more vulnerable to genetic swamping and genetic load.

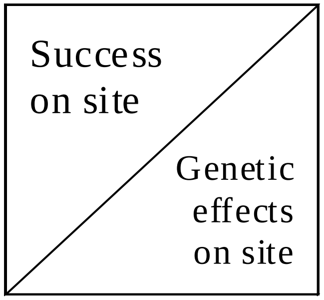
e) When the species is not extant on site or nearby, the issue of undesired genetic effects is minimal for the initial introduction

**** To extent possible distinguish between physical distance, environmental distance and effective dispersal distance***

Genetic Effects Rapid Assessment Matrix

Species Status and On-site/Nearby Extant Population Size	**Predom. Breeding System**	
	Selfing	**Outcrossing**
Sensitive species or hybridization issues Small population	DP / DP	DLP / DP++
Sensitive species or hybridization issues Large population	DP / DLP--	DLP / DP
Non-sensitive species, no hybridization issues Small population	DP / DLP	DLP / DP
Non-sensitive species, no hybridization issues Large population	DP / DLP--	DLP / DLP
Reintroduction species not extant on site or nearby	DP / NP	DLP / NP

Matrix tracks two issues: success on site and potential for undesirable genetic effects



Codes:
DP = Distance problematic
DLP = Distance less problematic
NP = Distance not problematic
-- or ++ → lesser or greater likelihood for problems

Genetic Effects Rapid Assessment Matrix

Elymus glaucus

Species Status and On-site/Nearby Extant Population Size	Predom. Breeding System	
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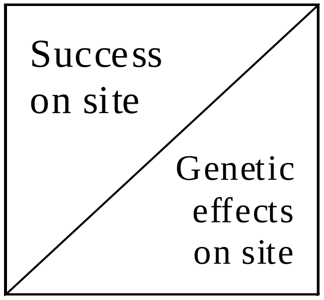

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Danthonia californica

<-- Ploidy issues?

Success on site / Genetic effects on site

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Genetic Effects Rapid Assessment Matrix

Roemer's Fescue

Species Status and On-site/Nearby Extant Population Size	Predom. Breeding System: Selfing	Predom. Breeding System: Outcrossing
Sensitive species or hybridization issues Small population	DP / DP	DLP / DP++
Sensitive species or hybridization issues Large population	DP / DLP--	DLP / DP
Non-sensitive species, no hybridization issues Small population	DP / DLP	DLP / DP
Non-sensitive species, no hybridization issues Large population	DP / DLP--	DLP / DLP
Reintroduction species not extant on site or nearby	DP / NP	DLP / NP

Success on site

Genetic effects on site

Codes:
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Common Garden of *Festuca roemeri*

Unpublished data of

Scott A. Pattison and Bitty A. Roy

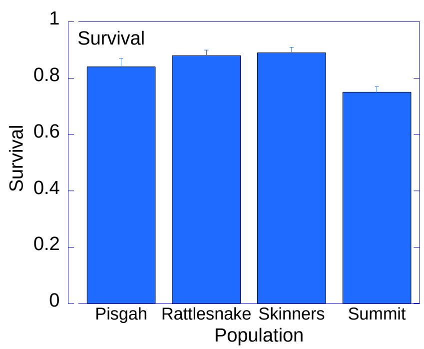
Garden set up at TNC's Willow Creek

(thanks to Gil Voss and Ed Alverson)

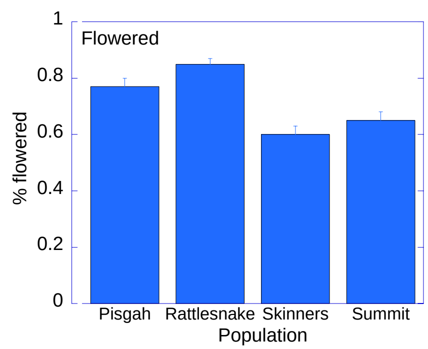
Common Garden At Willow Creek

Common Garden At Willow Creek

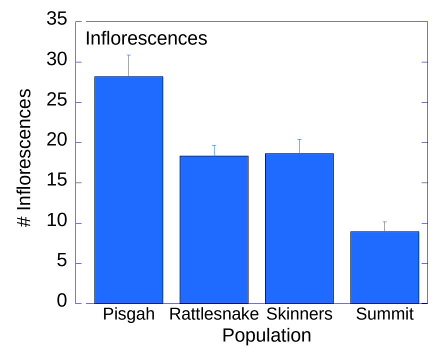
Survival



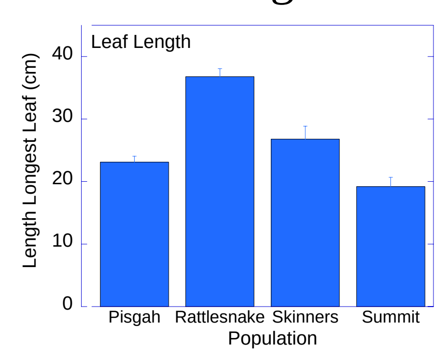
Flowered



Inflorescences



Leaf Length



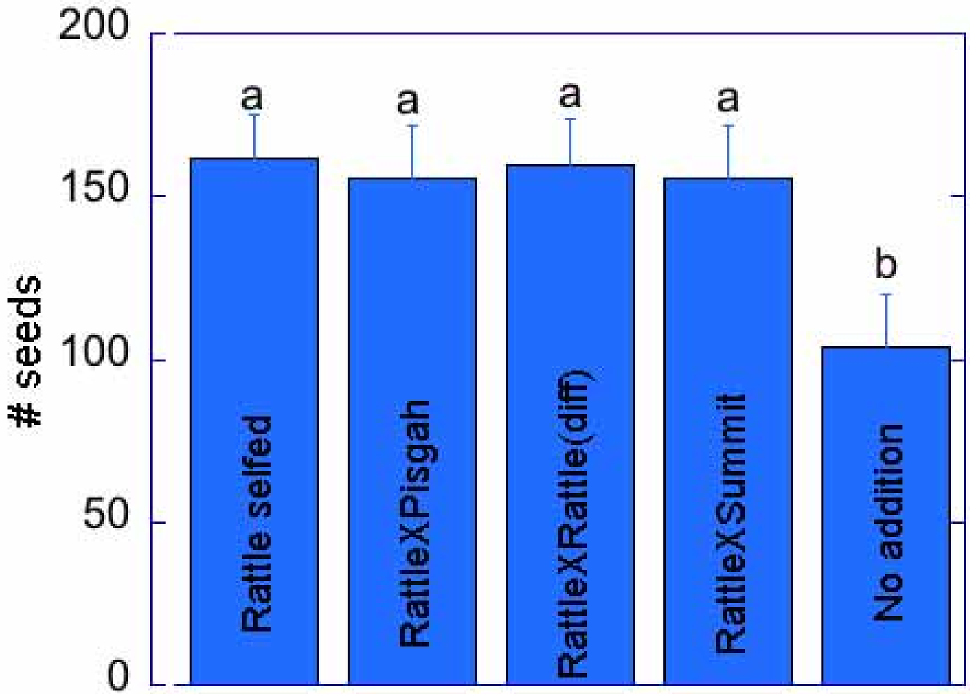
Pisgah

Rattlesnake

Skinner

Summit

A crossing study showed that *F. roemeri* is highly self-fertile and…



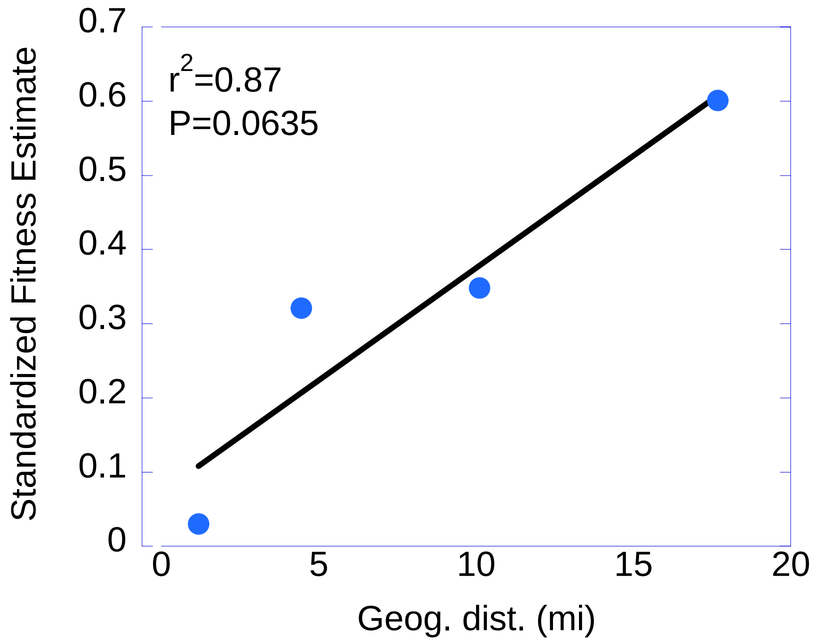
S. Pattison and B. A. Roy unpubl. data

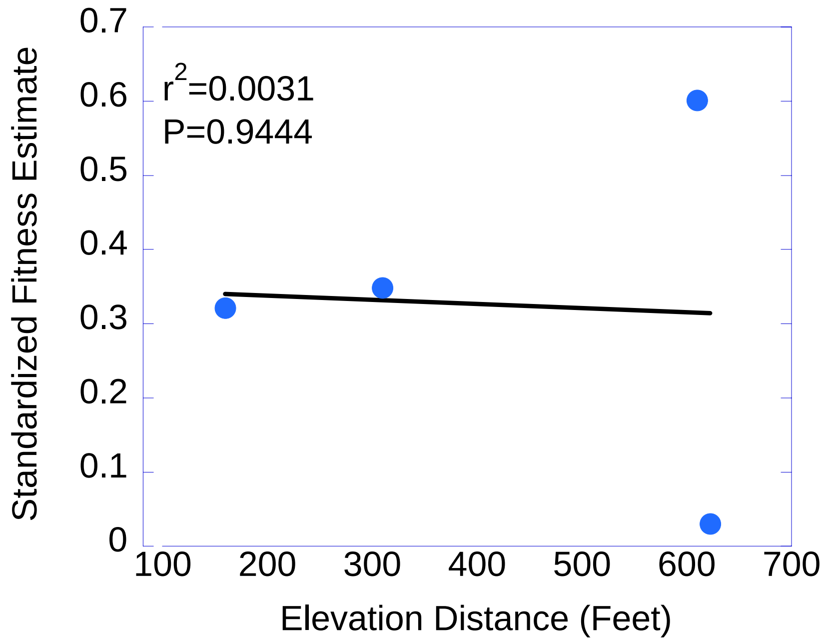
…In the common garden, fitness depended on population source

Source Site	GeogDist (miles)	Elevation (ft)	ElevDist (ft)	SFE
Rattlesnake Butte	17.69	1050	610	0.6011
Mt Pisgah	10.11	750	310	0.3484
Skinners Butte	4.45	600	160	0.3213
Summit Terrace	1.19	1062.5	622.5	0.0299

Standardized Fitness Estimate (SFE) was calculated as
(Survival Rate) x (% Flowering) x (Avg. Number of Inflorescences per Plant) x (Avg. Inflorescence Height) x (Avg. Leaf Height) x (Avg. Clump Diameter) x (% Plants w/o Leaf Damage)

Contrary to expectations, populations from the furthest away had higher fitness, and elevation did not matter





This result likely means that physical distance does not adequately describe the differences among sites or the differences are non-adaptive

Lessons from common garden experiment

- Populations differed by both adaptive and neutral genetic traits in a common garden
- Populations differed in survival and reproduction in a common garden
- The populations that did best at the site were not the ones that came from the nearest by
- Population genetic work indicated that all the populations all had fewer heterozygotes than expected; this may be due to mating with close relatives in small populations or due to selfing
- Selfed plants produced as many seeds as outcrossed ones

The price of success? The potential outcomes of large-scale seed production and distribution

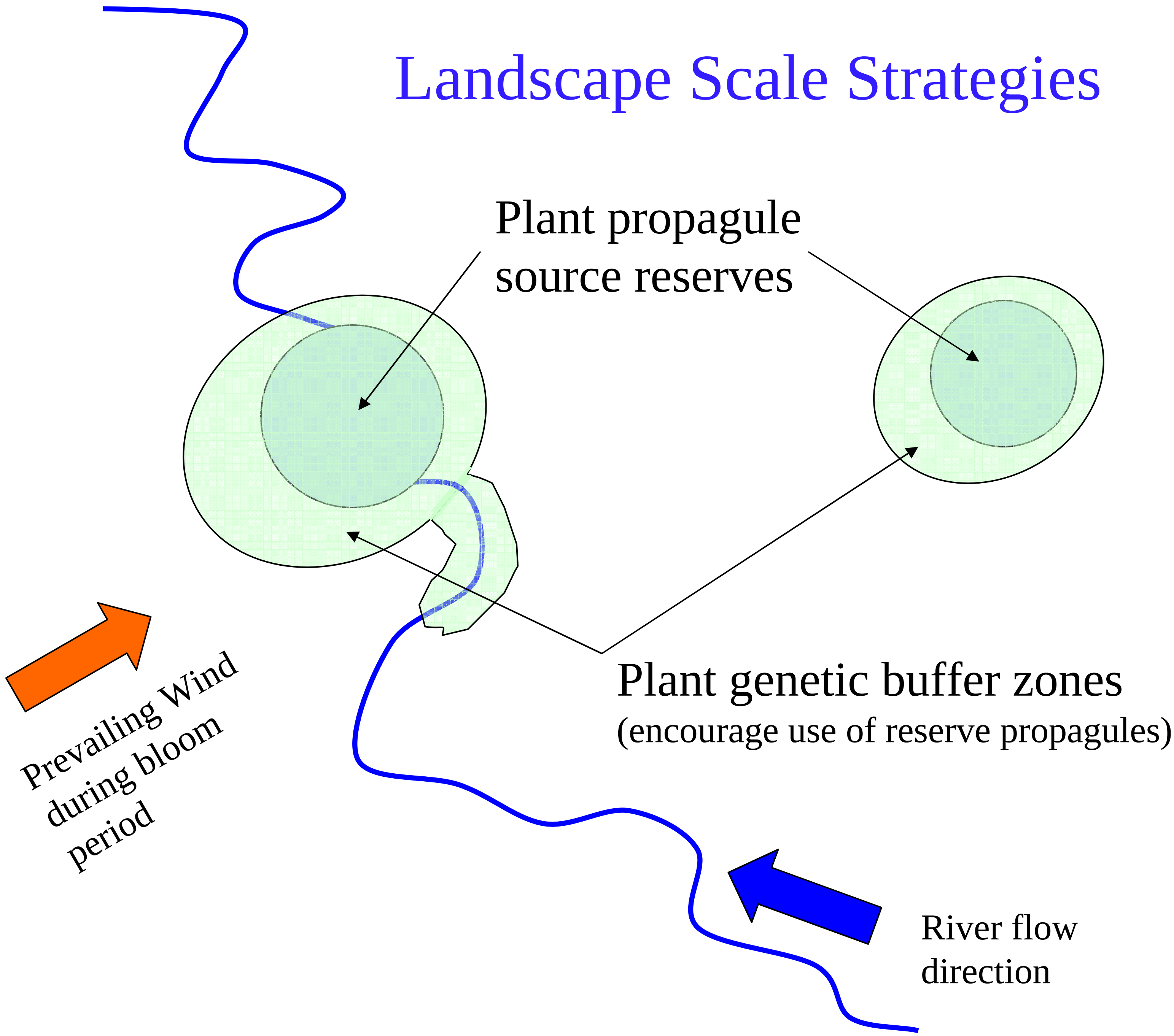
- Even the best-laid plans for replenishing farm stock with new wild-collected seed may be difficult to maintain
- High potential for selection due to cultivation, site conditions (relatively high-nutrient, mesic or irrigated farmfield) and seed collection in agricultural setting that is maladaptive in restoration sites, regardless of best management practices
- Have we thought enough about what happens if bulking out seed from multiple sites combined with broad-scale use become widespread and accepted as the standard best management practices?
- Will such practices be used in places and ways we did not intend and that may be inappropriate?

Thinking like a landscape

If we perform broad-scale landscape restoration using wide seed zones and bulked out seed, we should simultaneously work to protect important plant genetic source reserves

- Identify key sites for protection and genetic conservation
- Use only in-situ plant stock for restoration on those sites unless there is clear evidence of need (e.g., inbreeding depression)
- Establish several basic types of buffer zones for broad classes of species based on breeding systems and pollen/propagule dispersal mechanisms
- Within buffer zones, use only local or plant reserve stock on public lands and work with private landowners to provide plant stock and technical assistance for restoration

Landscape Scale Strategies



Challenges for ecological (and evolutionary-based) restoration

- The extent of recent landscape and site alterations, local species extirpations, expectations for rapid climate change, and economic constraints in the face of a desire to restore native plant species may suggest we should forge ahead with broad-scale mixing of genetic materials and let natural selection "sort it out"
- Data and knowledge are still rudimentary. There are substantial potential benefits and substantial risks from broad-scale mixing of genotypes
- Some of the choices we make now in the face of limited knowledge are irreversible in the foreseeable future. If we are not careful we may undo long-developed genetic structure and diversity at levels of species, subspecies, races, and populations.
- We need an ecological-evolutionary-economic perspective that looks backward and forward in time to enable sound decision-making