Plant of the Day

- ***Eichhornnia crassipes*** (water hyacinth)
- Native to the Amazon basin, South America
- Invasive in North America, Europe, Asia, Australia, Africa, and New Zealand
- Fast-growing - can reproduce both sexually and clonally
- Tristylous
- Quickly covers water bodies → blocks waterways, blocks sunlight, reduces oxygen, accumulates pollutants, breeding place for harmful pathogens, increases evapotranspiration
- Uses: clothing/furniture, biofuel, bioremediation
- Controls: chemical, physical, biological: manatees

Outline/Big Questions

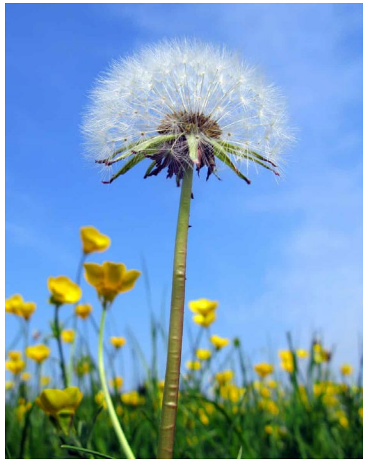
- What are weeds?
- Why can weeds be considered a natural experiment?
- What role does evolution play in invasion?
- Why do invasive species outcompete native species?

What is a weed?

“Any plant that crowds out cultivated plants”

“A plant that grows where it is not wanted”

“A plant out of place”



“ A plant is a weed if...its populations grow entirely or predominantly in situations markedly disturbed by man”- Baker 1965

weed = colonizer/ruderal

Ideal Weed Characteristics (Baker Traits)

What traits would help an introduced species become successful? Why?

Ideal Weed Characteristics (Baker Traits)

- Germination requirements fulfilled in many environments
- Discontinuous germination and great longevity of seed
- Rapid growth through vegetative phase to flower
- Continuous seed production for as long as growing conditions permit
- Very high seed output
- Utilized unspecialized pollinators or wind
- Adaptations for short- and long- dispersal
- Vigorous vegetative reproduction
- Ability to compete interspecifically (choking growth, allelochemicals etc.)

Baker 1974

Weedy, Introduced, or Invasive?

- **Weedy:**
  - Human disturbance
- **Introduced:**
  - Human-assisted dispersal – transferred outside range of natural dispersal
  - Alien, exotic, non-indigenous, non-native species
  - ~ ¼ of vascular plant species in Canada are introduced (1,229 species)
- **Invasive:**
  - Rapidly spread and dominant/weedy
  - 486 species are invasive in Canada
  - Globally, economic costs of invasive plant species are between $13.3 - $34.5 billion (includes only the top 16 non-native species)

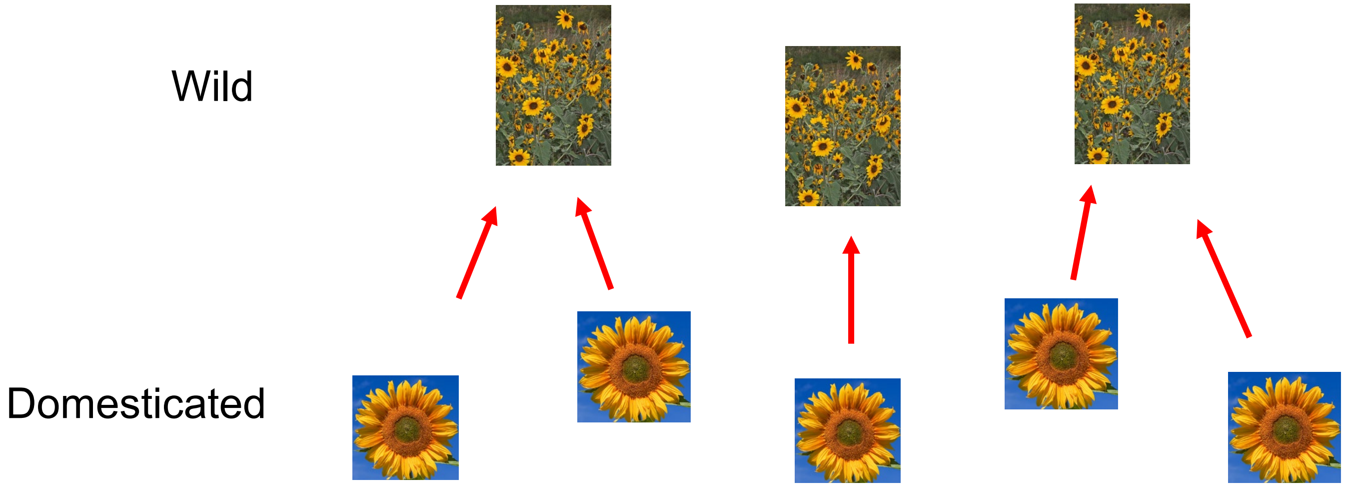
“Natural Experiments” in Plant Evolution

Agricultural Weeds

Derived from wild species/other crops

- Adaptation to crop environment
- Opportunities for repeated evolution of weedy forms
- Gene flow/hybridization with progenitors

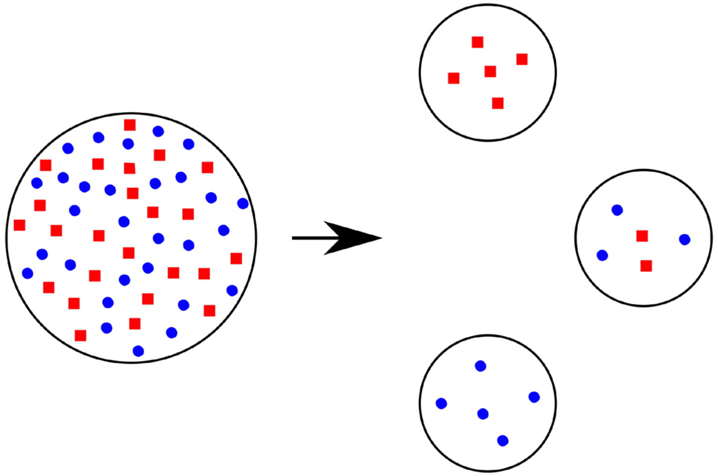
Amaranthus tuberculatus



“Natural Experiments” in Plant Evolution

Colonization

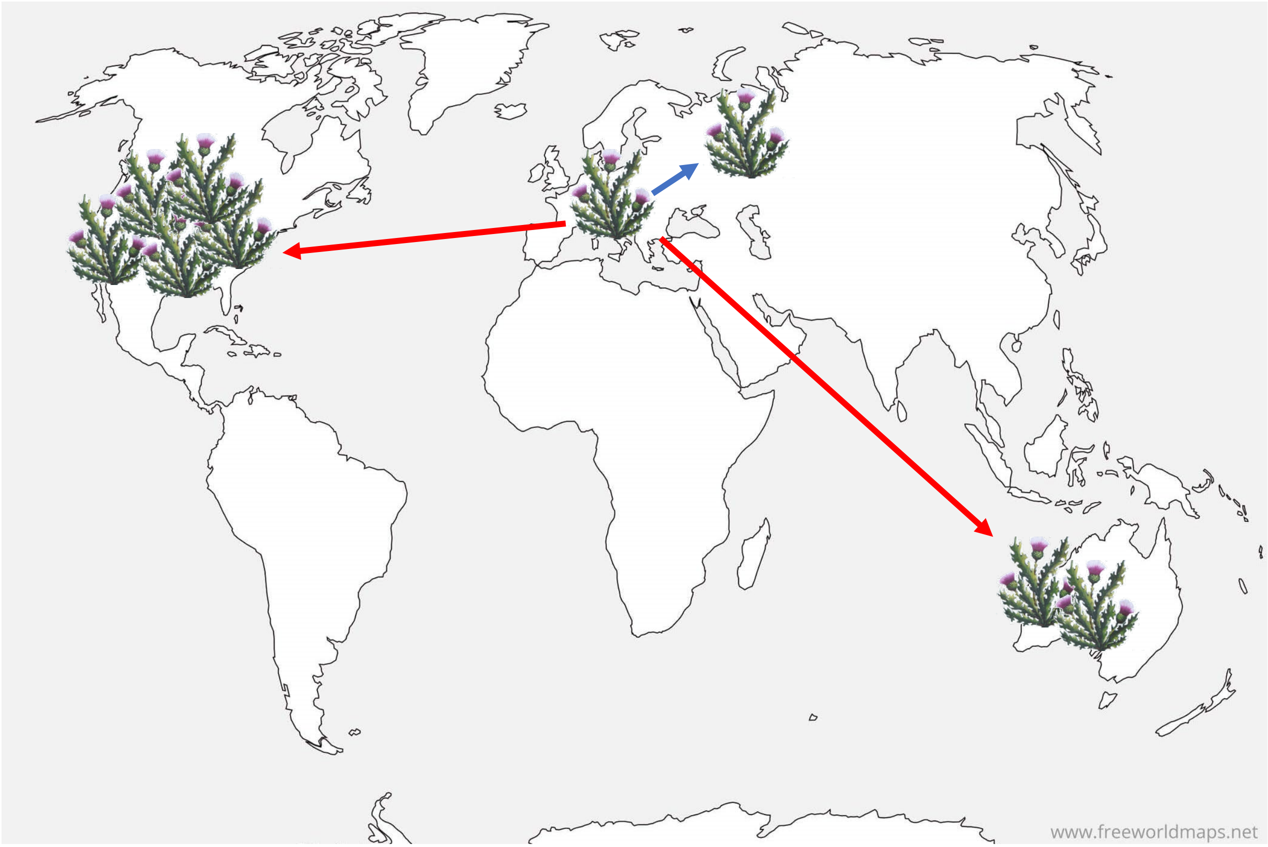
- Founder effects?



“Natural Experiments” in Plant Evolution

Colonization

- Founder effects?
- Opportunity for adaptation to novel environments
  - Pre-introduction adaptation
  - Post-introduction adaptation
- Range expansion/limits



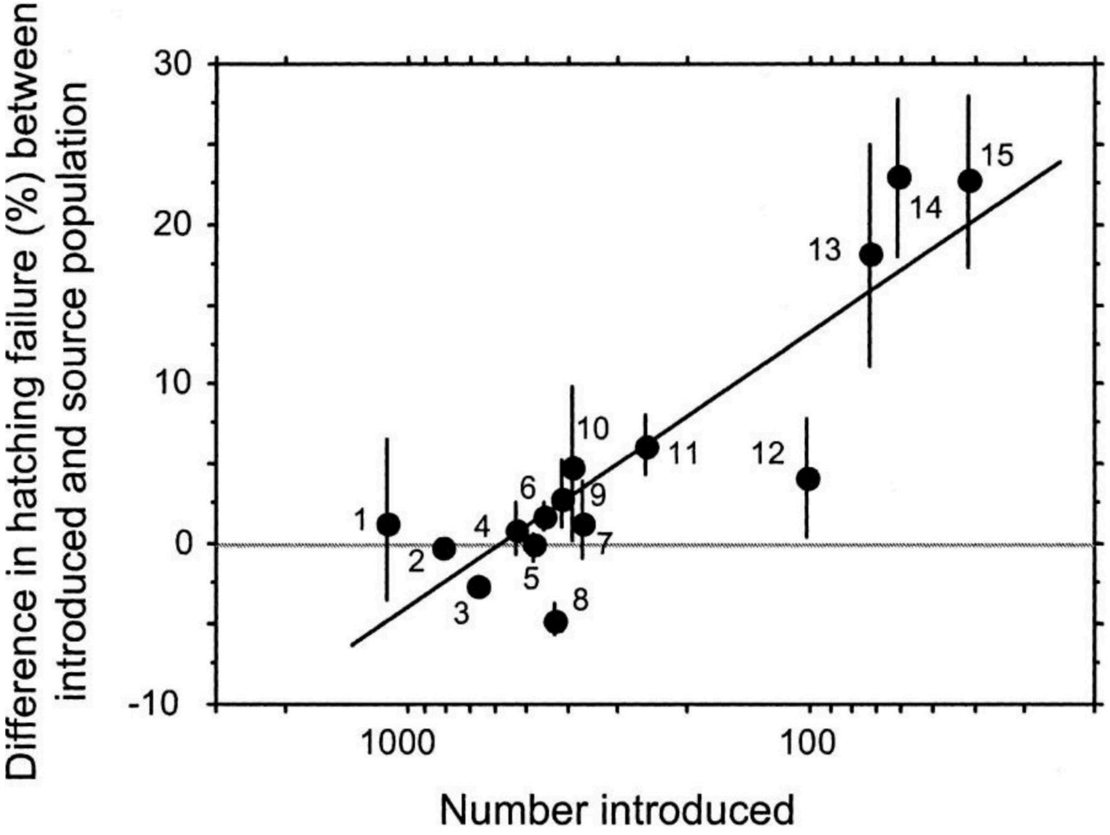
Founding Events: What processes occur?

- Genetic bottlenecks (probably common)

- Non-random mating/asexual reproduction (common)
  - Self-fertilization
  - Apomixis (asexual seed)
  - Vegetative reproduction

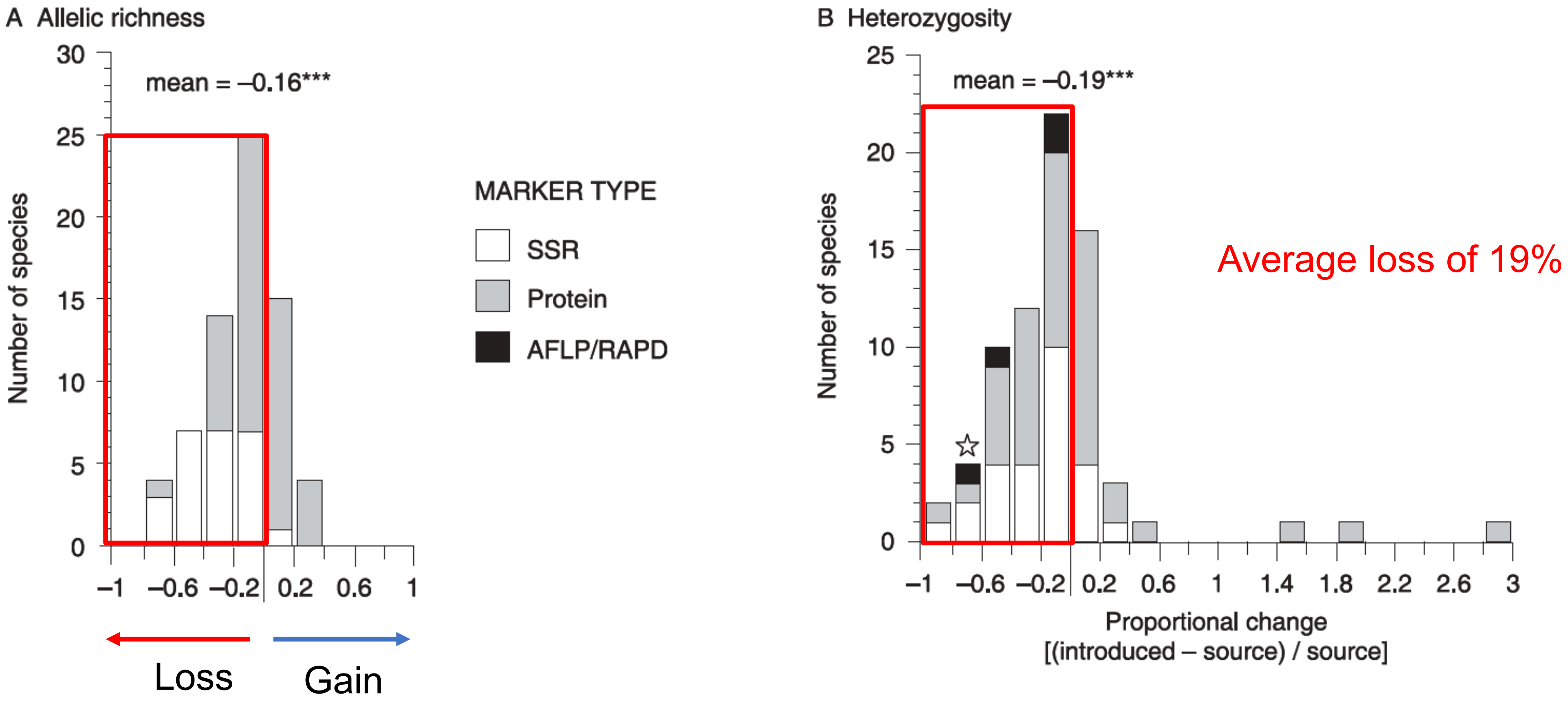
- Genetic drift (common)

Founding Events: Cost of Genetic Bottlenecks



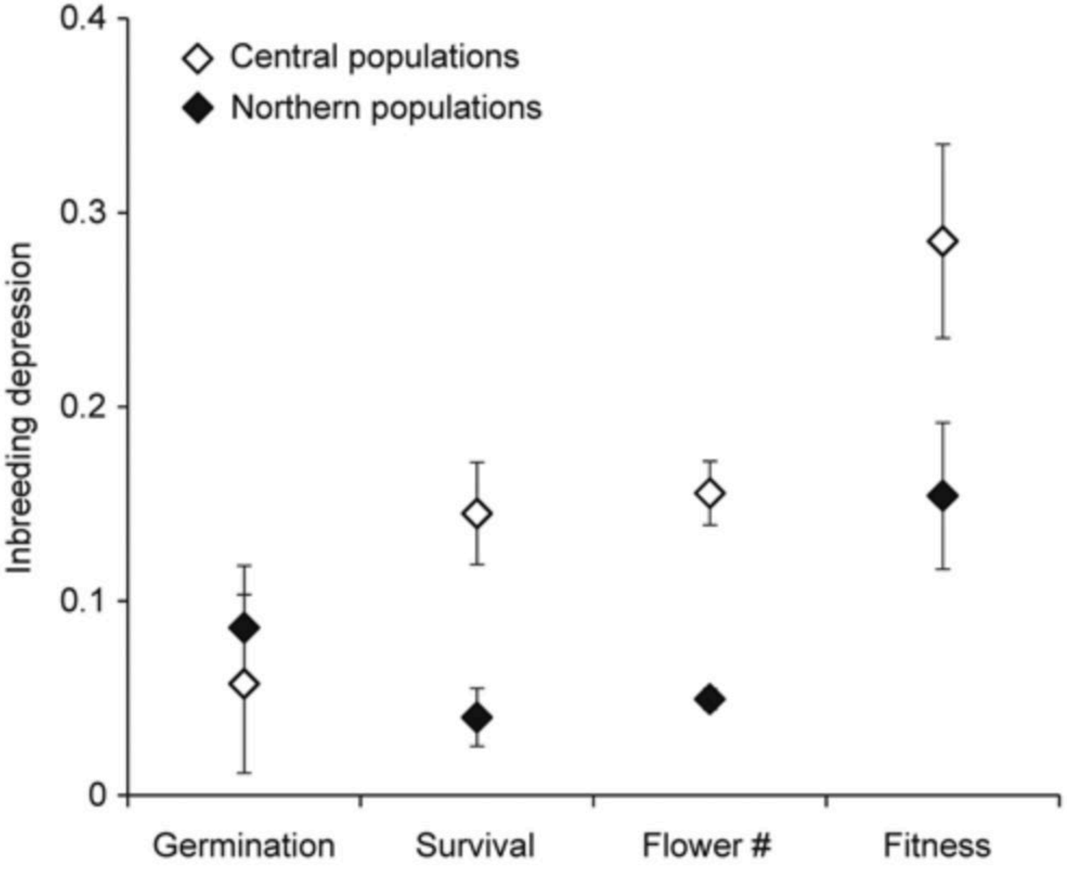
Briskie and Mackintosh 2004

Founding Events: Genetic Variation Loss



Dlugosch and Parker 2008

Founding Events: Reduced Inbreeding Depression



Campanulastrum americanum

Barringer et al. 2012

Founding Events: Genetic Variation Loss

Genetic Paradox: introduced species thrive in new environments when they should be suffering from deleterious losses of genetic diversity

How do colonizing species maintain genetic diversity and persist then?

Founding Events: Genetic Variation Loss

Genetic Paradox: introduced species thrive in new environments when they should be suffering from deleterious losses of genetic diversity

How do colonizing species maintain genetic diversity and persist then?

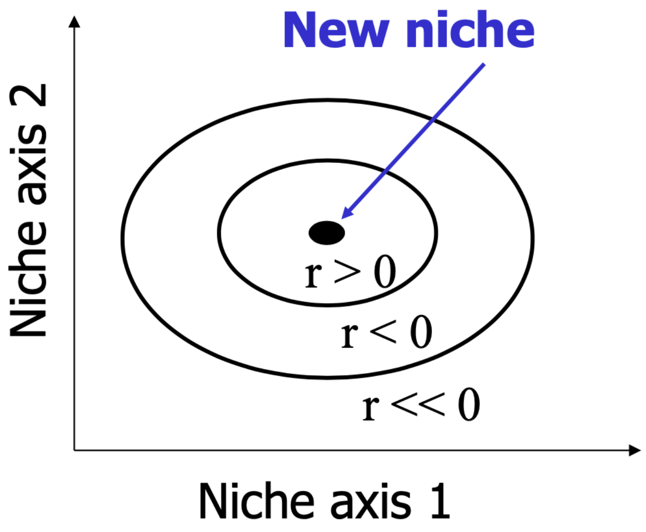
- **Multiple introductions from divergent source regions -> intraspecific admixture**
- **Interspecific hybridization -> transgressive segregation, adaptive introgression, heterosis**

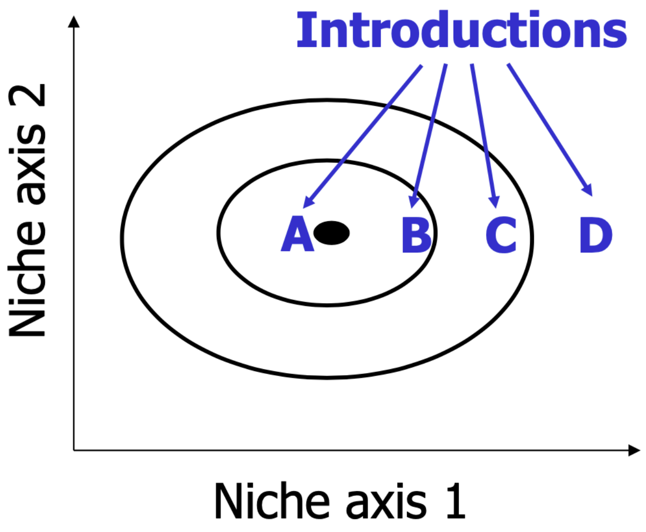
“Natural Experiments” in Plant Evolution

Adaptation

Depends on:

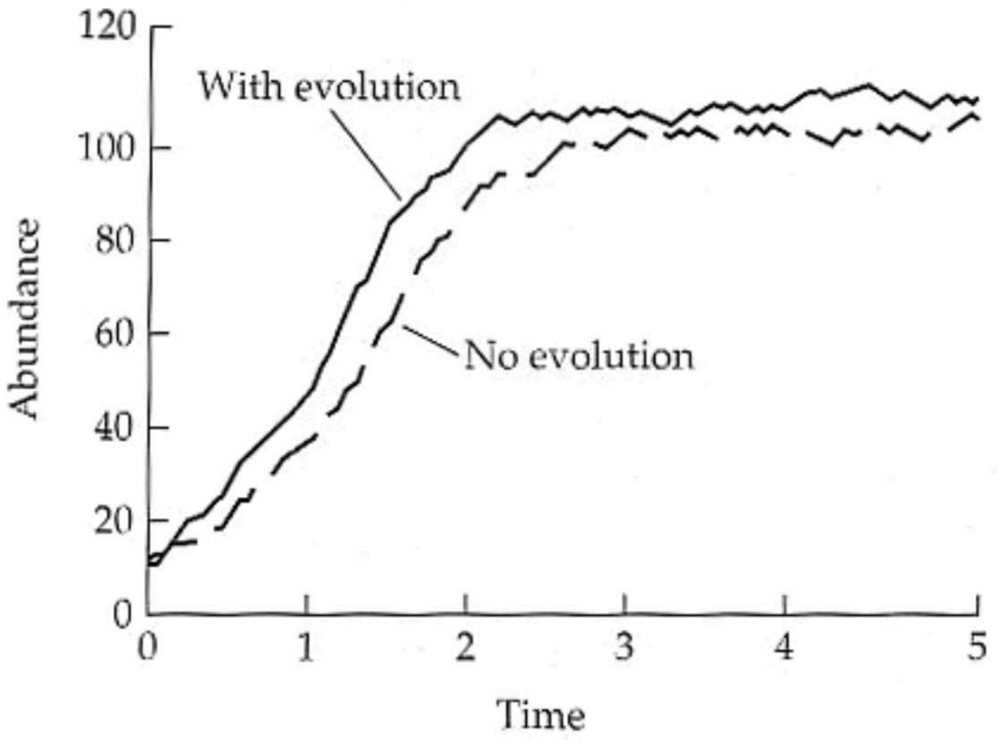
- Genetic variation
- Selection
- Extinction risk (population growth, r)

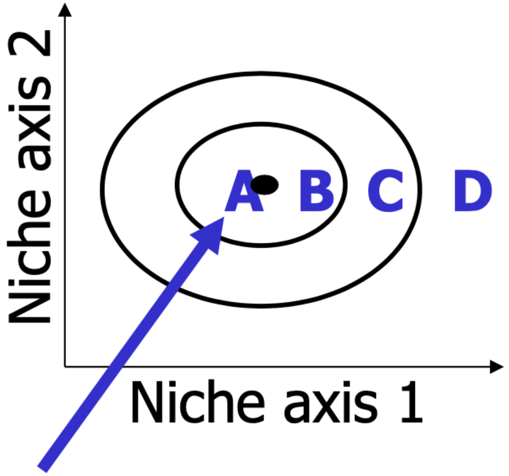




Adaptation in Introduced Populations

Simulation with demographic stochasticity



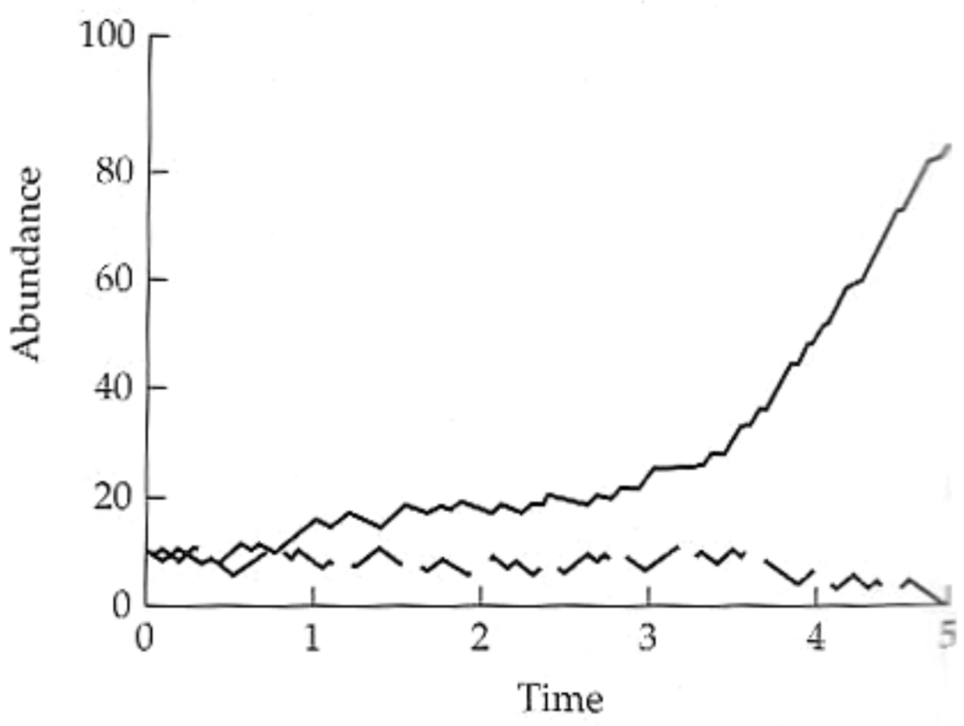


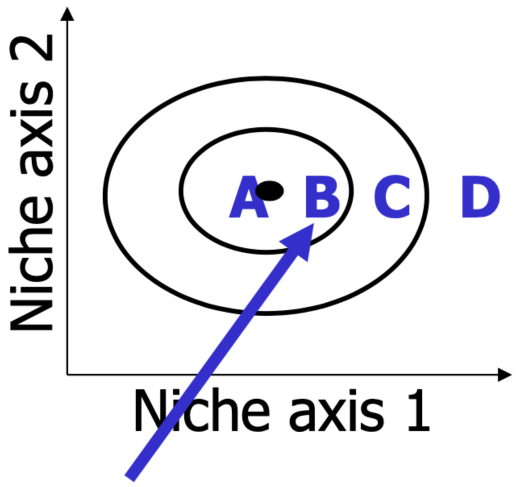
- Adaptation occurs
- But NOT required for invasion

Holt et al. 2005

Adaptation in Introduced Populations

Simulation with demographic stochasticity





- Adaptation beneficial
- Produces invasion lag

Holt et al. 2005

Adaptation in Introduced Populations

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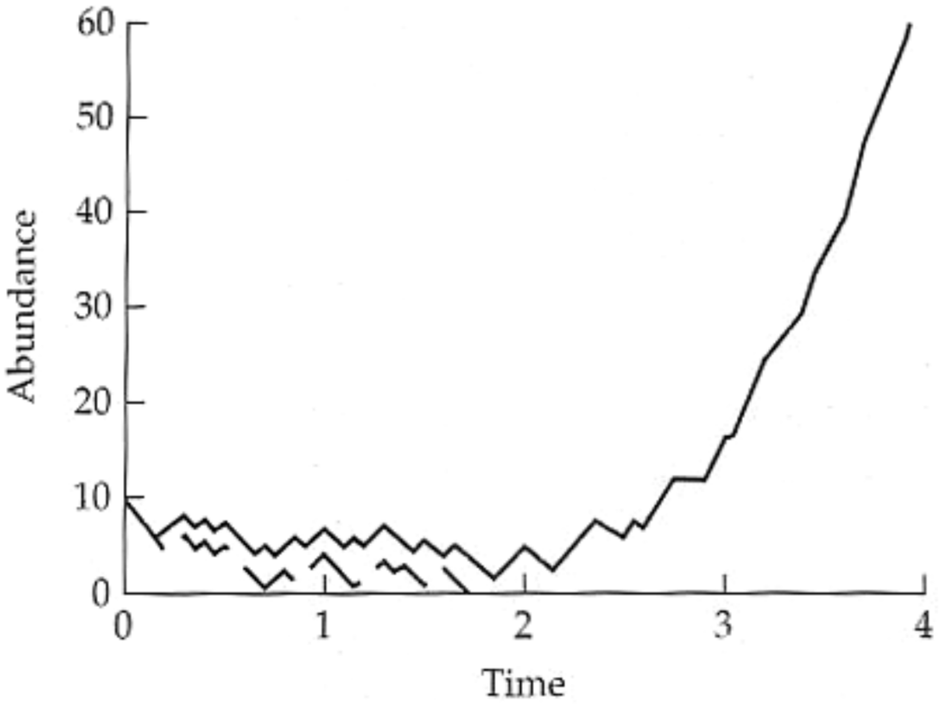

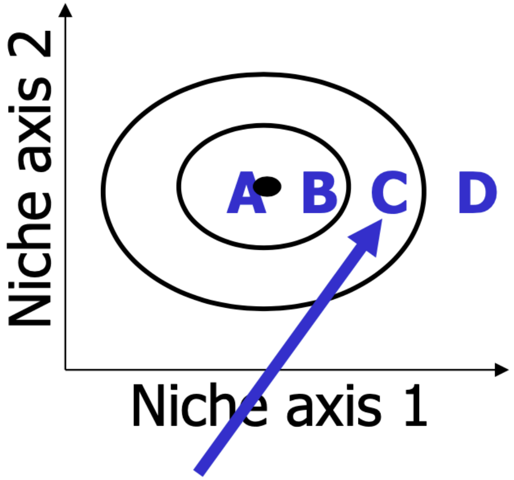

- Adaptation required
- Produces invasion lag

Holt et al. 2005

Adaptation in Introduced Populations

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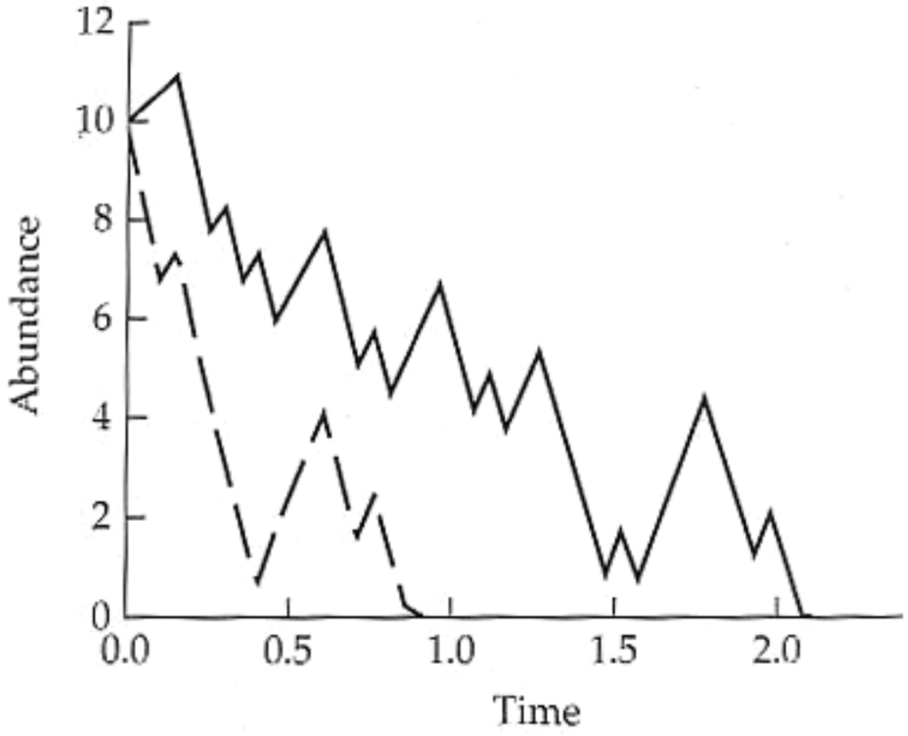
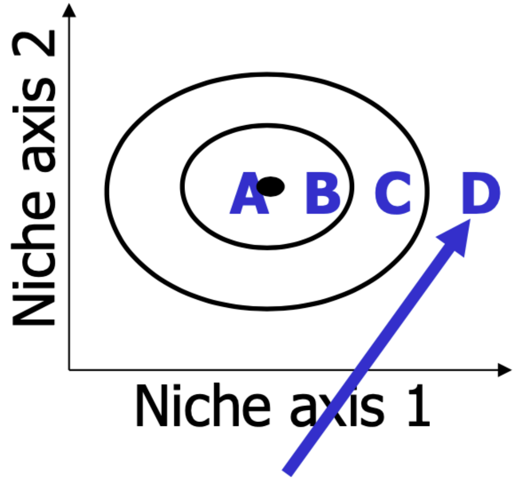




- Adaptation too slow to prevent extinction
- Hard to study failed introductions

Holt et al. 2005

Adaptation in Introduced Populations

Punchline

The relative difference in environments (niches) occupied by native and invading populations will dictate:

- Extinction risk
- Whether adaptation is needed for establishment
- Whether adaptation is needed for invasion

Evolution and Invasion

What type of evolutionary changes occur during invasion, and could these changes contribute to invasiveness?

Observation: many plant species grow larger, have greater reproduction, and spread more rapidly in the invaded range compared to the native range (Crawly 1987)

Why?

Evolution and Invasion

1. Plant trade off investment in self-defense for increased investment in growth and reproduction in the invasive range.

2. Plant trade off tolerance to abiotic stresses in native range for increased competitive and/or colonizing ability (EICA)

3. Invasive plants have greater vigor due to hybridization (e.g., heterosis, adaptive introgression, transgressive segregation)

Evolution and Invasion: Common Ragweed (*Ambrosia artemisiifolia*)

1. Do invasive populations have higher growth and reproduction in benign environments compared to native populations?

2. Is any advantage of the invasive populations lost in stressful conditions? i.e., is there evidence for a trade-off?

Goal: Compare growth rates, reproductive outputs, stress responses of native and invasive populations of ragweed in common gardens.

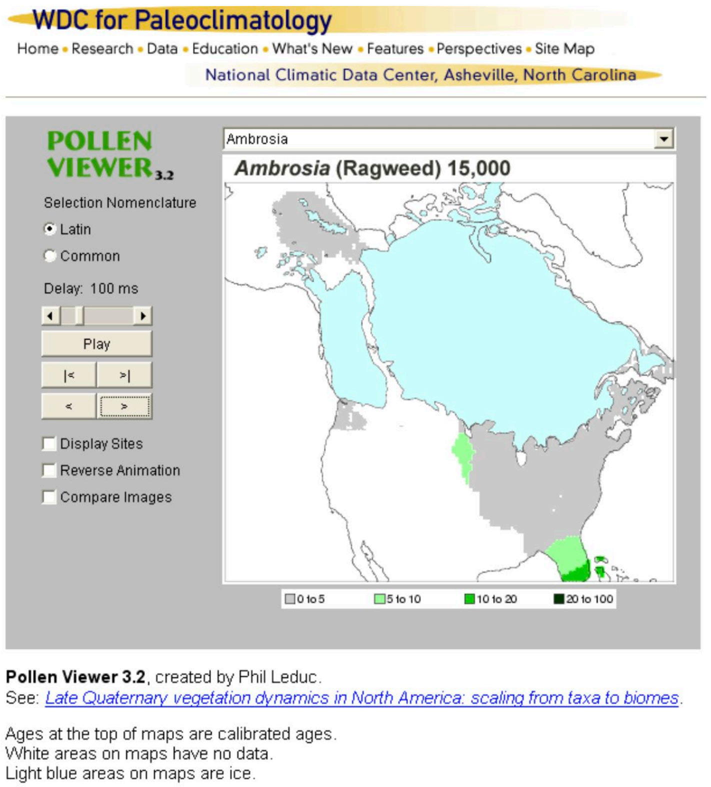
Hodgins and Rieseberg 2011

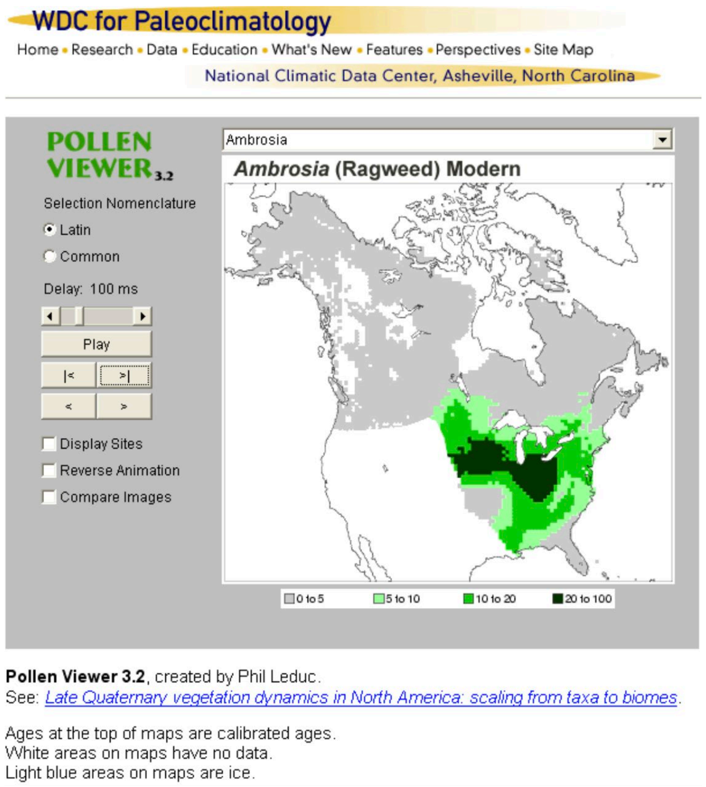
Common Ragweed (*Ambrosia artemisiifolia*)

- Monoecious annual
- Wind pollinated
- Self compatible
- Problematic weed native to North America
    - Sunflower, soybean, corn
- Invasive in parts of Australia, Asia, and Europe
- Severely allergenic (hay fever, dermatitis)

Distribution of Common Ragweed (*Ambrosia artemisiifolia*)

- Native to North America
- Common in the Great Plains for the past 15,000 years





Common Garden Experimental Design

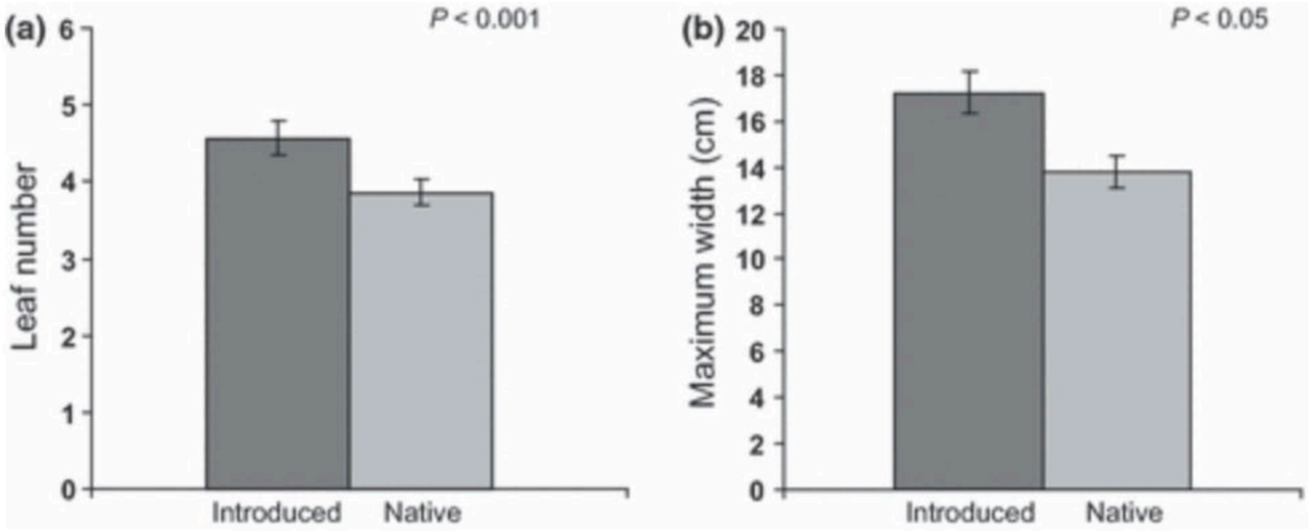
- 12 invasive (European) and 22 native populations (North American) grown in UBC greenhouse

- **Experiment 1**
  - 1278 plants
  - 7 families from each native population
  - 10 families from each invasive population
  - Control, light, nutrient, herbivory stress
- **Experiment 2**
  - 180 plants
  - Same families
  - Drought stress

Initial differences between the native and invasive populations

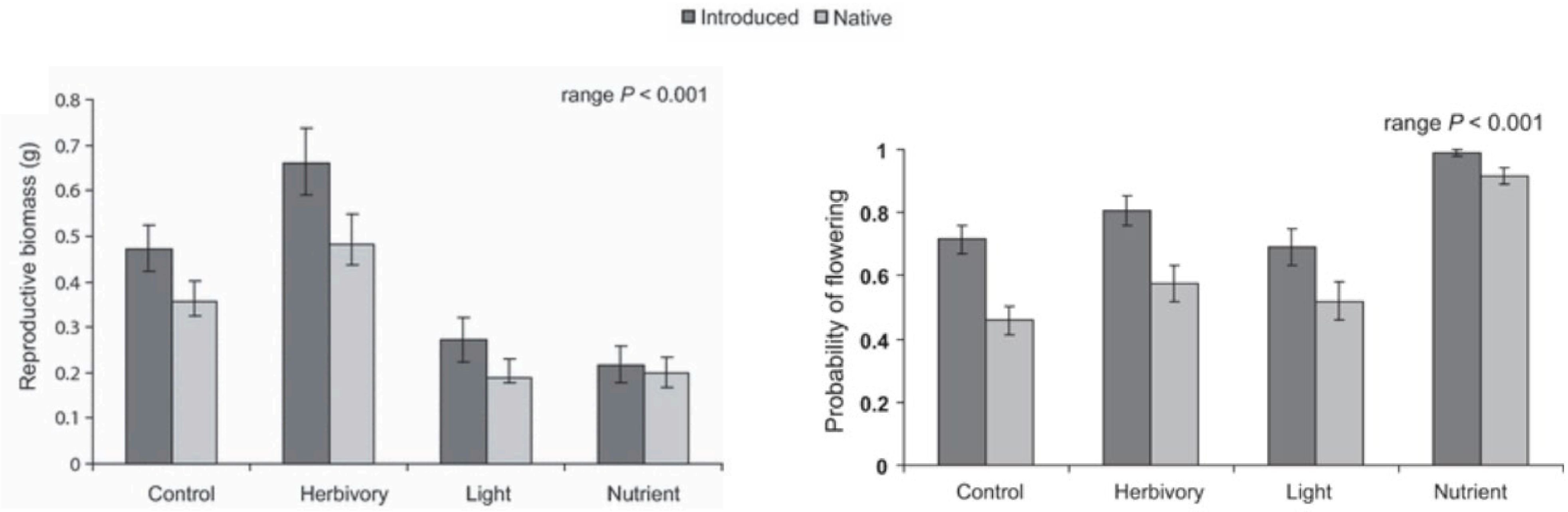
Two weeks after germination

One week after transplant



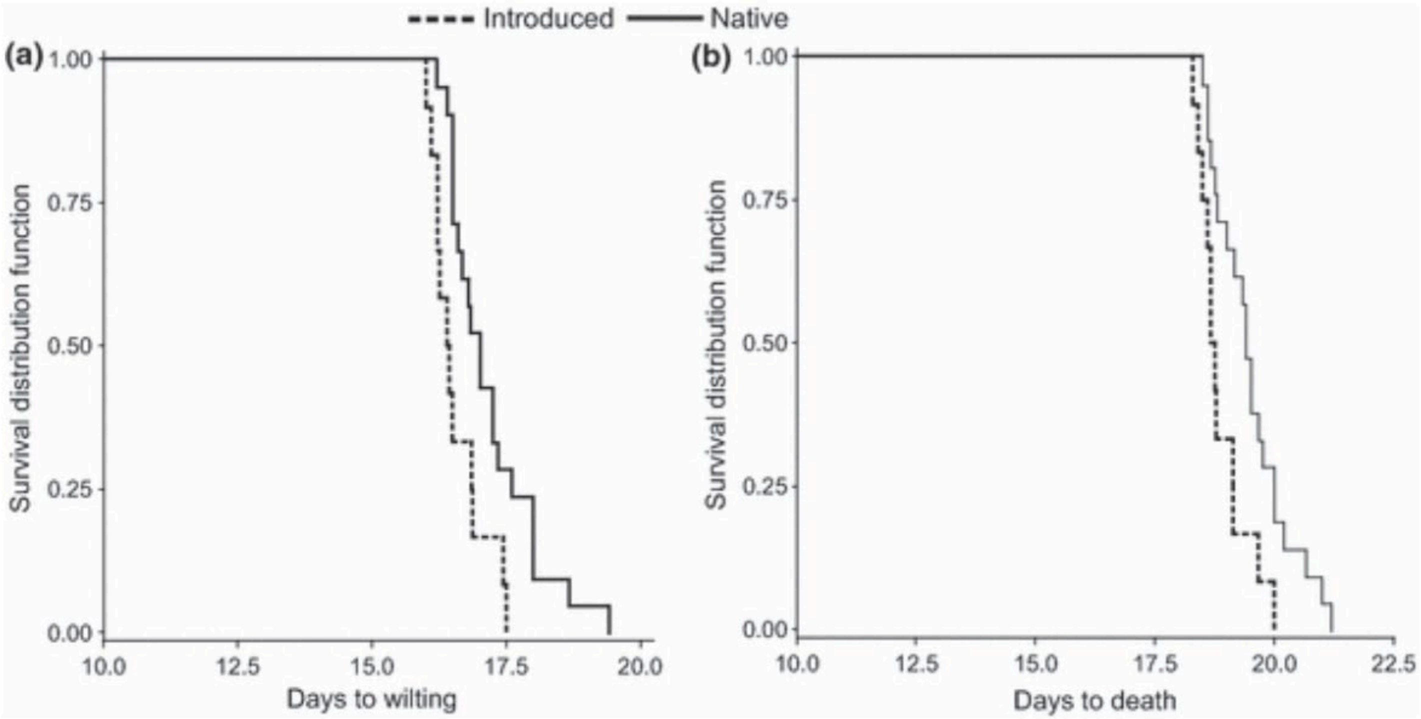
Invasive plants are larger than native plants

Reproductive Success



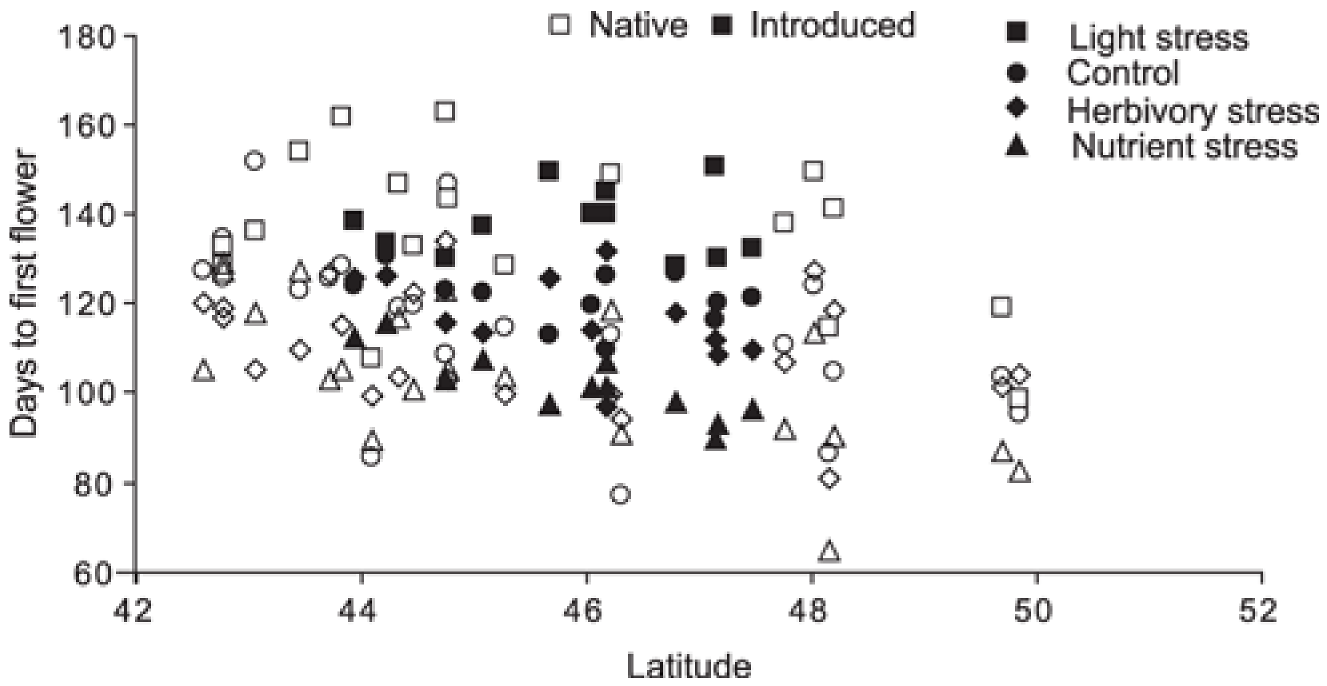
The invasive plants flowered more frequently and had greater reproductive biomass in all treatments

Drought Experiment



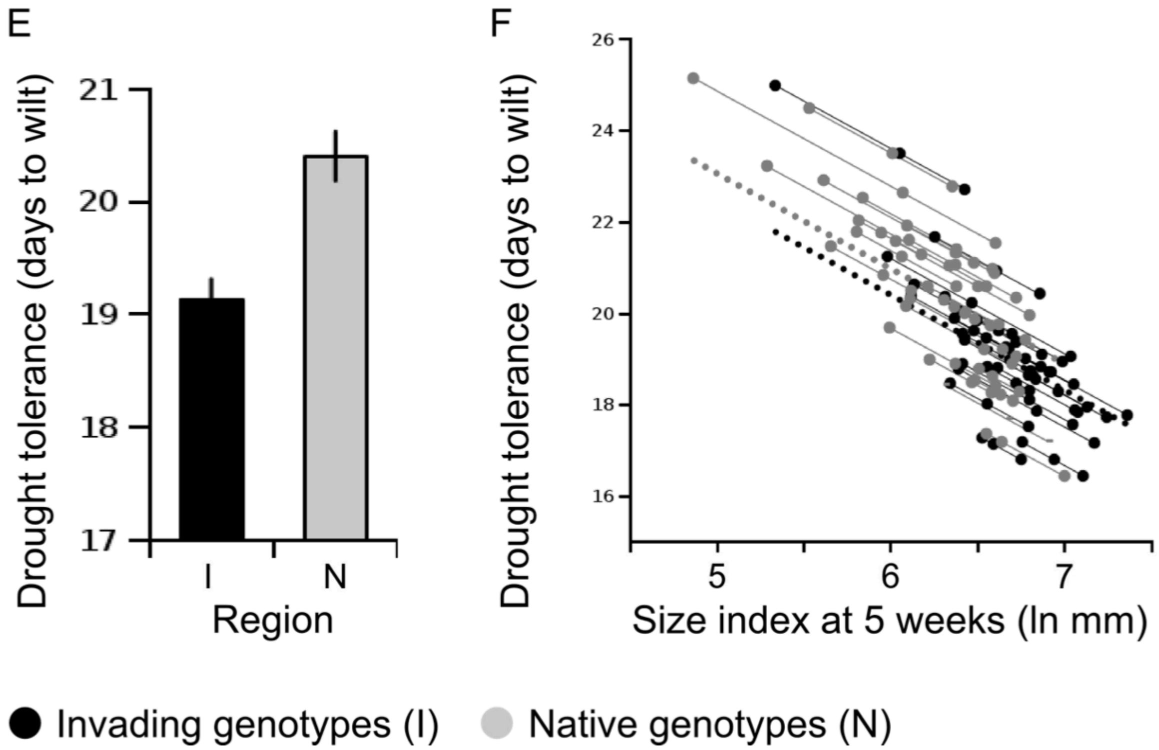
Invasive plants wilted and died more quickly than the native plants

Flowering Time and Latitude



Reproductive biomass and flowering time correlated with latitudinal cline – evidence for local adaptation

More Evolutionary Trade-Offs



Centaurea solstitialis

Evolutionary trade-off between drought tolerance and size also seen in yellow star thistle

Duglosch et al. 2015

Conclusions

1) Evolution can be very fast!

2) Biological invasions provide opportunities to study "evolution in action"

3) Genetic bottlenecks are probably common, BUT:
   - Does not last long (rapid population expansion)
   - Have weak effect on quantitative traits (many genes, many loci)

4) Rapid evolution is important for understanding ecology
   - Adaptive evolution (usually) increases survival and reproduction – the same parameters that determine population growth

5) Genetic constraints (e.g., trade-offs) limit the fitness benefits of adaptive evolution → Is this why species have range limits?