Plant of the Day

Eichhornia crassipes (water hyacinth)

Native to South America

Tristylous, clonal

Invasive in Asia, Africa, North America, Australia

Clogs waterways, blocks sunlight and reduces oxygen
(Kills fish, increases mosquitoes)

Uses: furniture, biofuel, bioremediation

Louisiana almost imported hippos to eat it.

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?

"Any plant that crowds out cultivated plants"
"A plant that grows where it is not wanted"
"A plant out of place"

What is a weed?

"A plant is a weed if…its populations grow entirely or predominantly in situations markedly disturbed by man."

- HG Baker, 1965

weed = colonizer / ruderal

“Natural experiments” in plant evolution

Colonization =
opportunity for adaptation to novel environments

“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

Colonizers Associated with Humans

- Weedy:

Human disturbance

- Introduced:

Human-assisted dispersal

-introduced, alien, exotic, non-indigenous, or non-native species

-about 1/4 of vascular plant species in Canada are introduced (1,229 species)

- Invasive:

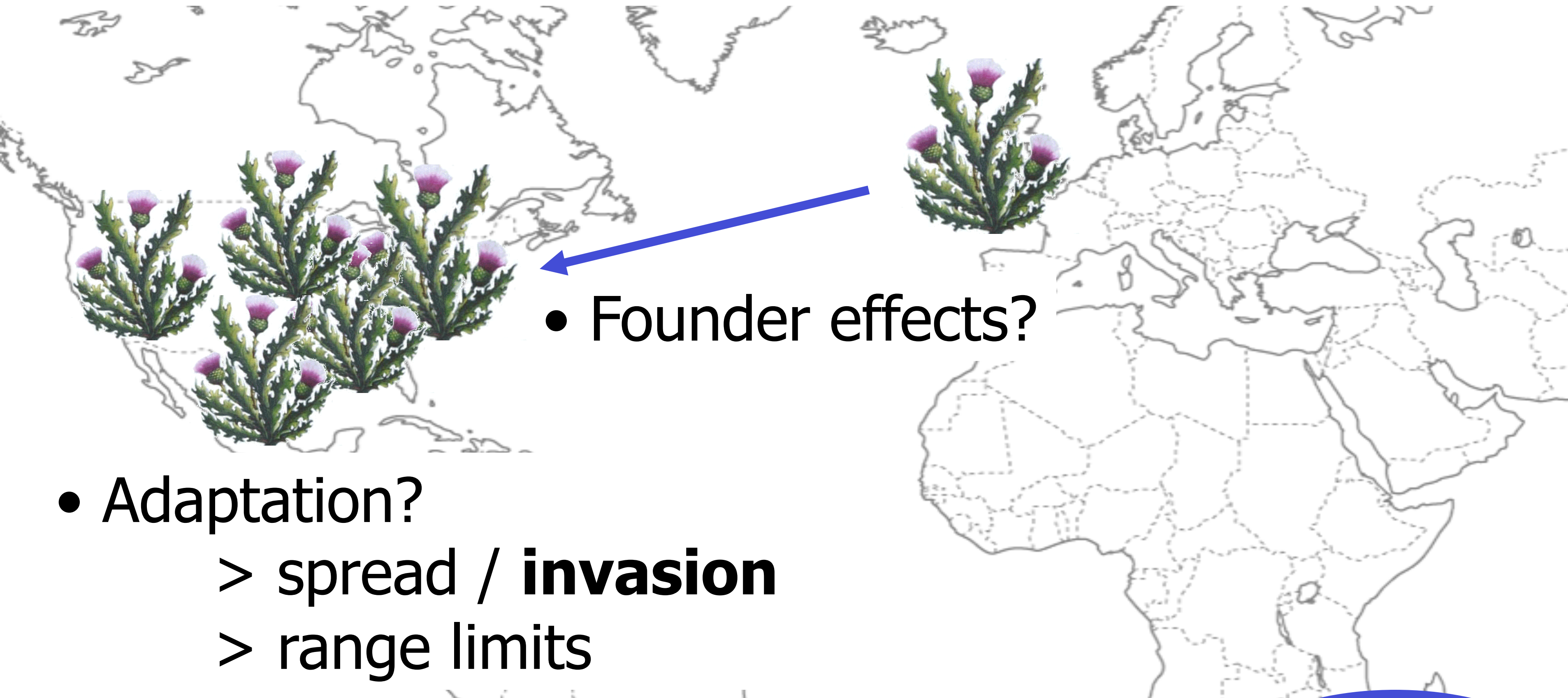
Rapid spread and dominance

-annual costs of invasive plants to the agricultural community are estimated at $2.2 billion

(496 are invasive)

"Natural experiments" in plant evolution

Introduced species
Transferred outside range of natural dispersal

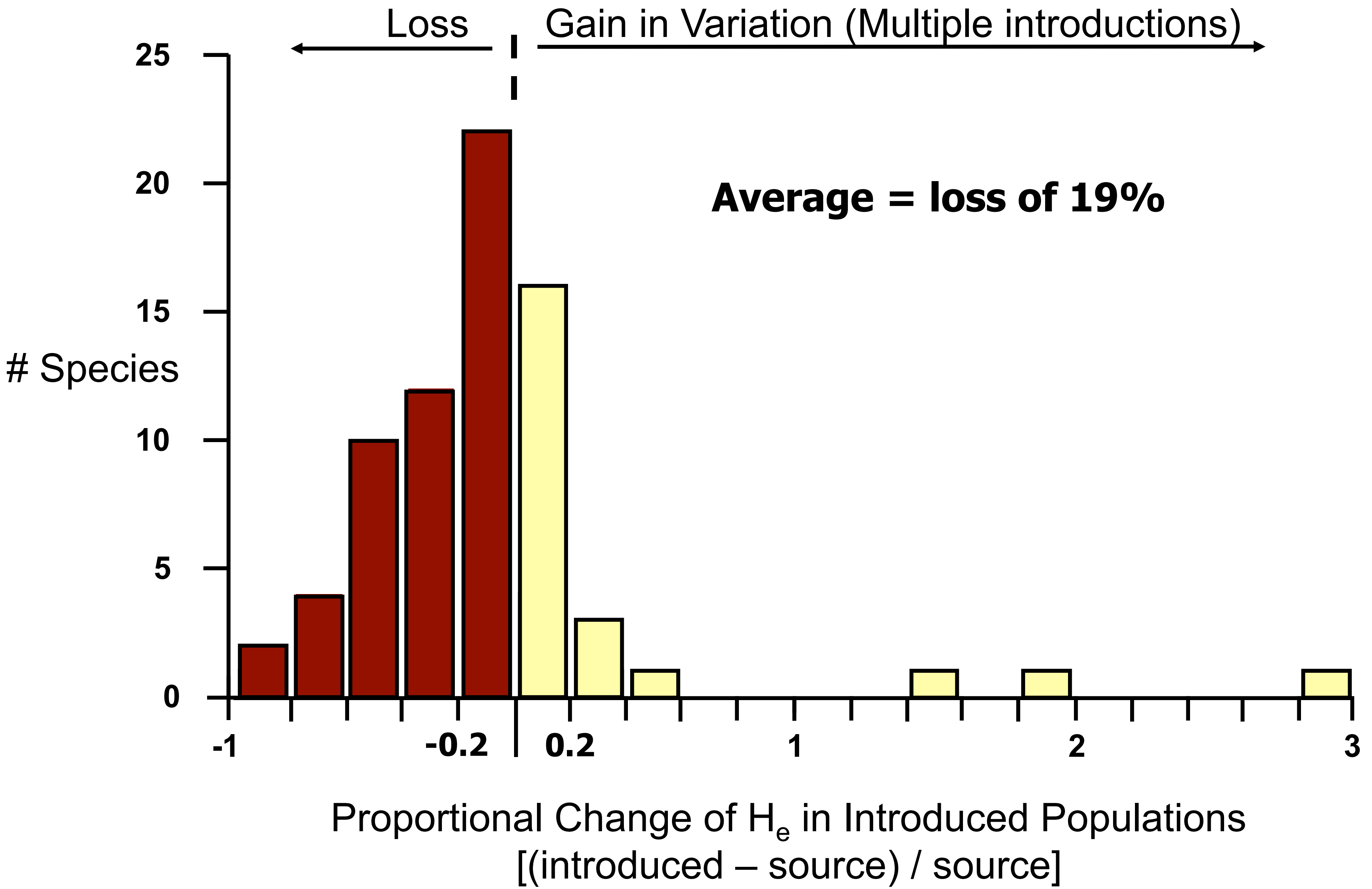


- Founder effects?

- Adaptation?
  - > spread / **invasion**
  - > range limits

= NOT just colonizers of disturbed areas **WEEDS**

Founding events: Genetic variation lost



Founding events

- Genetic bottlenecks probably common

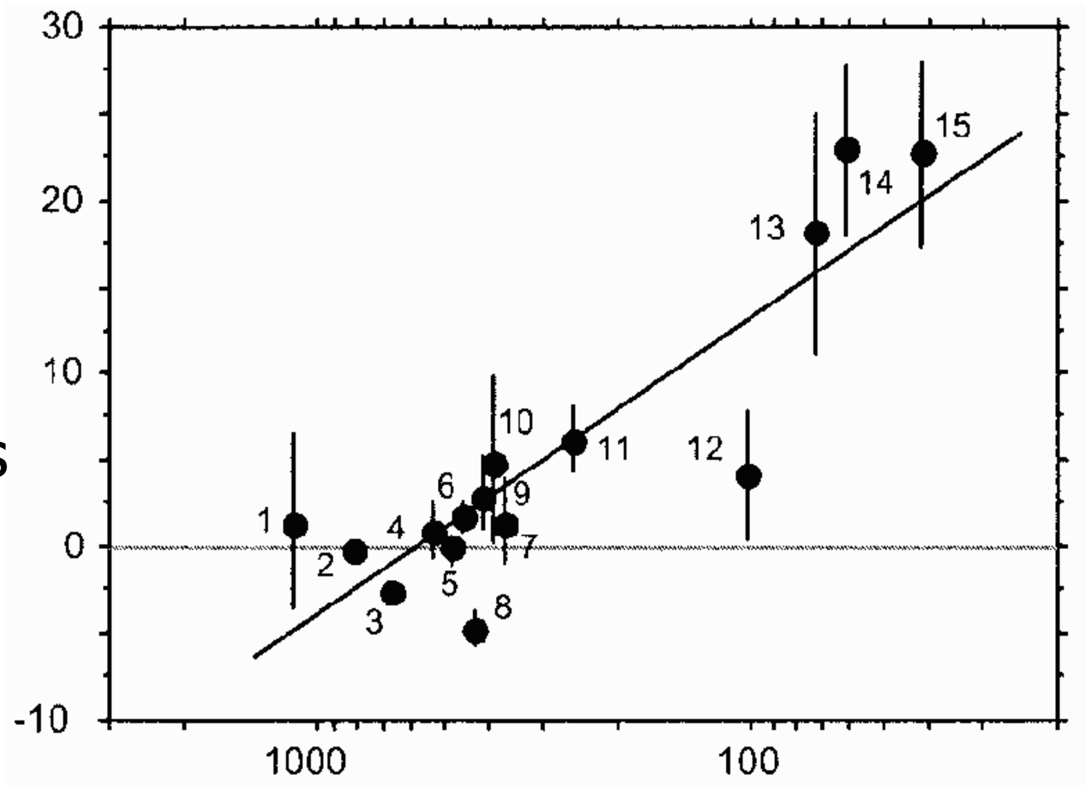
- Non-random mating/asexual reproduction common
  - selfing
  - apomixis (asexual seeds)
  - vegetative spread

- Genetic Drift

Founding events

We know genetic bottlenecks can have fitness costs

Decline in
Hatching Success
vs.
Source Populations



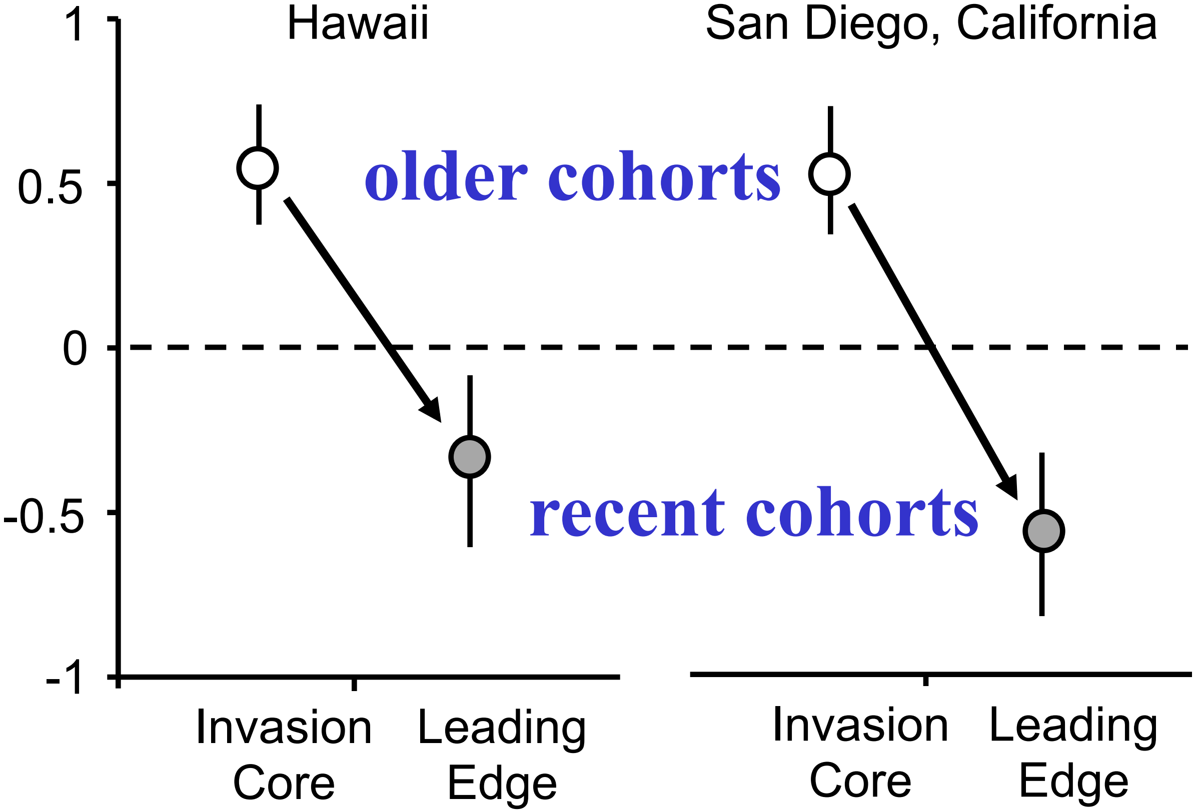
Number of Birds Introduced

Founding events

Loss of Inbreeding depression in *Hypericum canariense*

Inbreeding depression for germination

$$\delta = \frac{\text{outcross} - \text{self}}{\text{self}}$$



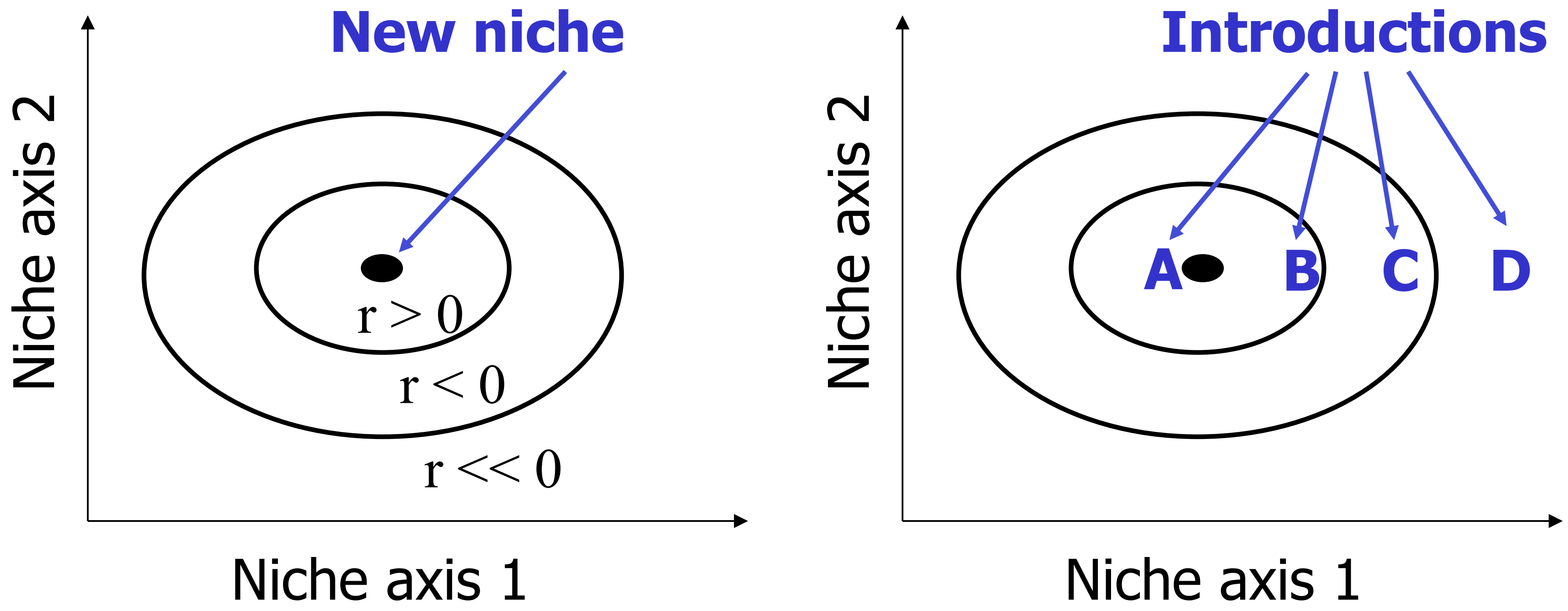
Adaptation in Introduced Populations

Depends on:

Genetic variation

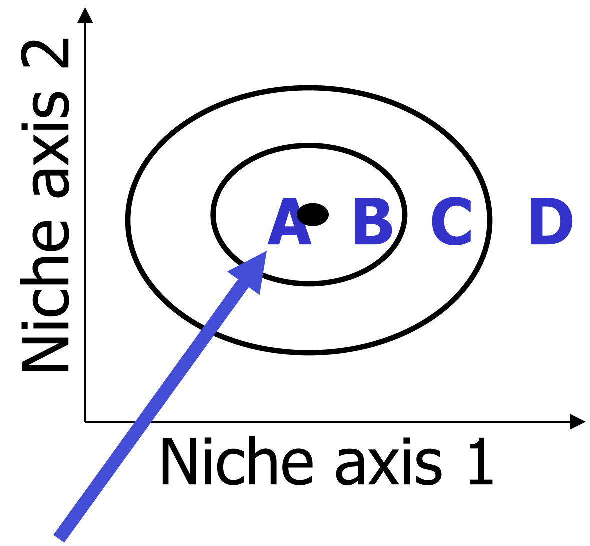
Selection

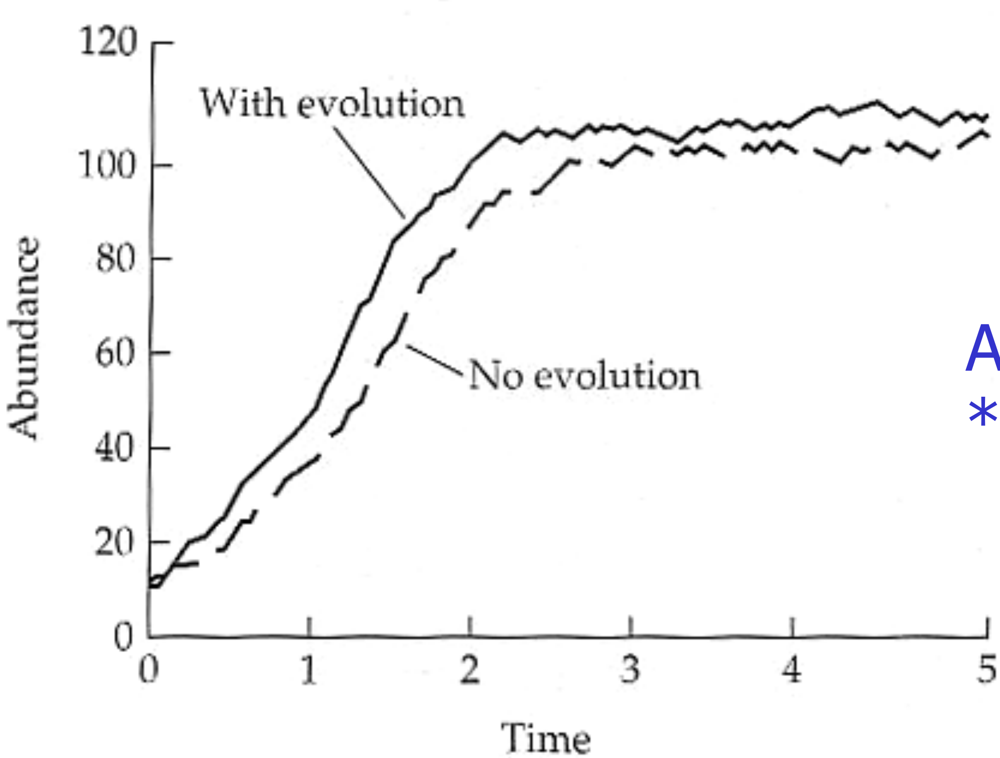
Extinction risk (population growth, r)



Adaptation in Introduced Populations

Simulation
with demographic stochasticity



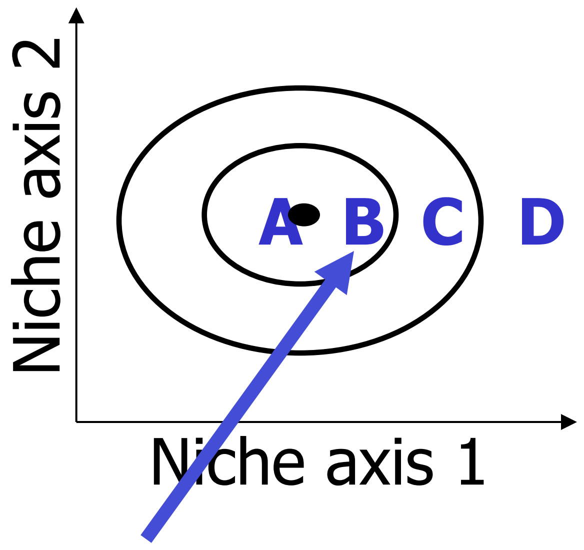


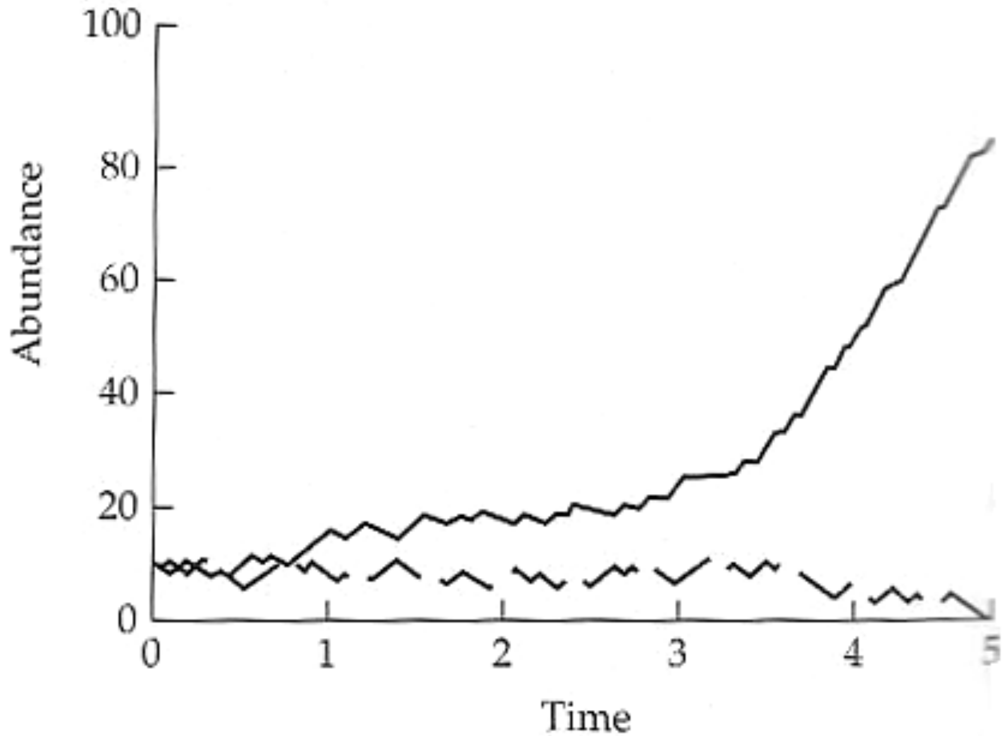
Adaptation occurs
** NOT required for invasion

Holt et al. 2005

Adaptation in Introduced Populations

Simulation
with demographic stochasticity





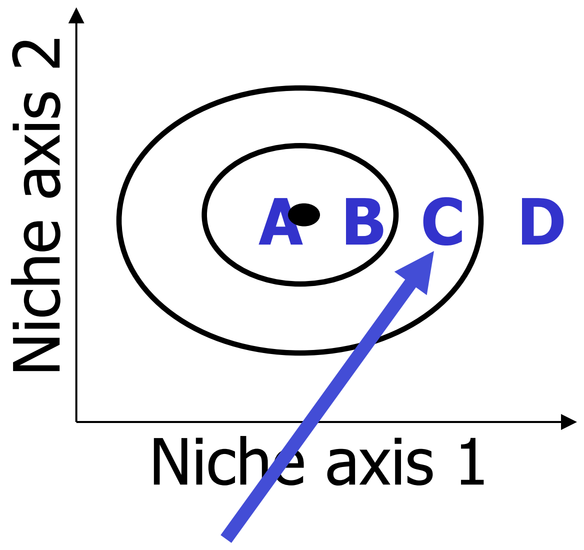
Adaptation beneficial

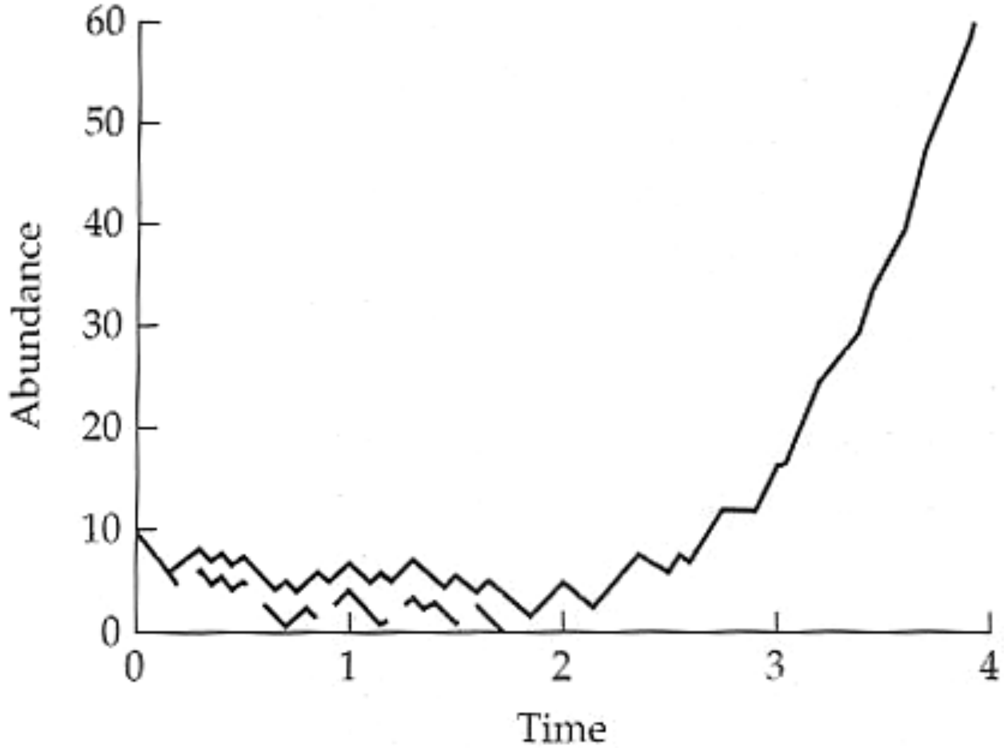
Produces invasion lag

Holt et al. 2005

Adaptation in Introduced Populations

Simulation
with demographic stochasticity





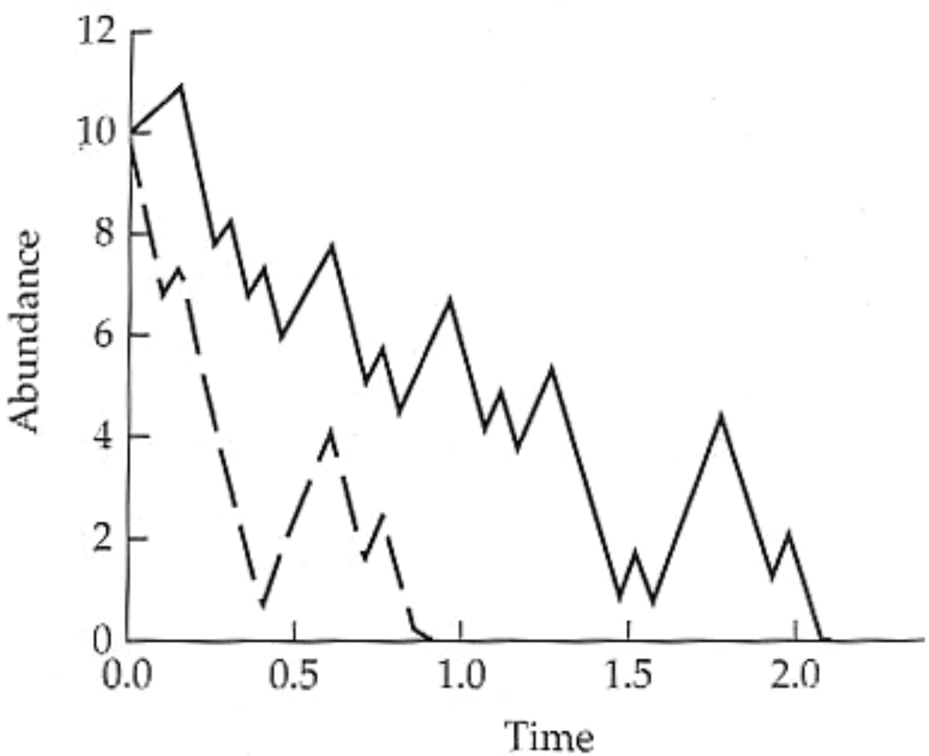
Adaptation required

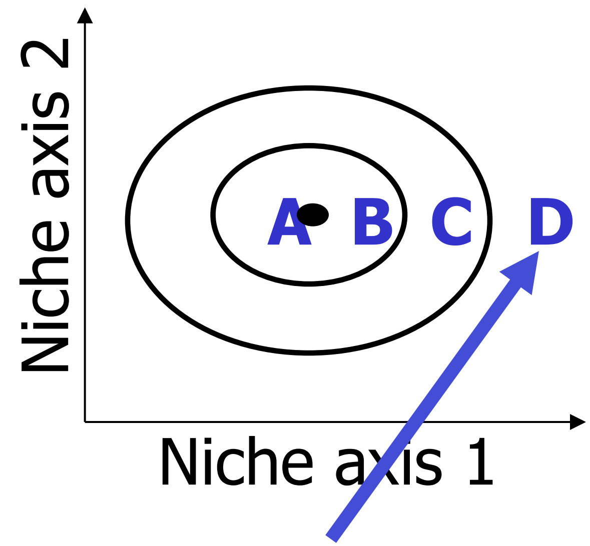
Produces invasion lag

Holt et al. 2005

Adaptation in Introduced Populations

Simulation
with demographic stochasticity





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 needed for establishment
- Whether adaptation needed for invasion

Evolution and invasion

What type of evolutionary changes occur during invasion?

Could these changes contribute to "invasiveness"?

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

Why?

<u>THINK – PAIR - SHARE</u>

Evolution and invasion

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

2. Plants trade off tolerance to abiotic stresses in native range for increased competitive and/or colonizing ability.

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

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.

Common Ragweed (*Ambrosia artemisiifolia*)

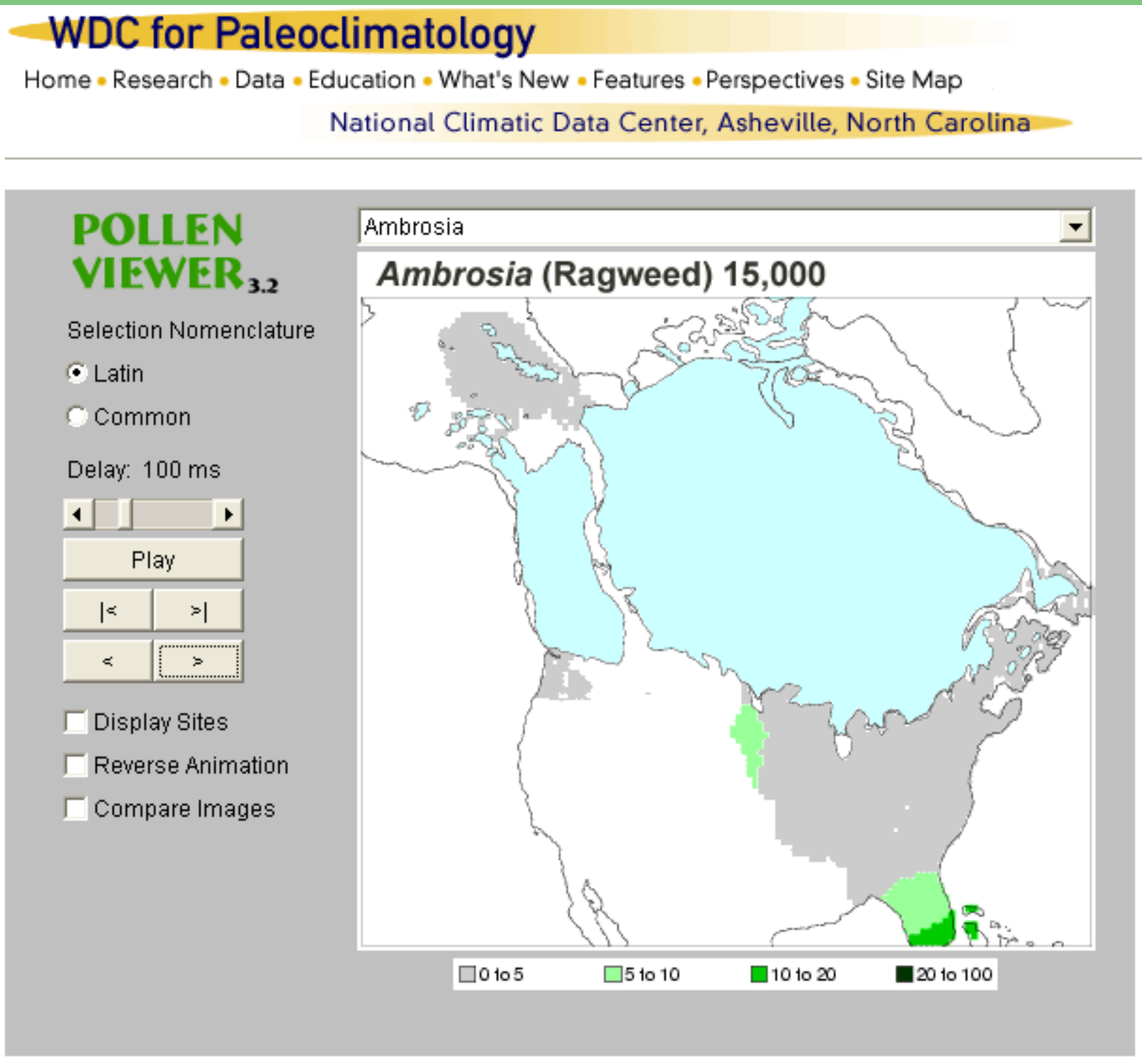
Wind pollinated, self incompatible monecious annual

Problematic weed native to North America (sunflower, soybean, corn)

Invasive in parts of Australia, Asia and Europe (e.g. 80% of arable land in Hungary is infested)

Severely allergenic (hayfever, dermatitis)

Distribution of *Ambrosia* over the last 15 000 yrs



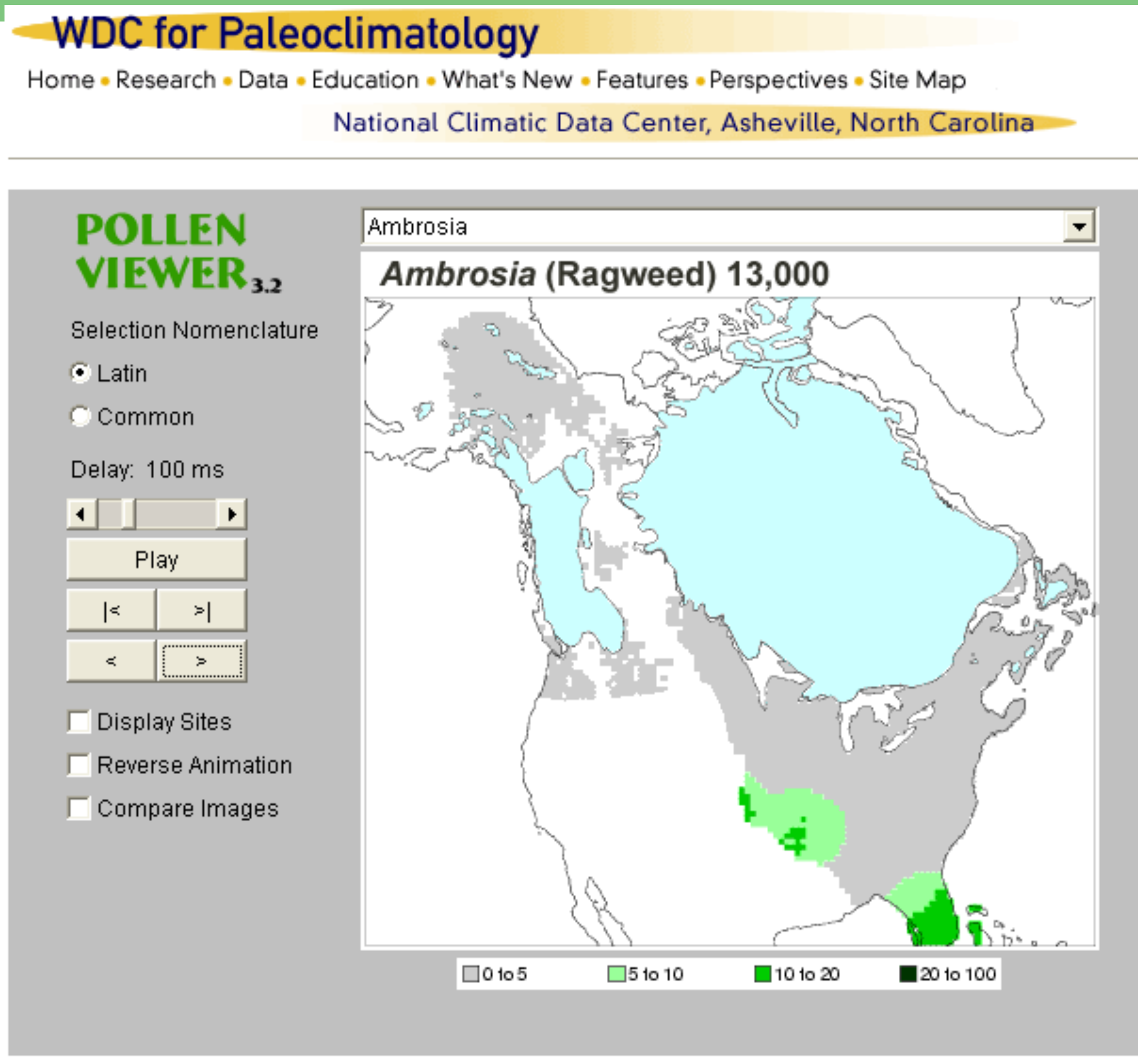
Pollen Viewer 3.2, created by Phil Leduc.
See: Late Quaternary vegetation dynamics in North America: scaling from taxa to biomes.

Ages at the top of maps are calibrated ages.
White areas on maps have no data.
Light blue areas on maps are ice.

Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs



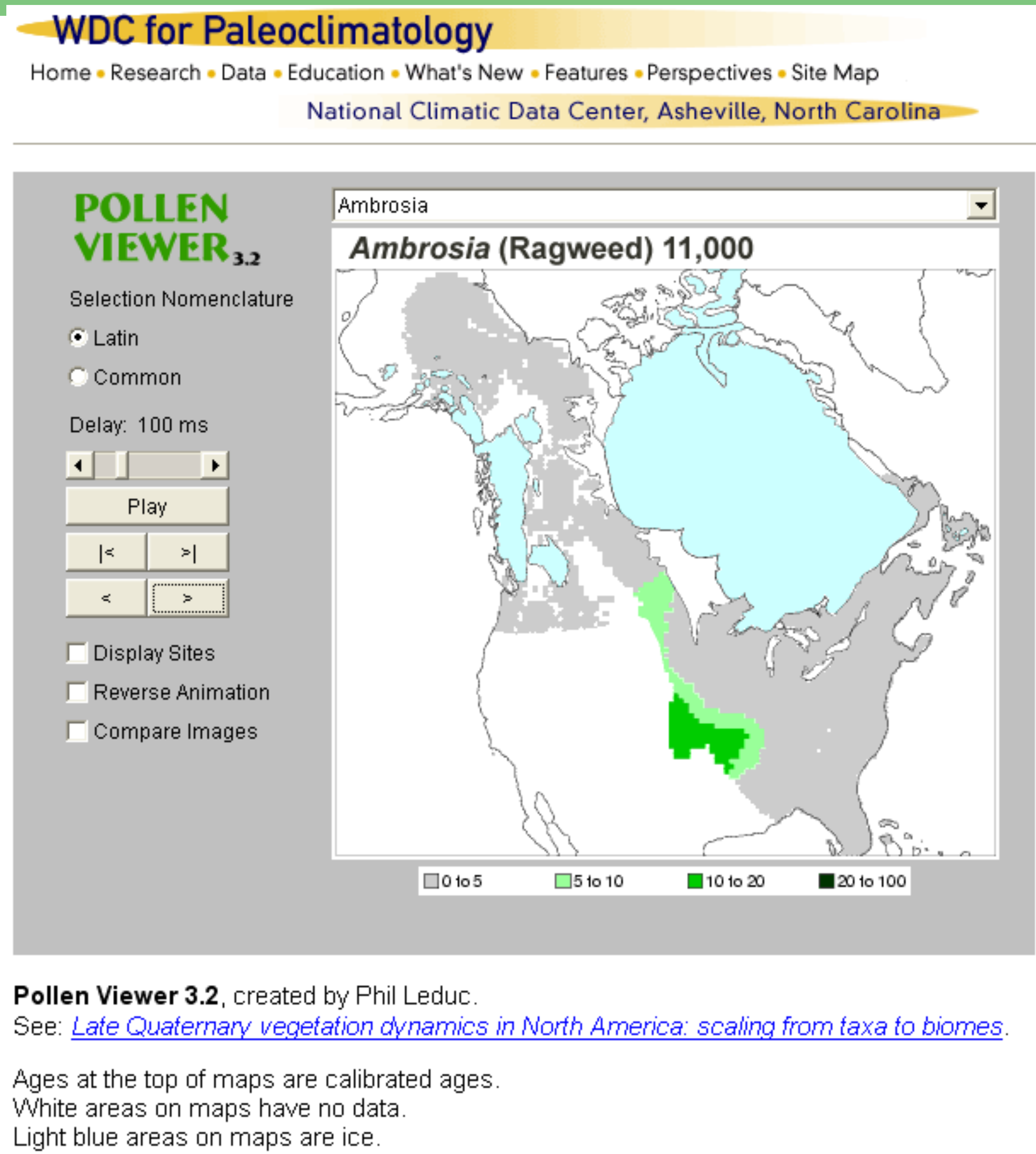
Pollen Viewer 3.2, created by Phil Leduc.
See: [Late Quaternary vegetation dynamics in North America: scaling from taxa to biomes]().

Ages at the top of maps are calibrated ages.
White areas on maps have no data.
Light blue areas on maps are ice.

Native to North America

Common in the great plains for the past 15 000 yrs

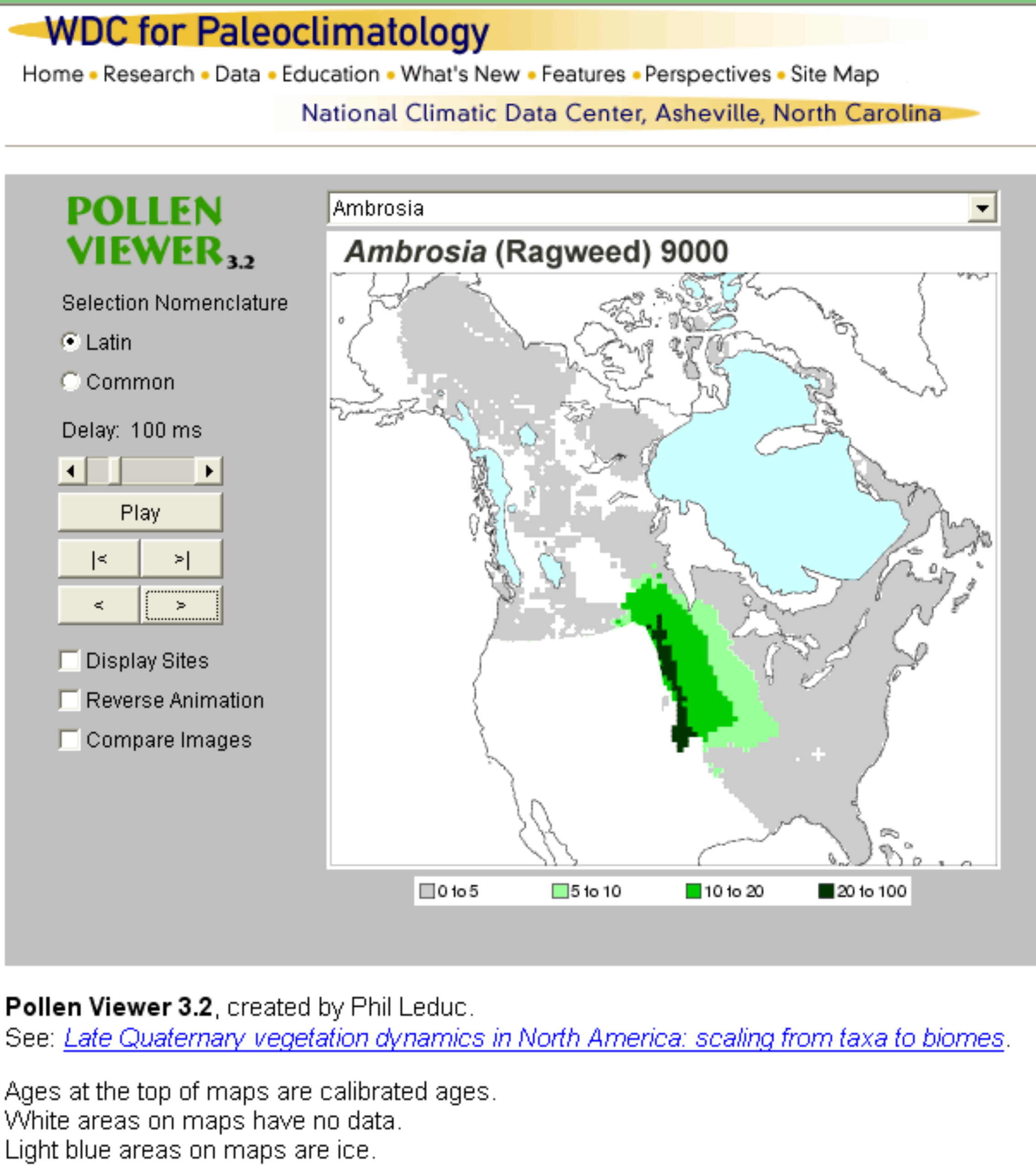
Distribution of *Ambrosia* over the last 15 000 yrs



Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs



Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs

WDC for Paleoclimatology

Home • Research • Data • Education • What's New • Features • Perspectives • Site Map

National Climatic Data Center, Asheville, North Carolina

POLLEN VIEWER 3.2

Selection Nomenclature

- Latin
- Common

Delay: 100 ms

Play

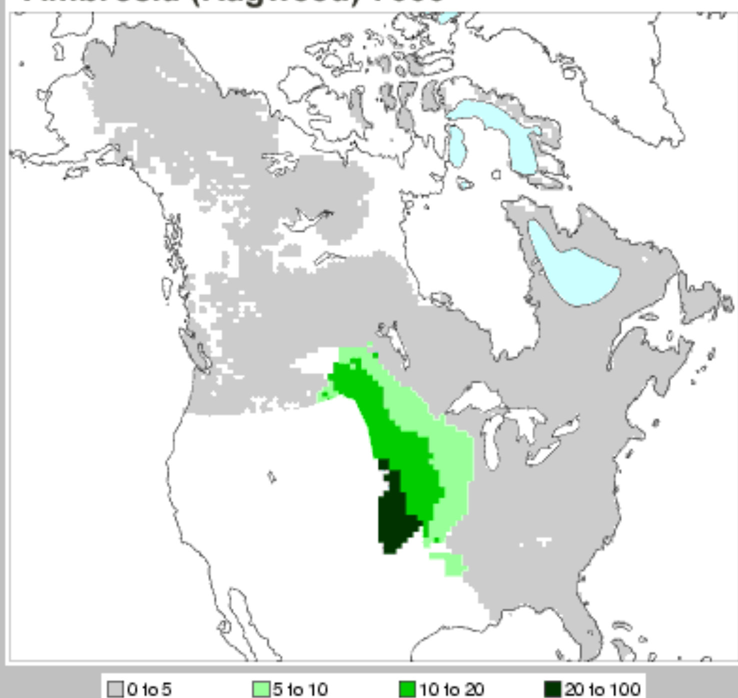
|< >|

< >

- Display Sites
- Reverse Animation
- Compare Images

Ambrosia

***Ambrosia* (Ragweed) 7000**



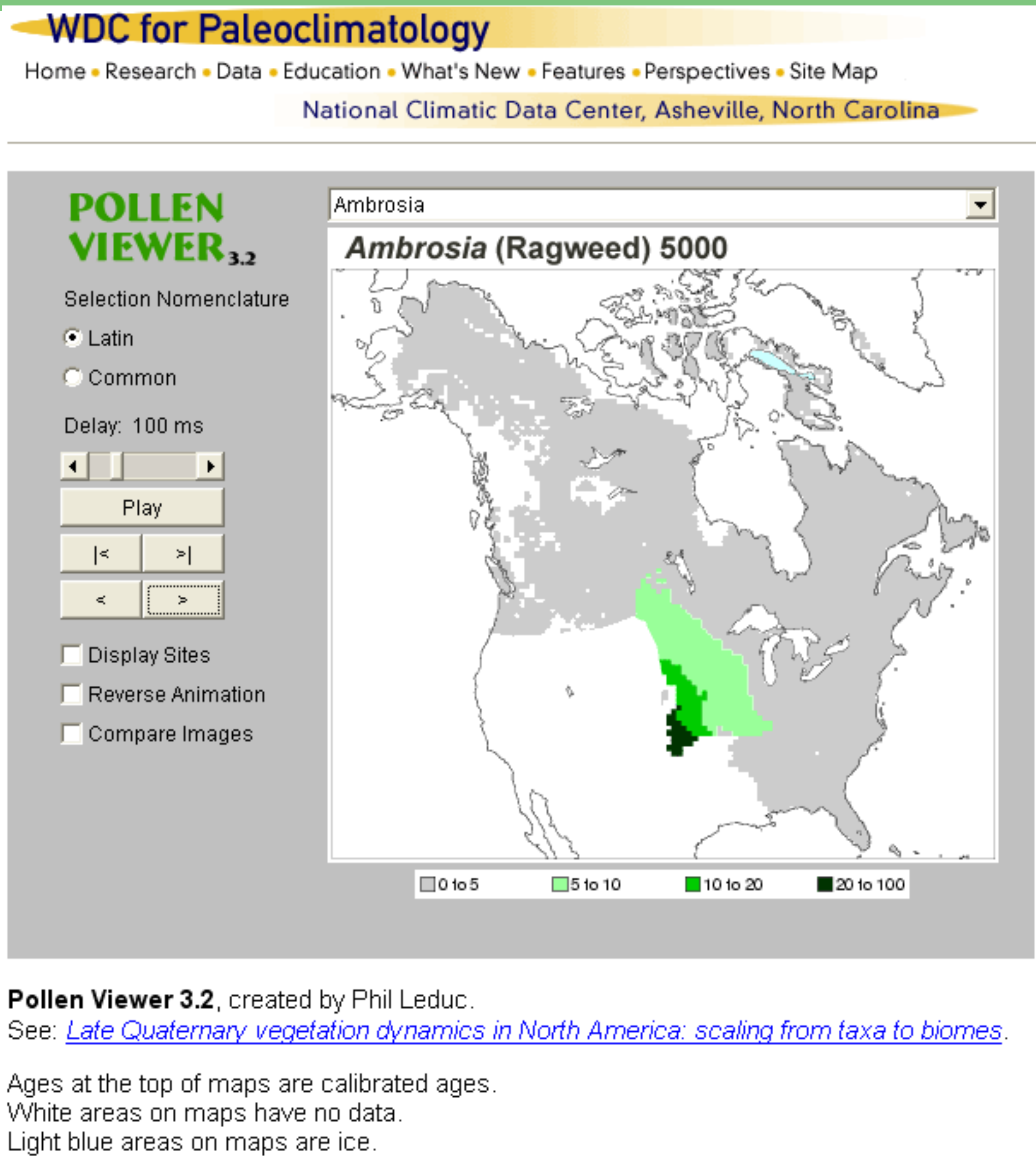
Pollen Viewer 3.2, created by Phil Leduc.
See: *Late Quaternary vegetation dynamics in North America: scaling from taxa to biomes*.

Ages at the top of maps are calibrated ages.
White areas on maps have no data.
Light blue areas on maps are ice.

Native to North America

Common in the great plains for the past 15 000 yrs

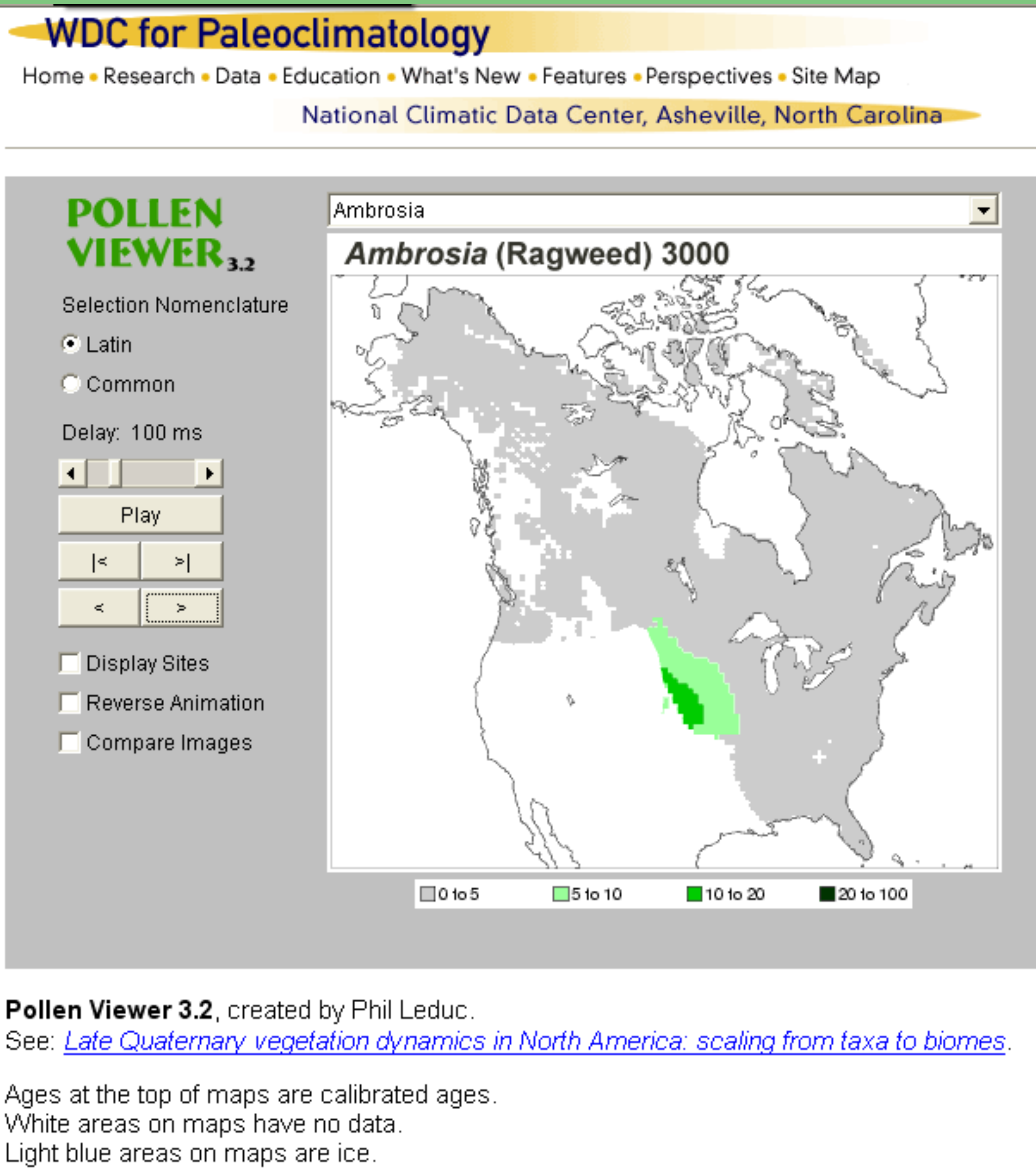
Distribution of *Ambrosia* over the last 15 000 yrs



Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs



Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs

WDC for Paleoclimatology

Home • Research • Data • Education • What's New • Features • Perspectives • Site Map

National Climatic Data Center, Asheville, North Carolina

POLLEN VIEWER 3.2

Selection Nomenclature

- Latin
- Common

Delay: 100 ms

Play

|< >|

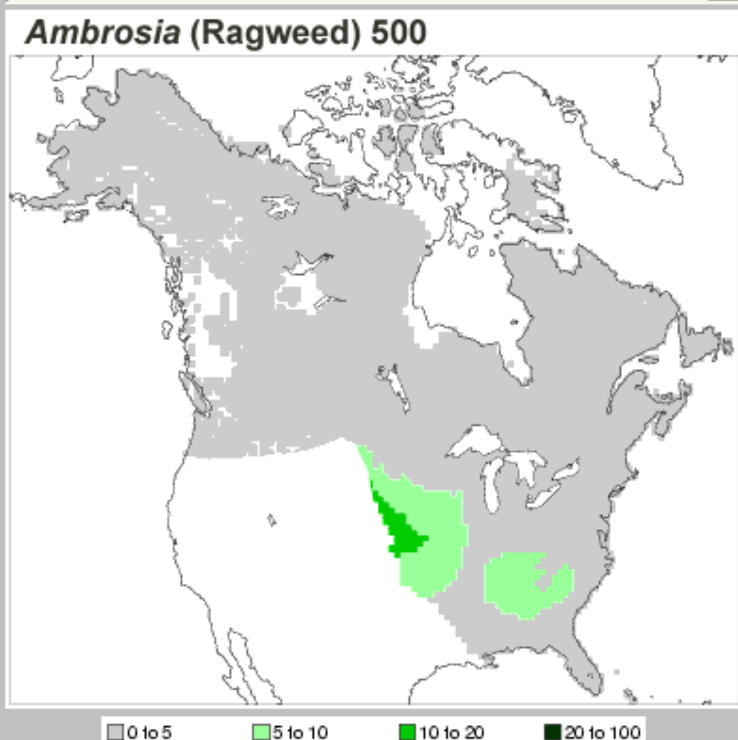
< >

Display Sites

Reverse Animation

Compare Images

Ambrosia



Pollen Viewer 3.2, created by Phil Leduc.
See: *Late Quaternary vegetation dynamics in North America: scaling from taxa to biomes*.

Ages at the top of maps are calibrated ages.
White areas on maps have no data.
Light blue areas on maps are ice.

Native to North America

Common in the great plains for the past 15 000 yrs

Distribution of *Ambrosia* over the last 15 000 yrs

WDC for Paleoclimatology

Home • Research • Data • Education • What's New • Features • Perspectives • Site Map

National Climatic Data Center, Asheville, North Carolina

POLLEN VIEWER 3.2

Selection Nomenclature

- Latin
- Common

Delay: 100 ms

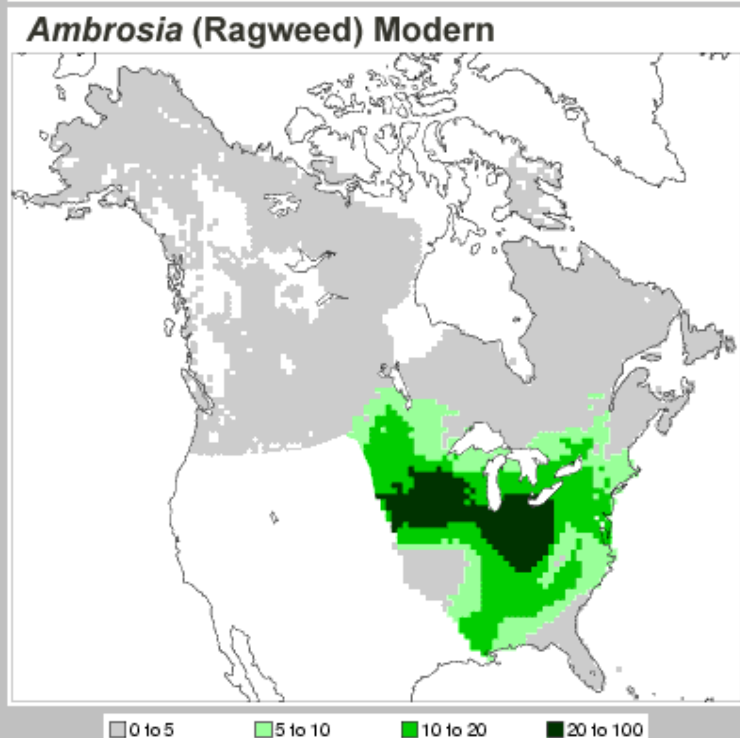
Play

|< >|

< >

- Display Sites
- Reverse Animation
- Compare Images

Ambrosia



Pollen Viewer 3.2, created by Phil Leduc.
See: *Late Quaternary vegetation dynamics in North America: scaling from taxa to biomes*.

Ages at the top of maps are calibrated ages.
White areas on maps have no data.
Light blue areas on maps are ice.

Native to North America

Common in the great plains for the past 15 000 yrs

Common garden experimental design

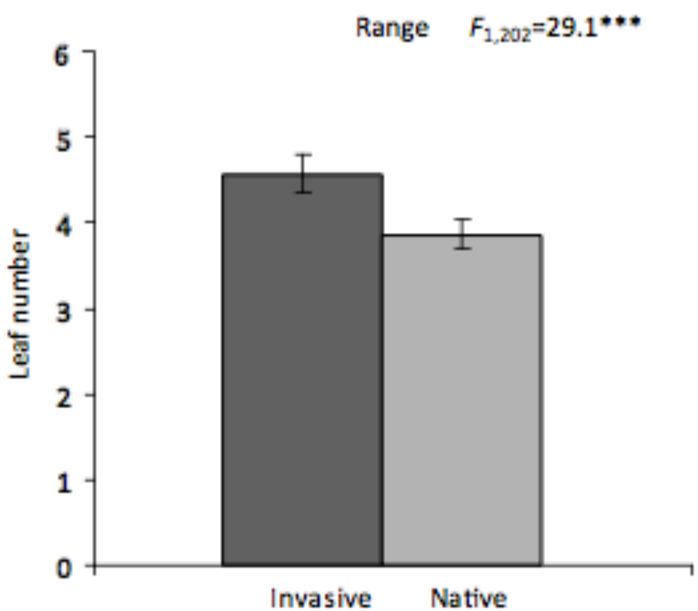
12 invasive, 22 native populations grown in UBC glasshouse

Experiment 1 - 1278 plants
•6.4 families/native population
•9.6 families/invasive population
•Control, light, nutrient, herbivory stress
•3 blocks

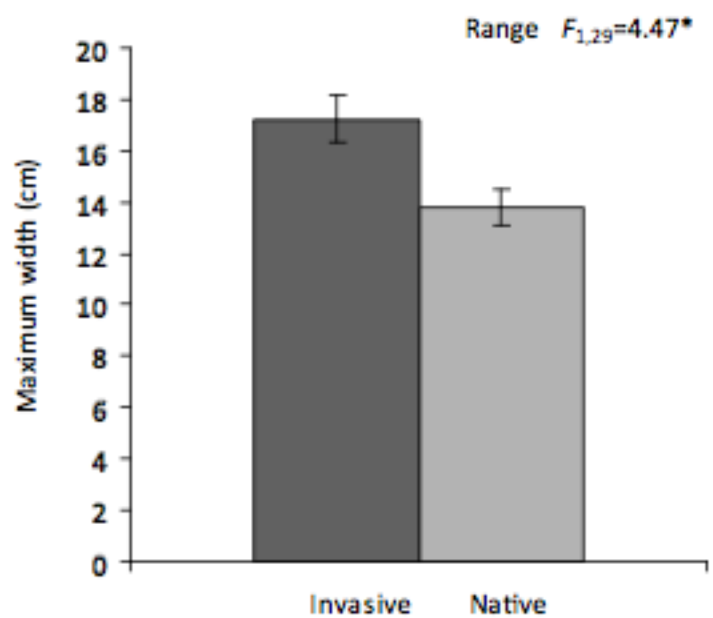
Experiment 2 - 180 plants
•3.8 families/native population
•8.1 families/invasive population
•Drought stress

Initial differences between the native and introduced range

Two weeks after germination

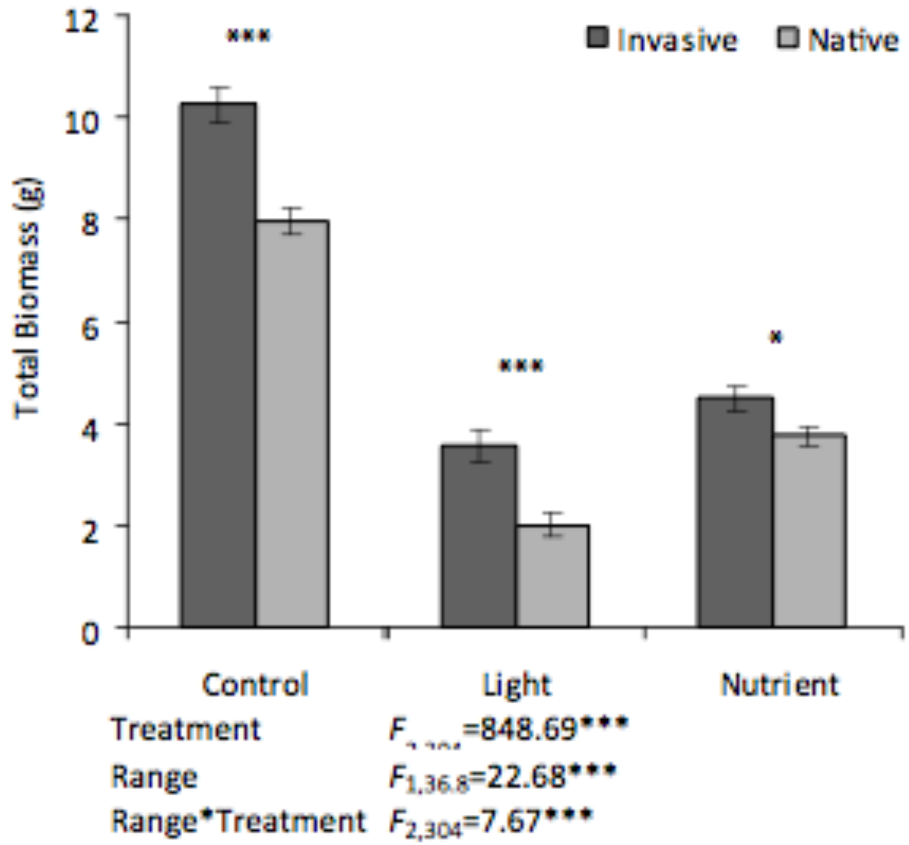


One week after transplant



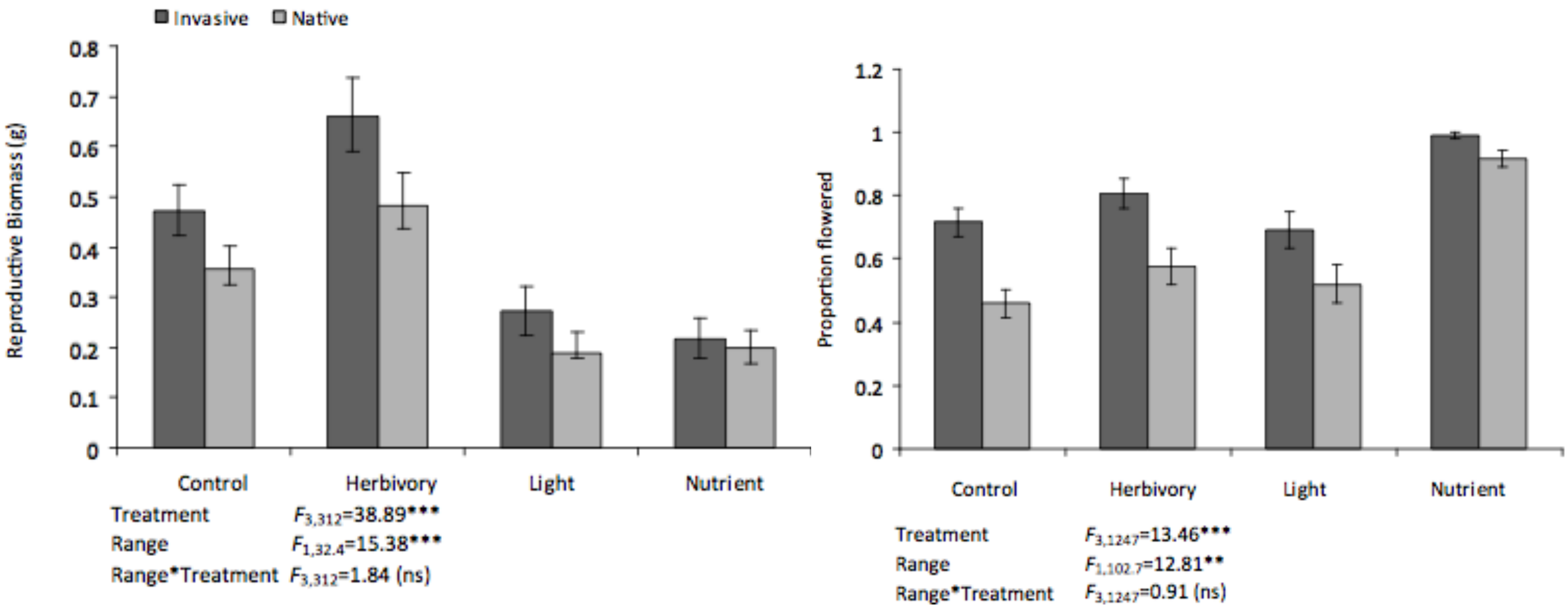
Invasive plants are larger than native plants

Biomass



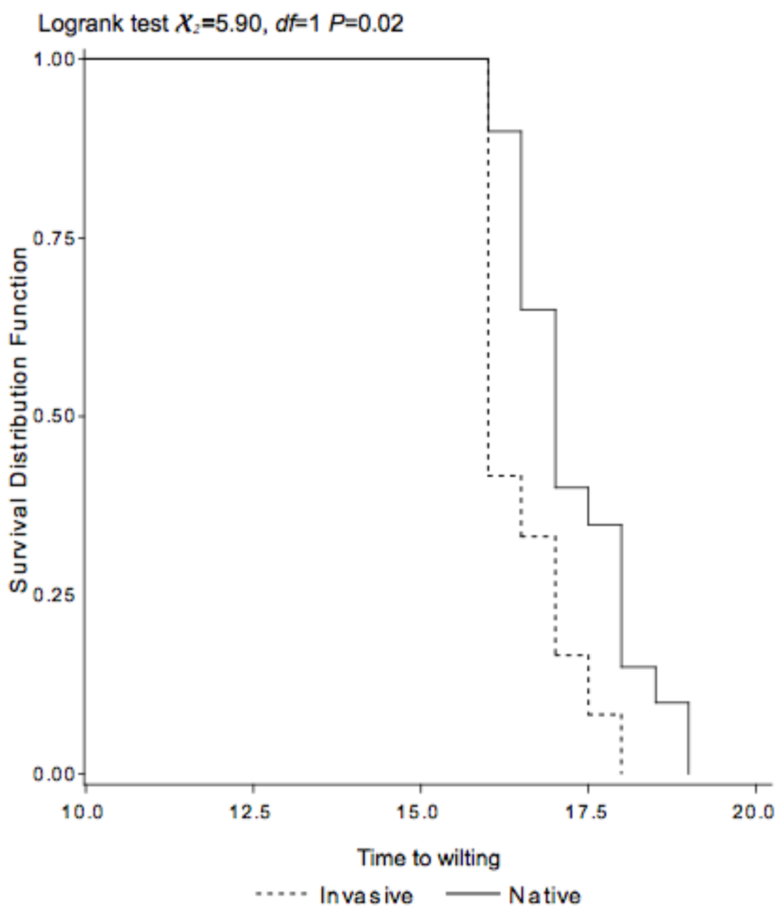
- There is a significant range*treatment interaction for biomass
- Invasive plants tend to grow larger in the control and light stress
- More equivalent growth in the nutrient stress

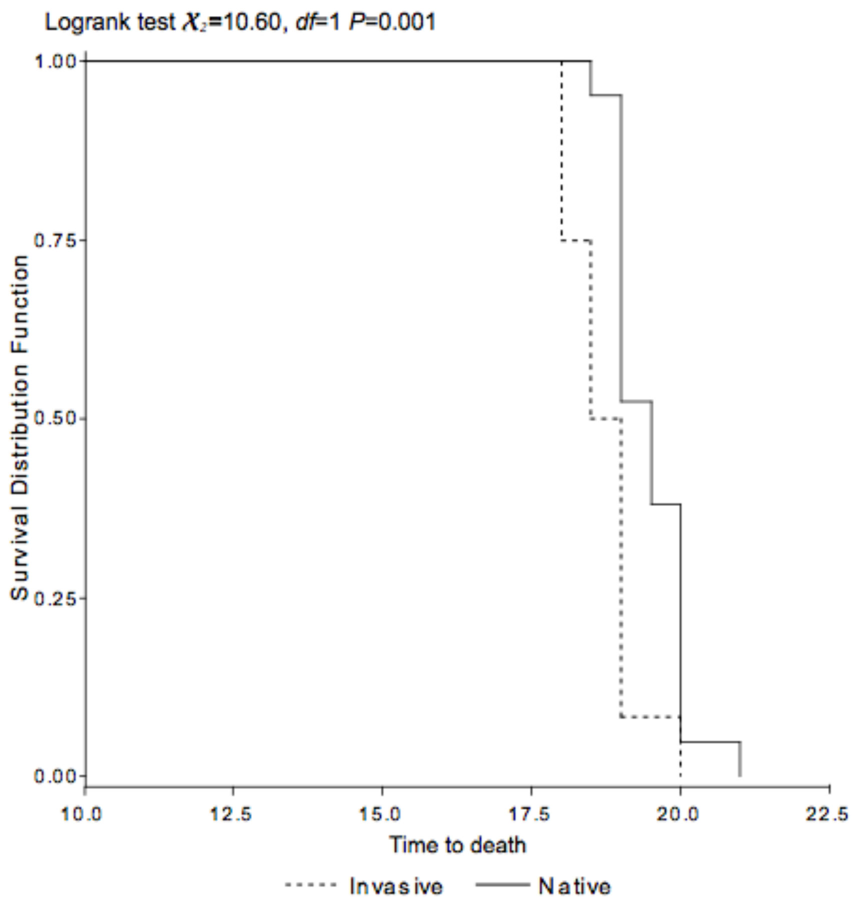
Reproductive success



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

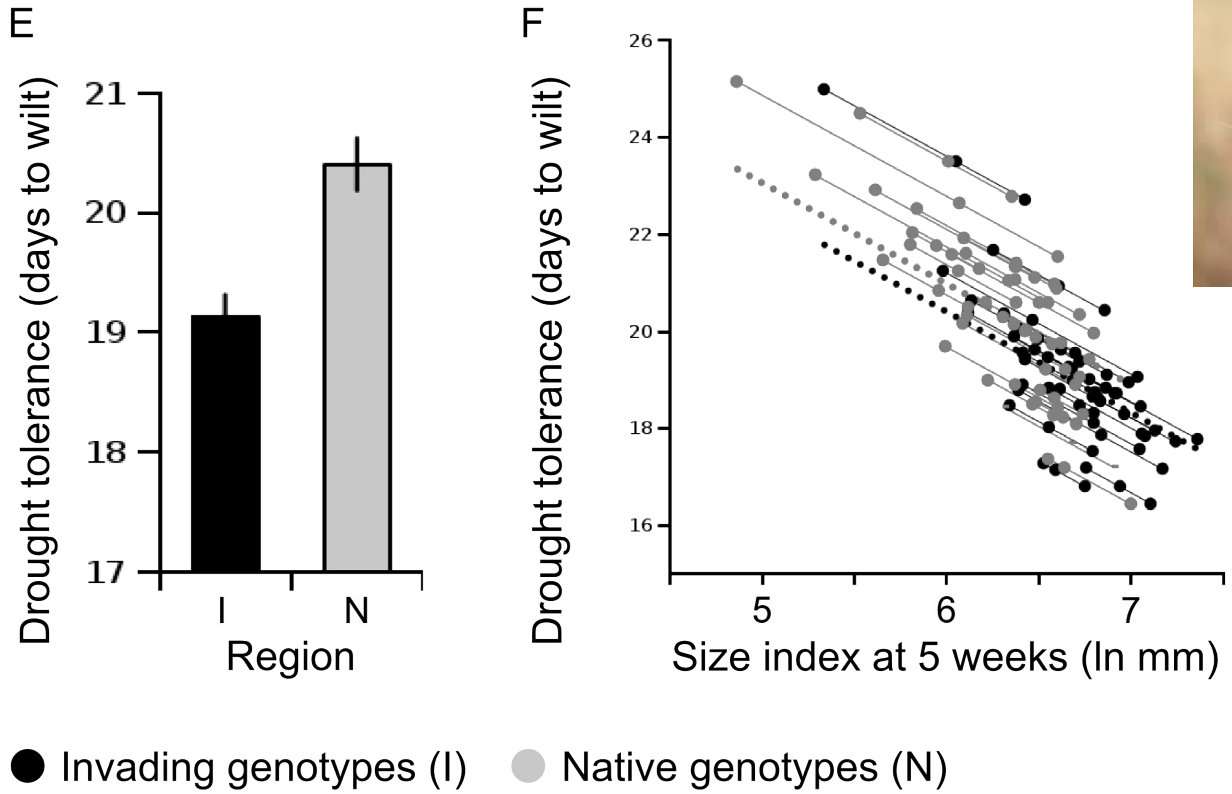
Drought Experiment





- Invasive plants wilted and died more quickly than native plants

More Evolutionary Trade-offs



Evolutionary trade-off between drought tolerance and size also seen in yellow starthistle (Dlugosh 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:
    - Don't 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?