Establishment and consumer mechanisms limit native plant regeneration and promote continued dominance of garlic mustard

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Outline

- Forest herb layer and invasive species
- The role of direct and indirect effects in maintaining garlic mustard dominance
  - Seeds/seedlings
  - Deer
  - Slugs

Importance of forest understories

- Most diverse forest strata
- Regulates nutrient cycling/ soil biota
- Competition with overstory
  - Can affect overstory regeneration

Gilliam 2007 *Bioscience*

The ~50,000 non-native species in the US produce an undesired cost of ~$120 billion y^{-1}

- Many invaders of forest understories

(Pimentel et al. 2005).

The ~50,000 non-native species in the US produce an undesired cost of ~$120 billion y^{-1}

- Many invaders of forest understories

Restoration of biodiversity and Ecosystem Services

Subject: Alliaria petiolata (garlic mustard)

Rodgers et al. 2008

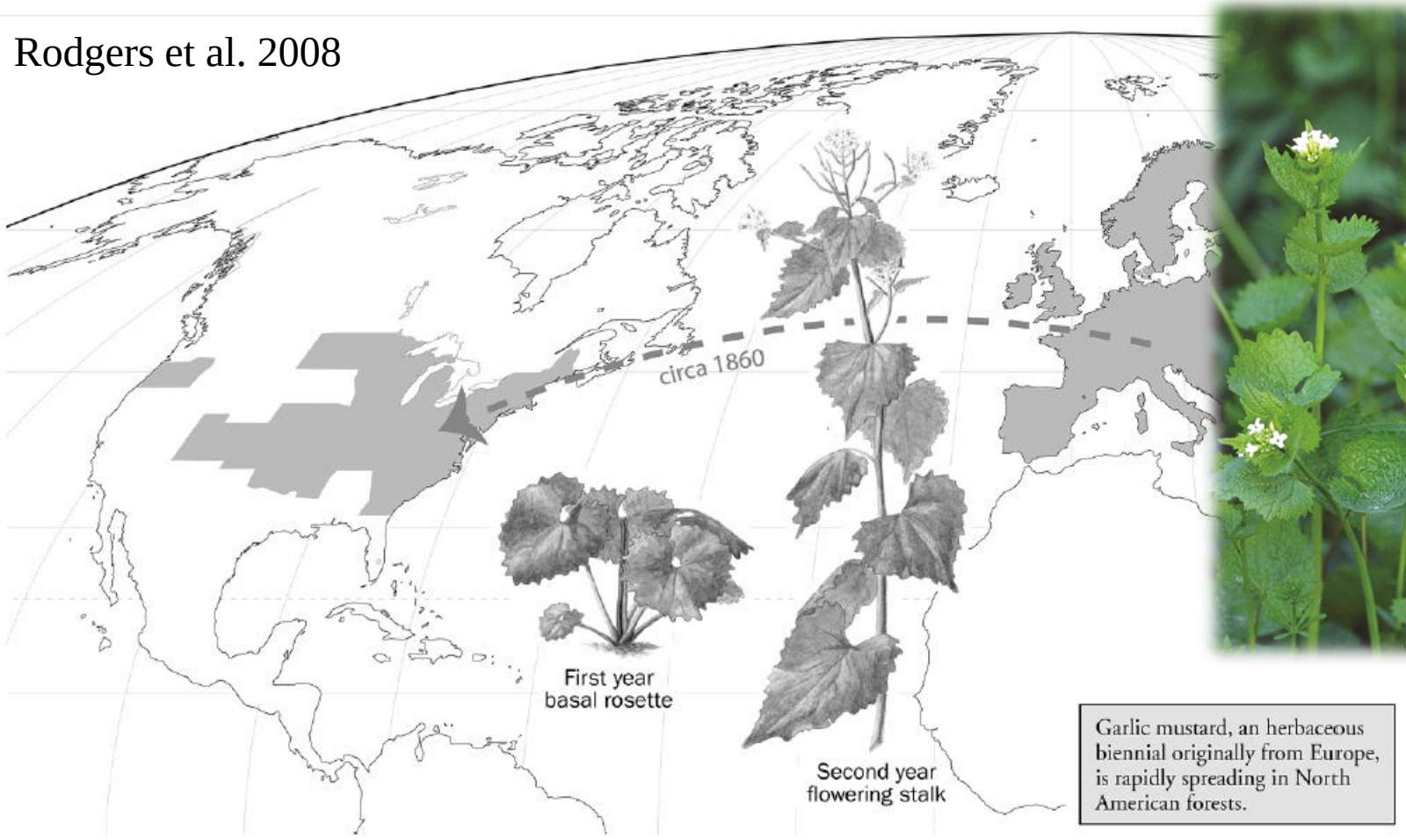
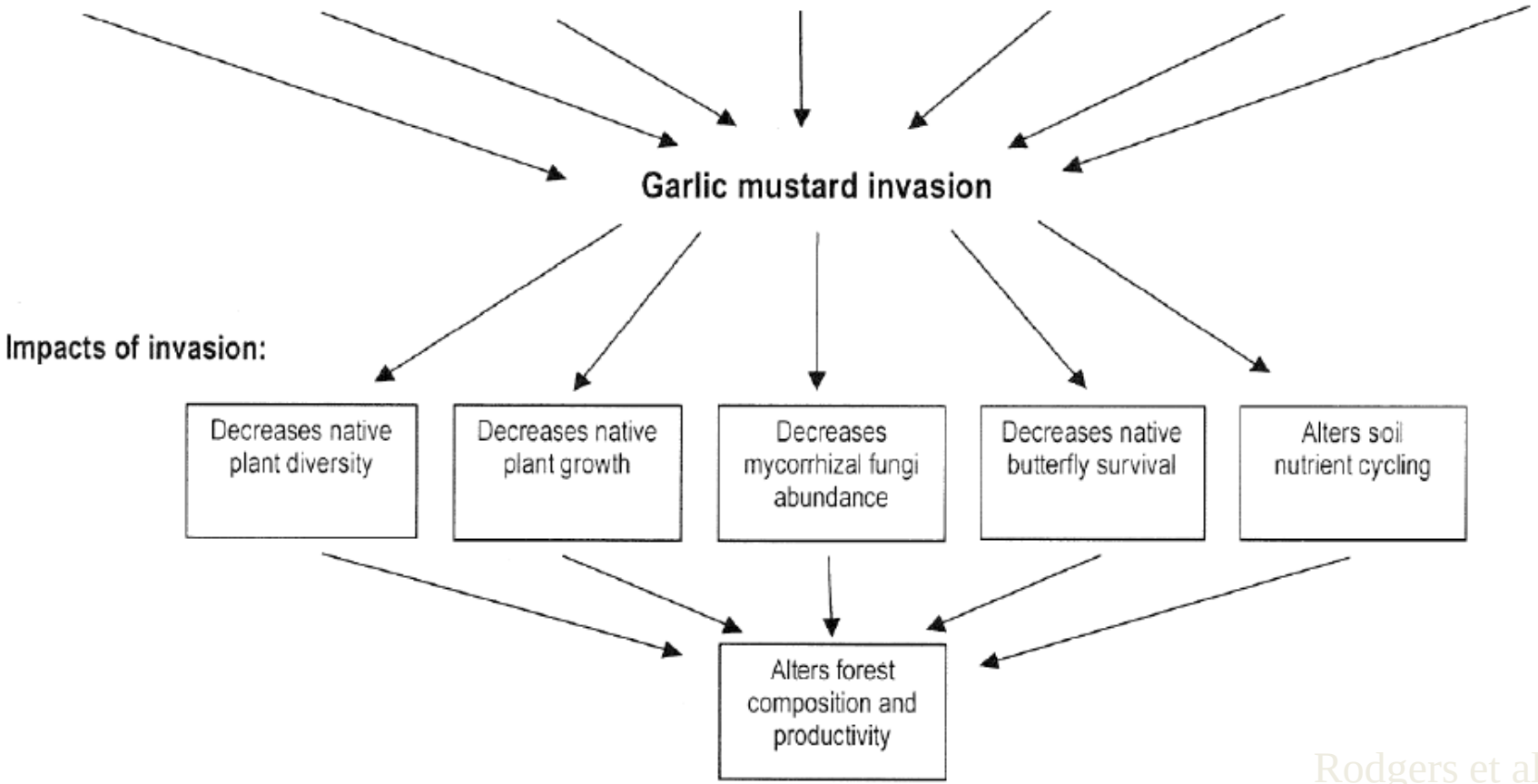


Figure 2. Image of first- and second-year garlic mustard plants and geographical introduction pattern. Illustration by Eliza K. Jewett; used courtesy of Kristin C. Lewis. © 2004 Eliza K. Jewett.

"Ready or Not, Garlic Mustard Is Moving In …"

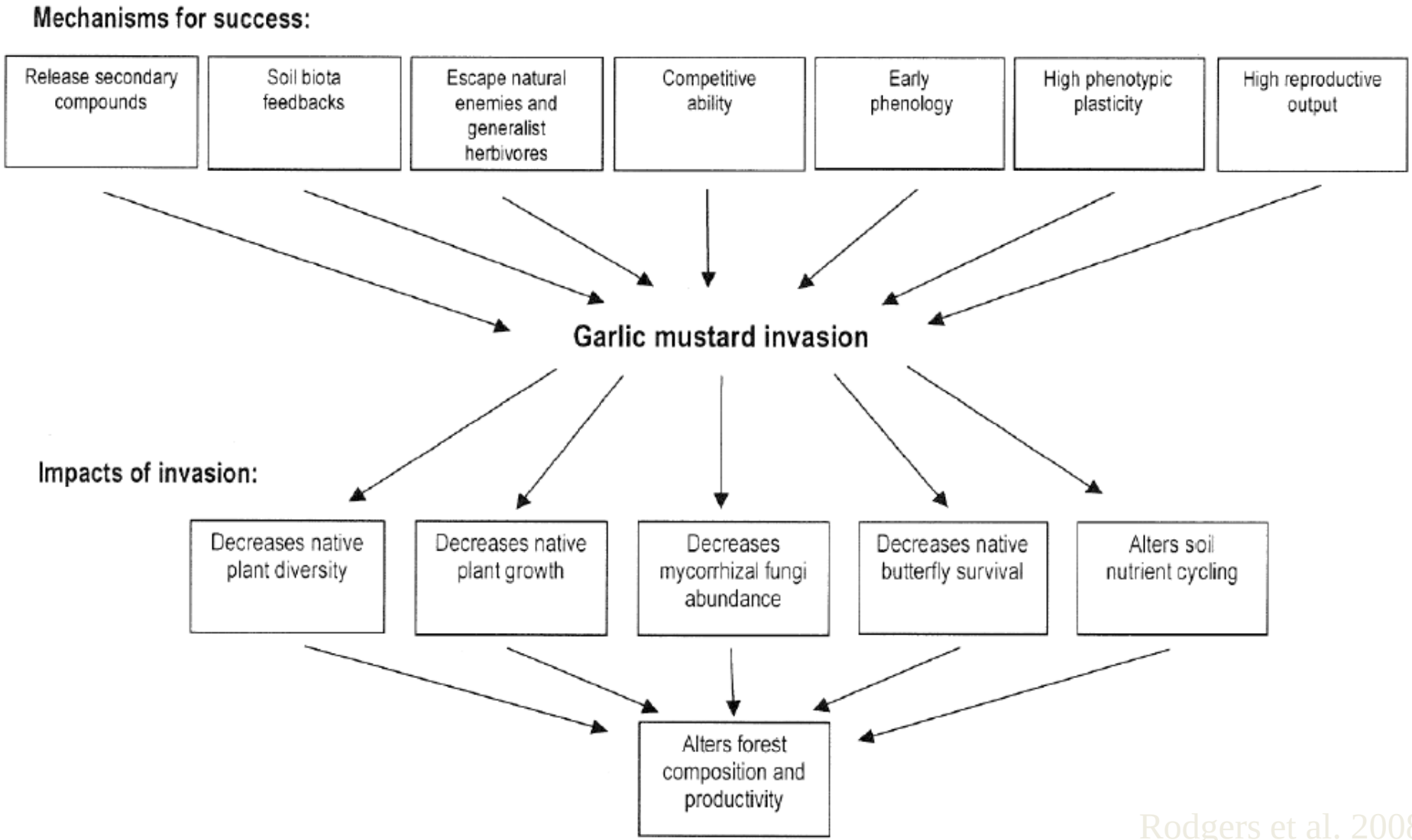


Rodgers et al. 2008

Figure 1. Conceptual diagram illustrating the mechanisms for the success of garlic mustard in its new range and the impacts of its invasion on eastern North American forests.

Rodgers et al. 2008

"Ready or Not, Garlic Mustard Is Moving In …"



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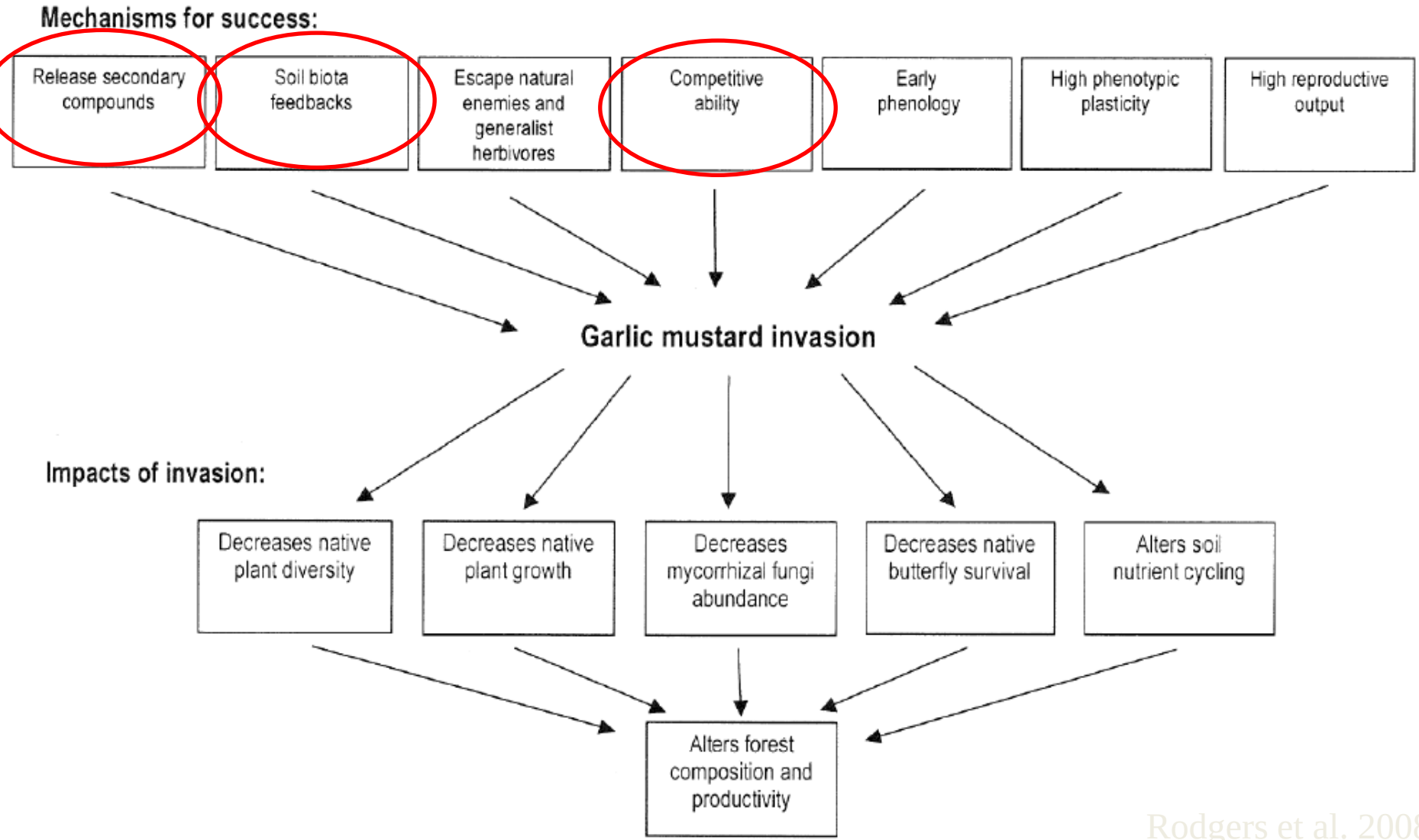

Rodgers et al. 2008

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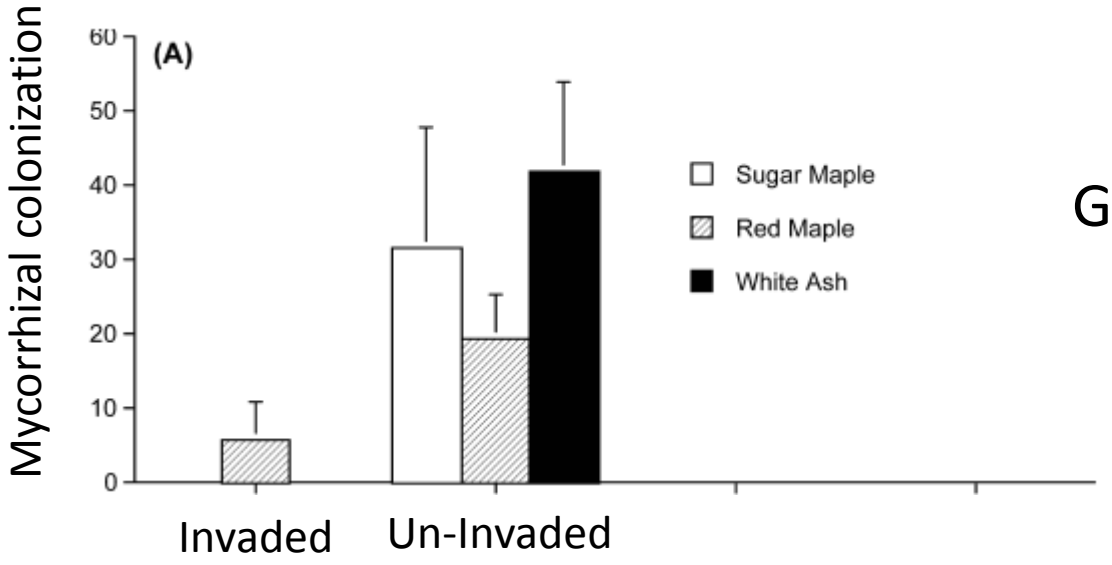
Rodgers et al. 2008

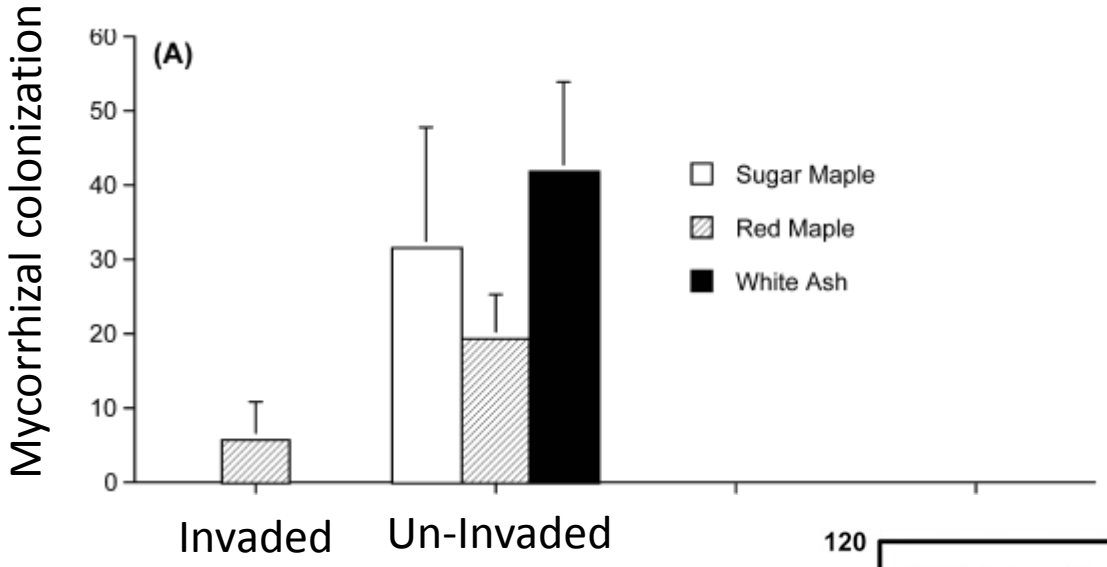
GM can disrupt mycorrhizal colonization



Greenhouse “pot” study

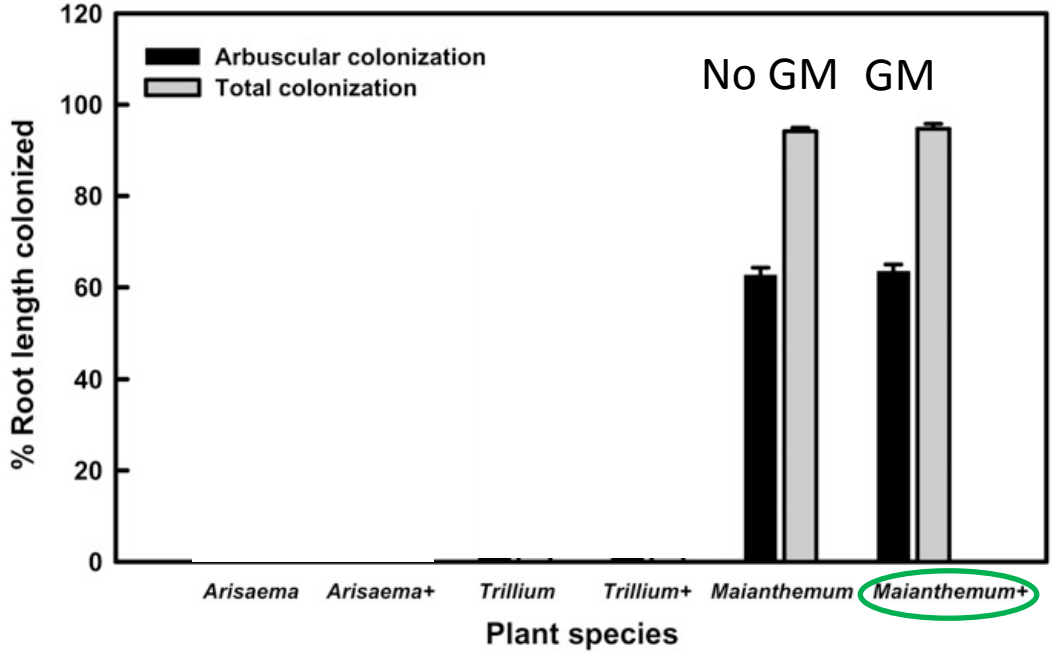
Stinson et al. 2006 *PLoS Biol*

GM can disrupt mycorrhizal colonization



Field study

Burke 2008 *Am J Bot*



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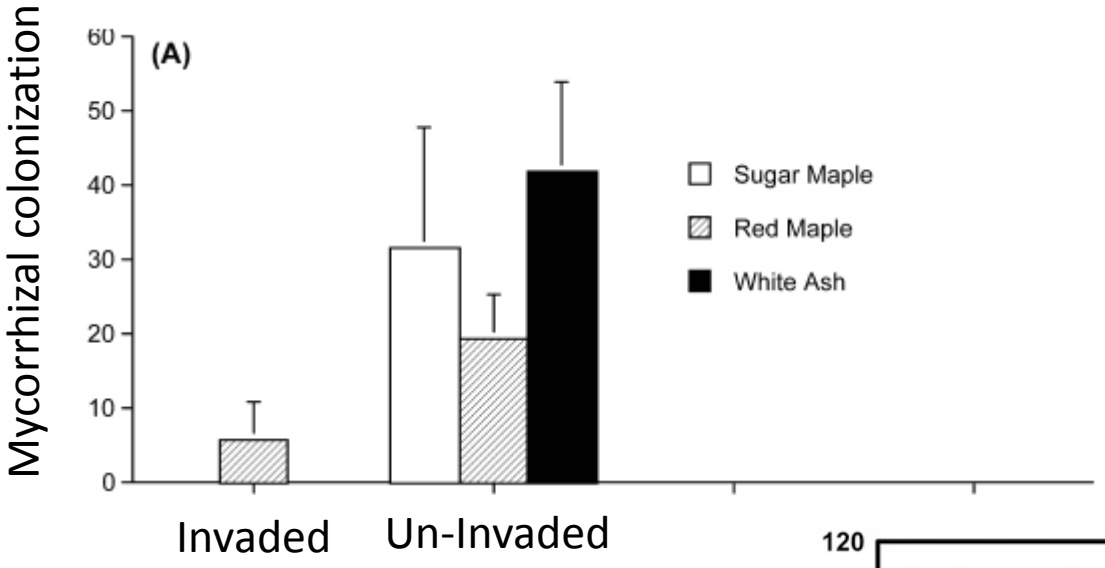
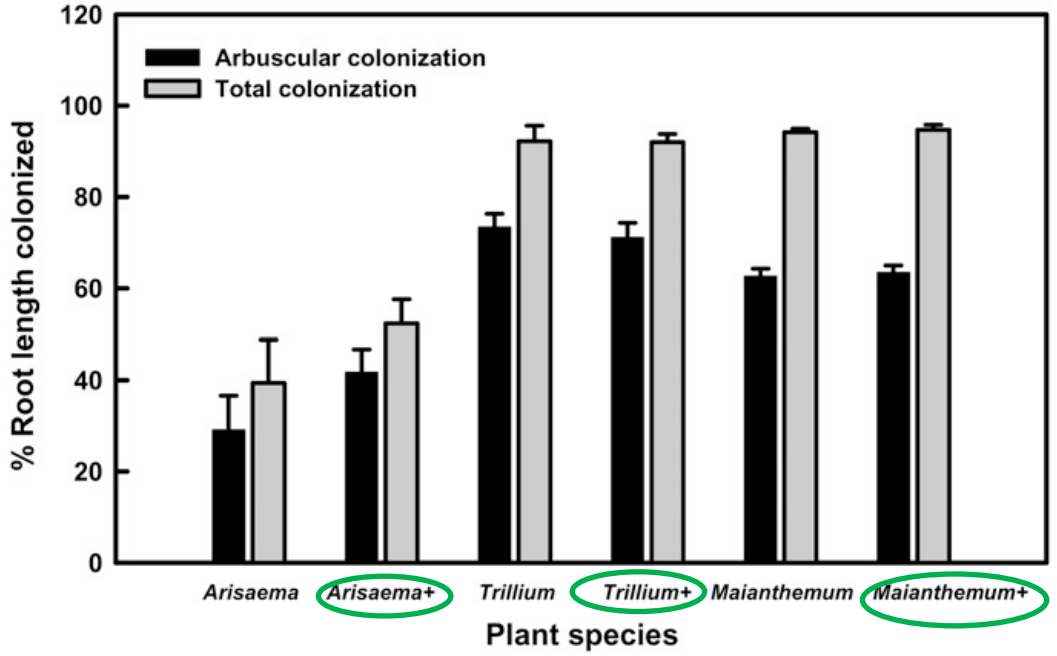
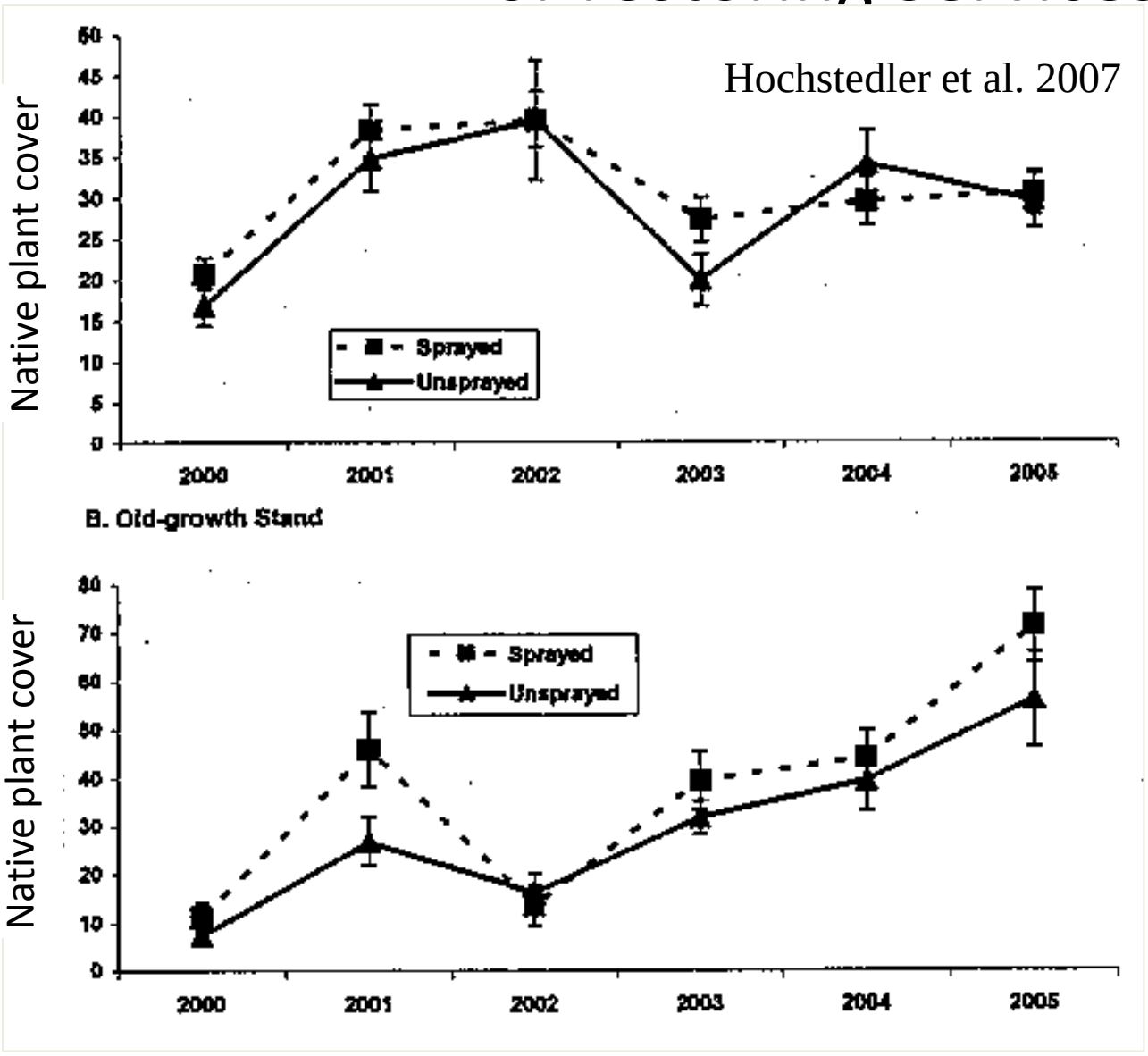




Are control efforts focused on eliminating exotics or restoring Services?

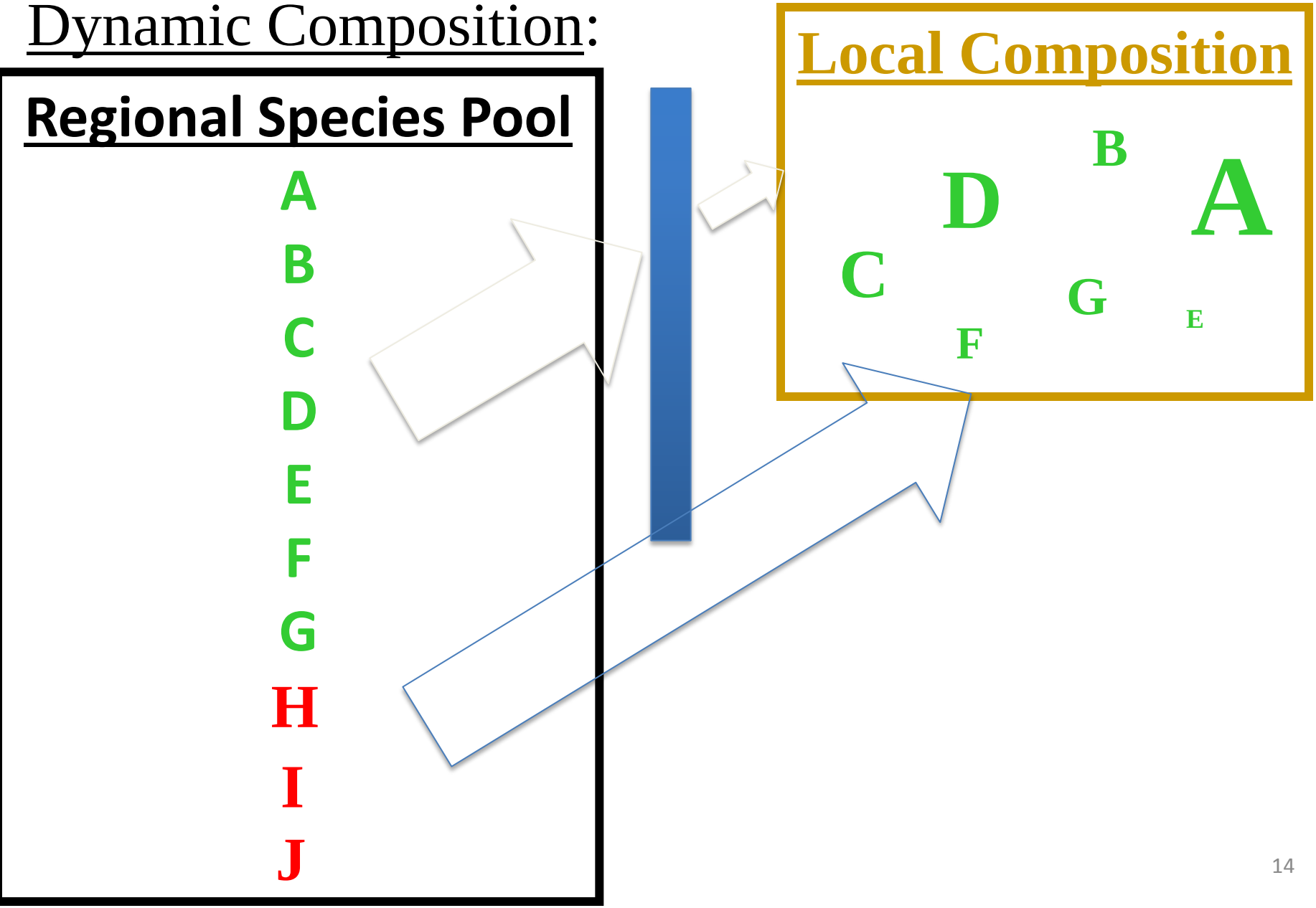


Q: Does control equate to ***Restoration****?*

Q: What limits native plant recover?

What Limits Natives? - Route 1: Invasive Traits

Dynamic Composition:



What Limits Natives? - Route 1: Invasive Traits

Dynamic Composition:

Regional Species Pool

A
B
C
D
E
F
G
H
I
J

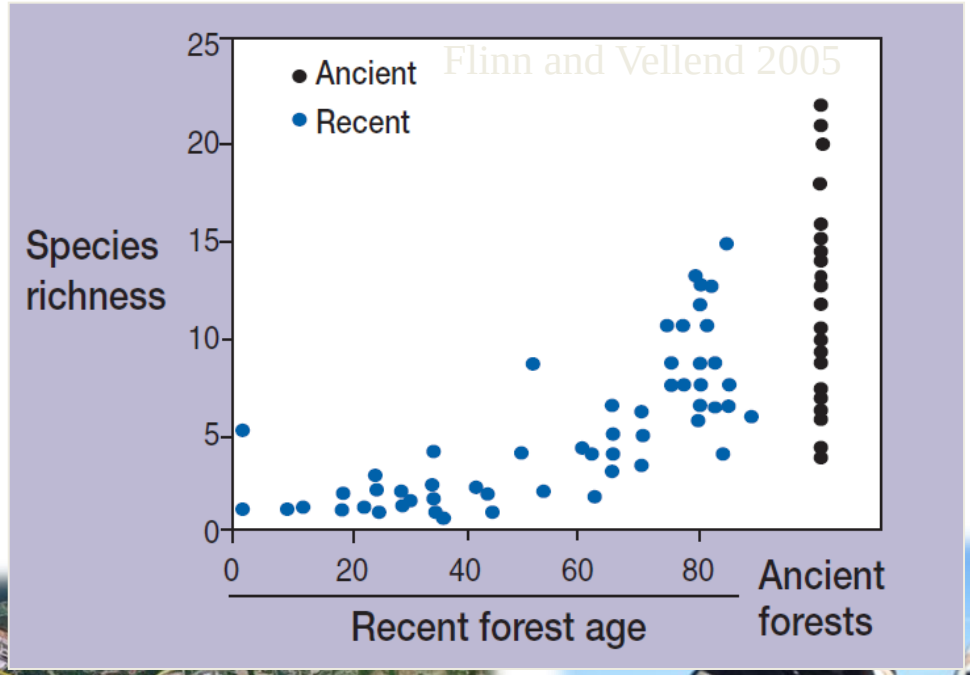
Local Composition

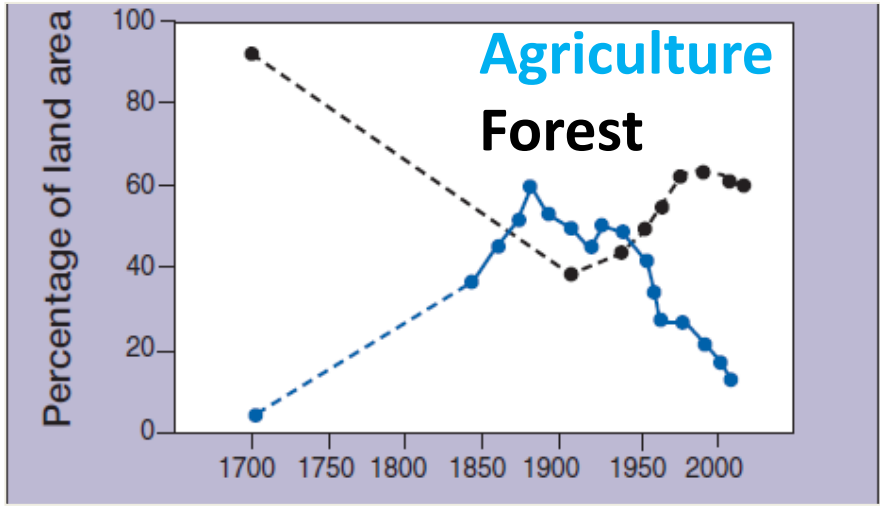
I D B J A C H G F E

Exotics dominate by increasing native plant extinction or by reducing their establishment.

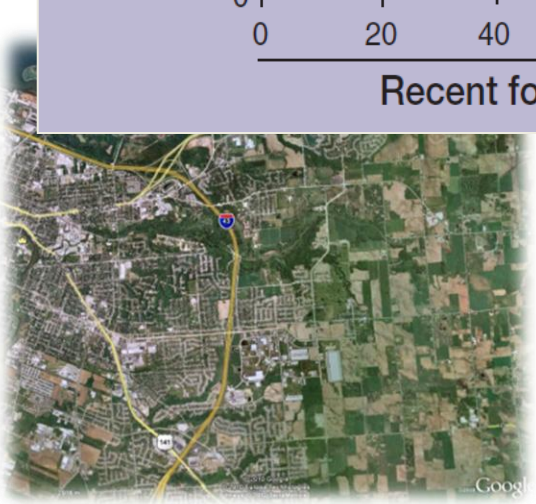
What Limits Natives? - Route 2: Ecosystem States

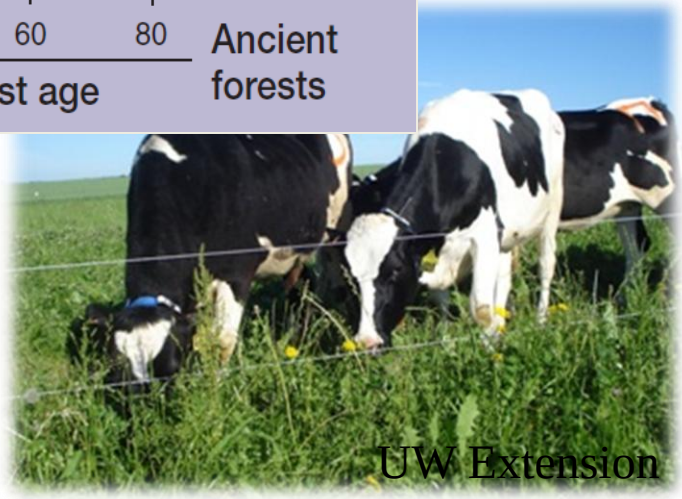
Low native understory diversity may just reflect past land use





Flinn and Vellend 2005





UW Extension

WHAT LIMITS NATIVES? - ROUTE 2: ECOSYSTEM STATES

Asymmetric herbivory may promote loss of preferred (native) species

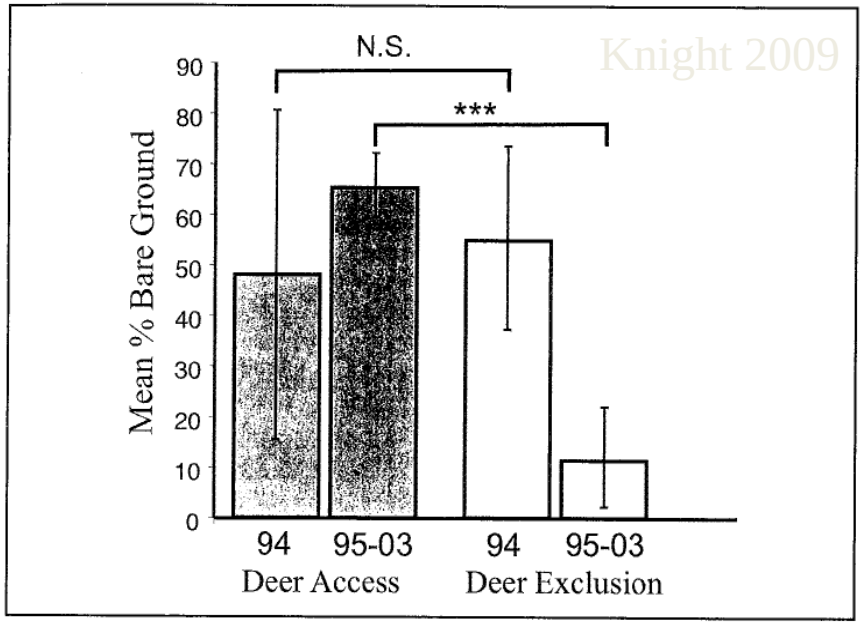
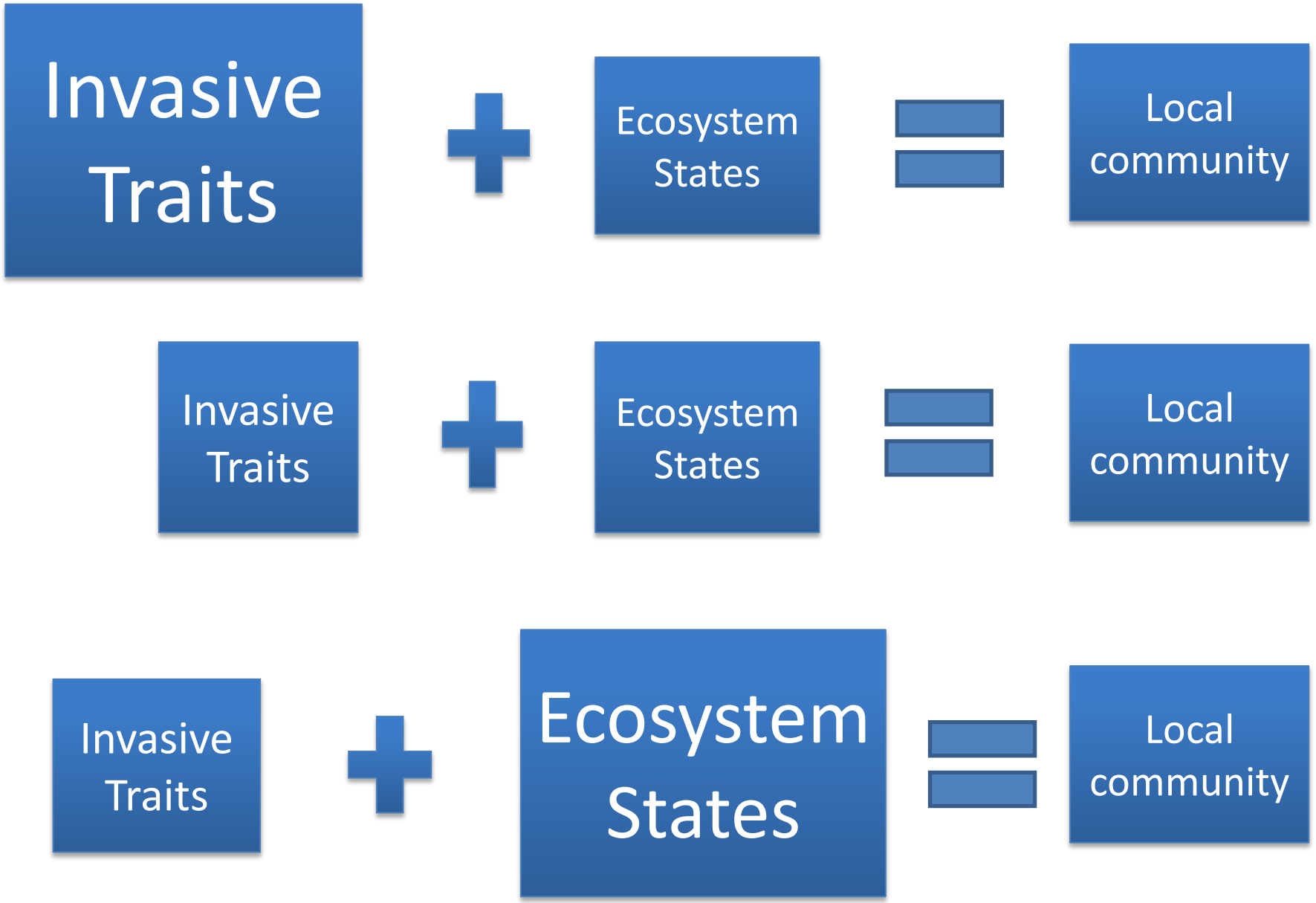


Figure 3. Percent bare ground (mean ± SE) is significantly greater in deer access vs. deer exclusion plots. Plots did not differ at beginning of the experiment (1994), but % bare ground decreased significantly in deer exclusion plots (grand mean of plots 1995-2003; *** $p<0.0005$, t-test, $t = 3.73$)..

Local Composition

I A B J E C H D

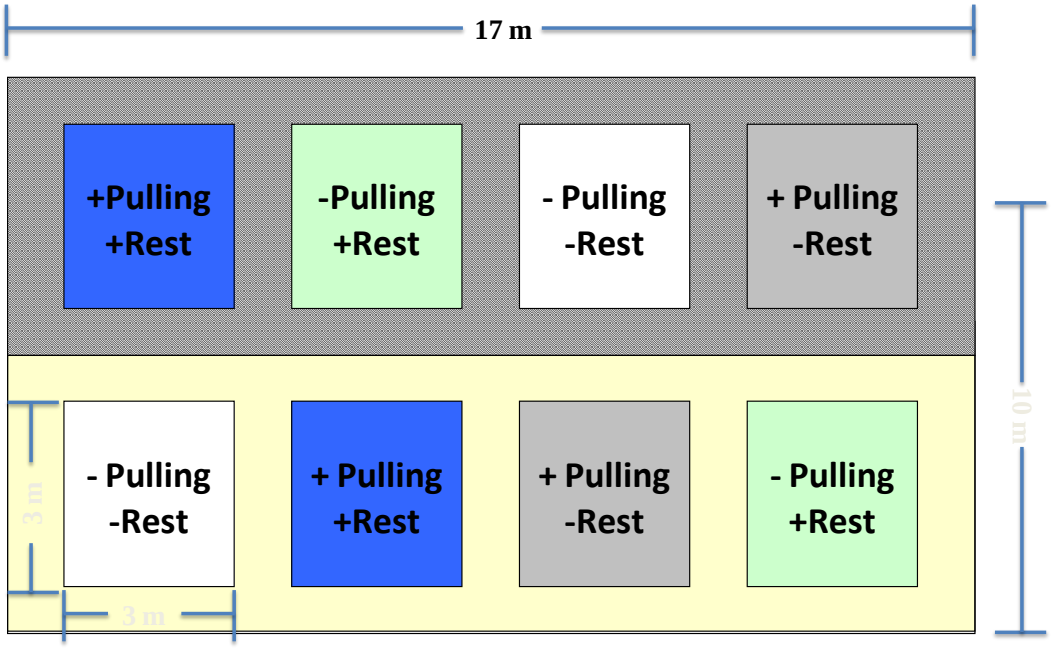

Invasive Traits
Ecosystem States
Local community
Invasive Traits
Ecosystem States
Local community
Invasive Traits
Ecosystem States
Local community

Study Site:

- **Beach Wildlife Sanctuary, Green Bay, WI**
- **Overstory**
  - **Basswood**
  - **Box elder**
  - **Green ash**
- **Understory**
  - **Garlic mustard**
  - **Few native plants**

Experimental treatments

- Invasive plant traits / competition:
  - Garlic mustard (pulled or not pulled)
- Ecosystem States:
  - Deer exclosures
  - Native plant restoration

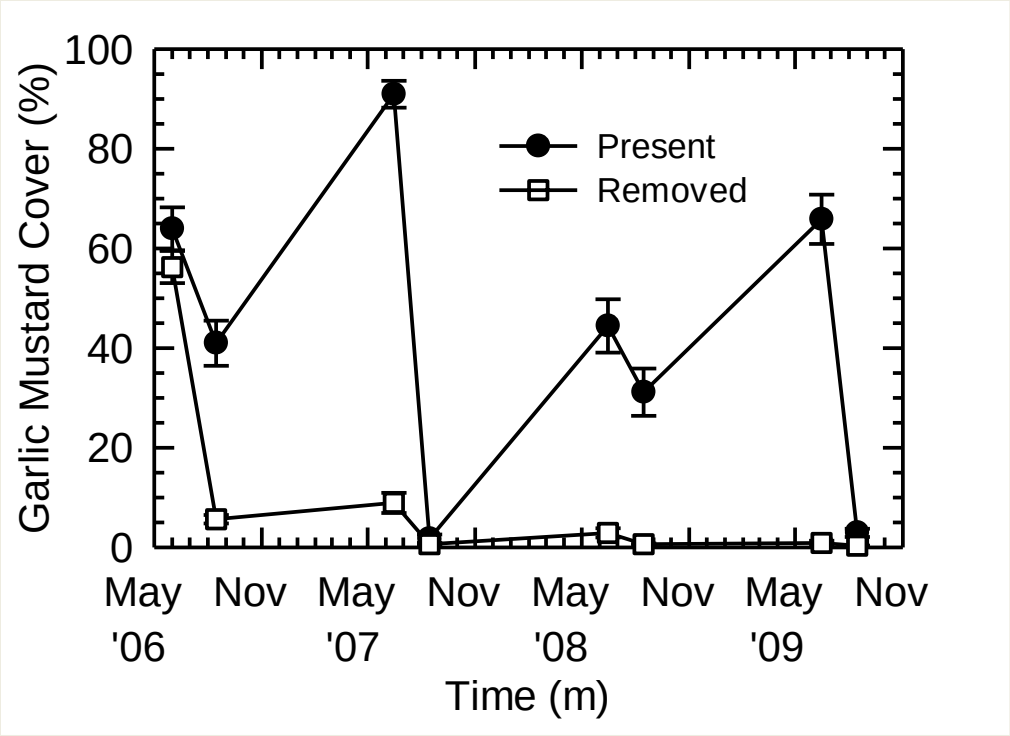


Replicated in 4 blocks

Restored native plant species

Species	Planting years	Density (#/9 m^2)	Seeding (seeds/9 m^2)
Ageratina altissima	2006/2008	27/8	608
Asarum canadense	2008	–/8	–
Aster cordifolius	2008	–/8	–
Bidens frondosa	2008	–/8	–
Cryptotaenia canadensis	2006/2008	7/8	158
Desmonium glutinosum	2006/2008	7/4	23
Elymus virginicus	2008	–/8	–
Geranium maculatum	2008	–/4	–
Hydrophyllum virginiatum	2008	–/8	–
Mertensia virginica	2006	2/–	45
Onoclea sensibilis	2008	–/3	–
Phlox divaricata	2006	1/–	23
Polemonium reptans	2006/2008	1/3	158
Prenanthes alba	2008	–/8	–
Rudbeckia laciniata	2008	–/8	–
Scutellaria lateriflora	2008	–/4	–
Solidago flexicaulis	2006/2008	27/8	608

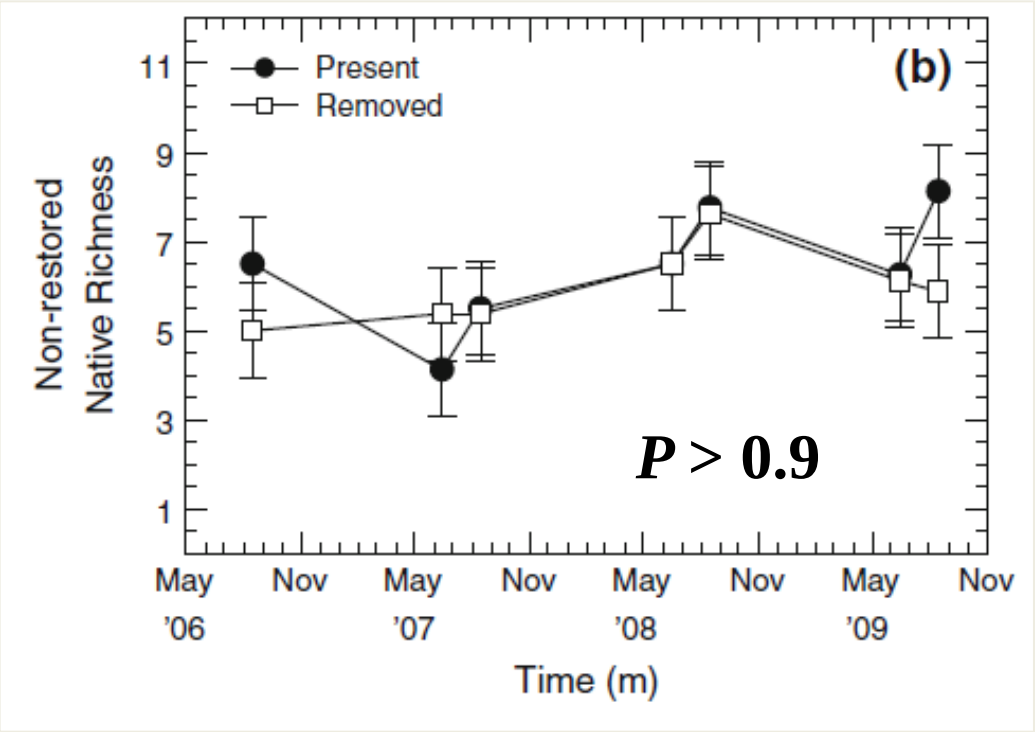
Results & Conclusions



Removal was very successful at eliminating garlic mustard

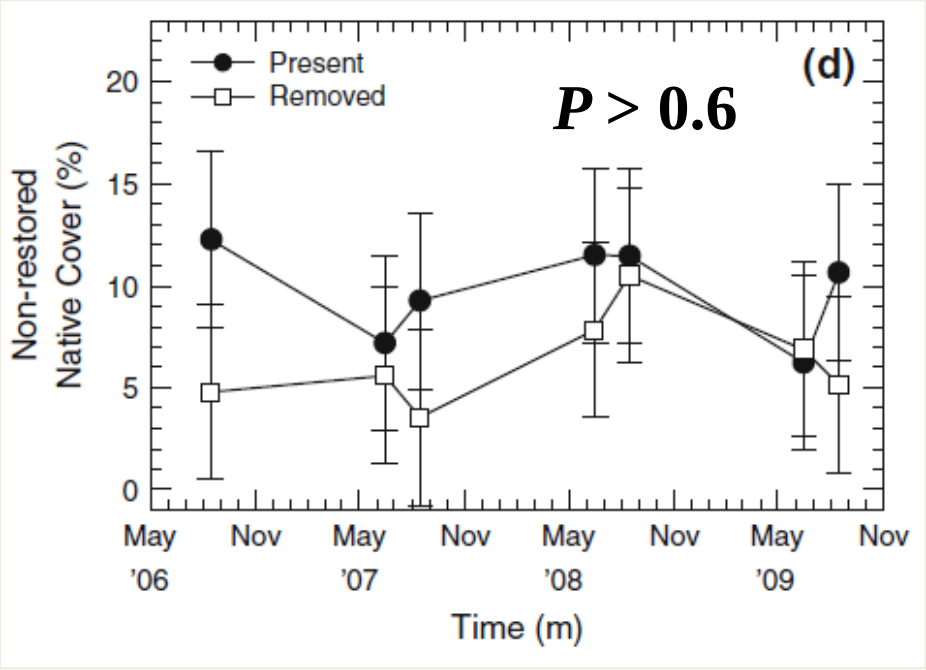
Dornbush and Hahn (2013) *Biol Invasions*

Removal alone was unsuccessful at restoring native richness



Dornbush and Hahn (2013) *Biol Invasions*

Removal alone was also unsuccessful at restoring native cover



Dornbush and Hahn (2013) *Biol Invasions*

Local Composition

I A J D H

Regional Species Pool

A
B
C
D
E
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I
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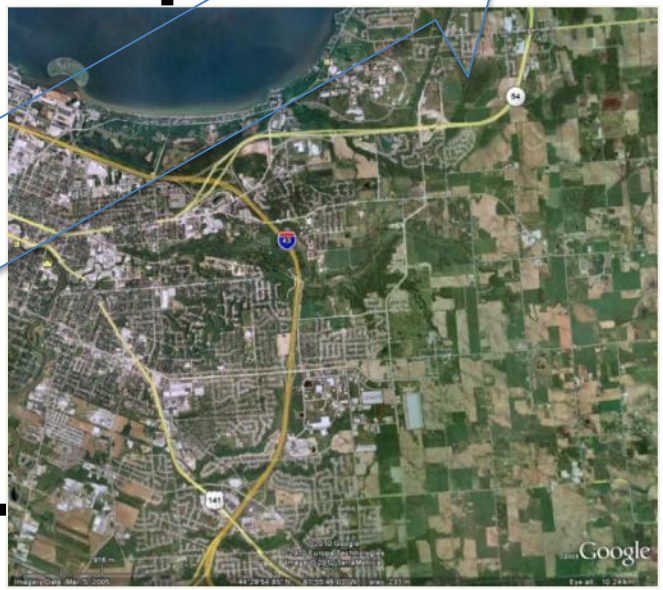
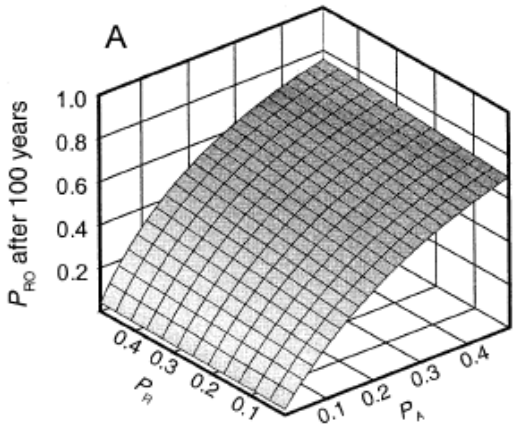
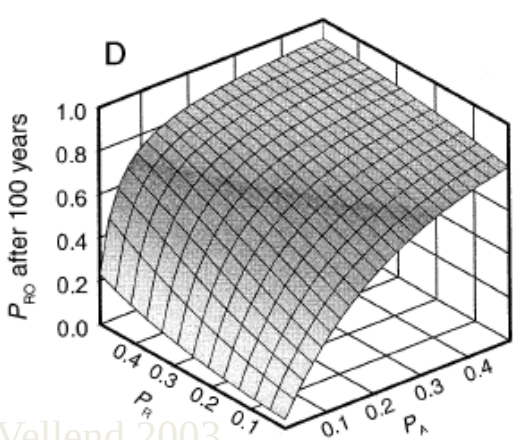


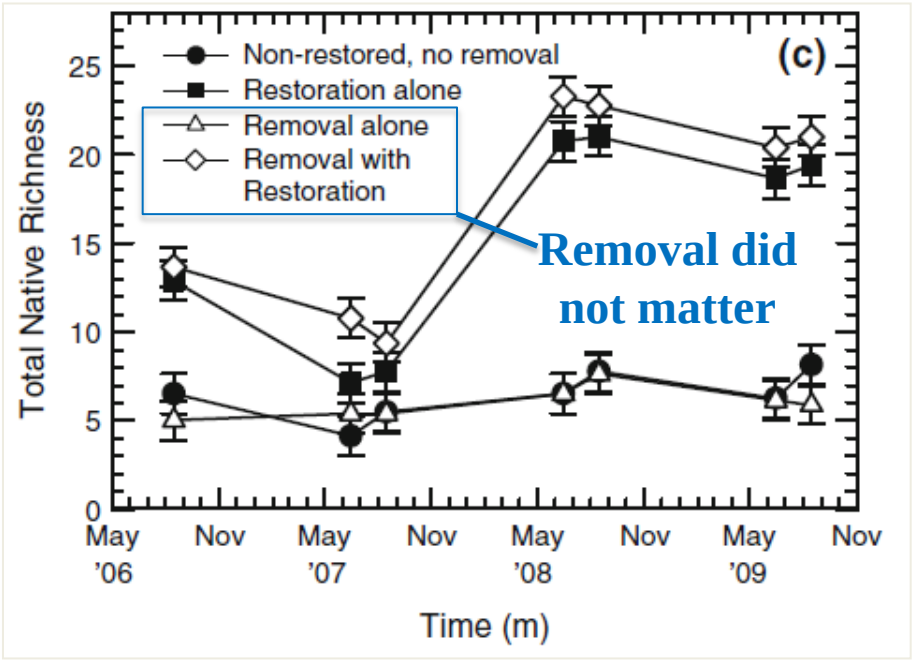


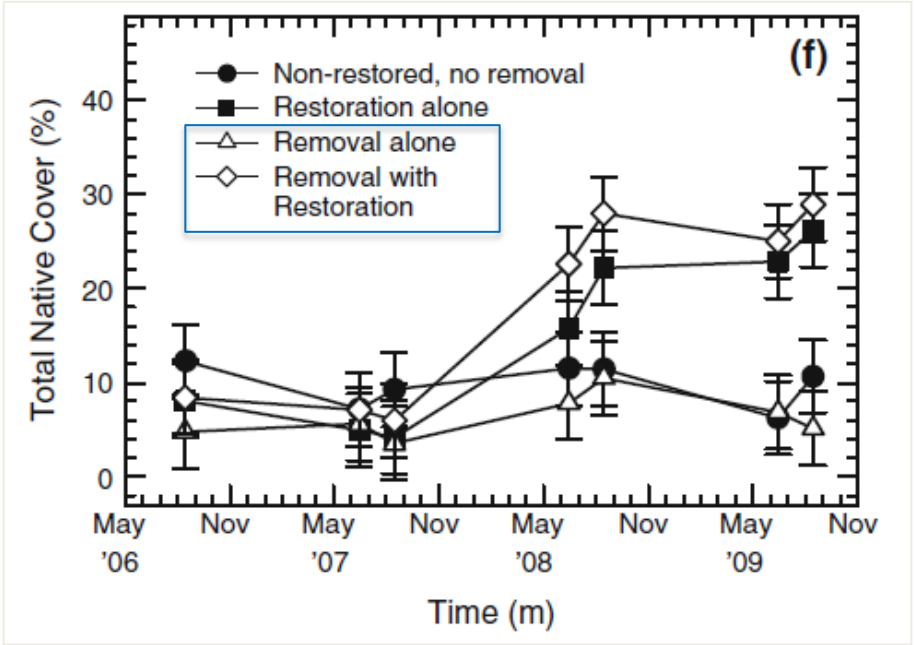


Low native diversity appeared due, in large part, to establishment limitations

Vellend 2003

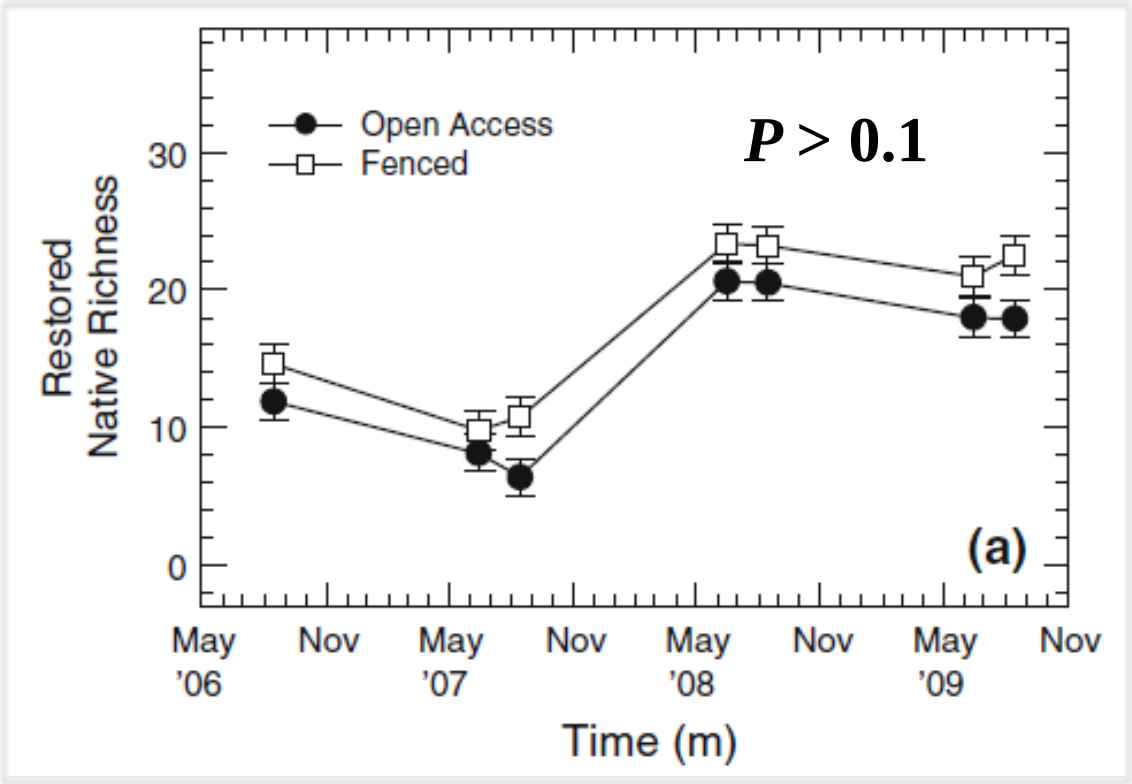
Restoration was required, but garlic mustard removal had no effect





Dornbush and Hahn (2013) *Biol Invasions*

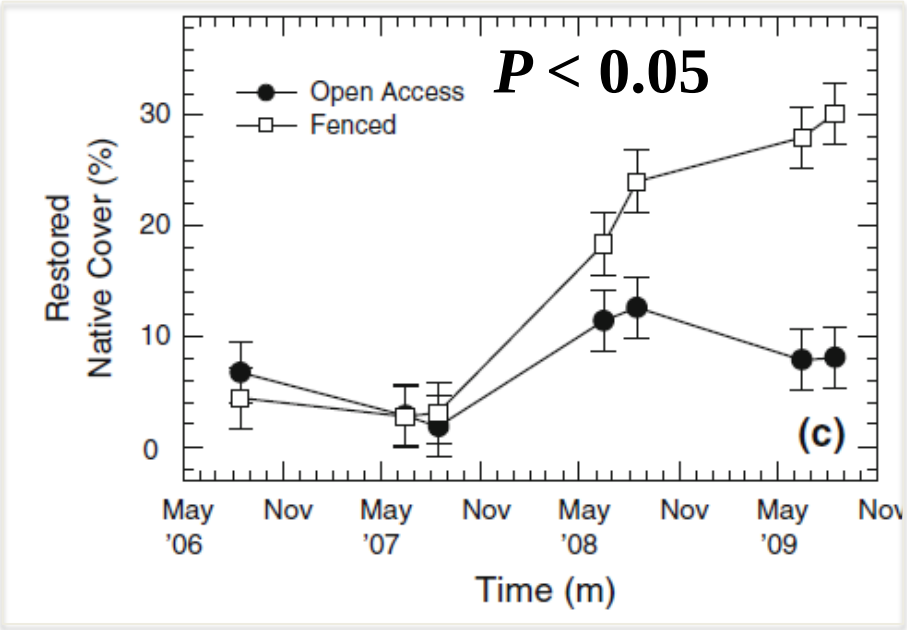
Excluding deer did not affect restored richness: many small plants remained



Dornbush and Hahn (2013) *Biol Invasions*

Excluding deer strongly increased native plant cover in restored plots

White-tailed Deer



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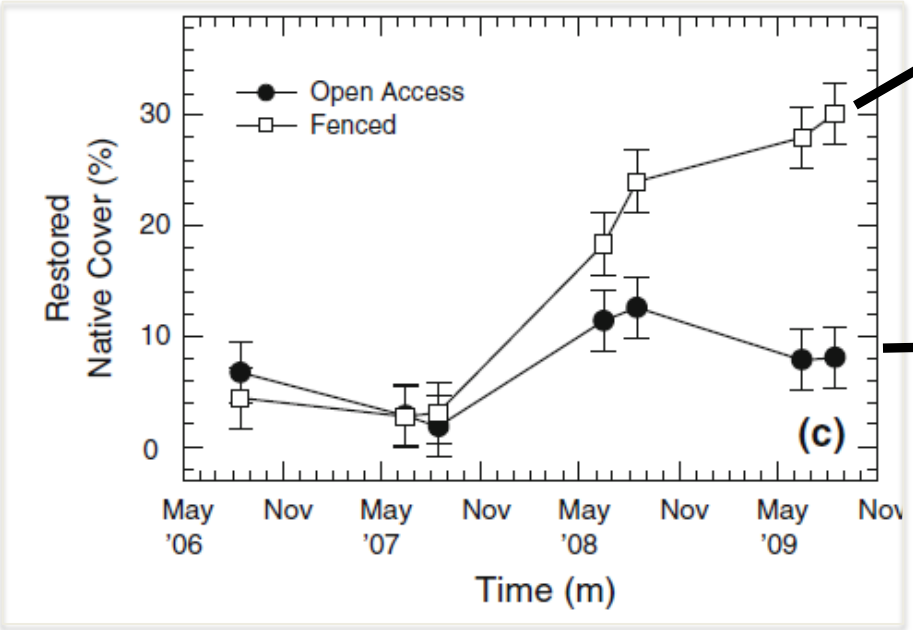

Deer Access

$F = 9.98, P < 0.05$

Dornbush and Hahn (2013) *Biol Invasions*

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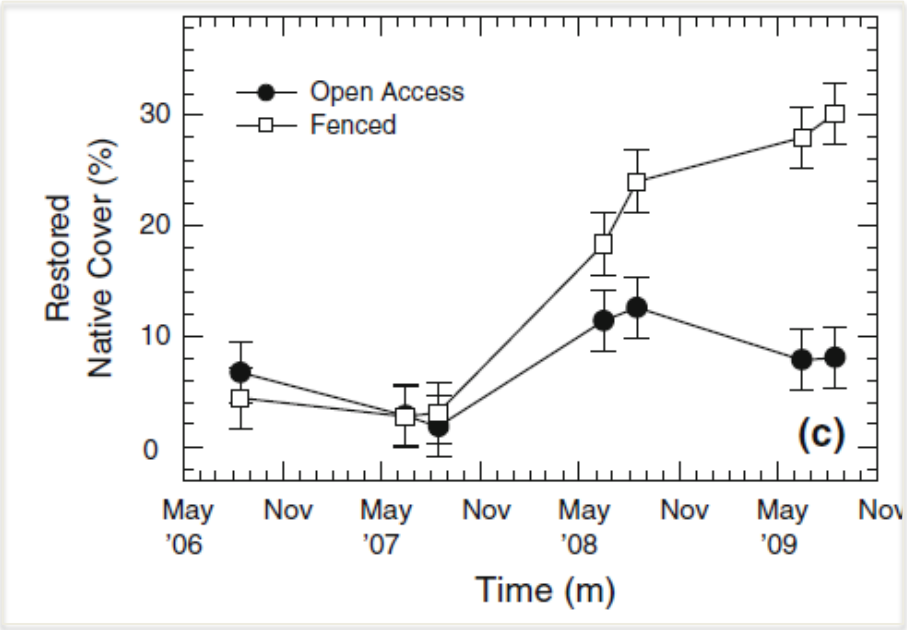
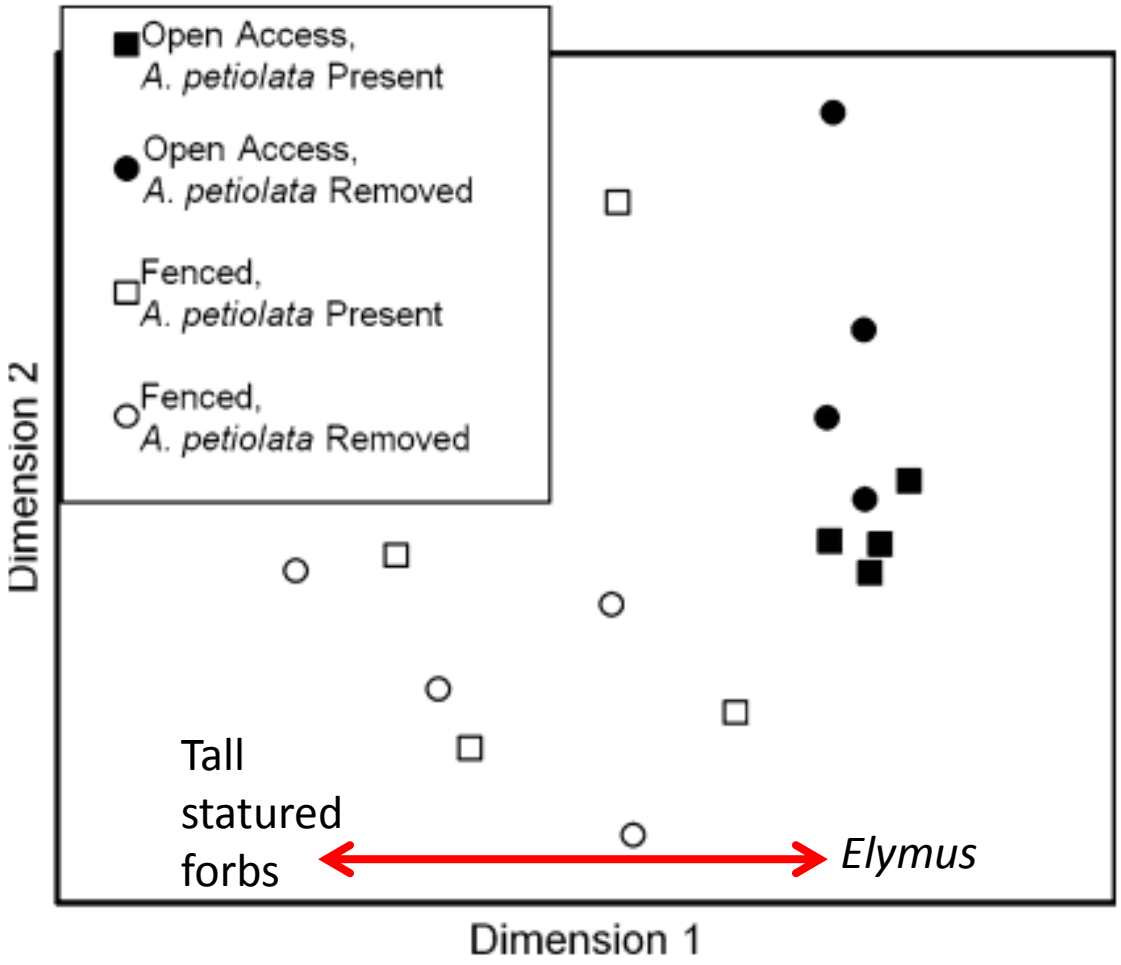


Dornbush and Hahn (2013) *Biol Invasions*

Deer herbivory effects were strong, and selective toward native, non-grass, erect forbs



Dornbush and Hahn (2013) *Biol Invasions*

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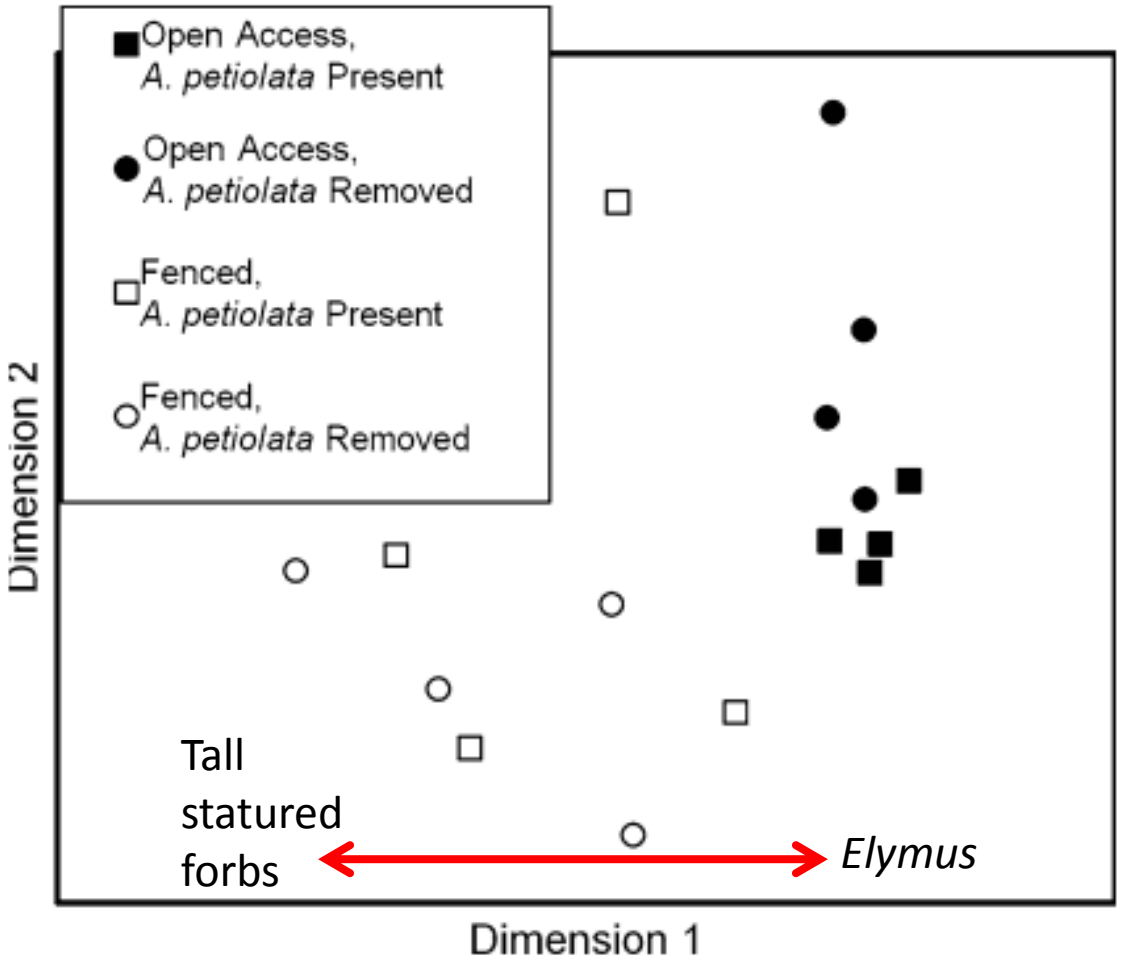
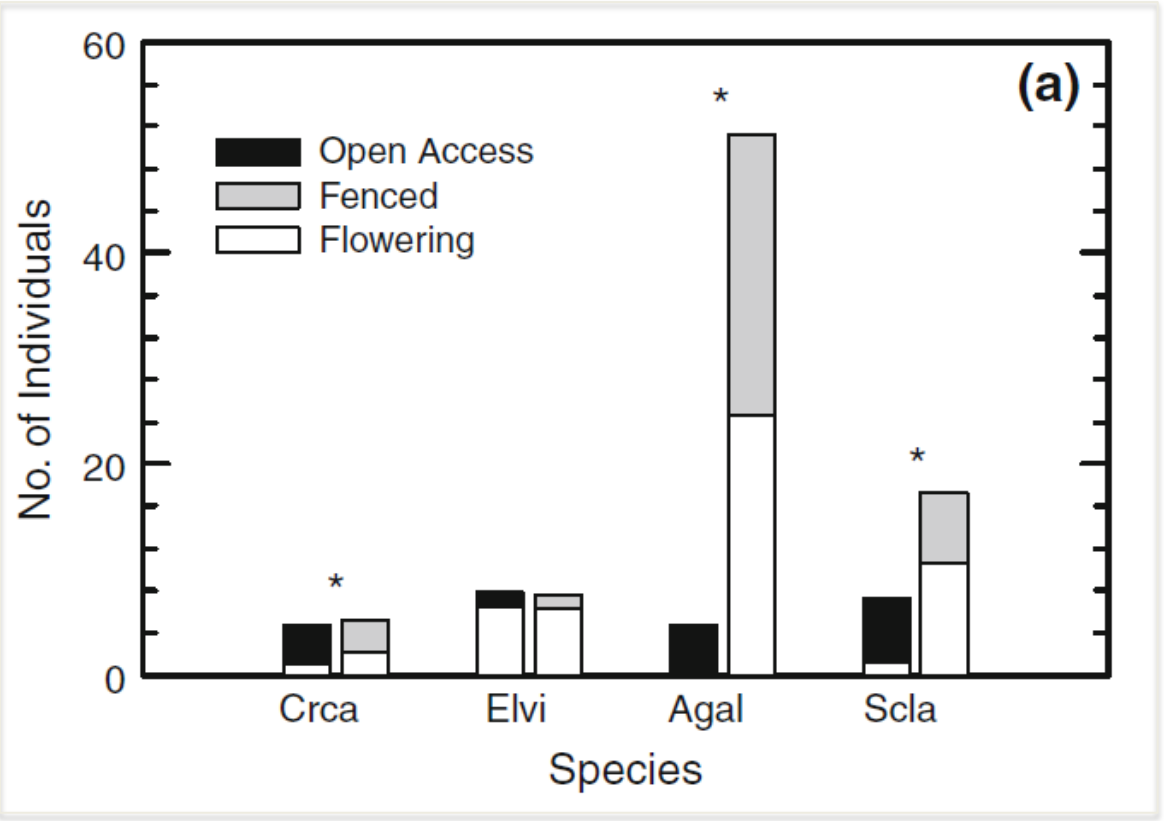


Dornbush and Hahn (2013) *Biol Invasions*

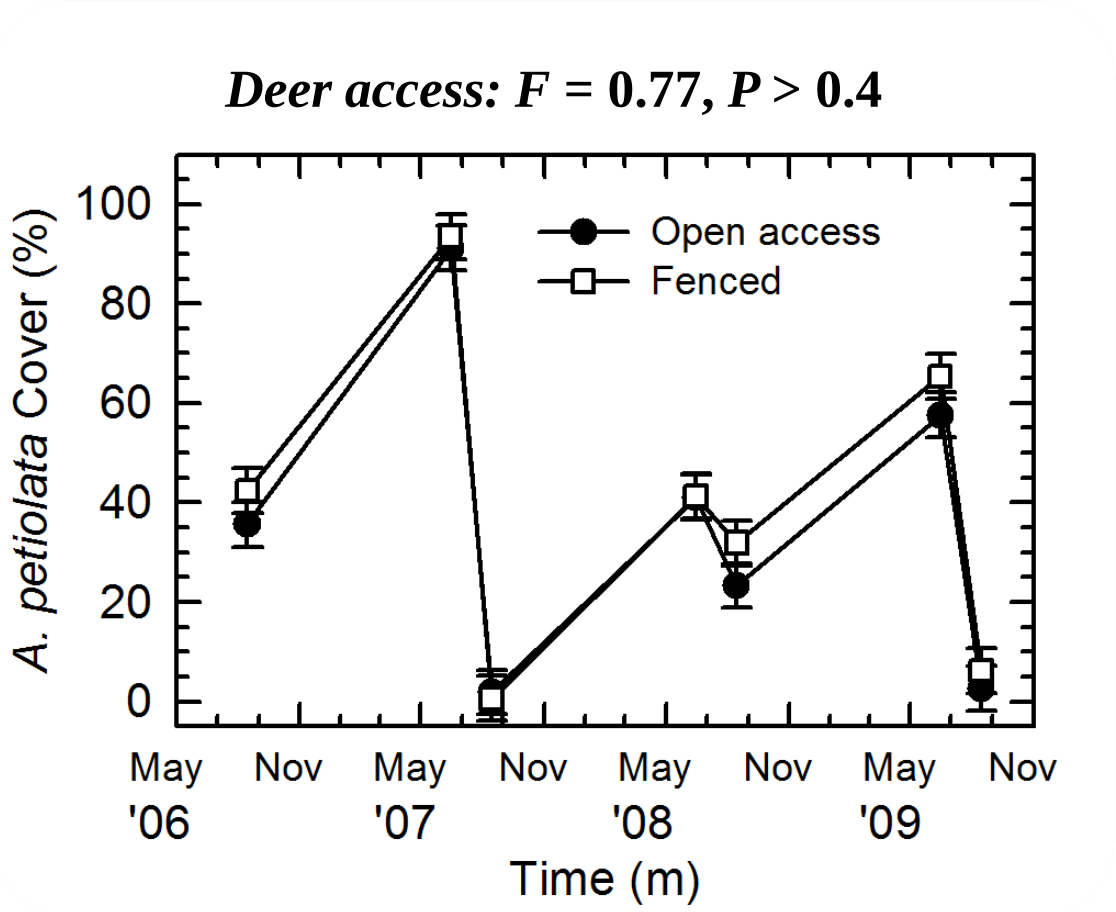
Deer access, but not garlic mustard removal, strongly affected native flowering



- **Four other native species only flowered inside fencing**

Dornbush & Hahn (2013) *Biol Invasions*

No deer effects on GM: Asymmetric Herbivory



Hahn and Dornbush (2012) *Biol Invasions*

Cryptic Herbivory

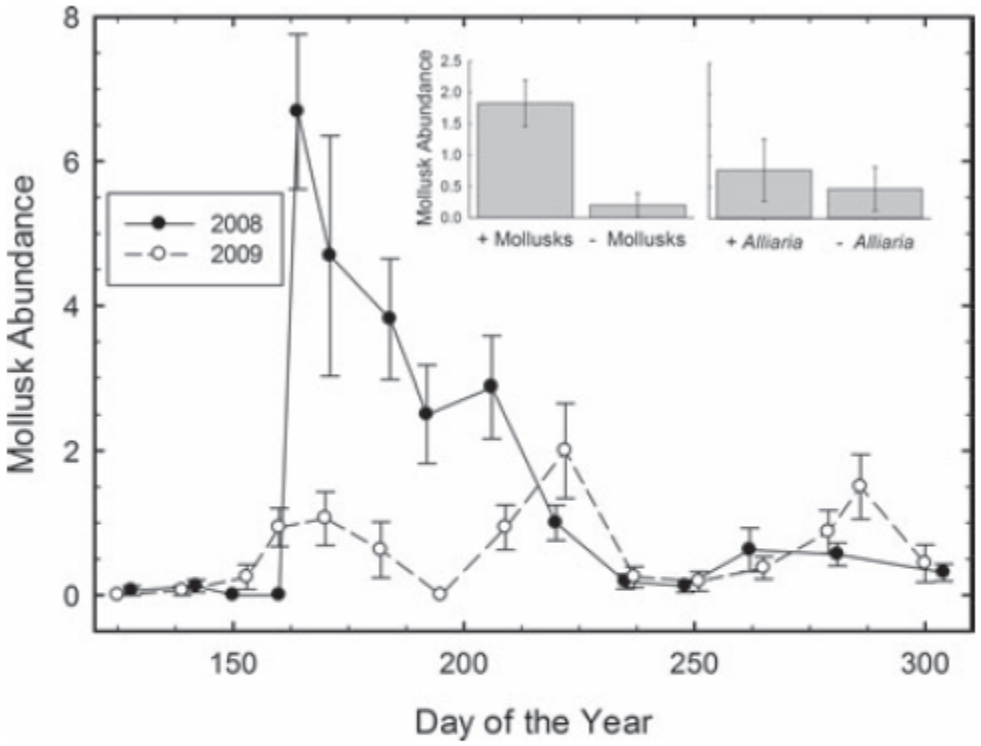
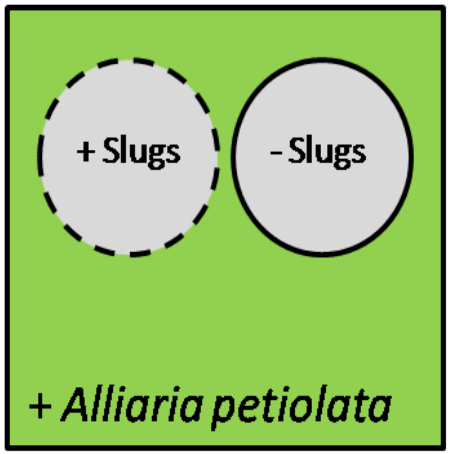
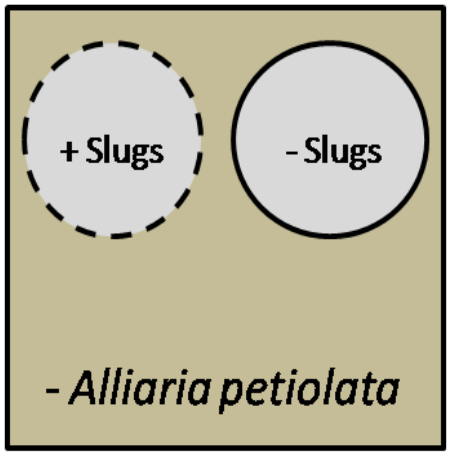


Fig. 1 Temporal trends of mollusk abundance measured over two years in a Midwestern forest. Data are means (±1 SE) of mollusks counted on 10 cm × 10 cm cardboard traps from all split-plots sampled on each date. Inset figures are pooled treatment means analyzed using a generalized linear mixed model for the three peak abundance dates for each year (see Methods)

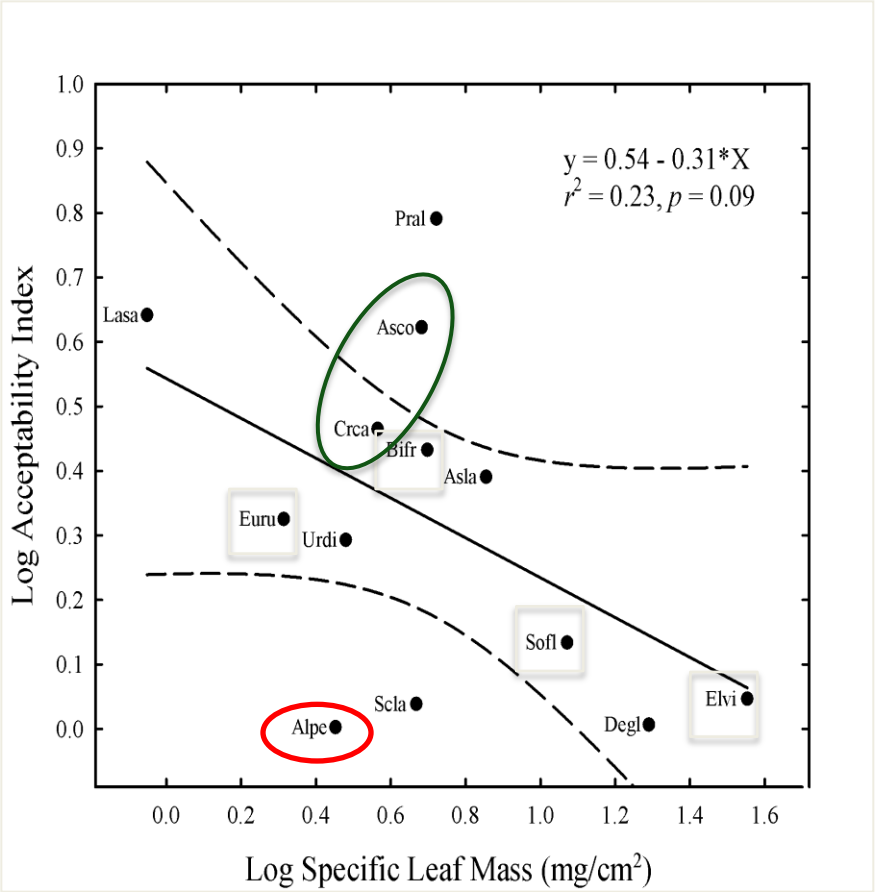
- Generalist herbivore native to Europe
- Introduced to North America ca. 1850

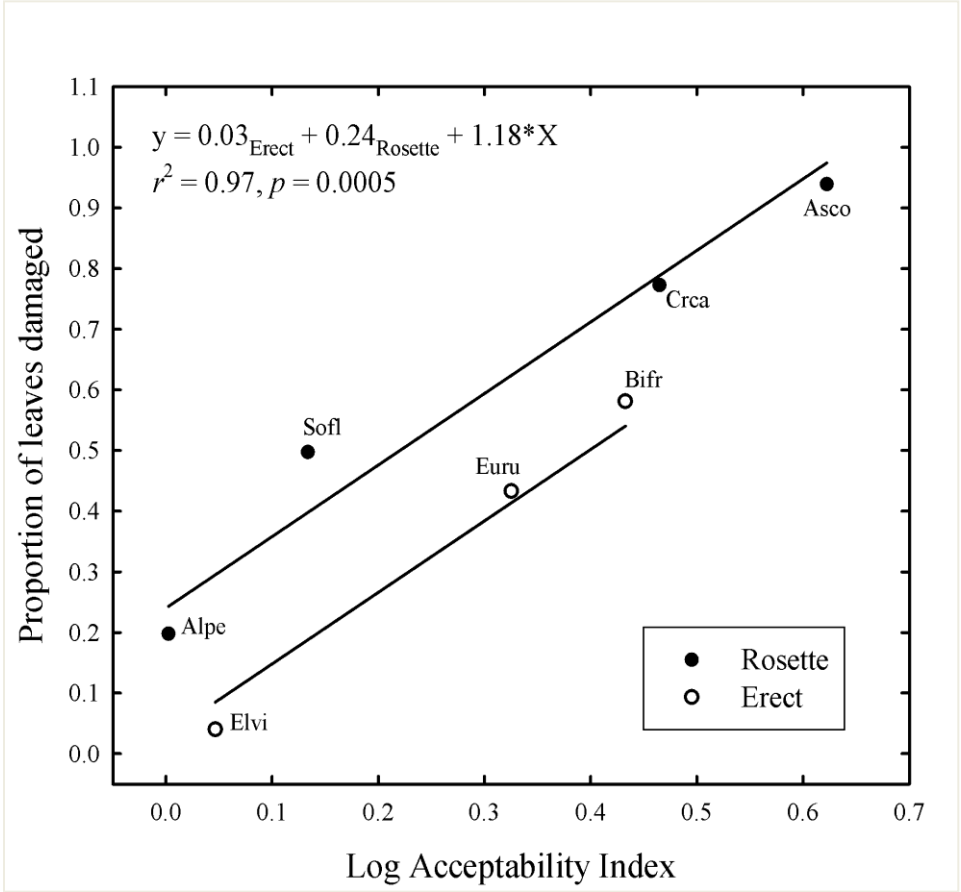
Slug Exclosures





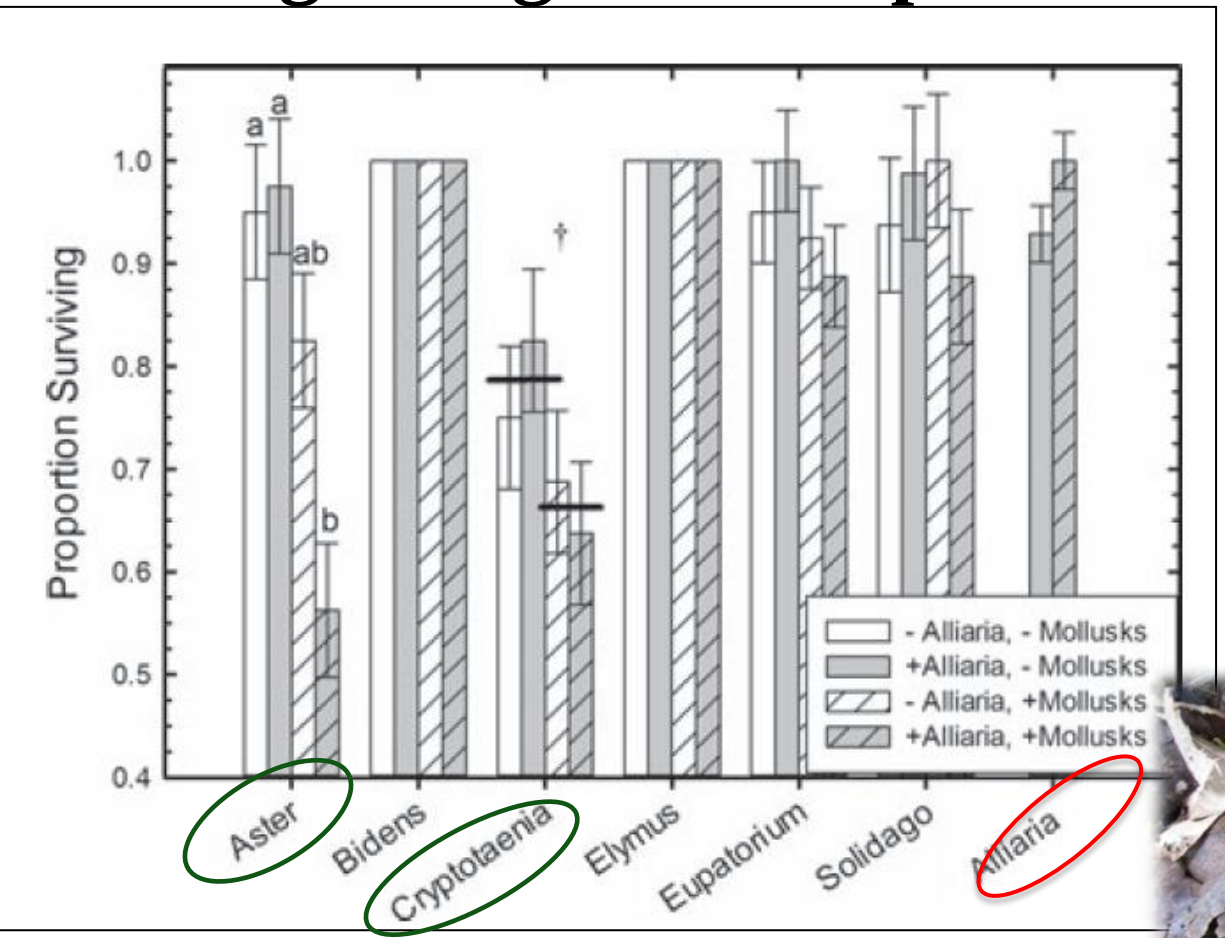
Trait dependent slug herbivory





D. reticulatum selectively affected growth and survival of rosettes and thinner leaved species

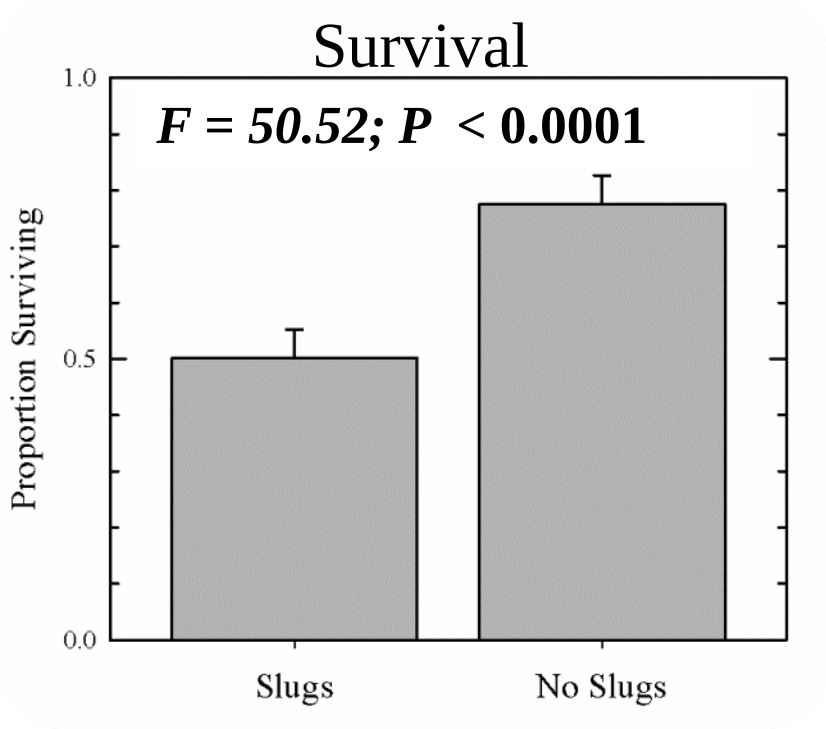
Seedling growth and survival was reduced by slug grazing for two species of native plants



Hahn and Dornbush (2012) *Biol Invasions*

Hahn & Dornbush (*2012*)

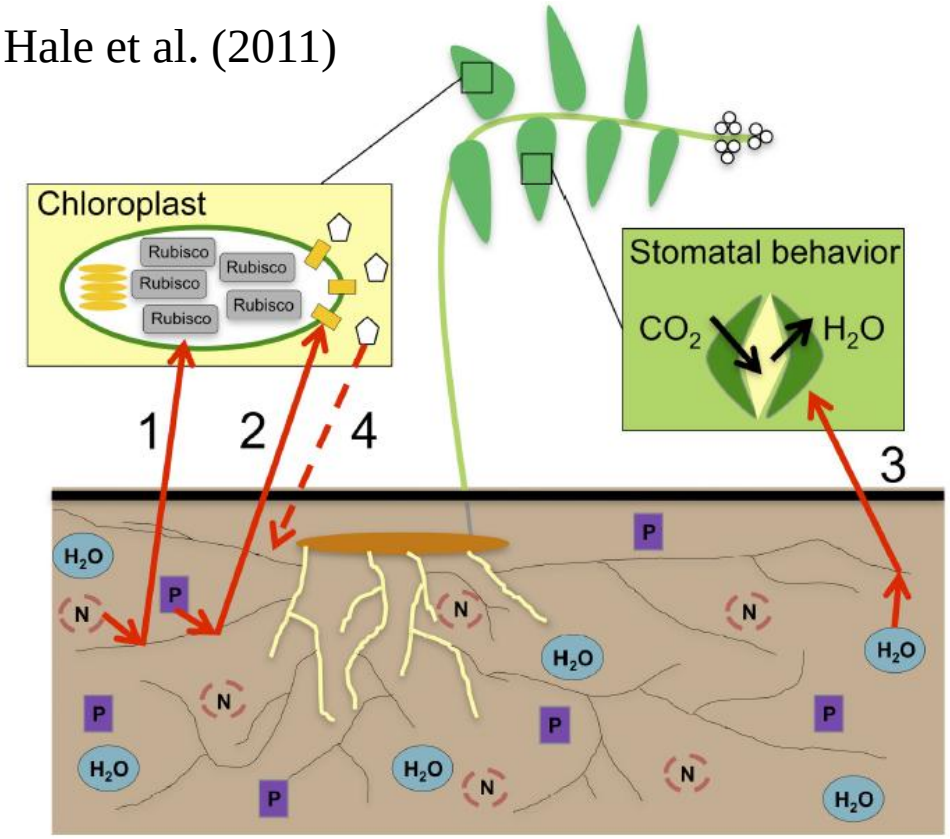
One-month *Aster* seedlings

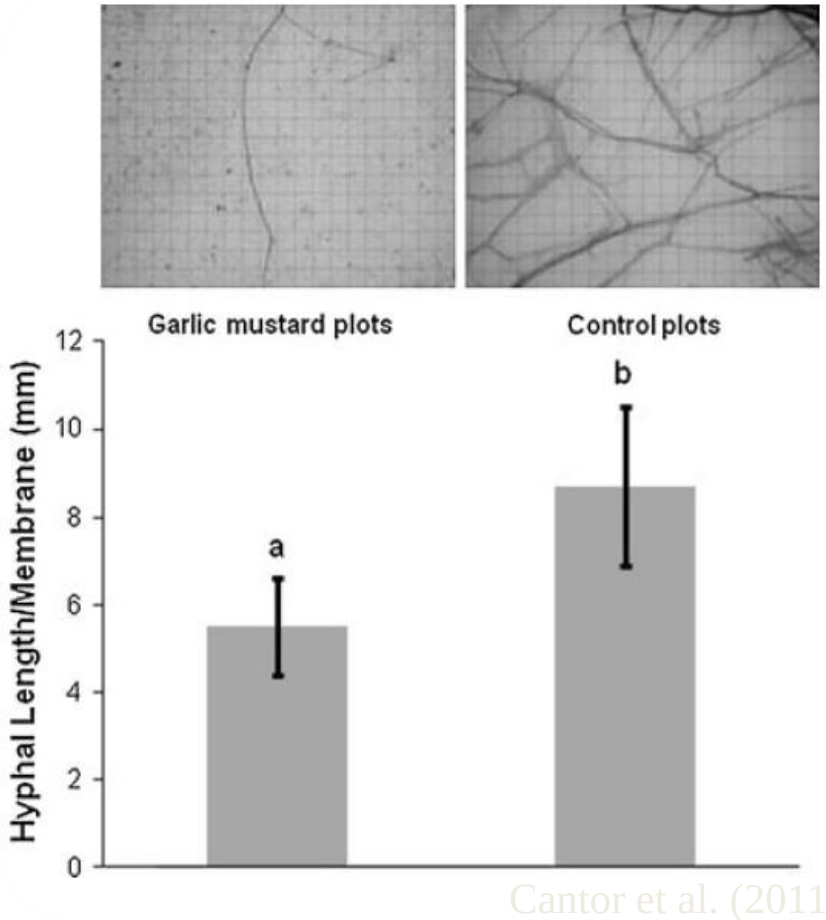


Slug grazing effects were stronger on smaller seedlings

Herbivory may enhance susceptibility to competition from GM

Hale et al. (2011)

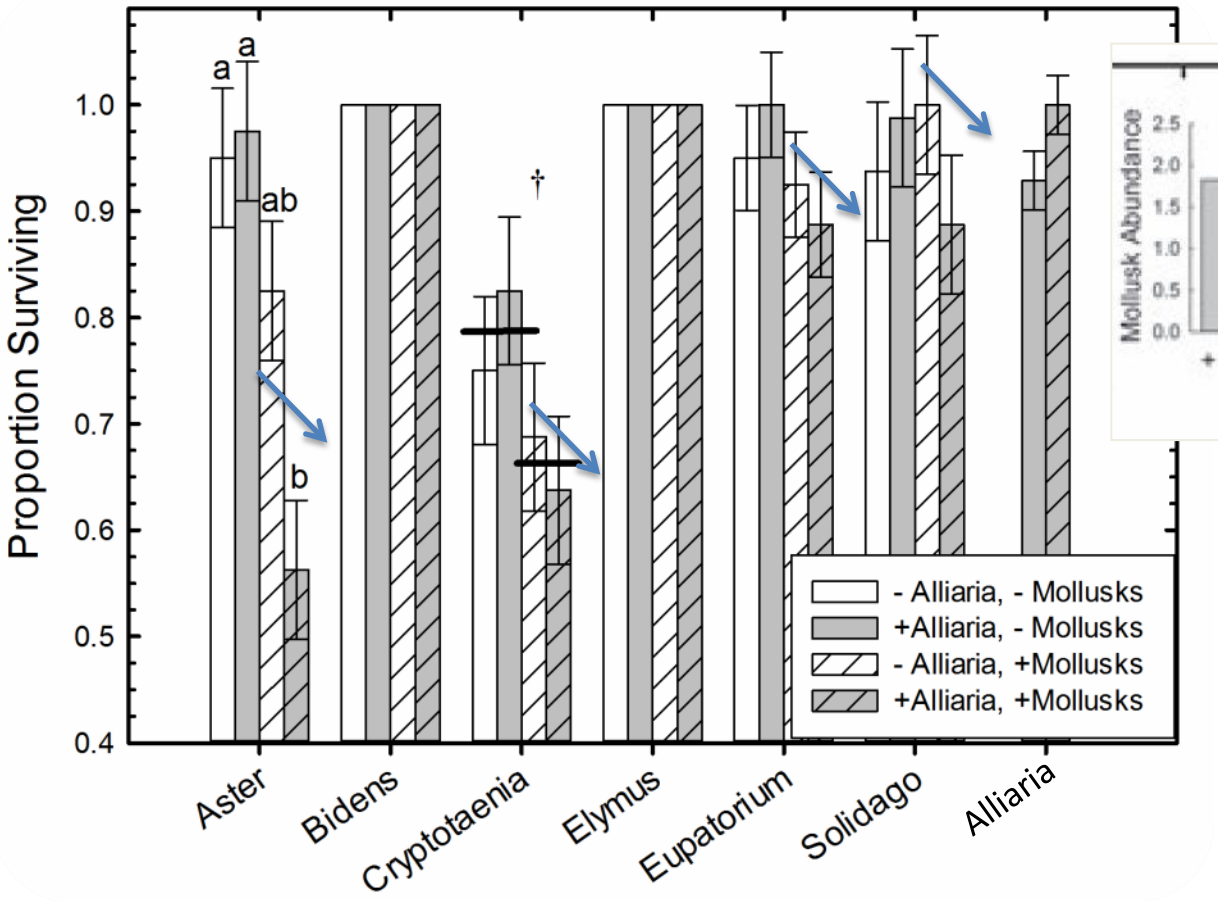


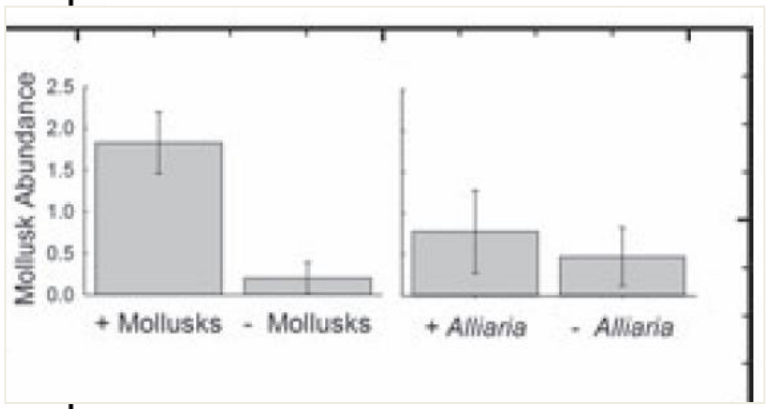


Cantor et al. (2011)

Hahn and Dornbush (2012)

Context dependency of competition

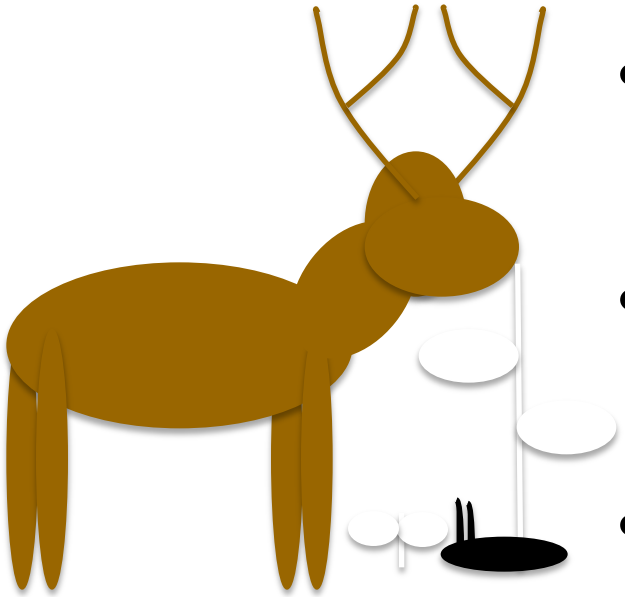




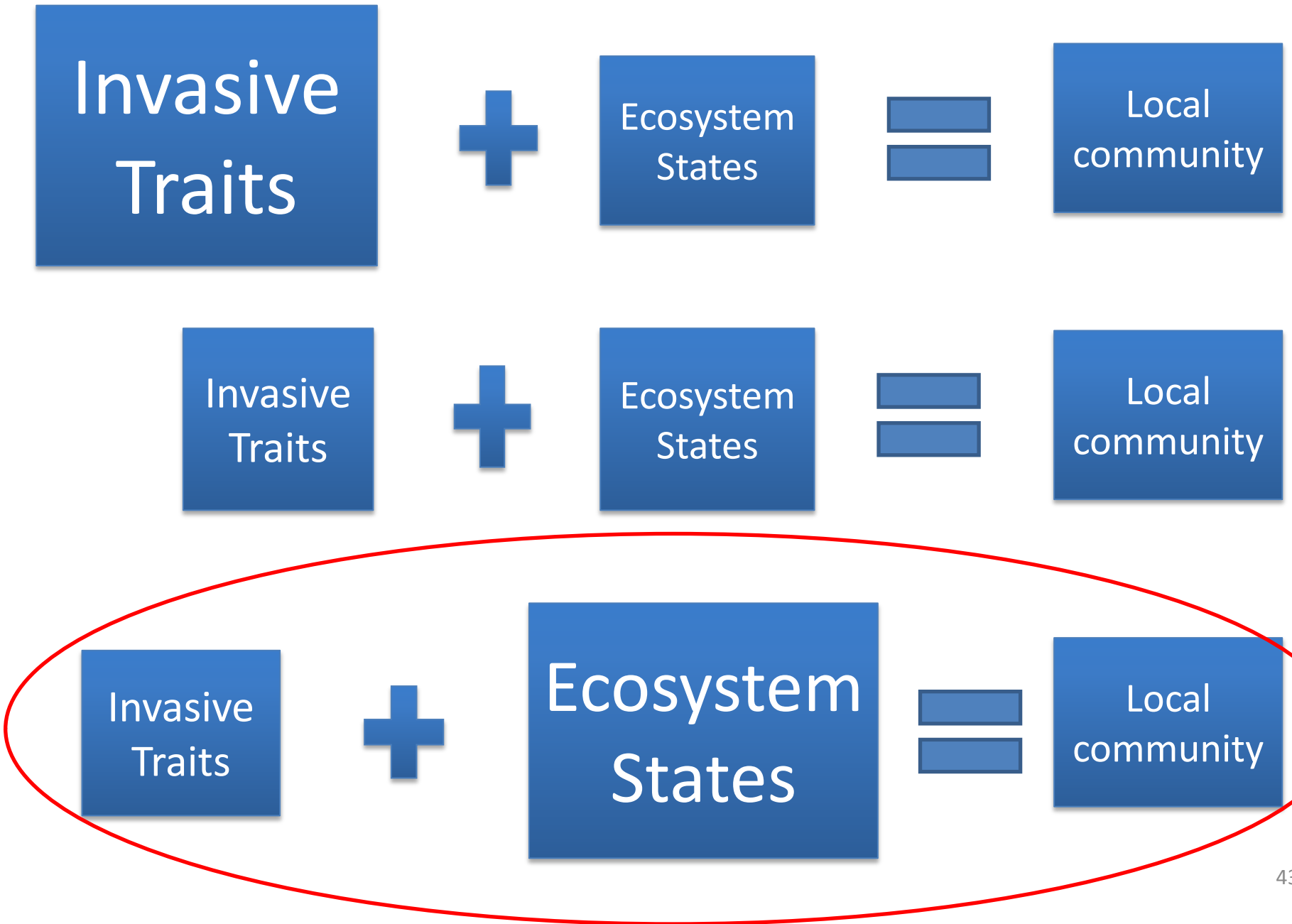
Slug abundance 60% greater in GM plots

For all palatable native species seedling survival was lowest in plots containing garlic mustard

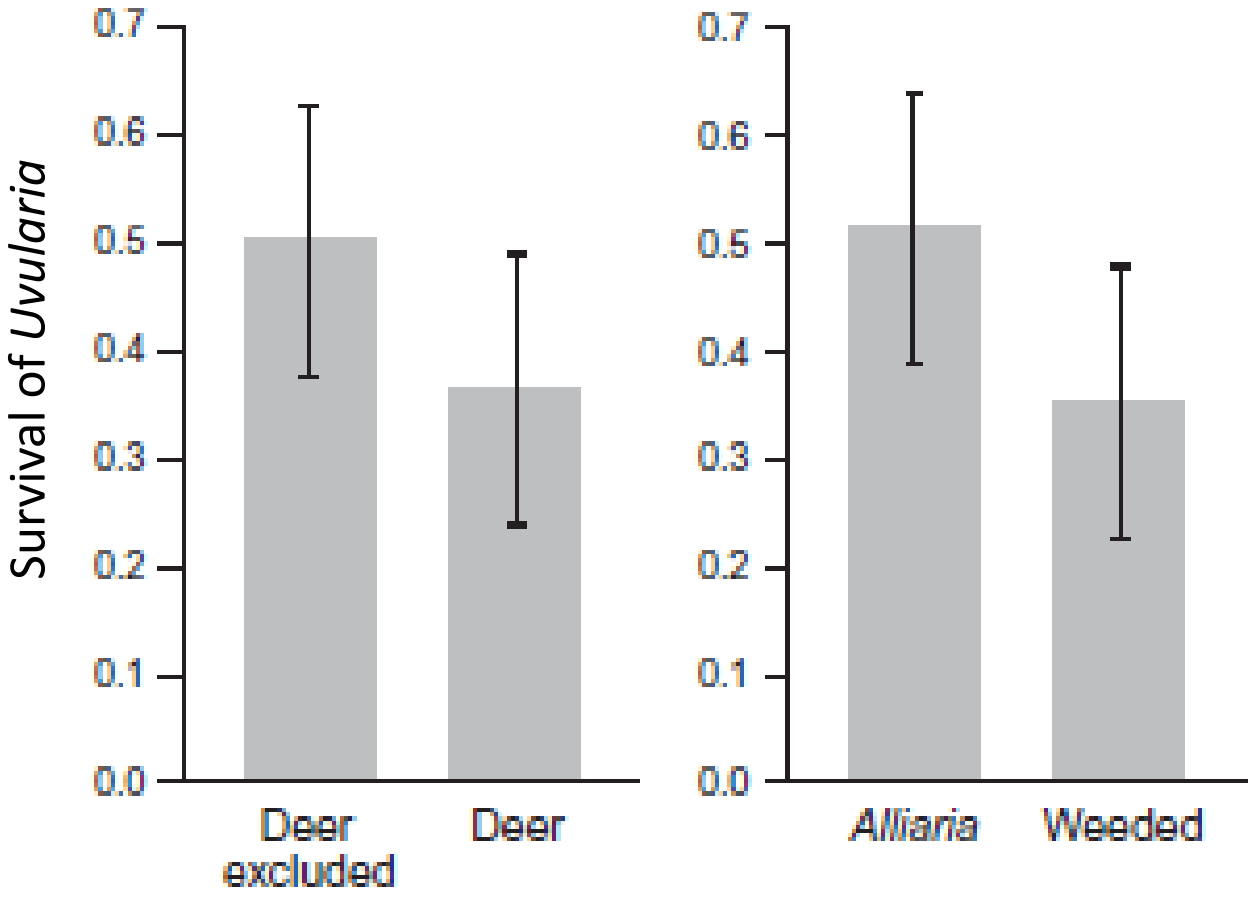
Take Home Conclusions:



- Removing garlic mustard did not increase regeneration of understory herbs
- Restoration of understory plants was required
- Herbivory affected native plants, but not garlic mustard
- Focus should be on ecosystem states rather than invasive plant traits


Invasive Traits
Ecosystem States
Local community
Invasive Traits
Ecosystem States
Local community
Invasive Traits
Ecosystem States
Local community

Unpalatable plants deter herbivory?



Waller and Maas 2013 *Forest Ecol Manag*

Future directions

- **How widespread are these effects?**
- Study sites in UP, Green Bay, and Milwaukee
- Examine spring ephemerals and tree species

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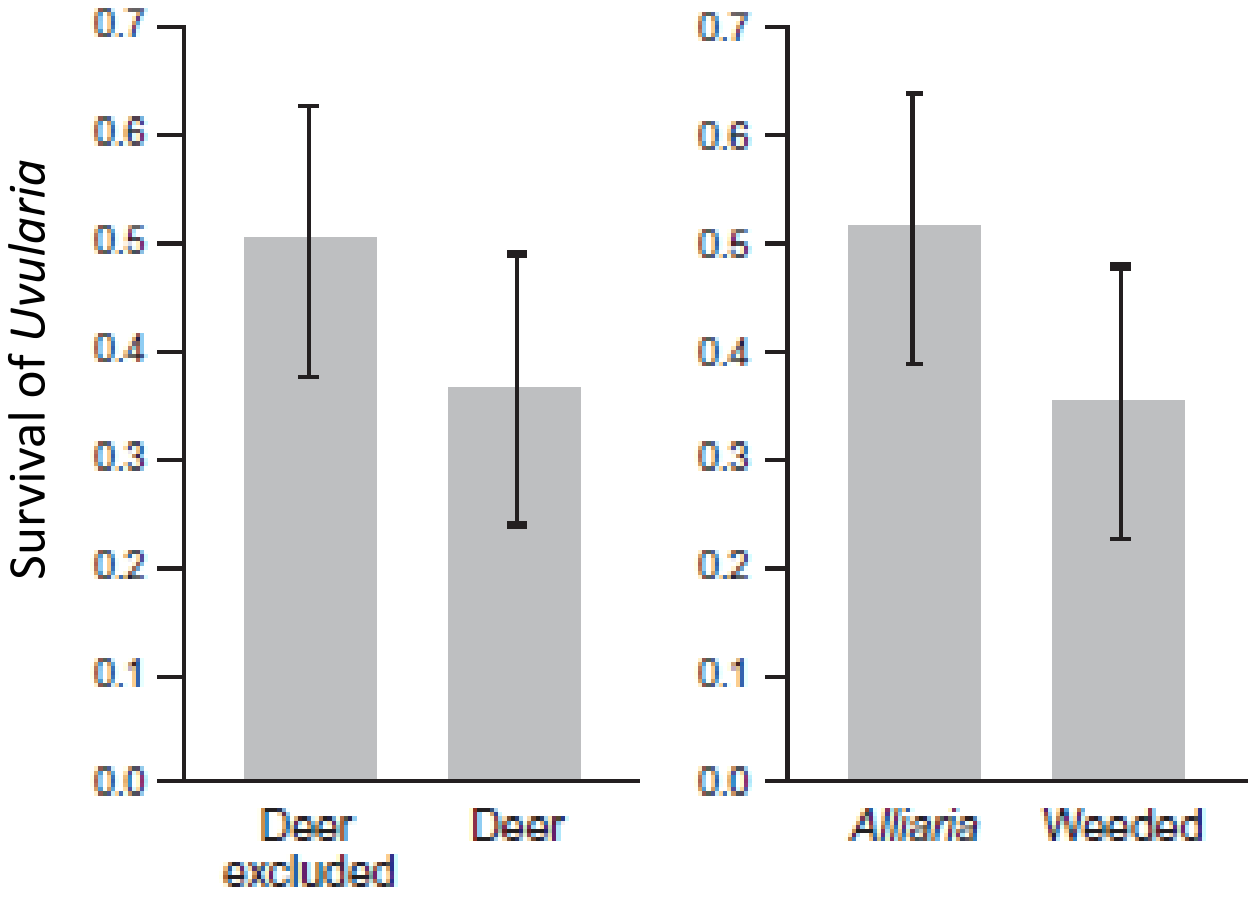
- Collaborators: M. Draney, M. Peterson, J. Heraly, L. Caelwaerts, R. Wactl, and S. Kolb.

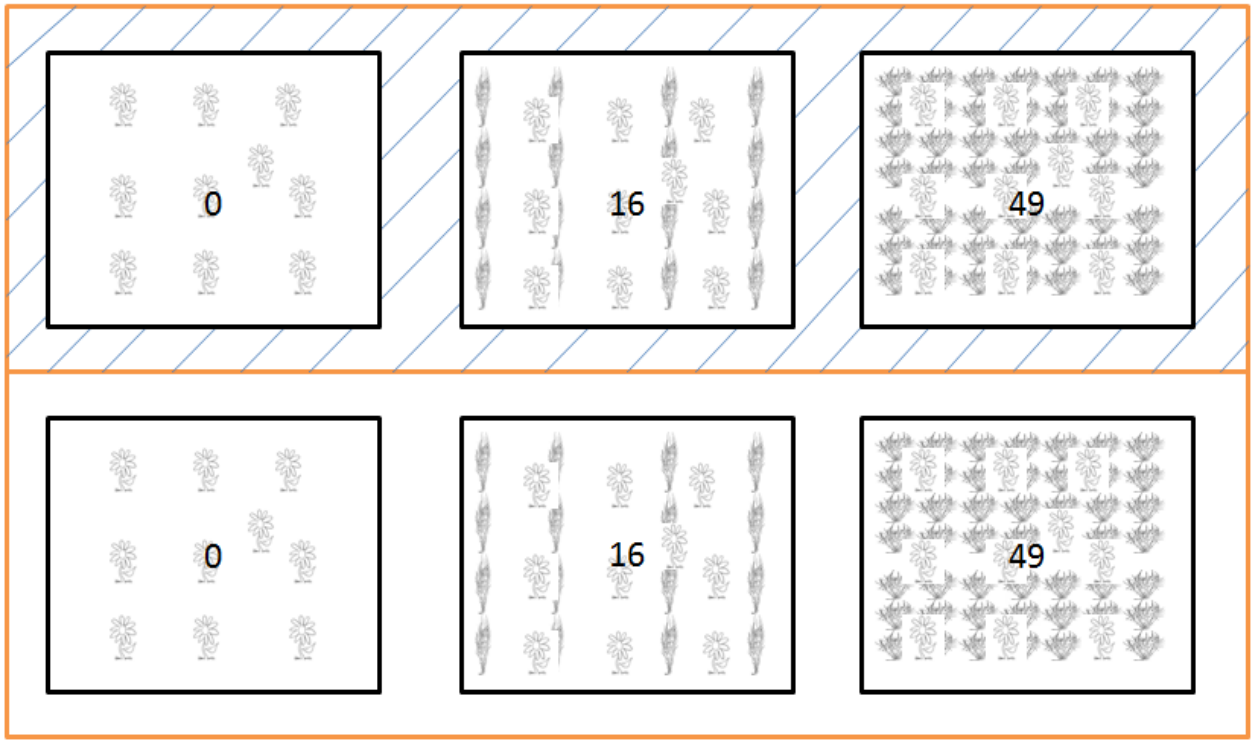
Questions?

Unpalatable plants deter herbivory?



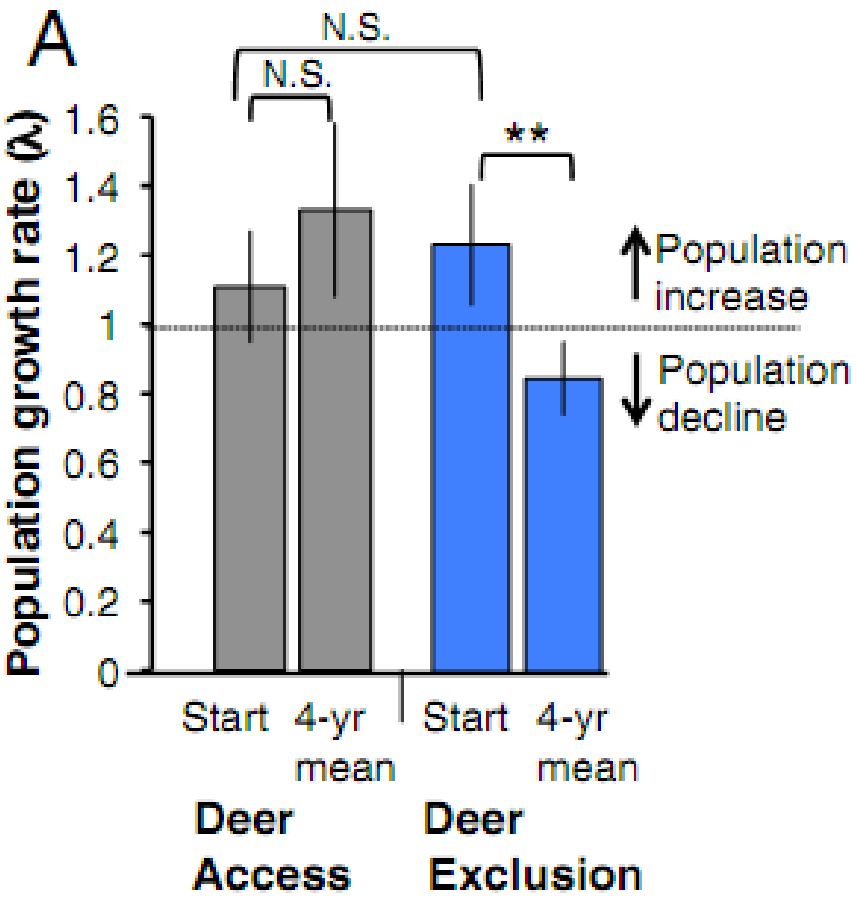
Waller and Maas 2013 *Forest Ecol Manag*

Protective effects of garlic mustard



Martinez and Dornbush 2013 *Inv Plant Manag*

GM needs deer to be invasive



Kalisz et al. 2014 *PNAS*