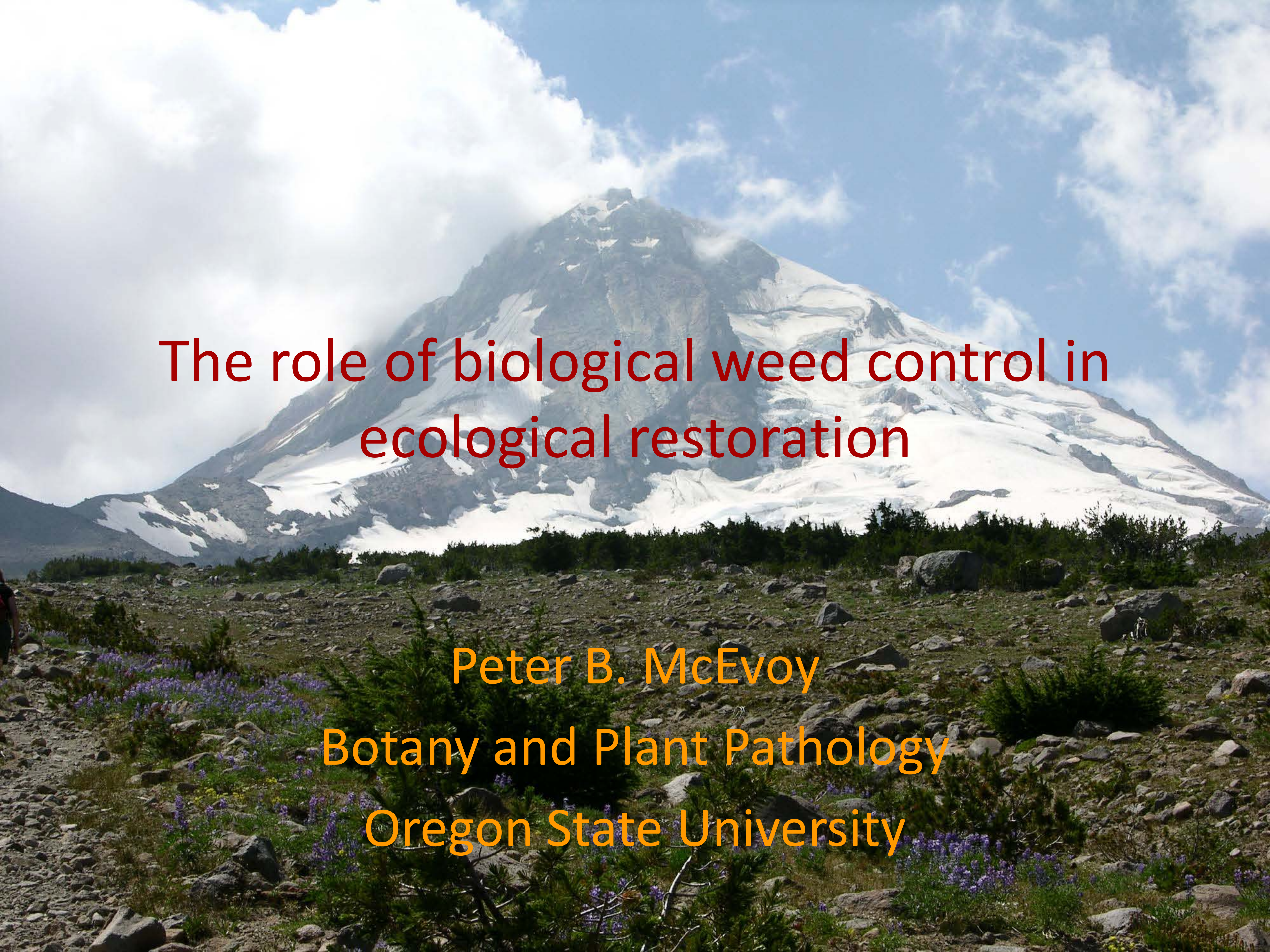

The role of biological weed control in ecological restoration

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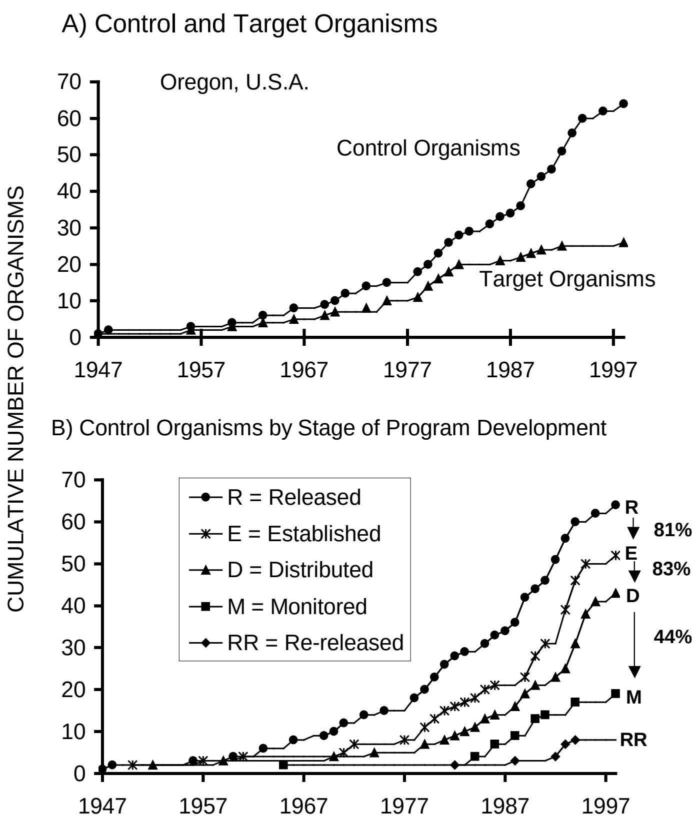
Outline

- Current evaluation of biological control systems is inadequate (Carson et al. 2008, Denslow & D'Antonio 2005, etc, etc)
- Possibly due to a lack of funding, will-power, scientific know-how, time-delays in emergence of impacts, lack of an appropriate theoretical framework linking communities and ecosystems(McEvoy and Coombs 2000; Maron et al 2010)
- We need to couple biological control research with a wider evaluation of the impact of alien invasive species on biodiversity, ecosystems, agriculture, trade, and human health

Focus of Practitioners
Biological Control as a Lottery



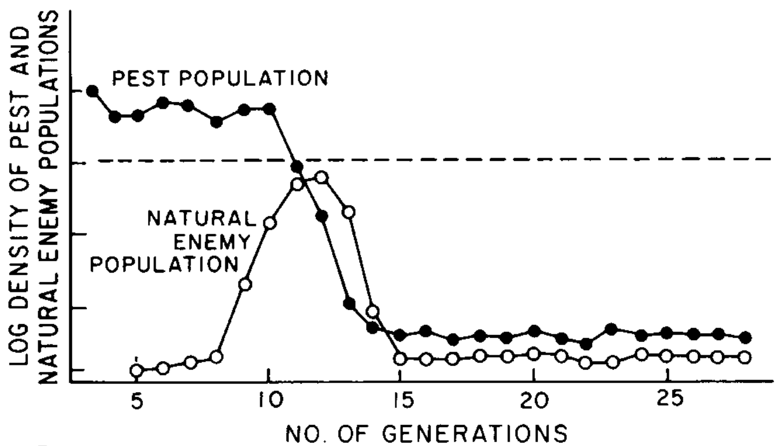
- "Runaway importation rates"
- "Monitoring and evaluation gap"

McEvoy and Coombs 2000

Population ecology: theoretical framework

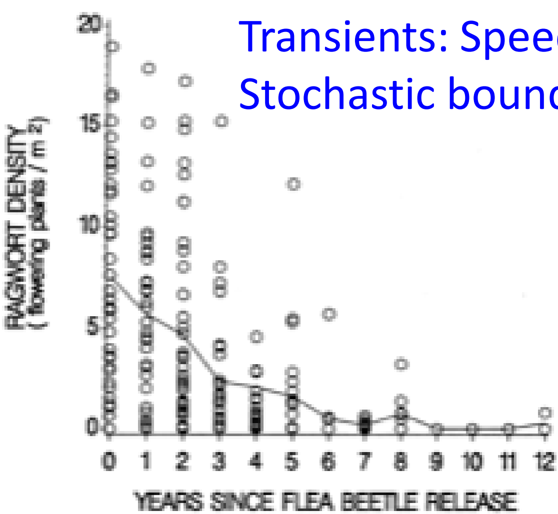
A

Equilibrium



B

Transients: Speed of control
Stochastic boundedness



- Models linking structure and dynamics (Caswell 2001)
- Asymptotic and transient behavior
- Perturbation analyses (elasticity, sensitivity, contributions) improve the targeting of weed vulnerabilities
- Interaction strengths in ecological networks

(Maron et al 2010 JE)

Model 1: Equilibrium and transient dynamics revealed by observations, models and experiments with the ragwort system

Ragwort *Senecio jacobaea*

1. **Activation-Inhibition hypothesis**

- Short-range activation due to seed source and local disturbance
- Long-range inhibition due to herbivory and plant competition
- Stability due to balance in activation and inhibition

2. **Parsimonious prescription for effective control using fewer control organisms using**

- Critical attributes of successful control organisms
- Targeted-disruption of pest life cycles
- Combinatorial ecology of ‘top-down’ and ‘bottom-up’ forces in food webs

McEvoy and Coombs 1999. Ecol. Appl.

A Model System

Ragwort and introduced biological control organisms

Cinnabar moth

Tyria jacobaeae

(Lepidoptera: Arctiidae)

1929 NZ ex UK

1959 USA ex France

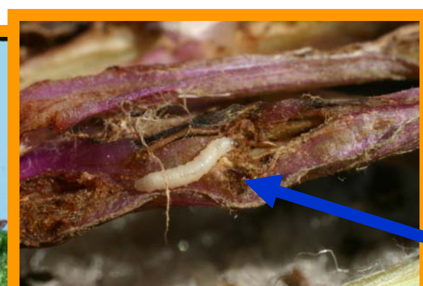
larva

Seed-head fly

Botanophila seneciella

(Diptera: Anthoymiidae)

1966 USA ex France



larva

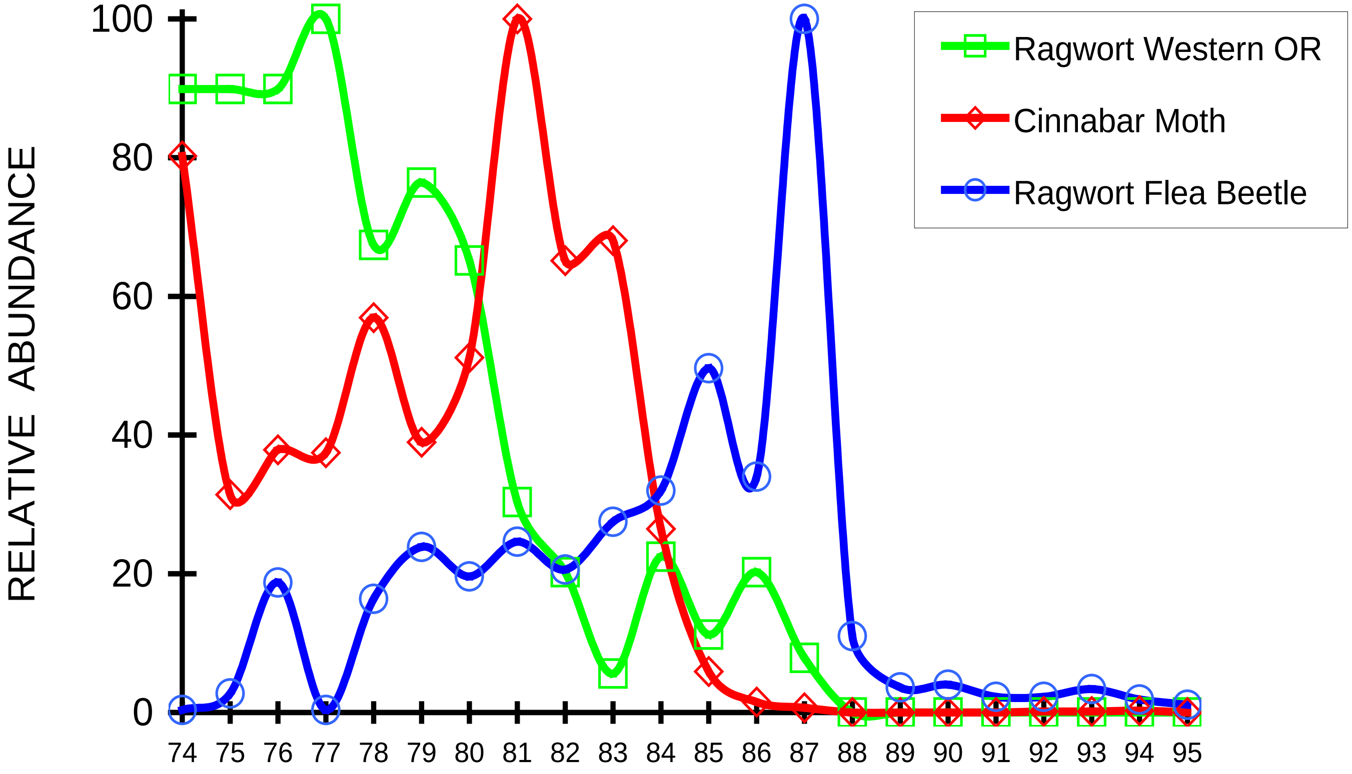
Ragwort flea beetle

Longitarsus jacobaeae

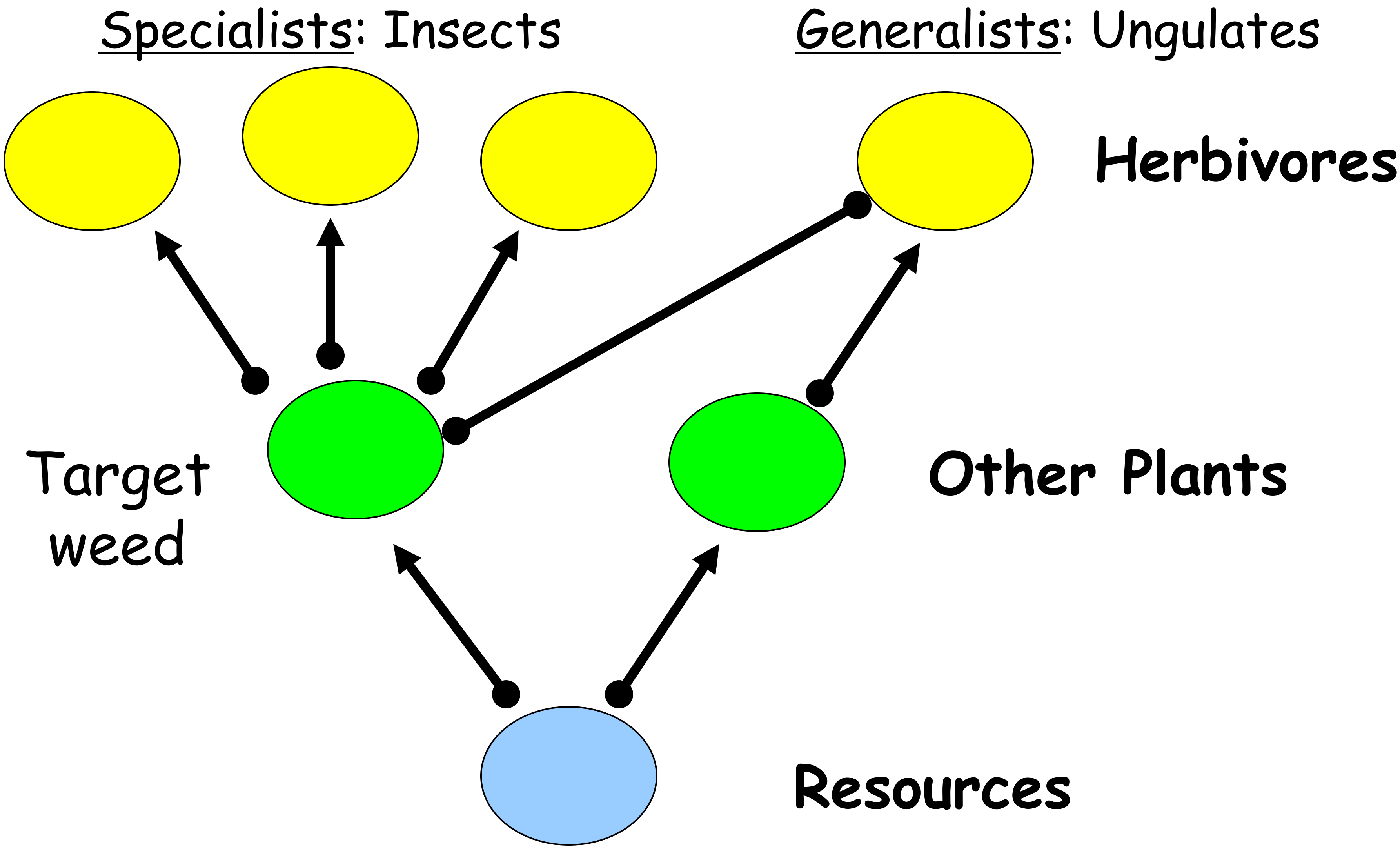
(Coleoptera: Chrysomelidae)

1969 USA ex Italy

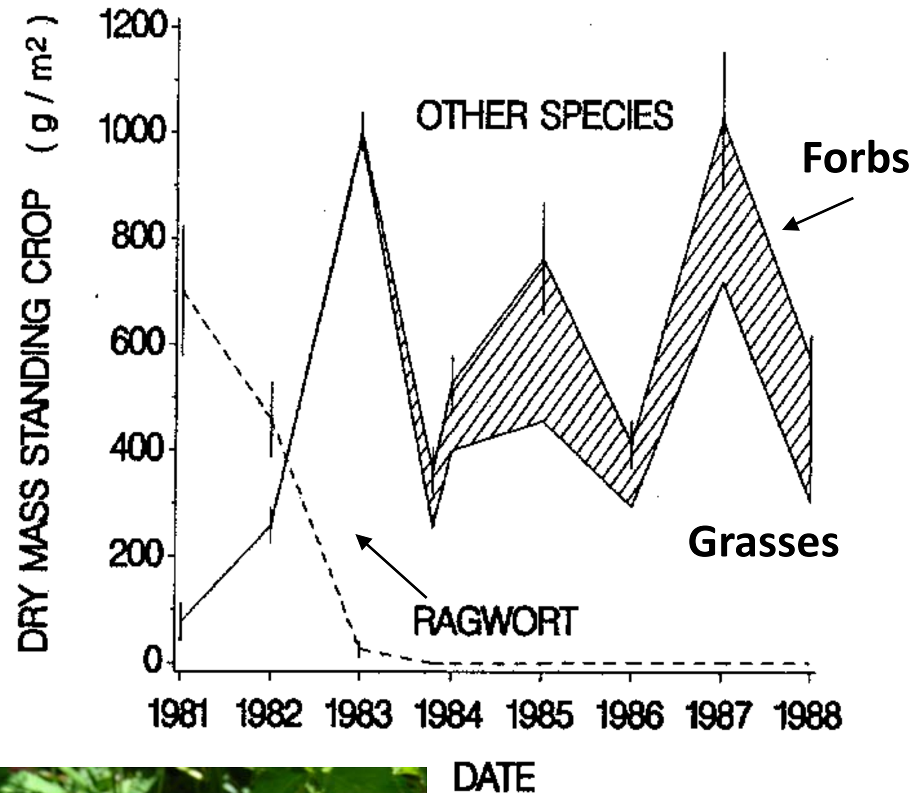
Observational studies:
Decline of Ragwort in Western OR



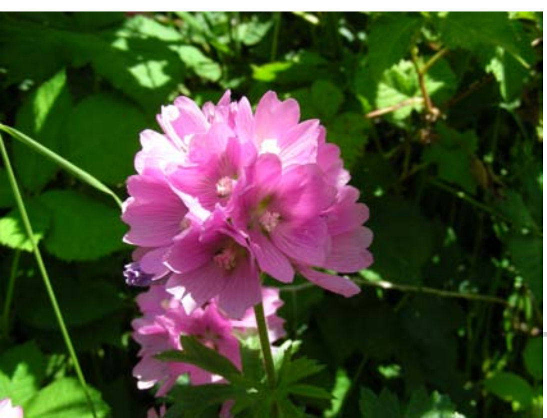
Combinatorial Ecology of Biological Weed Control



Restoring biodiversity and ecosystem function and services



- Biodiversity
  - Mostly Exotic
  - Some Native
- Ecosystem function
  - Productivity?
  - Decomposition & nutrient cycling?
- Ecosystem services
  - Animal and human health
  - Harvest of hay
  - Production of grass seed



Sidalcea hirtipes (Malvaceae)

McEvoy et al 1991
Gruber and Whytemare 1997

Causes and cures for Prairie loss

Stanley, Kaye, Dunwiddie 2010

- Habitat loss - Prairies in the Pacific Northwest are a critically endangered ecosystems primarily due to **habitat change**
- Invasive species - Remnant prairies and oak savannas are in turn threatened by invasive plants, **especially non-native perennial grasses**
- Biodiversity loss an effect with multiple causes – Move beyond single-species control strategies to evaluate manager-recommended treatment combinations using factorial experiments. All treatment combinations crossed with **native seed addition**
  - **summer and fall mowing,**
  - **grass-specific and broad- spectrum herbicide**
  - **fall burning**
- No magic bullet for prairie restoration: In all cases, disturbance treatments reduced exotic cover to varying degrees but had no positive effect on native diversity; only seed addition increased native species richness. Ecosystem processes not measured.
- Management achieved by coordinated manipulation of **Disturbance, Colonization, Local organism interactions**

Model 2:

Transient dynamics revealed by the purple loosestrife system

1. **Biological control resembles an invasion process**

- Releasing and Establishing Control Organisms
- Increasing and Redistributing Control Organisms
- Damaging and Suppressing the Target Organism
- **Managing Plant Succession**

2. **Ecology can guide development of biological control step-by-step**

Purple Loosestrife *Lythrum salicaria*

Should we care about purple loosestrife?
(Lavoie 2010)

- Some native species likely suffer from an invasion of purple loosestrife
- Claims of negative impacts on wetlands are exaggerated or undocumented
  - cause and effect has not been established,
  - evidence in 38 peer reviewed papers on the subject is often equivocal, based on unpublished information
- If loosestrife were not a primary cause of biodiversity decline, but an indicator of anthropogenic disturbance, then it would be better to protect wetlands by reducing disturbance

Selecting targets by ranking their impacts

I = A x D x PCE

Impact (I) is a function of

- A = Abundance
- D = Distribution
- PCE = Per Capita (Per Unit Biomass) Effect

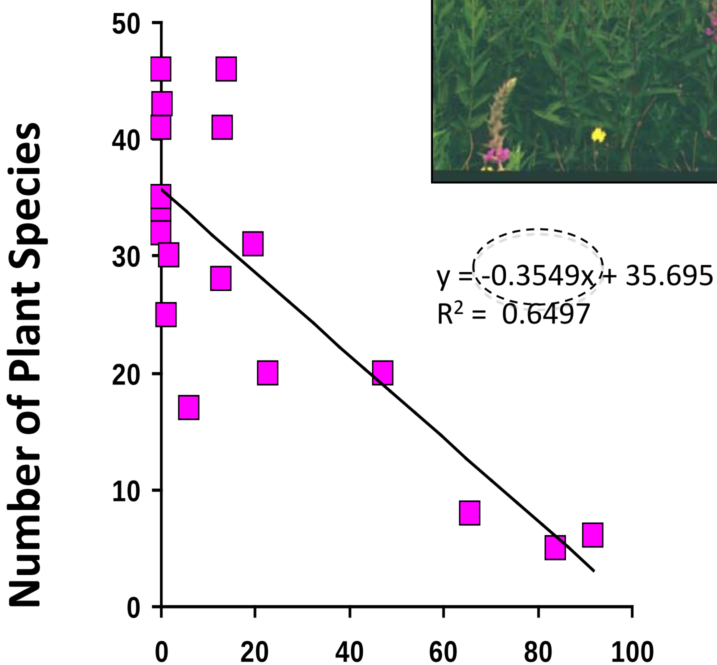
Goodell, Parker, Gilbert 2000

Invader abundance goes up…. Diversity goes down

Impact *I* = Abundance *A* * Distribution *D* * Per Capita (Biomass) Effect *PCE*

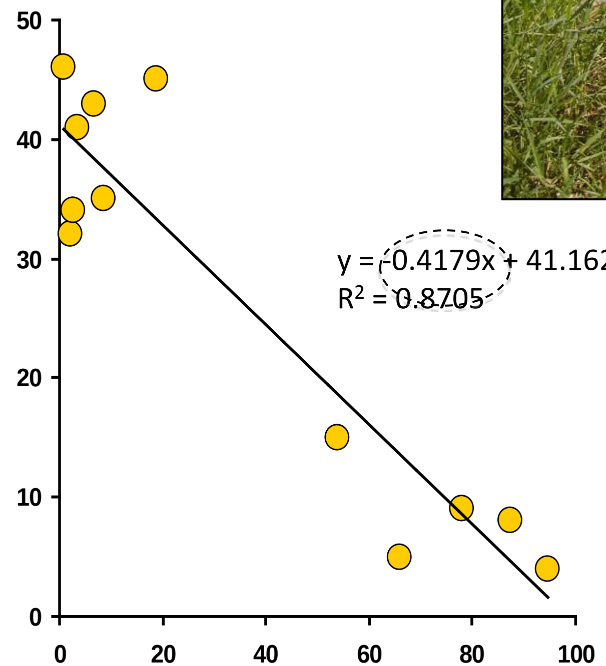
PCE estimated as the slope   Parker et al. 1999 Biological Invasions

Purple loosestrife
(Lythrum salicaria)



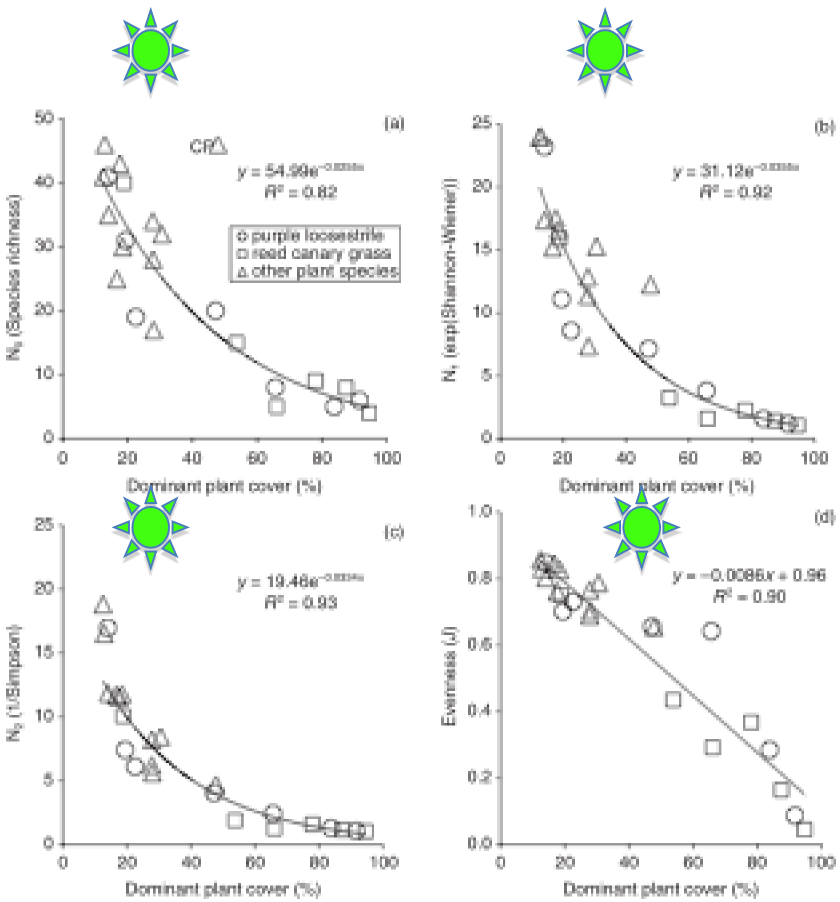
Purple Loosestrife % Cover

Reed canary grass
(Phalaris arundinacea)



Reed Canary Grass % Cover

How does plant diversity vary with the abundance of invasive plant species?



Horizontal, observational study used to estimate per capita effects (PCEs) of purple loosestrife and reed canary grass on plant diversity in 24 wetland communities in the Pacific Northwest, USA?

How do PCEs vary among four measures of diversity:

the number of species (S)

evenness of relative abundance (J)

the Shannon-Wiener index (H')

Simpson's index (D)

Conclusions and Contingencies

(1) PCEs on biotic diversity are similar for both invasive species across four measures

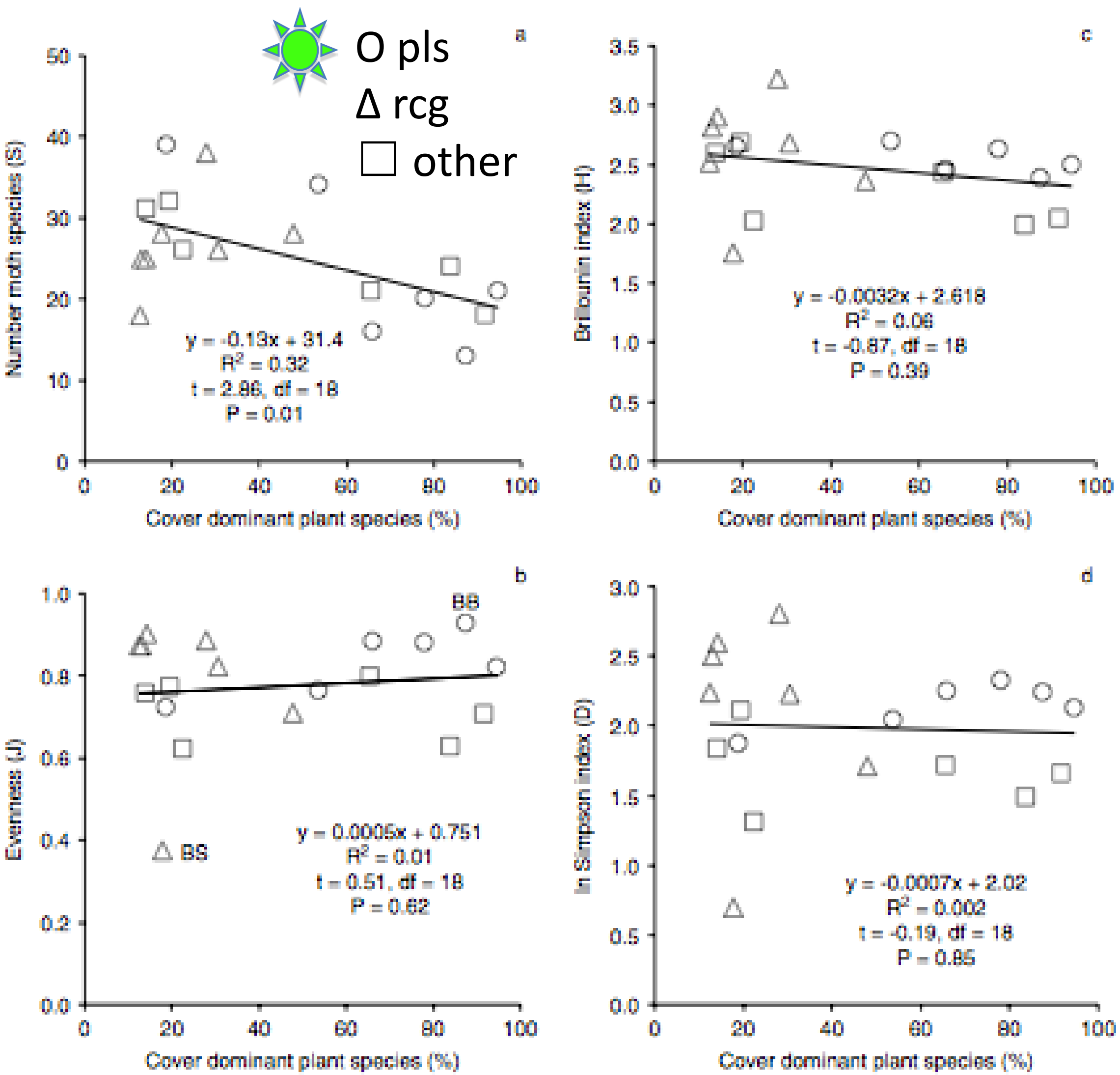
(2) Relationships range from **linear** (constant slope) to **negative exponential** (variable slope), the latter signifying that the PCEs are density-dependent,

(3) PCEs are **density-dependent** for measures of diversity sensitive to the **number of species** (S, H', D) but not for the measure that relied solely upon **relative abundance** (J), and

(4) invader abundance was not correlated with other potential influences on biodiversity (**hydrology, soils, topography**).

Schooler, S. S., P. B. McEvoy, and E. M. Coombs. 2006. Diversity and Distributions **12**:351-363.

How does moth diversity vary with invader abundance?



How do per capita effects of two invasive plants, purple loosestrife (Lythrum salicaria) and reed canary grass (Phalaris arundinacea), on moth diversity in wetland communities at 20 sites in the Pacific Northwest, USA?

Four measurements were used to quantify diversity: species richness (S), community evenness (J), Brillouin's index (H) and Simpson's index (D).

We identified 162 plant species and 156 moth species across the 20 wetland sites.

Conclusions and contingencies

The number of moth species was positively correlated with the number of plant species (not shown).

Invasive plant abundance was **negatively correlated with species richness** of the moth community (linear relationship), and the effect was similar for both invasive plant species.

However, not correlated with 3 other measures of moth diversity (J, H, D) which included moth abundance in their calculation. So, only **species richness within, and among, trophic levels** is adversely affected by these two invasive wetland plant species.

Schooler, S. S., P. B. McEvoy, P. Hammond, and E. M. Coombs. 2009. Bull. Ent. Res. 99:229-243.

Cause and Effect are Unresolved

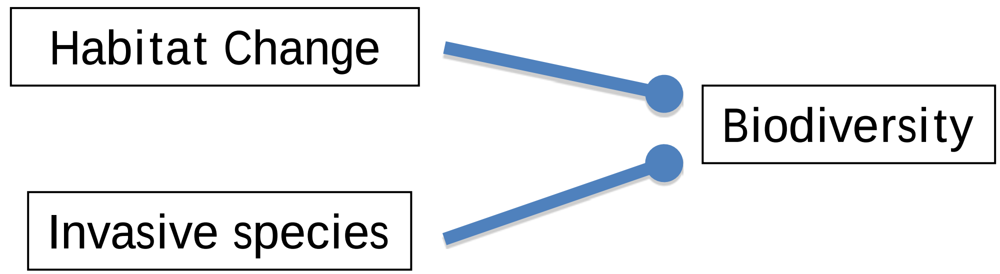
MacDougall and Turkington 2005

Threats to Biodiversity

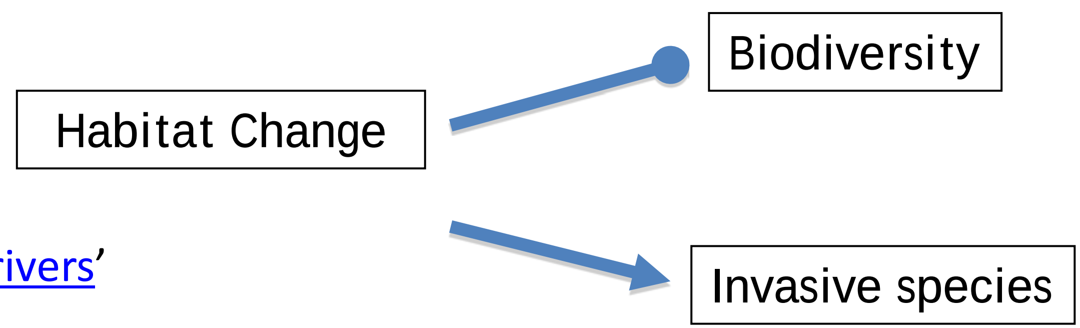
(Convention on Biological Diversity)

1. Habitat change
2. Invasive species
3. Over-exploitation
4. Pollution and nutrient loading
5. Climate change

Hypothesis A: Invaders as ‘drivers’



Hypothesis B: Invaders as ‘passengers’



Hypothesis C: Invaders are ‘back seat drivers’

Conclusion: we must diagnose the reasons for decline of a species, using standard experimental manipulations and testing of hypotheses, before taking action aimed at reversing the decline (Caughley and Gunn 1996)

Purple loosestrife and introduced biological control agents

adult

Seed weevil ***Nanophyes marmoratus***

adult

Root weevil ***Hylobius transversovittatus***

larva

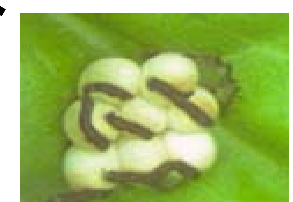
adult

Leaf beetles

***Galerucella* spp.**

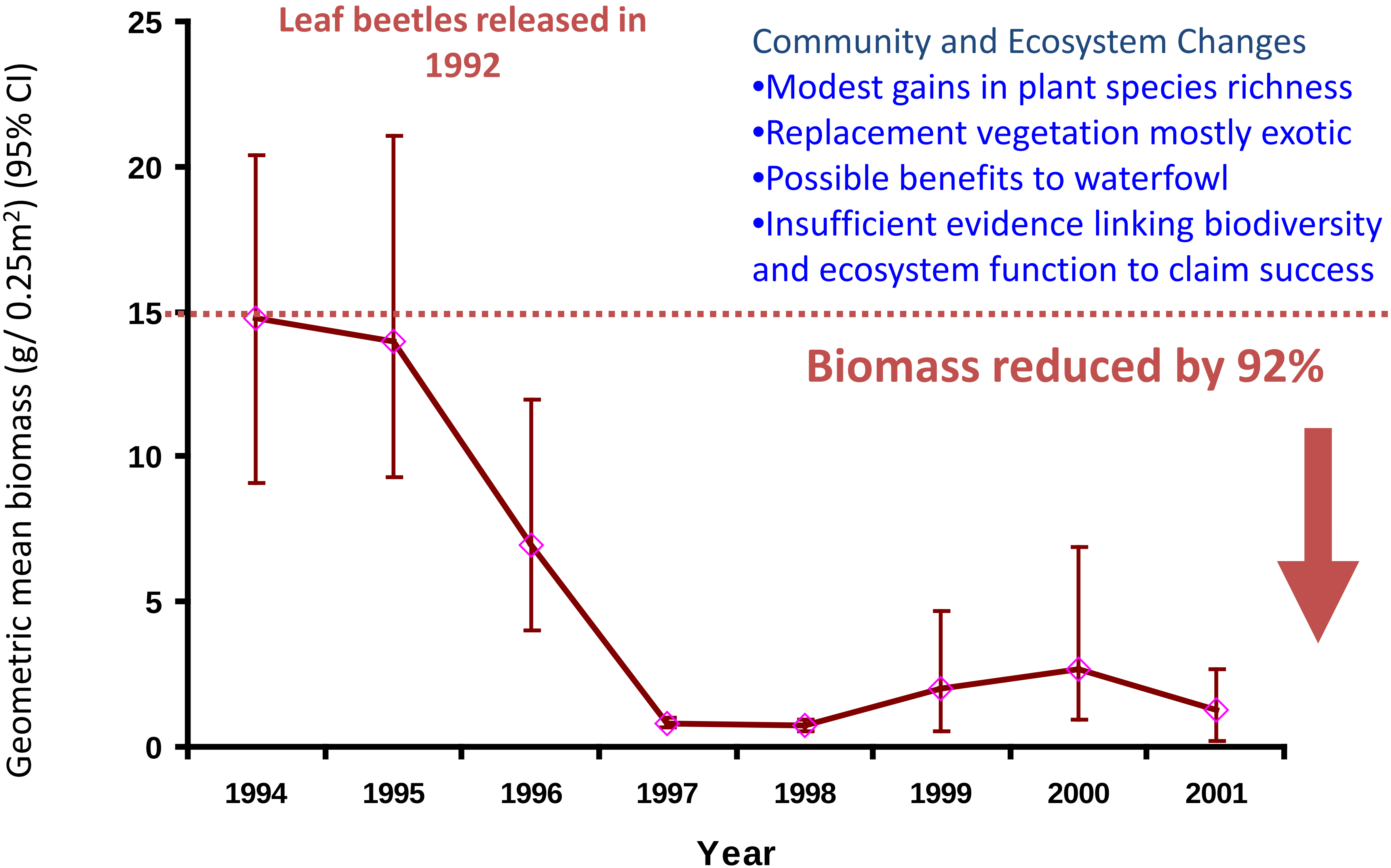
larva

eggs



Leaf Beetle Damage

Damage Translates into Decline in Loosestrife Population (Biomass)



Community and Ecosystem Changes

- Modest gains in plant species richness
- Replacement vegetation mostly exotic
- Possible benefits to waterfowl
- Insufficient evidence linking biodiversity and ecosystem function to claim success

Causes and cures for wetland loss

- Habitat loss ~ 50% - Of ~ 221 million acres of wetlands at the time of European settlement in the 1600's, ~103 million acres (46%) remained as of mid-1980's
  - 6 states lost ≥ 85%
  - 22 states lost ≥ 50%
- Restoring a disturbance regime: Wetland creation and restoration depend on our ability to recreate the hydrologic regime of functional wetlands (Magee et al. 1999, 2005)

Conclusions

- Causes, consequences, and cures of invasions need to be better resolved using observational, experimental, and modeling approaches
- Biological control is more likely to restore native biodiversity by managing succession through controlled disturbance, colonization, and local interactions (competitors, herbivores, and mutualists)
- We need to couple biological control research with a wider evaluation of the impact of alien invasive species on biodiversity, ecosystems, agriculture, trade, and human health