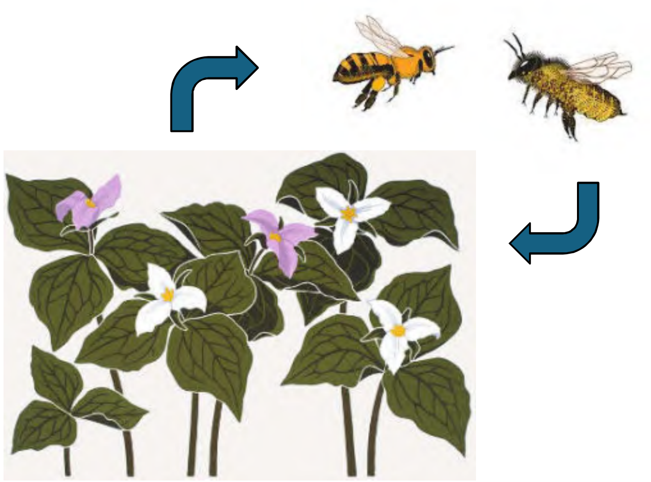
Are N American plant communities becoming less pollinator friendly? 50-year changes in forest understories and pollinator resources



Don Waller

University of Wisconsin – Madison

USA

Plant Ecology Laboratory

Plant Ecology Laboratory · University of Wisconsin

Introduction to forestREplot

A DATABASE OF FOREST HERB LAYER RESURVEY PLOTS

Background & Outline

- The world is changing . . . many forces drive change
- Long-term data are key for understanding ecological change
  - Such data are **rare** – few **baselines**, little **monitoring**
  - → *Need to collect & analyze such data,* e.g, forestREplot
- Focus: Forests of N America & Wisconsin
  - Understory plant changes in **abundance**
  - Local & regional changes in abundance are linked
  - Which species increase? decrease? Linked to pollination?
  - Are trees regenerating?
  - Q: *Are plant declines driving pollinator declines?*

Nature is changing in more ways than one

Donald M. Waller and Thomas P. Rooney

Department of Botany, University of Wisconsin, 430 Lincoln Drive, Madison, WI 53706, USA

Simple **species counts** reveal species losses

Table 1. Losses of herbaceous plant species in historical studies[a]

Location (period)	No. of species lost per site	% loss per year	Refs
Bialowieza forest, Poland (1969–1992)	45% of 133 species	2.2	[11]
Middlesex Fells, MA, USA (1894–1993)	37% of 422 species	0.37	[4]
Staten Island, NY, USA (1879–1991)	41% of 1082 species	0.36	[5]
Heart's Content, PA, USA (1929–1995)	59% and 80% (2 stands)	1.12–1.21	[9]
N Wisconsin, USA (1950–2000)	18.5% (average over 62 sites)	0.37	[6]
S Wisconsin prairies, USA (32–52 years)	8–60% (54 sites)	0.5–1	[10]

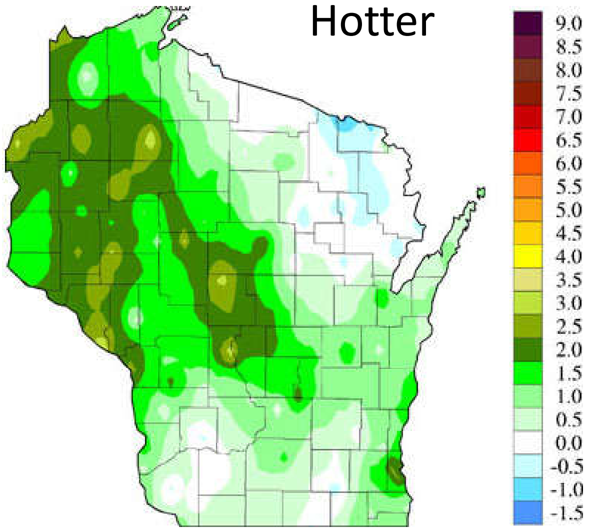
[a] All but the last study focused on temperate forests.

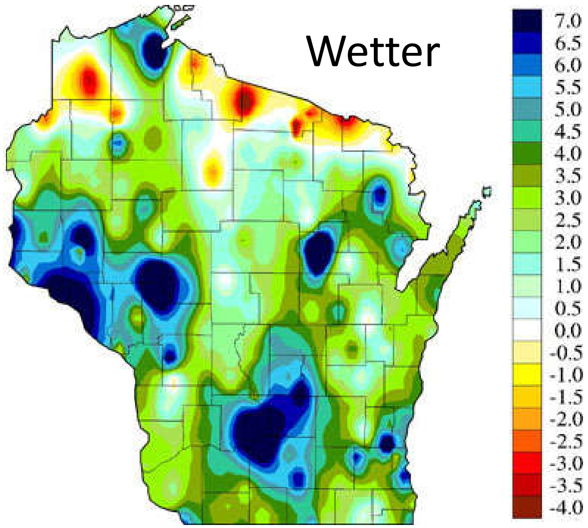
TRENDS in Ecology and Evolution Vol.19 No.1 January 2004

***All** these studies show serious losses*

Global change: Climate

Change since 1950s

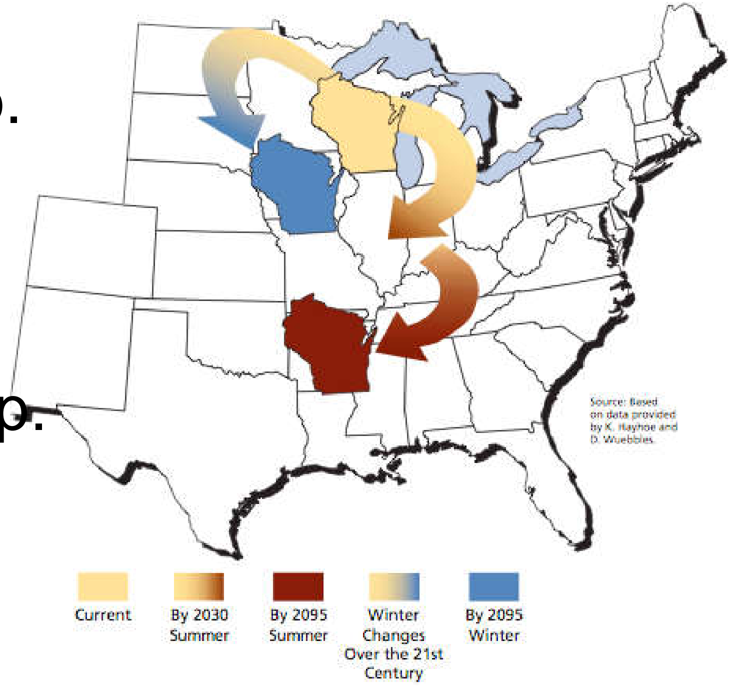




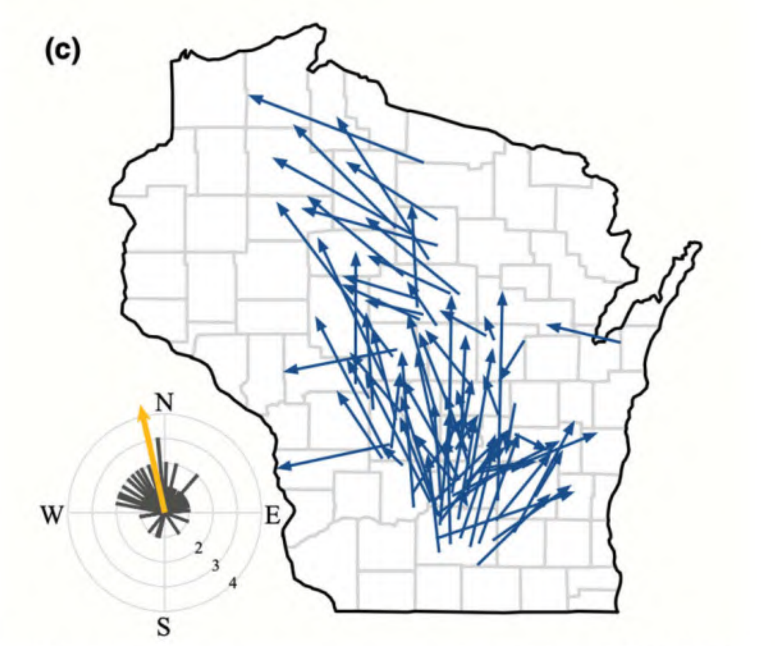
FUTURE:

Temp.

Precip.



Species are moving N & W



and climate-change vectors (mean = 0.19 ± 0.29), indicating an acute angle between the vectors (Table S1). Among these positive dot products, over half (32) show

But not fast enough . .

Global Change Biology (2017) **23**, 1305–1315, doi: 10.1111/gcb.13429

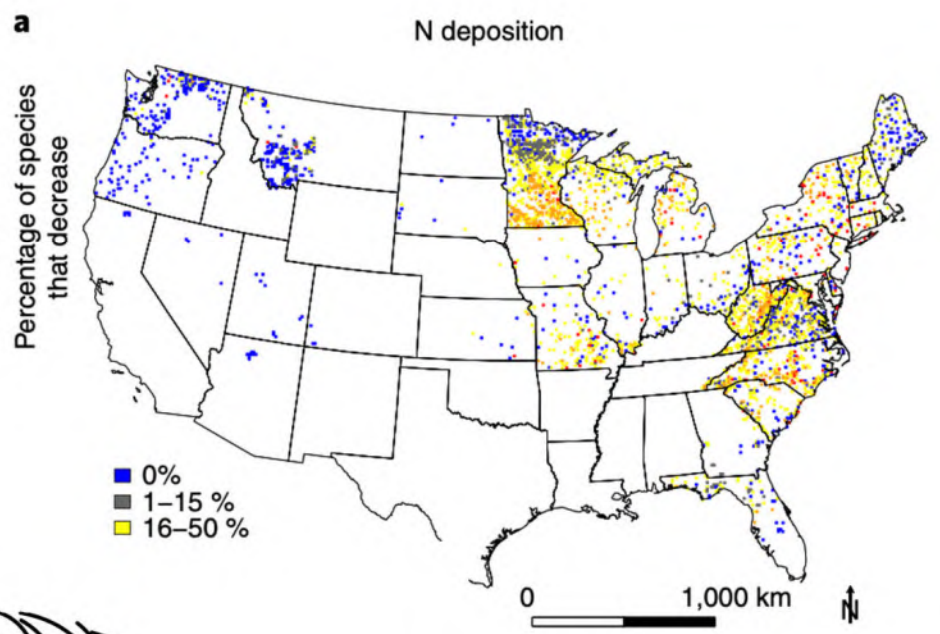
Tracking lags in historical plant species' shifts in relation to regional climate change

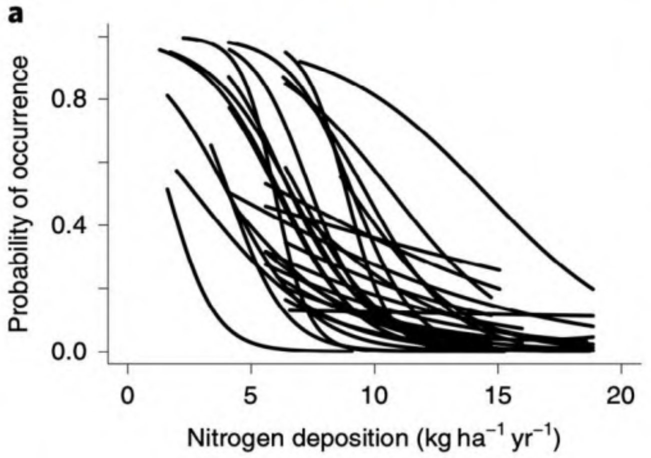
JEREMY D. ASH, THOMAS J. GIVNISH and DONALD M. WALLER
Department of Botany, University of Wisconsin – Madison, Madison, WI 53706, USA

Global change: Habitat Fragmentation

Global change: N-deposition

NATURE PLANTS

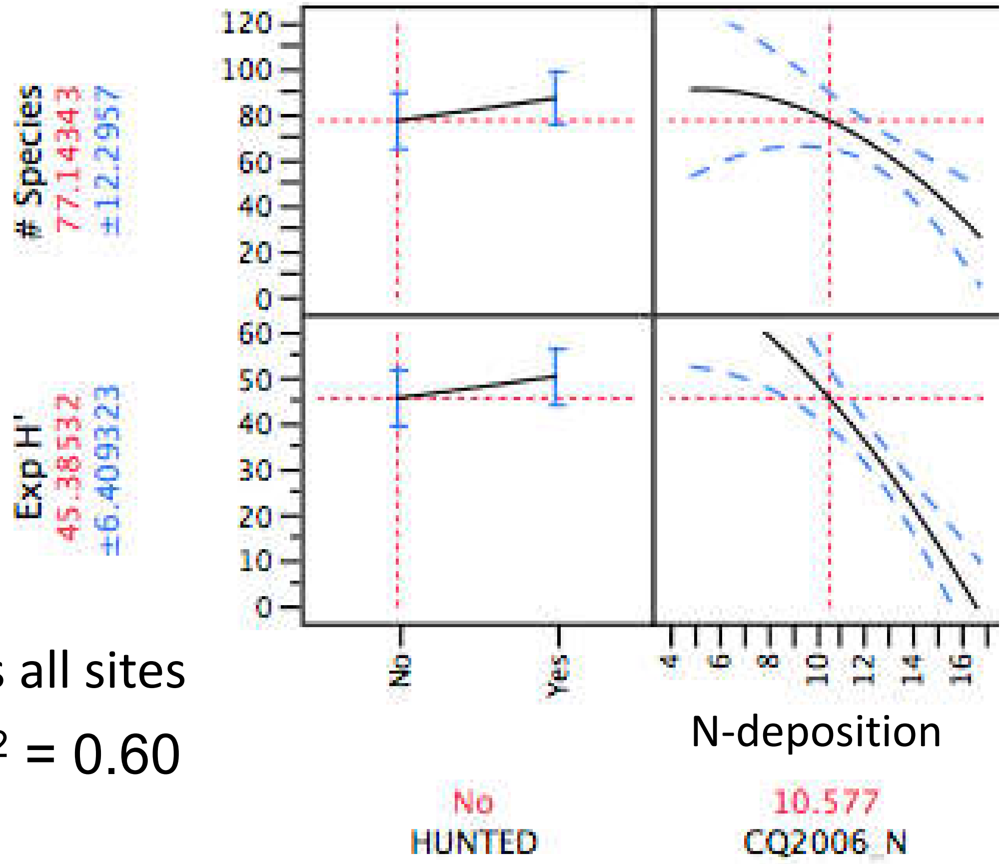




Potential vulnerability of 348 herbaceous species to atmospheric deposition of nitrogen and sulfur in the United States

Christopher M. Clark[1,18*], Samuel M. Simkin[2,17,18], Edith B. Allen[3], William D. Bowman[2], Jayne Belnap[4], Matthew L. Brooks[5], Scott L. Collins[6], Linda H. Geiser[7], Frank S. Gilliam[8], Sarah E. Jovan[9], Linda H. Pardo[10], Bethany K. Schulz[11], Carly J. Stevens[12], Katharine N. Suding[13], Heather L. Throop[14,15] and Donald M. Waller[16]

Diversity effect - Wisconsin



GLM across all sites

$r^2 = 0.60$

Waller et al., unpublished

Historical data: John Curtis & student 1950s

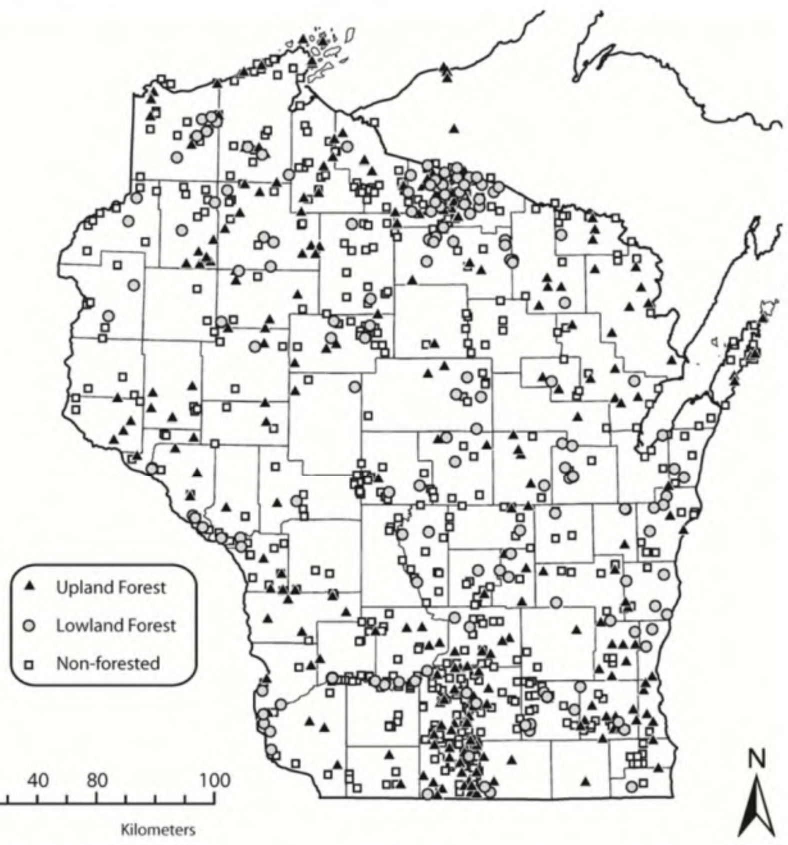
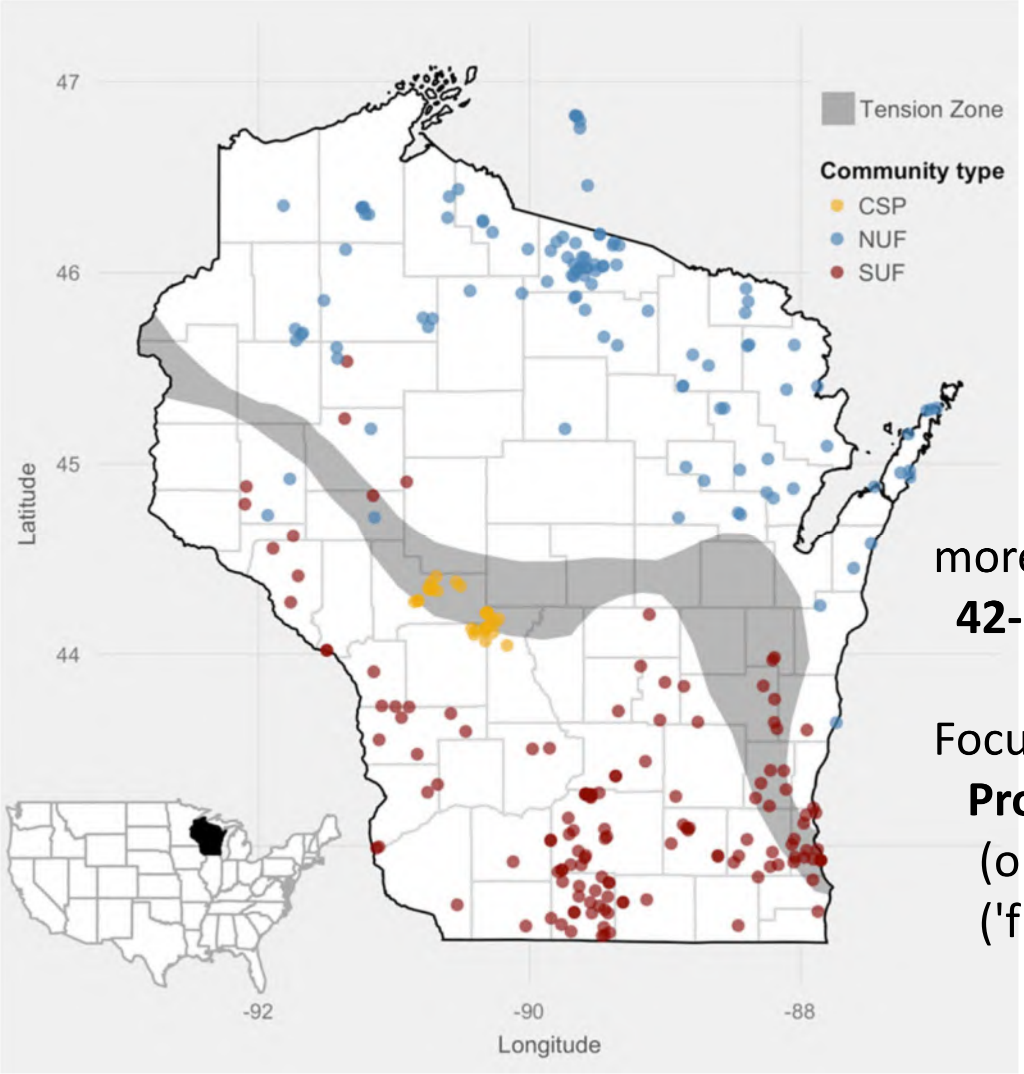


Fig. 1: Locations of the sites in Wisconsin and the western Upper Peninsula of Michigan sampled for plant community composition by John Curtis and his colleagues in the 1940s and 1950s.

Forest Surveys



293 sites

more **intensive**:
42-120 1m^2 quads vs. **20**

Focus on **abundance =**
Proportion of quadrats
(or sites) occupied
('frequency')

Sampling Layout – 1950s

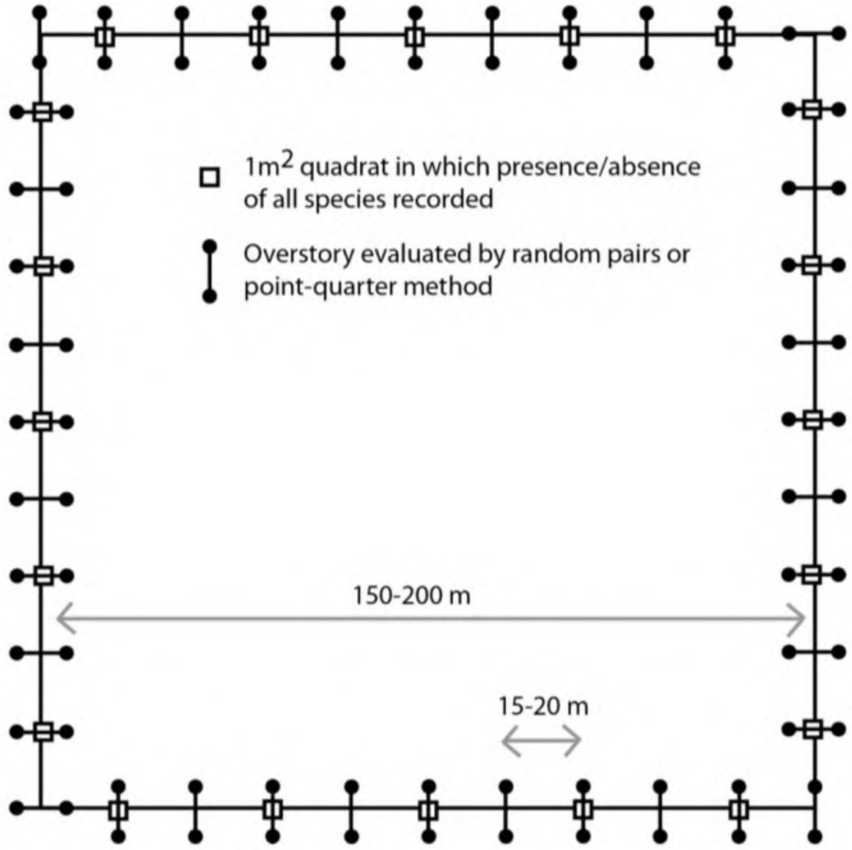
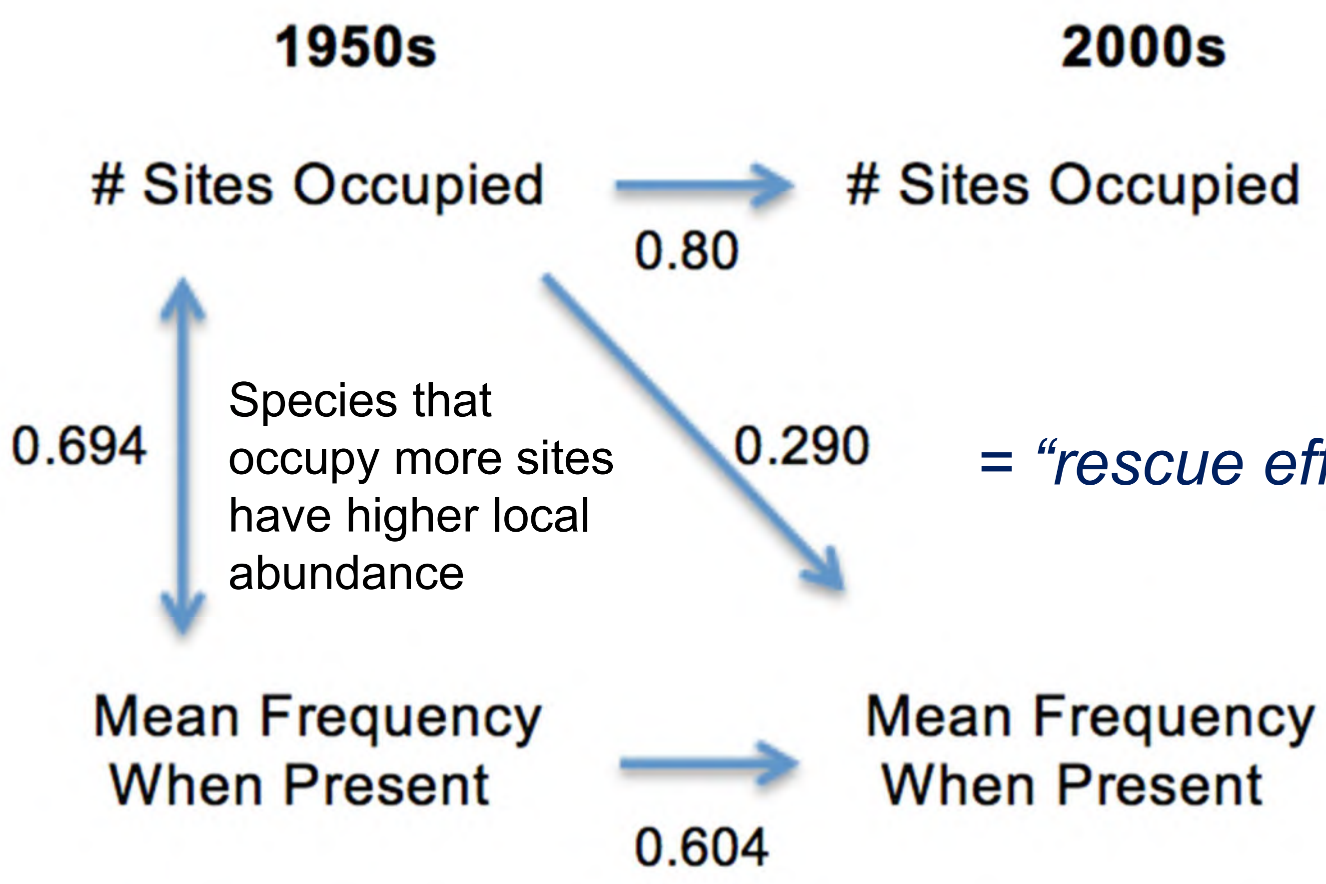


Fig. 3: Basic sampling design that J.T. Curtis and colleagues often used to sample the southern and northern upland forest stands. Researchers would begin at a corner and pace out either three perpendicular linear transects (in the shape of a large U) or four transects in the shape of a square (as shown below). These were flexibly sized and placed to fit the size of the stand. Overstory sampling occurred at every point and 1 m² understory quadrats were placed at every other point. In most cases, 40 points were sampled for trees and 20 for understory vascular plants

2 Components of Abundance



Demographic inertia

= *"rescue effect"*

Demographic inertia in both **site occupancy** and **local abundance**

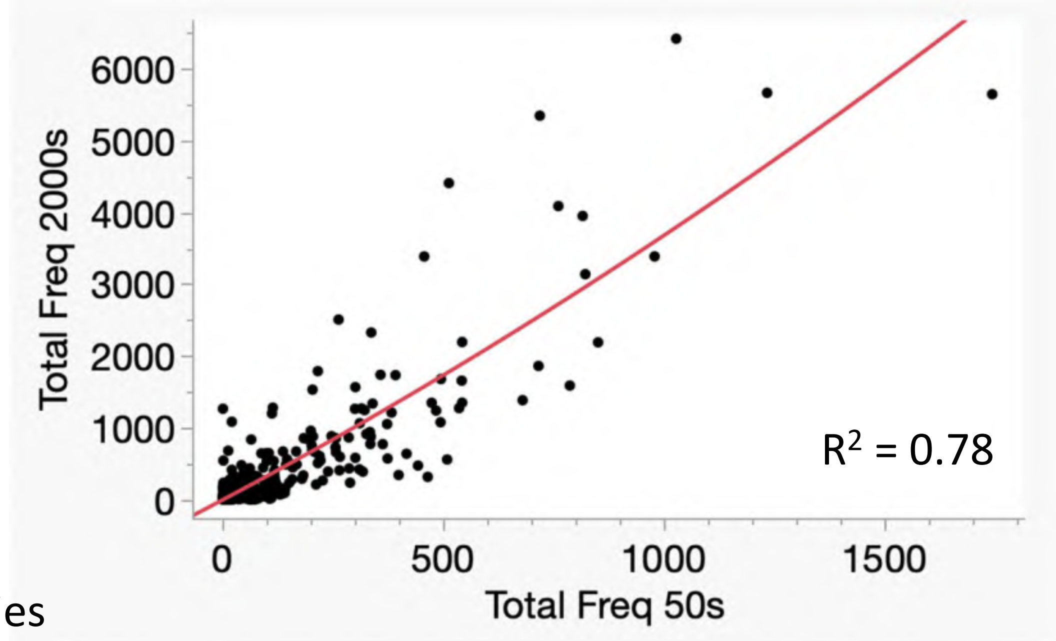
More pervasive species boost local abundance

Path analysis (SEM)

Demographic Inertia

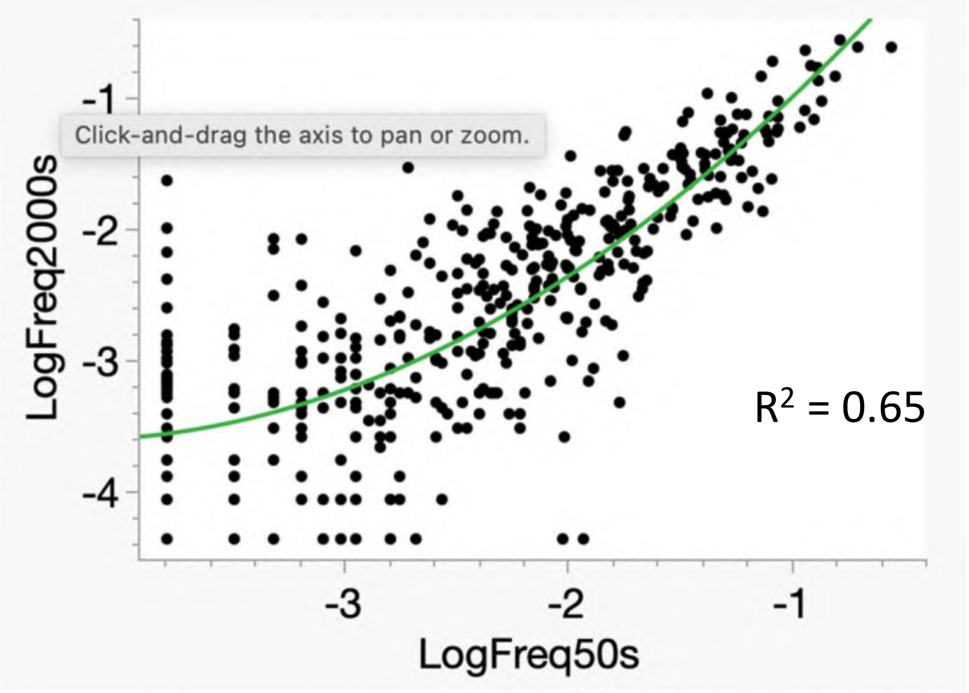
- Abundance in 2000s reflects abundance in 1950s
  - Rare species stay rare

N = 691 species



- But also considerable variation

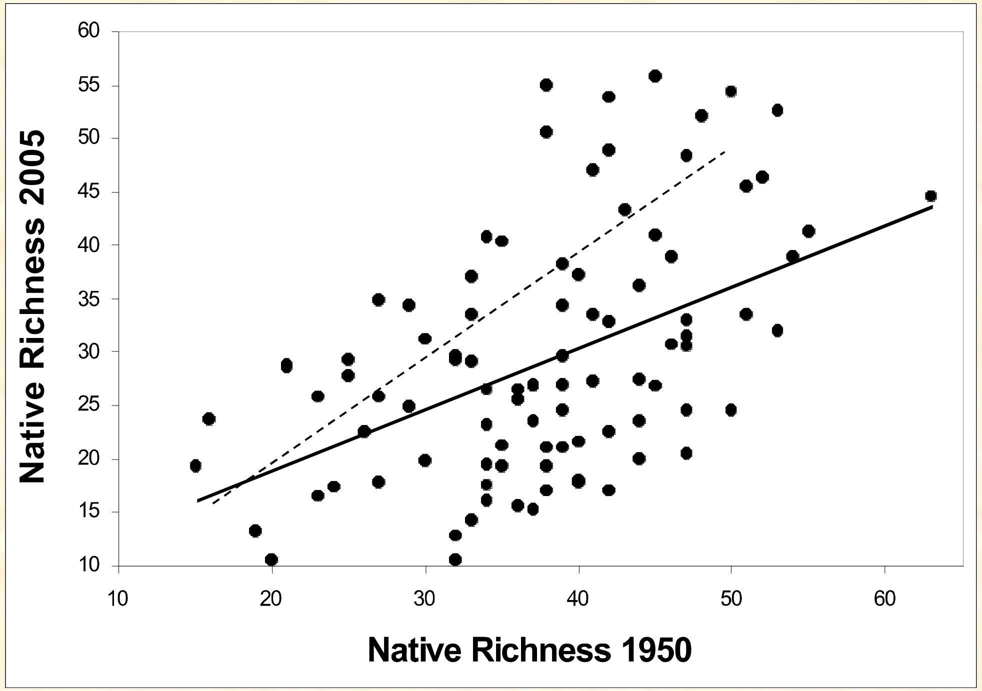
N = 431 species



Community changes - S Forests

of tree **seedlings** declined by **50+%**

Tree species **richness** down 16%



80% of sites lost herb diversity

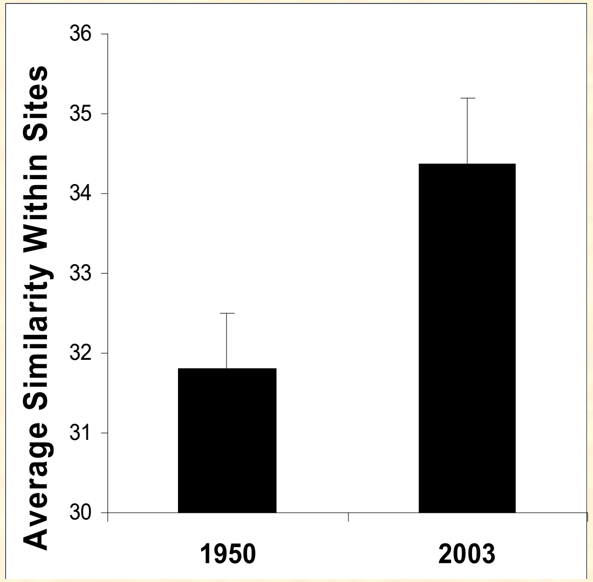
Species density declined by:

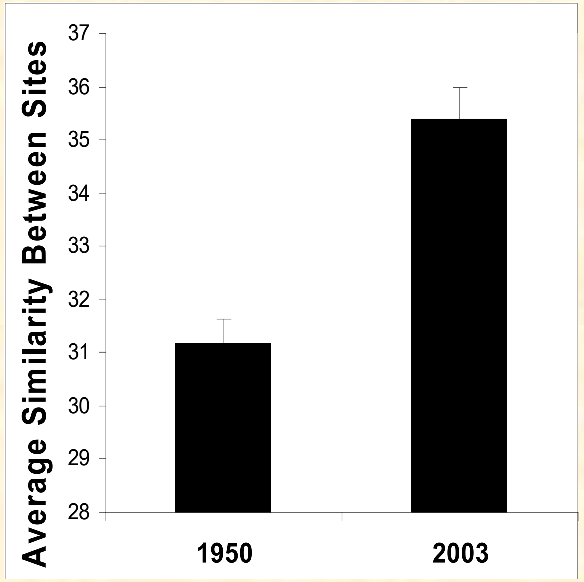
25% per 1 m2

22.4% over 20 m2

β diversity also decreased

= Biotic Homogenization





Rogers et al. 2008, 2009

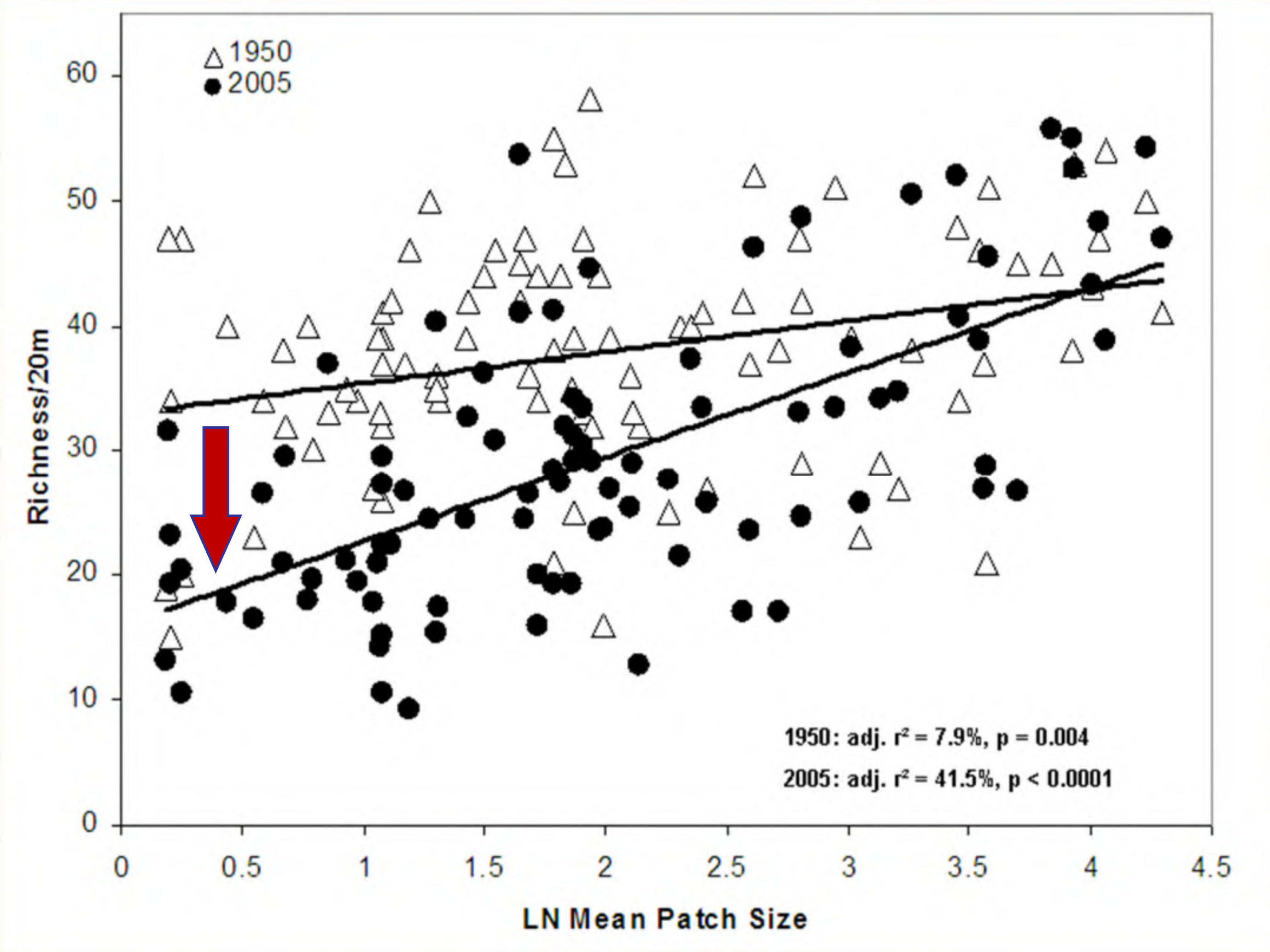
Paying the ‘extinction debt’

The **species - area** relationship has grown stronger:

Conclusions:

Isolation is taking a toll

More **extinctions** may occur in the future



Rogers et al. 2009 Cons Bio

Changes in abundance

Of 274 species over all sites:

35% Increased over ~50 years

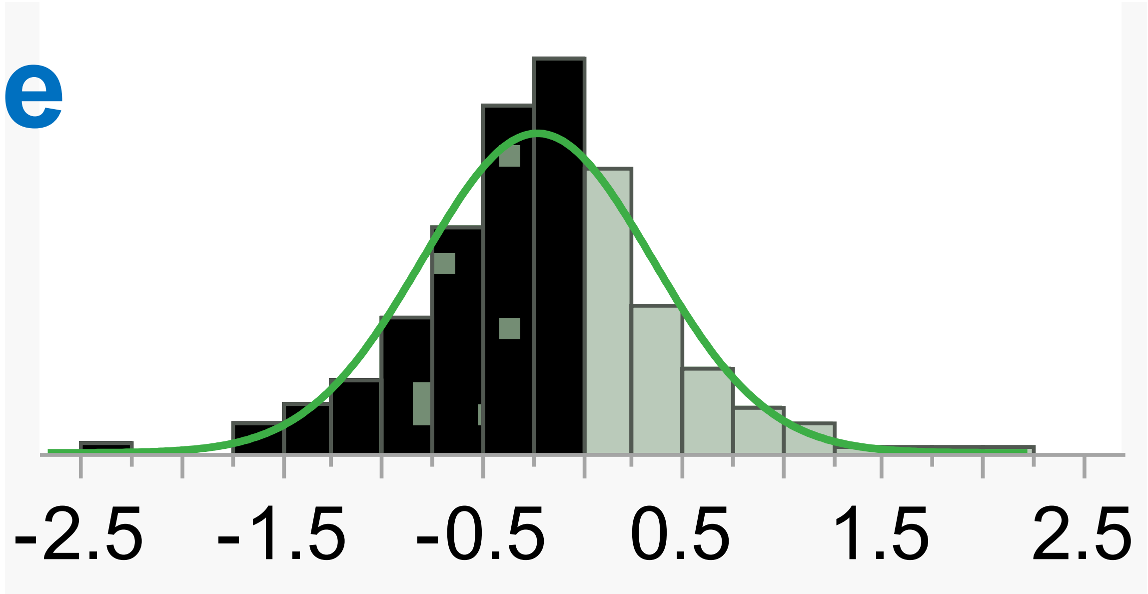
65% **Decreased**

Mean Change = -0.216

or **39% decrease** in abundance

Native species **declined** by **41%**

Non-native species **increased** by **584%**



Log (proportional Change in Abundance)

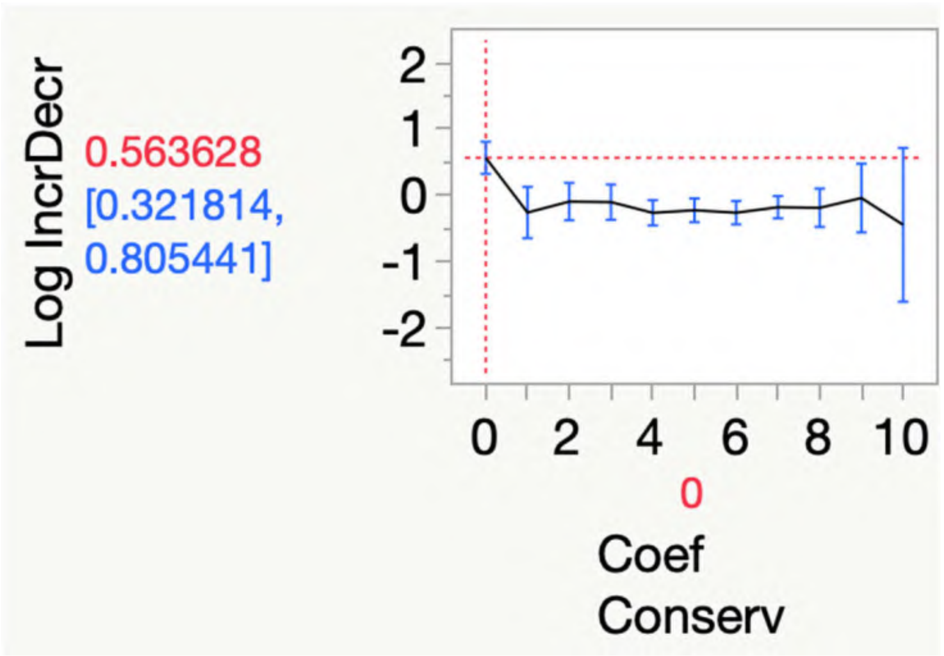
Mean	-0.215954
Std Err Mean	0.0276236
Upper 95% Mean	-0.16166
Lower 95% Mean	-0.270248
N	168
Difference from 0	***

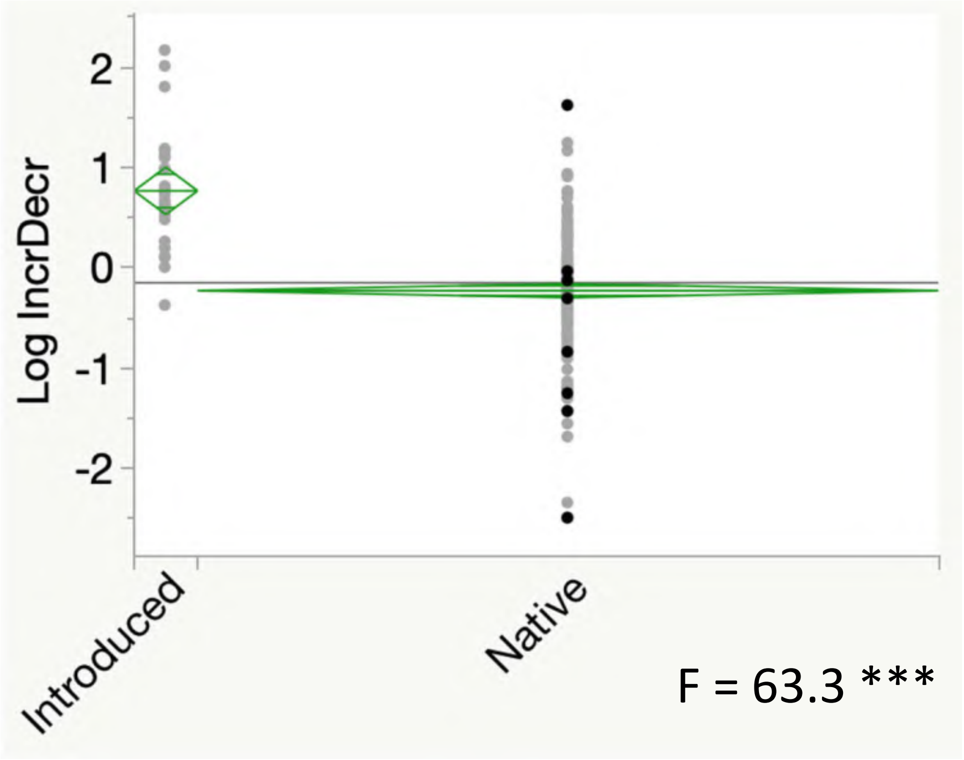
Which species increase?

Introduced ‘exotic’ species

- Includes invasive species

And common natives





Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Introduced	23	0.76651	0.11995	0.5304	1.003
Native	269	-0.22783	0.03507	-0.2969	-0.159

‘Winner’ Introduced Taxa

Familiar?

Species	Common Name	IV	Sites	Avg Freq
Alliaria petiolata	garlic mustard	19.1256	60	0.32
Rhamnus cathartica	common buckthorn	7.5730	60	0.13
Taraxacum officinale	common dandelion	4.6323	90	0.05
Lonicera x bella	Bell's honeysuckle	1.6960	48	0.04
Solanum dulcamara	bittersweet nightshade	1.2921	39	0.03
Arctium minus	common burdock	0.8905	46	0.02
Rosa multiflora	multiflora rose	0.8559	36	0.02
Leonurus cardiaca	lion's-tail	0.7408	11	0.07
Chenopodium album	lamb's-quarters	0.6753	21	0.03
Hesperis matronalis	dame's rocket	0.6708	13	0.05
Cirsium arvense	Canada thistle	0.4819	8	0.06
Cirsium vulgare	bull thistle	0.4483	17	0.03
Acer platanoides	Norway maple	0.3933	7	0.06
Poa pratensis	Kentucky bluegrass	0.3688	19	0.02
Morus alba	white mulberry	0.3578	14	0.03
Berberis thunbergii	Japanese barberry	0.2653	11	0.02
Silene latifolia	bladder campion	0.2625	2	0.13
Polygonum persicaria	spotted lady's-thumb	0.2614	8	0.03
Euonymus alata	winged burning-bush	0.2491	12	0.02
Glechoma hederacea	creeping-Charlie	0.2417	9	0.03

Winners - S Wisconsin forests

- **Shrubs** & woody **vines**
  - Exotics: *Rhamnus & Lonicera*
- **Clonal herbs**
- **Exotic** herbs: e.g., *Alliaria*

Already common native species:

Parthenocissus spp

Geranium maculatum

Exotics:

Rhamnus cathartica

Alliaria petiolata

3 Eurasian invaders – S forests

- *Alliaria petiolata* - biennial introduced to the U.S. in mid-1800's. Most abundant exotic herb (45/94 sites) with a mean frequency of **30%**.
- *Rhamnus cathartica* – large understory **shrub** invaded North America in the mid-1800's. Most common woody exotic (45/ 94 sites) with mean freq. **11.7%**.
- *Lonicera x bella* – Asian hybrid **shrub** in 38/94 sites with mean frequency **3.7%**.
- These species thrive in disturbed landscapes & fragmented forests, efficiently intercept resources, and produce allelochemicals that interfere with the growth of native plants and facilitate further invasions (e.g., **earthworms**), altering **soils** & **nutrient cycling**

'Winner' Species in the North

Ferns - *Athyrium filix-femina* (up 400%) &
Dryopteris intermedia (up 100%)

Arisaema triphyllum – up 195%

Grasses & sedges:
Carex (up 286%)
Oryzopsis asperifolia (up 54%)
Schizachne purpurascens (up 217%)

Exotics: *Hieracium, Epipactis, Galeopsis*

Athyrium filix-femina

Schizachne purpurascens

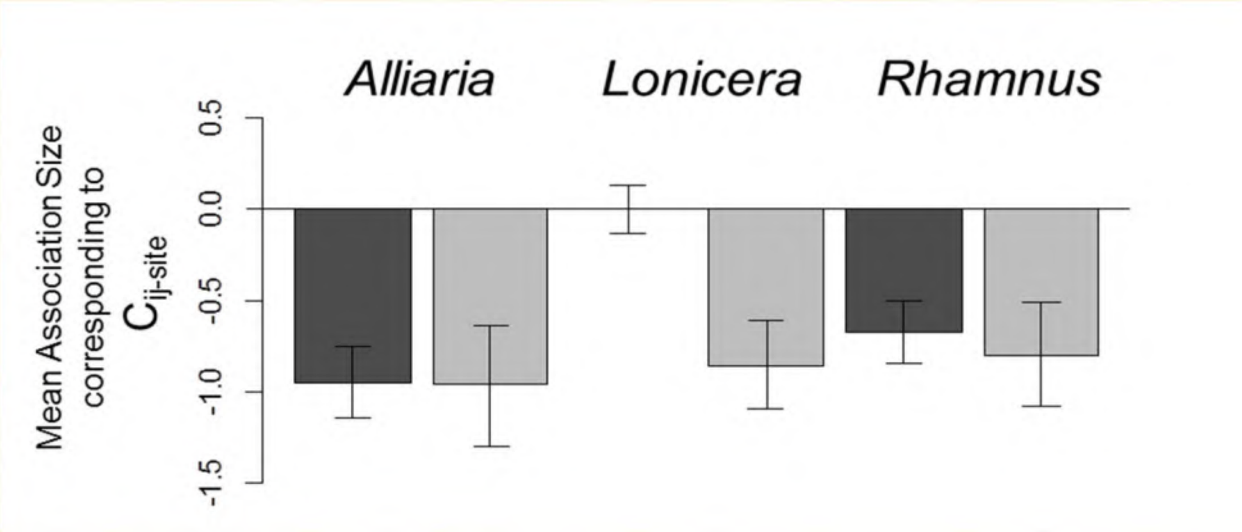
Arisaema triphyllum

Hieracium

Carex pensylvanica

Wiegmann & Waller 2006

Exotic & other 'winner' species **displace** native species



Association sizes between these 3 invasives and 70 native species across 94 sites

All negative

Not just 'passengers'

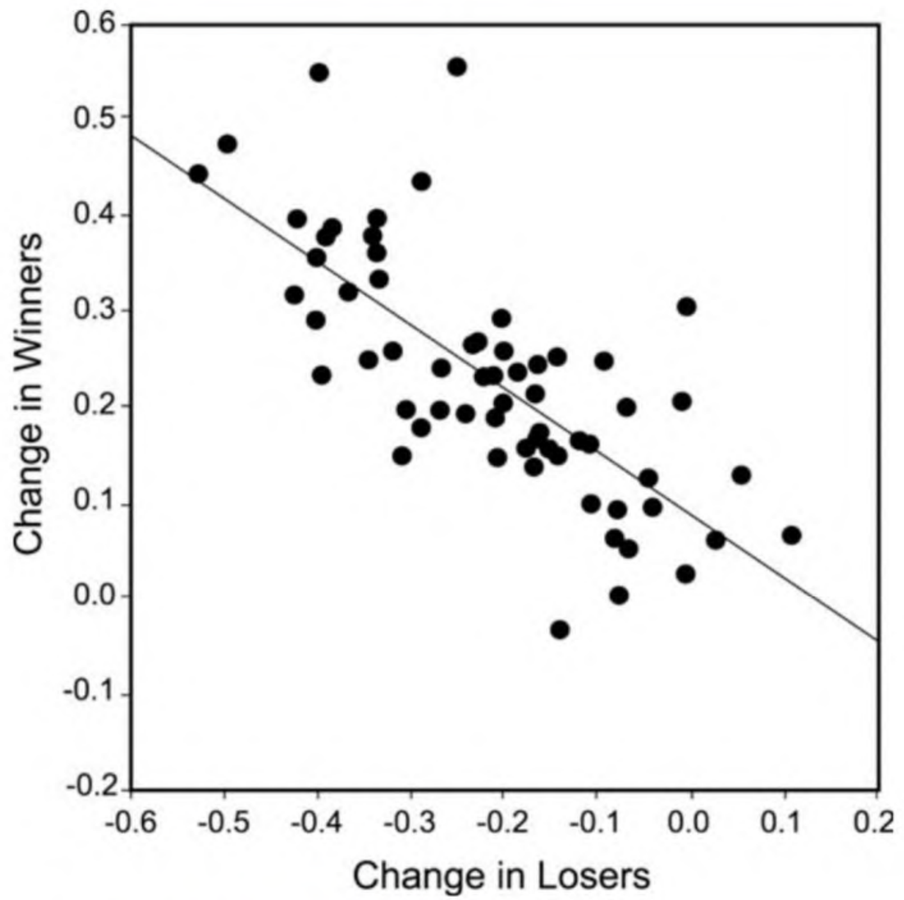


Fig. 4 – Test of Hubbell's (2001) zero sum assumption. Changes in the relative frequency of winners at each site k ($\Delta R_{k,\,winners}$) are plotted against changes in the relative frequency of losers at the same site ($\Delta R_{k,\,losers}$). Regression: $y = -0.659x - 0.089$; $r^2 = 0.537$, $p = 0.000$, N = 62 sites.

Waller et al. 2016. Biological Invasions

Southern Forests

Northwoods "Losers"

Orthilia secunda

Linnaea borealis

Mitchella repens

Viola blanda

Uvularia sessilifolia

Pretty, insect pollinated wildflowers

Clintonia borealis

Mitella diphylla

Cornus canadensis

Fragaria viginiana

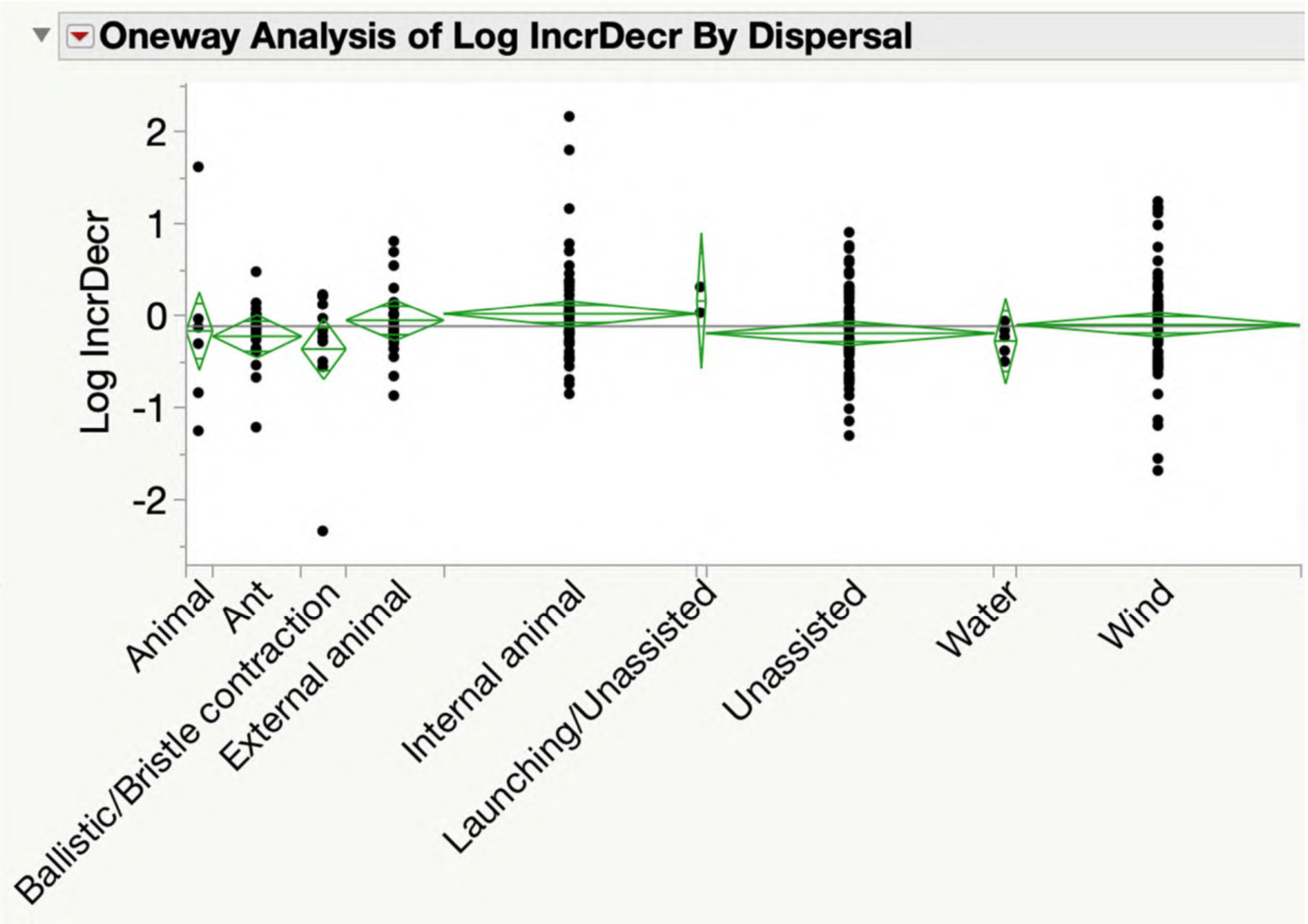
Does dispersal matter?

NO:

Mode of seed dispersal had no effect on species increases and decreases

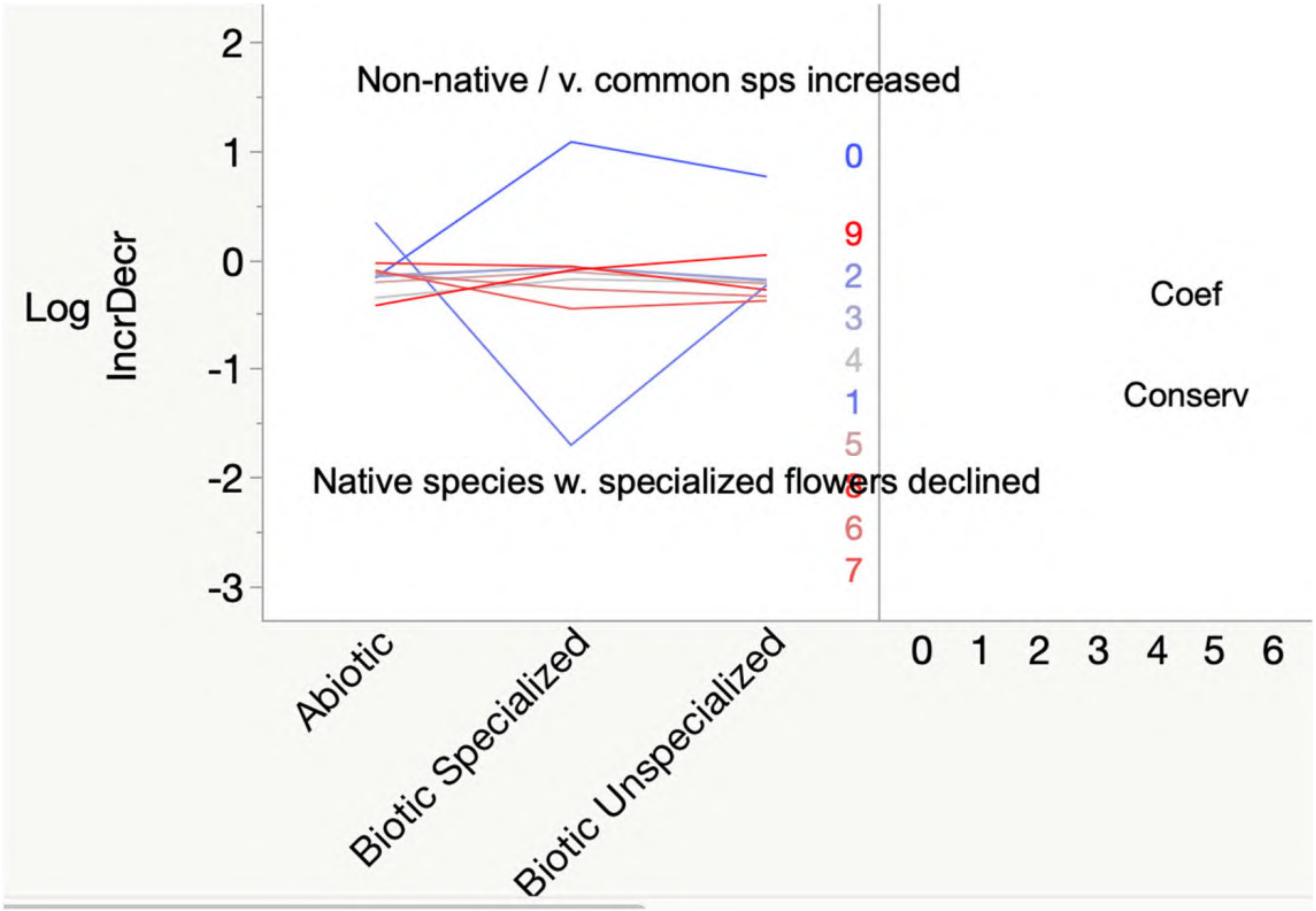
F = 1.2   NS

Except that exotics with internal animal dispersal increased faster



Does pollination matter?

- **YES** – but interacts with species ‘conservative’ status . .
  - Introduced species *benefit* from biotic pollination
  - Habitat specialist natives *declined more* when dependent on specialized pollinators



Results – N Wisconsin

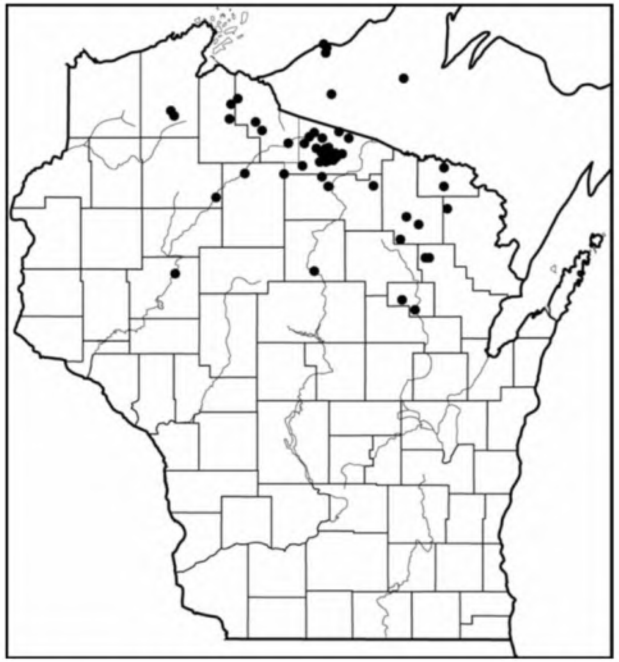
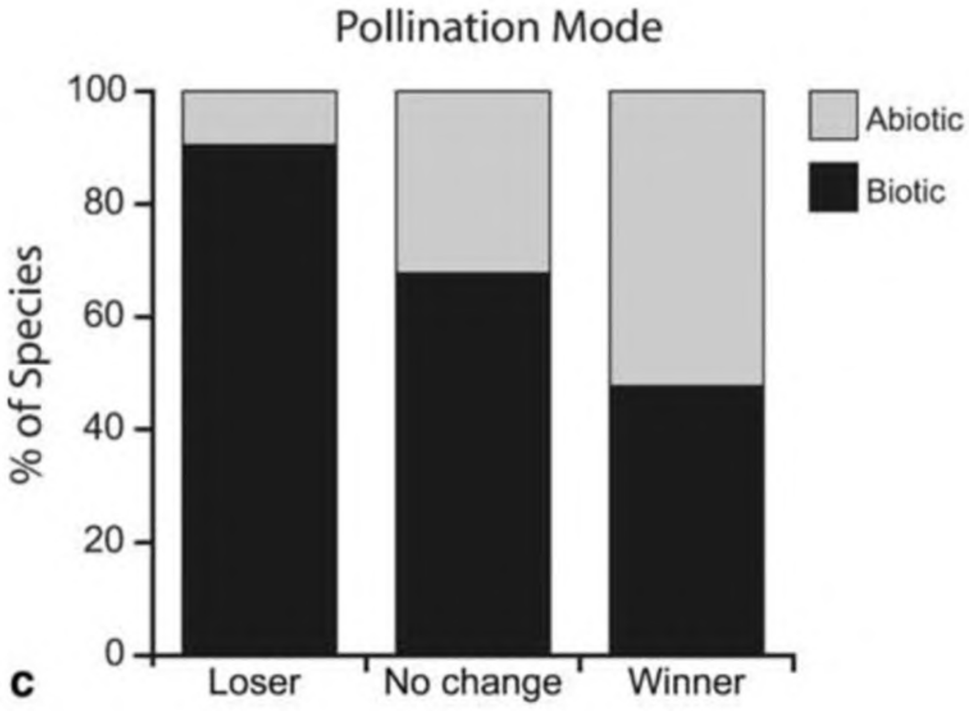


Fig. 1 – Map showing study site locations in Northern Wisconsin and the western Upper Peninsula of Michigan.



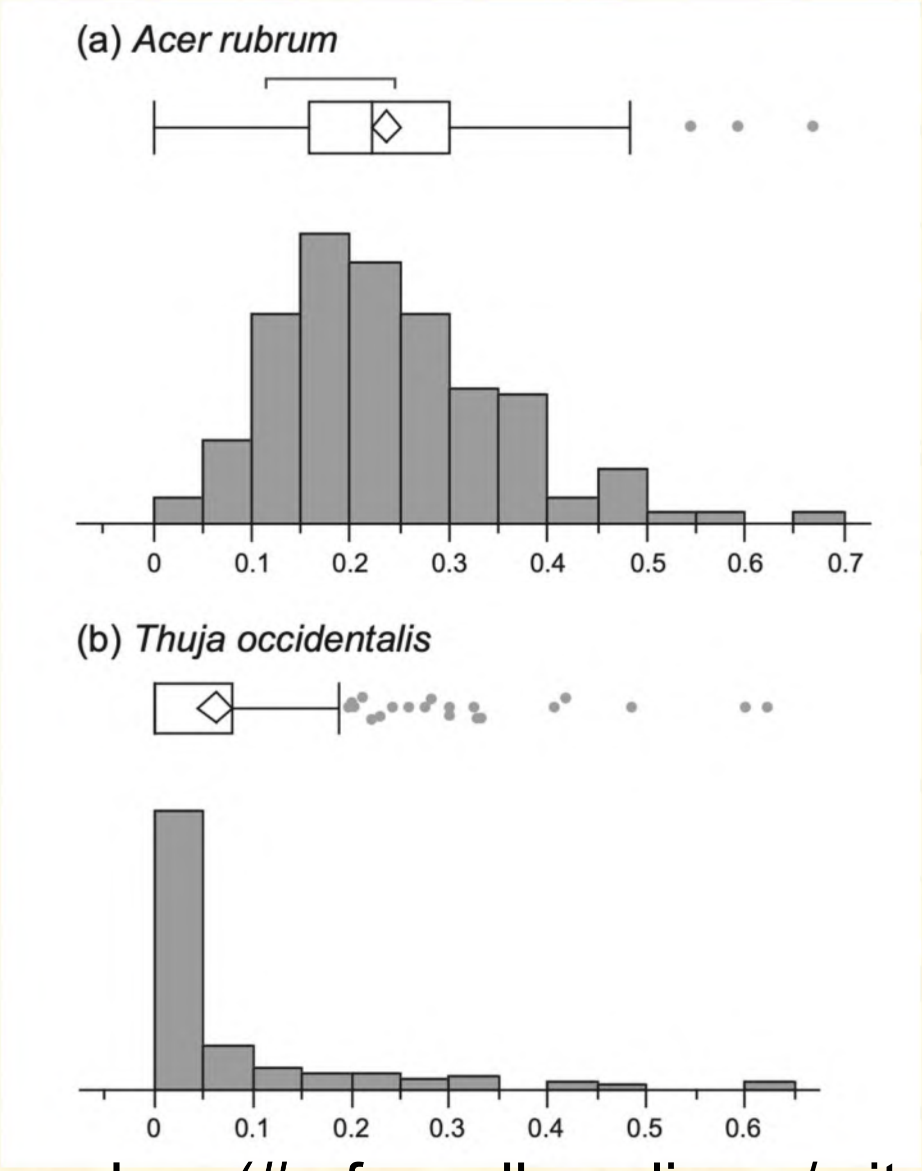
Losing **insect**-pollinated species

Gaining **wind**-pollinated species

Tree regeneration

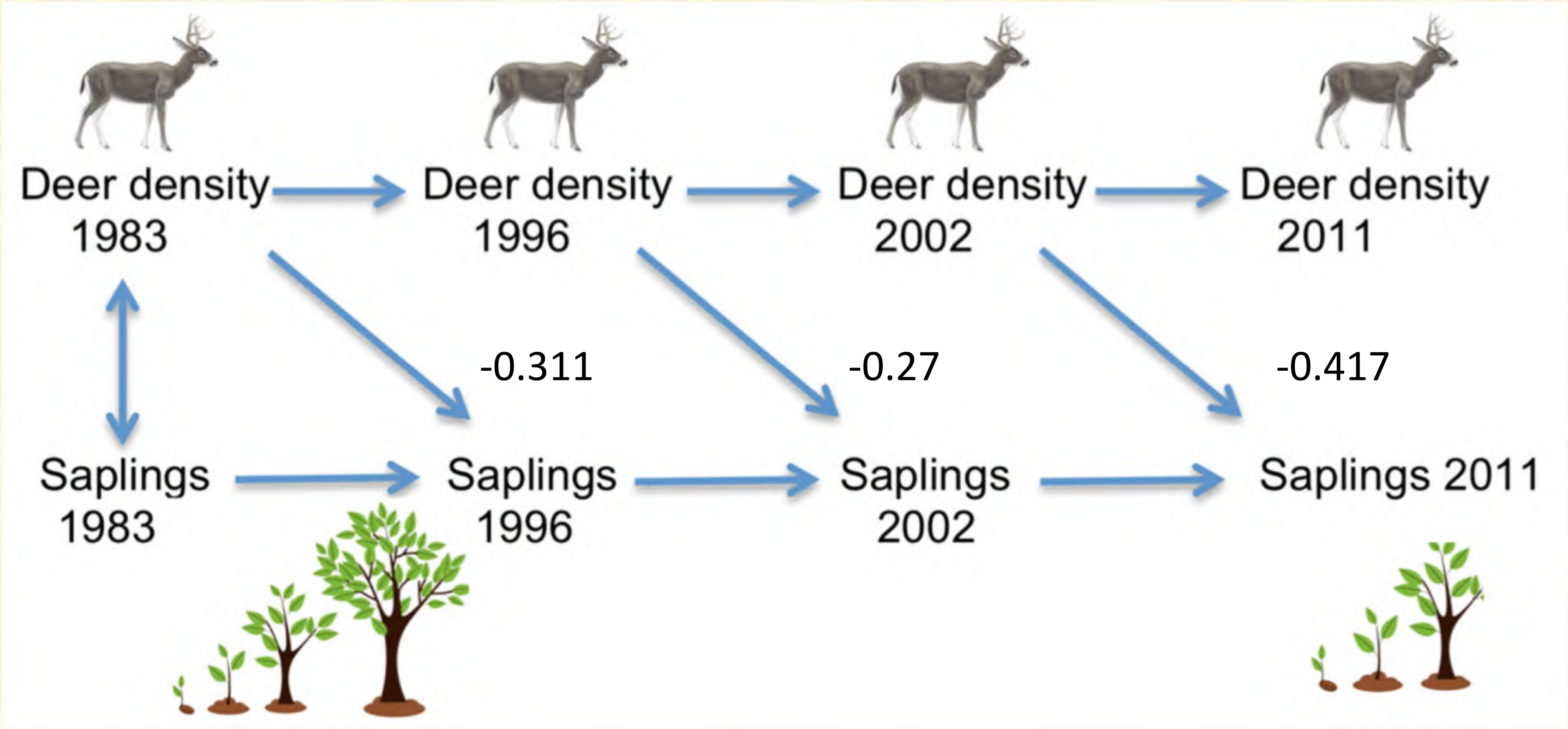
- Data – N Wisconsin
  - 13,105 US Forest Service FIA plots sampled 1983 to 2013
  - # of 2.5-5 cm saplings
- variation is often log-normal
  - e.g. *Acer rubrum*
- But distributions in ***Tsuga*** and ***Thuja*** are highly **skewed** & **mostly 0's**

WHY?



Log (# of small saplings / site)

Tree regeneration



Deer cumulatively reduced *Acer* & *Populus* sapling numbers over past 30 years

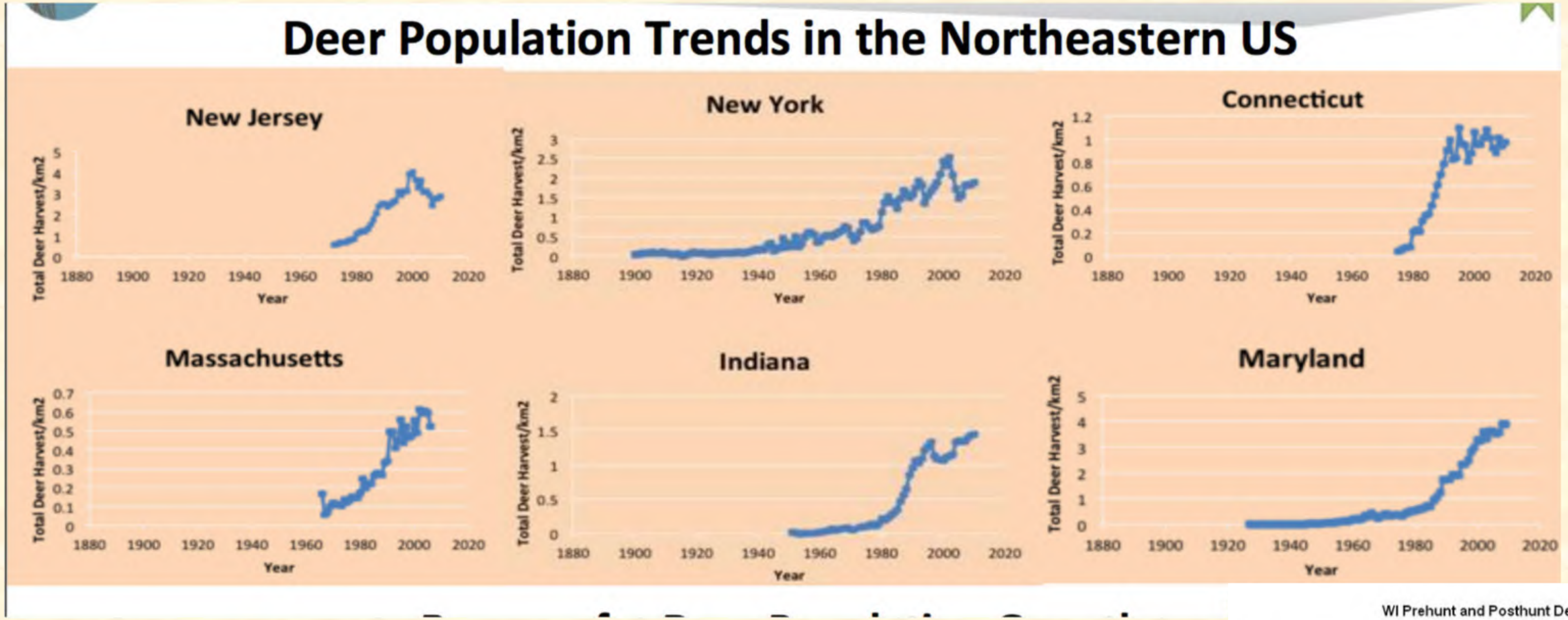
Total **deer effect** (betas):
-0.31 in 1996
-0.59 in 2002
-1.18 in 2011

SEM analysis

Impacts of white-tailed deer on regional patterns of forest tree recruitment

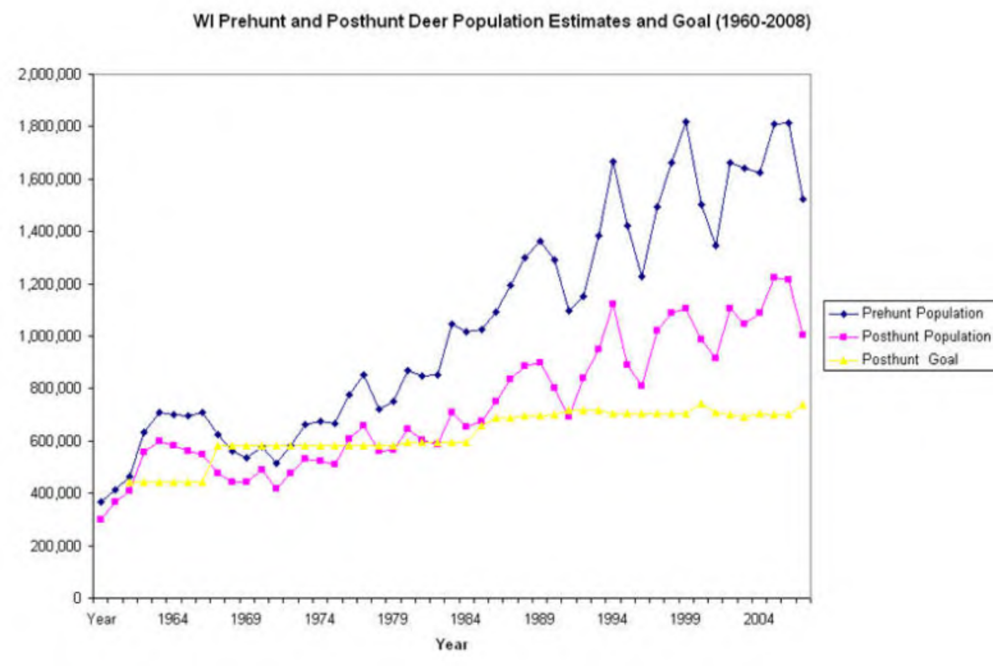
Lauren Bradshaw, Donald M. Waller *

Forest Ecology and Management 375 (2016) 1–11



Deer have increased regionally

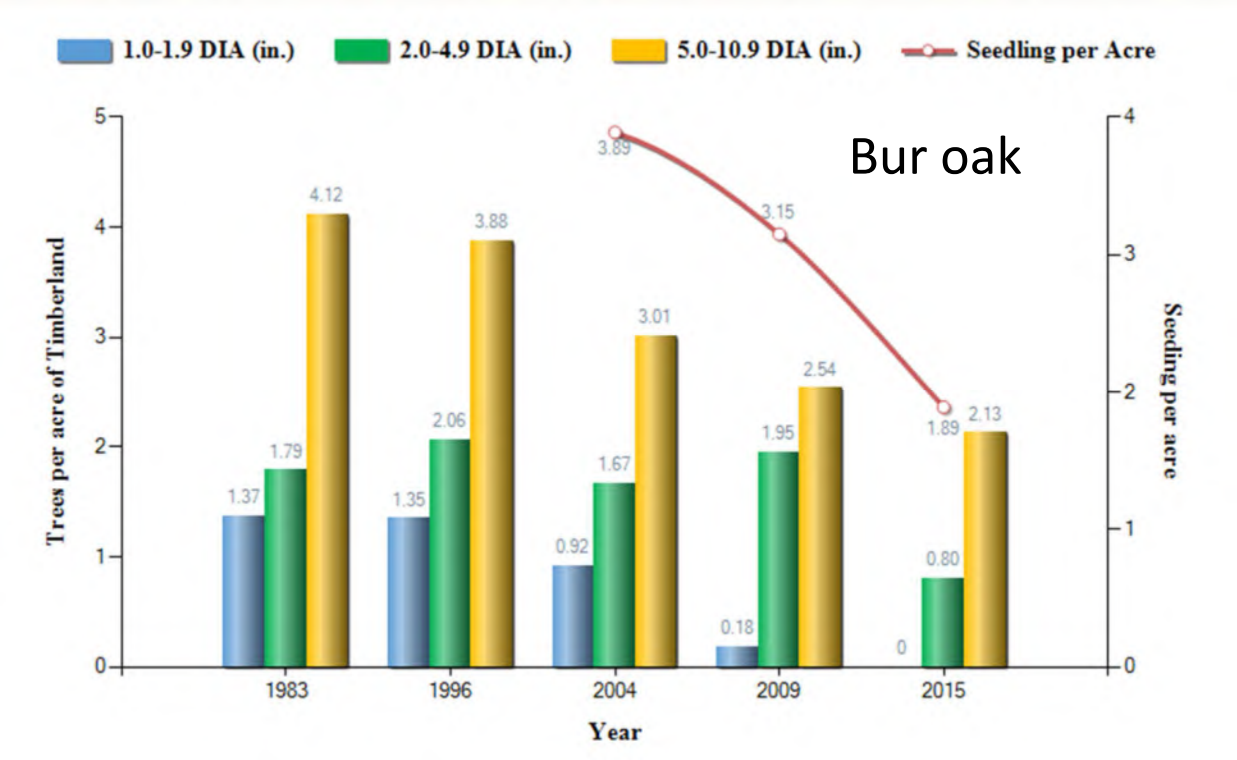
Wisconsin

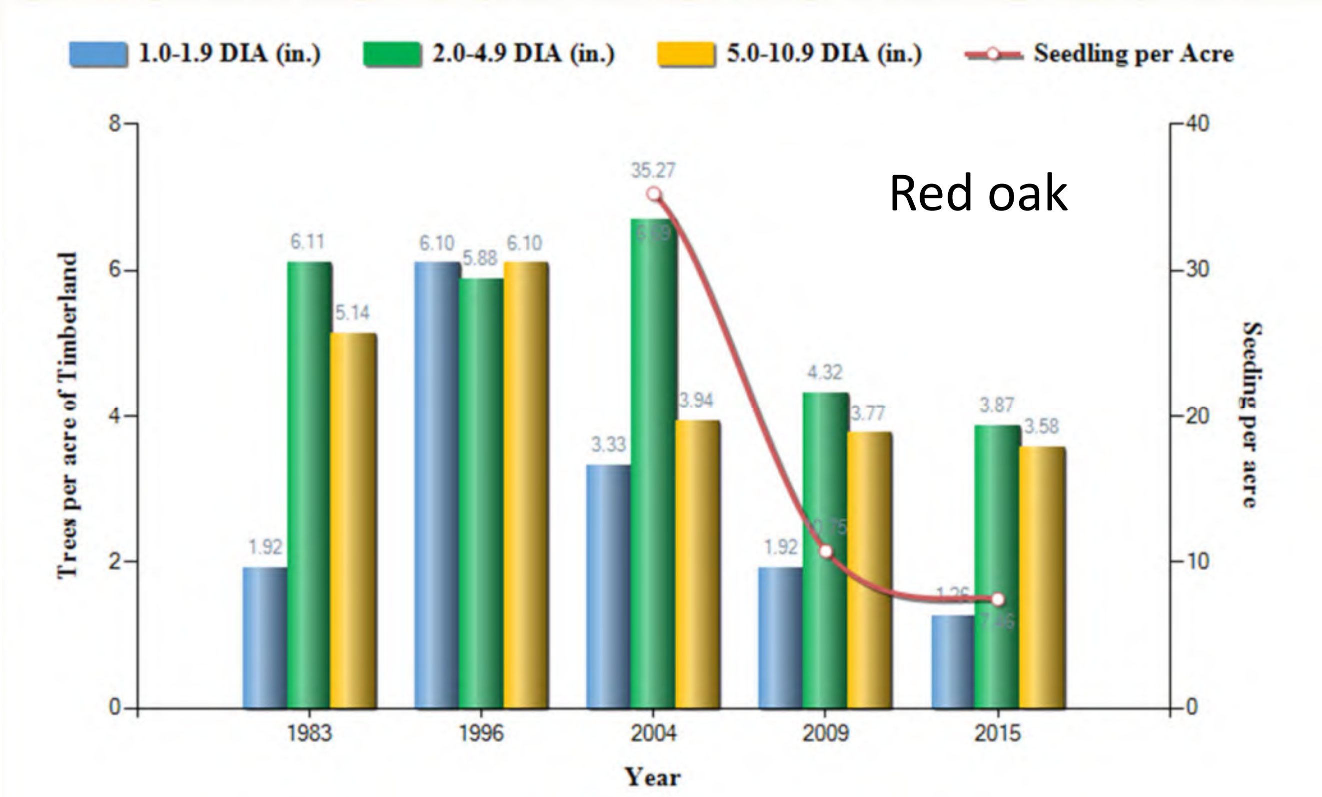


Deer Impacts on Trees

- Forests shifting in composition due to failed recruitment
- Also in S Wisconsin

25 year old
Quercus rubra

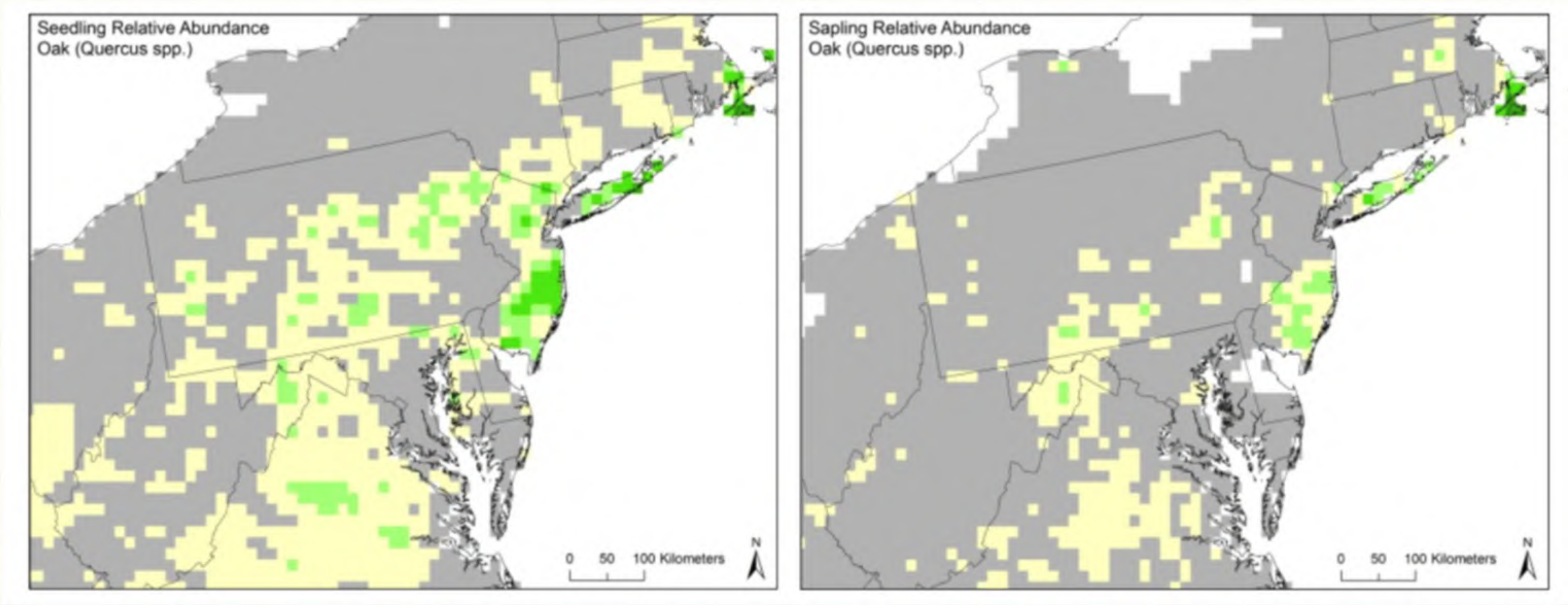




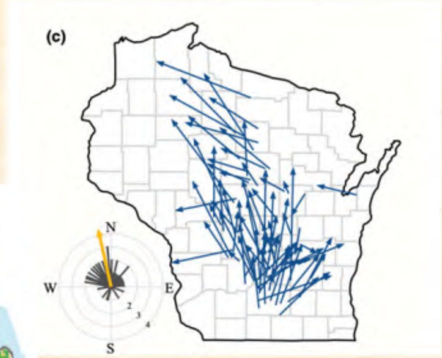
Tree “Regeneration Debt” - Eastern U.S.

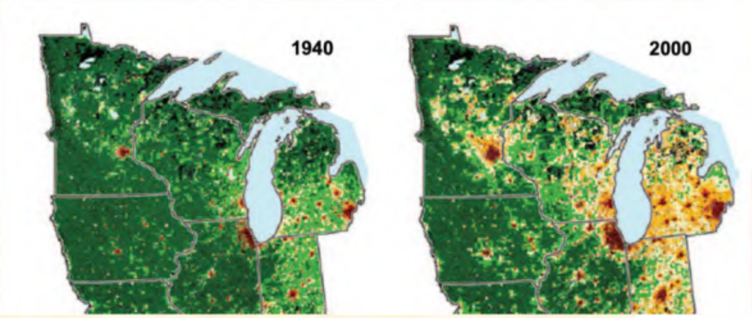
“Regeneration was severely lacking, and where present, was composed of **suboptimal species**, such as disease-prone or low canopy species.”
“Without management, the **regeneration debt** we identified . . could lead to **widespread loss in forest cover** that will have cascading effects on forest-dependent taxa and ecosystem services.”

Miller, K.M. & McGill, B.J. (2019) Compounding human stressors cause major regeneration debt in over half of eastern US forests.
J. Appl Ecol 56: 1–12.



Summary: Understories in trouble





- Many forces threaten plant diversity:
  - Climate change
  - S Wisc: Fragmentation, N-dep, Invasives
  - Deer herbivory

- 50-year declines in:
  - Community diversity at most sites
  - Abundance of majority of species, esp. those with **specialized flowers / pollinators**

?

?

- Trees face 'Regeneration Debt' from diseases, deer herbivory . .

- Even major changes are **invisible** without long-term **monitoring**

→. Standardize metrics & methods!

Merci á tous

NSF

CSREES
EDUCATION
RESEARCH
EXTENSION
USDA

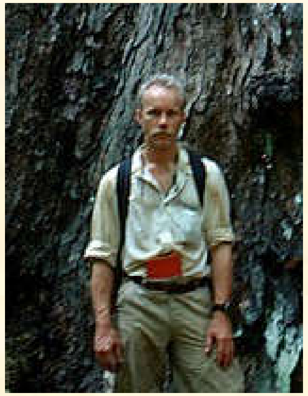
USDA

Aldo Leopold

John Curtis

Dave Rogers

Bil Alverson



Plant Ecology Laboratory

Plant Ecology Laboratory
University of Wisconsin

Sarah Johnson

Erika Mudrak

Shannon Wiegmann

Steve Horn