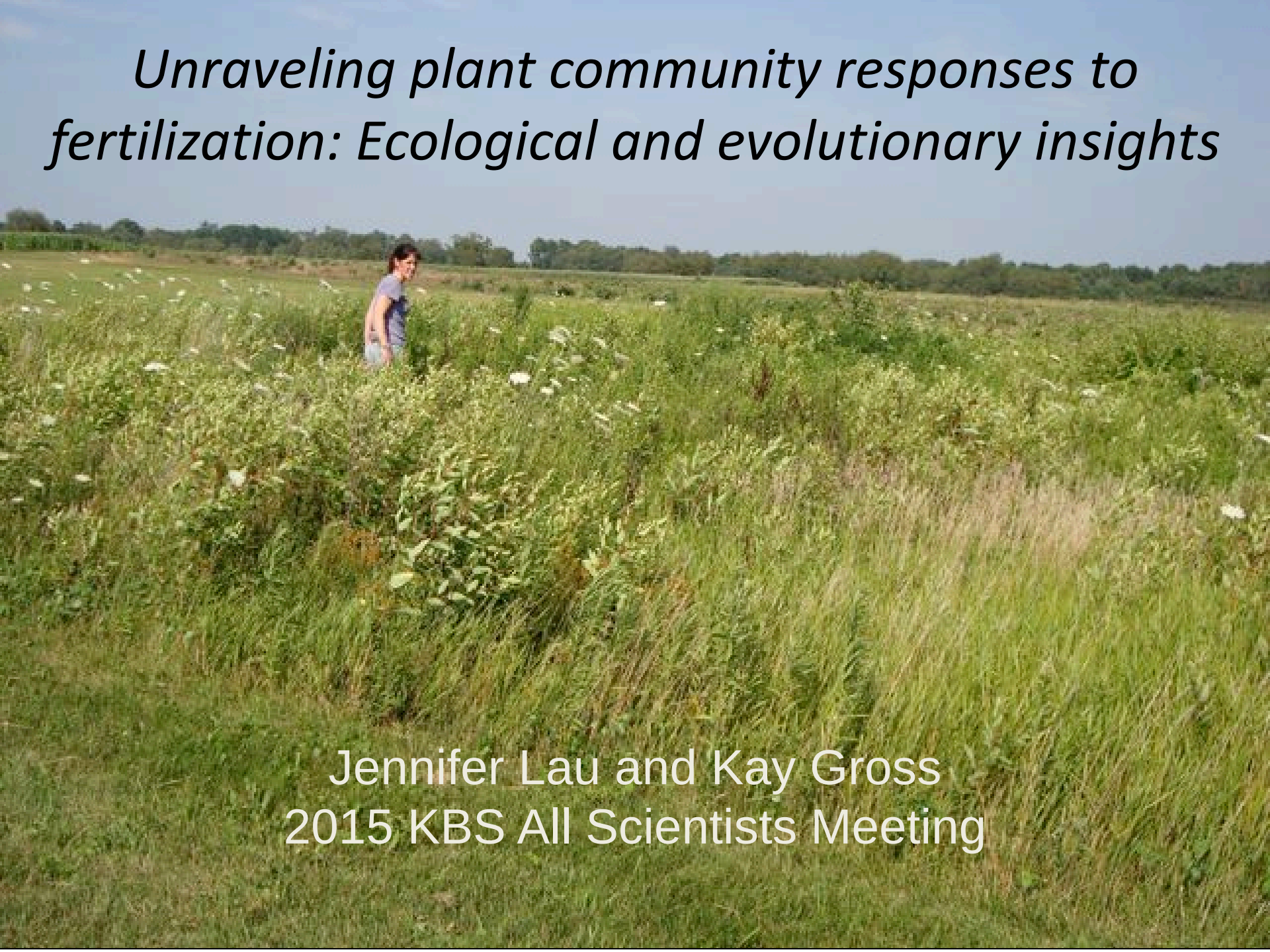
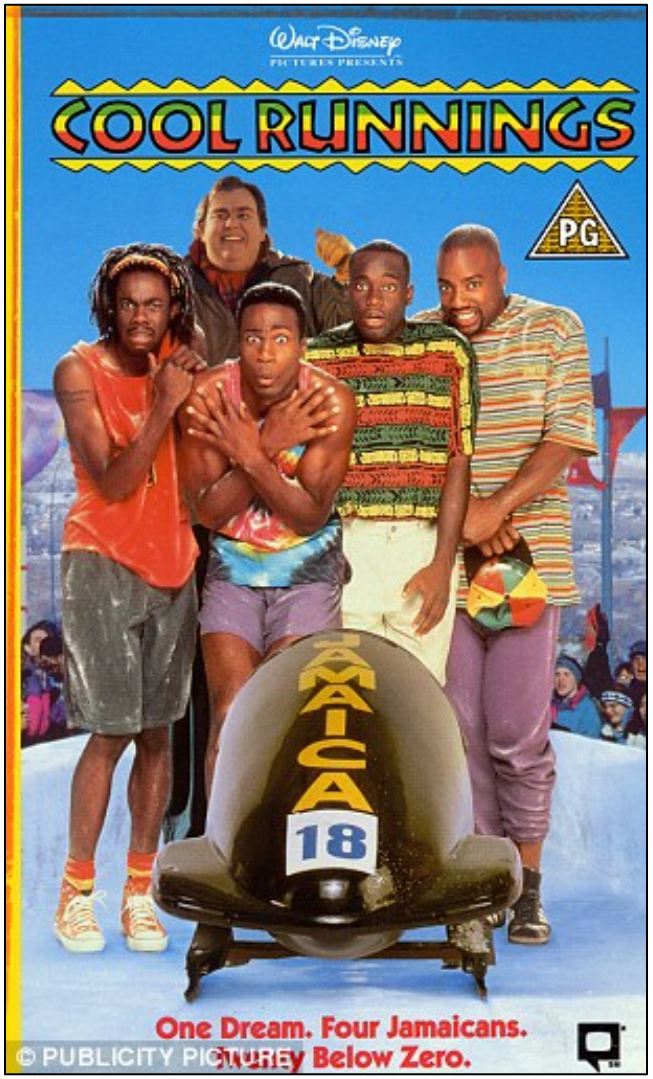
Unraveling plant community responses to fertilization: Ecological and evolutionary insights

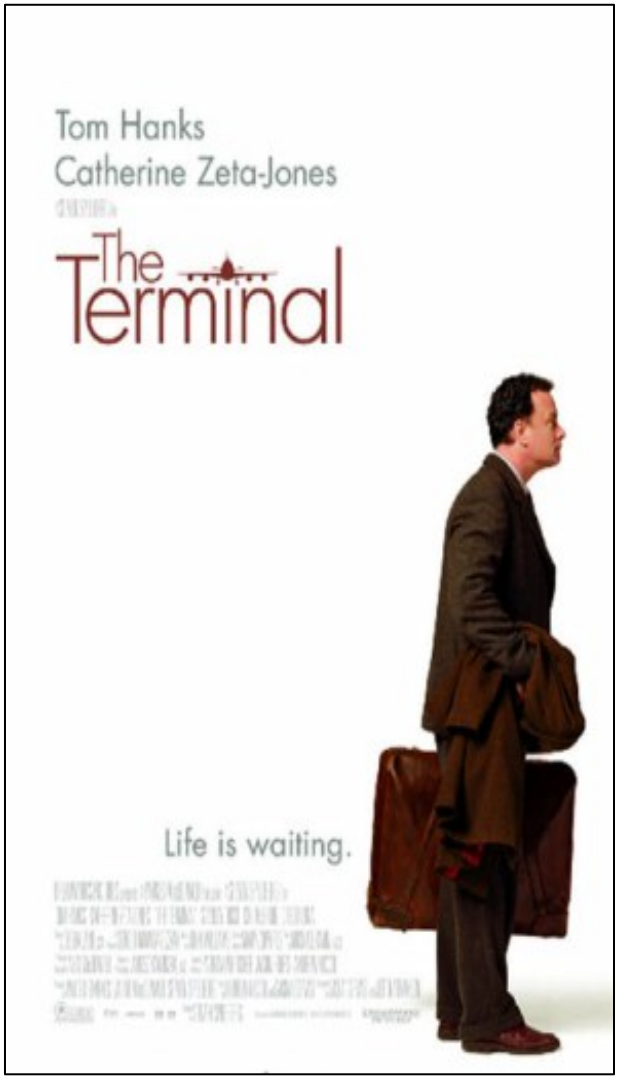


Jennifer Lau and Kay Gross

2015 KBS All Scientists Meeting

1988 was a really big year…





LTER

Walt Disney

PICTURES PRESENTS

The Ecology of Agricultural Landscapes

LONG-TERM RESEARCH ON
THE PATH TO SUSTAINABILITY

Starring: Tom Hanks

as Phil Robertson

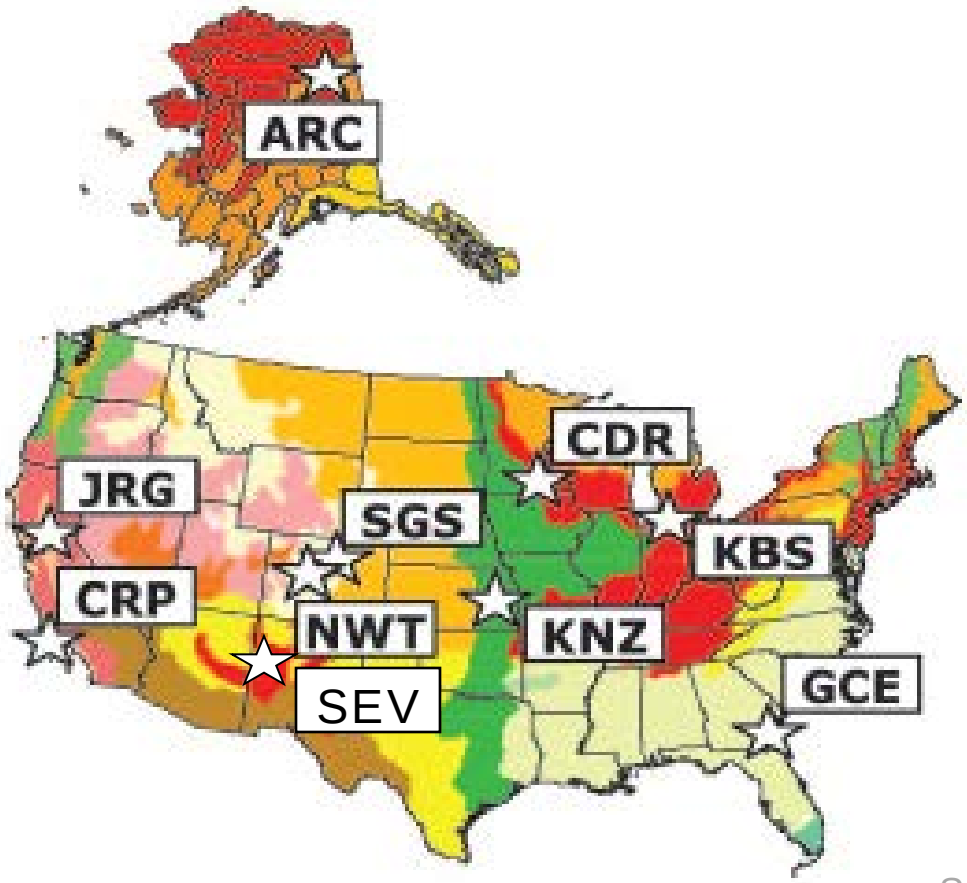
Since 1988 KBS has been addressing 3 key questions in plant community ecology:

1) What controls the diversity and composition of plant communities associated with agricultural systems?
2) How do diversity and composition of these communities change in response to “externalities” (e.g. increased Nitrogen input, variation in precipitation)?
3) What are the consequences of these changes for ecosystem services?

Central questions in plant community ecology:

1) What controls the diversity and composition of plant communities associated with agricultural systems?
2) **How do diversity and composition of these communities change in response to "externalities" (e.g. increased Nitrogen input~~, variation in precipitation)?~~**
3) What are the consequences of these changes for ecosystem services provided by these systems?

The Surprise: How does N-addition influence plant community composition and diversity?



-PDTnet, a compilation of 37 experiments

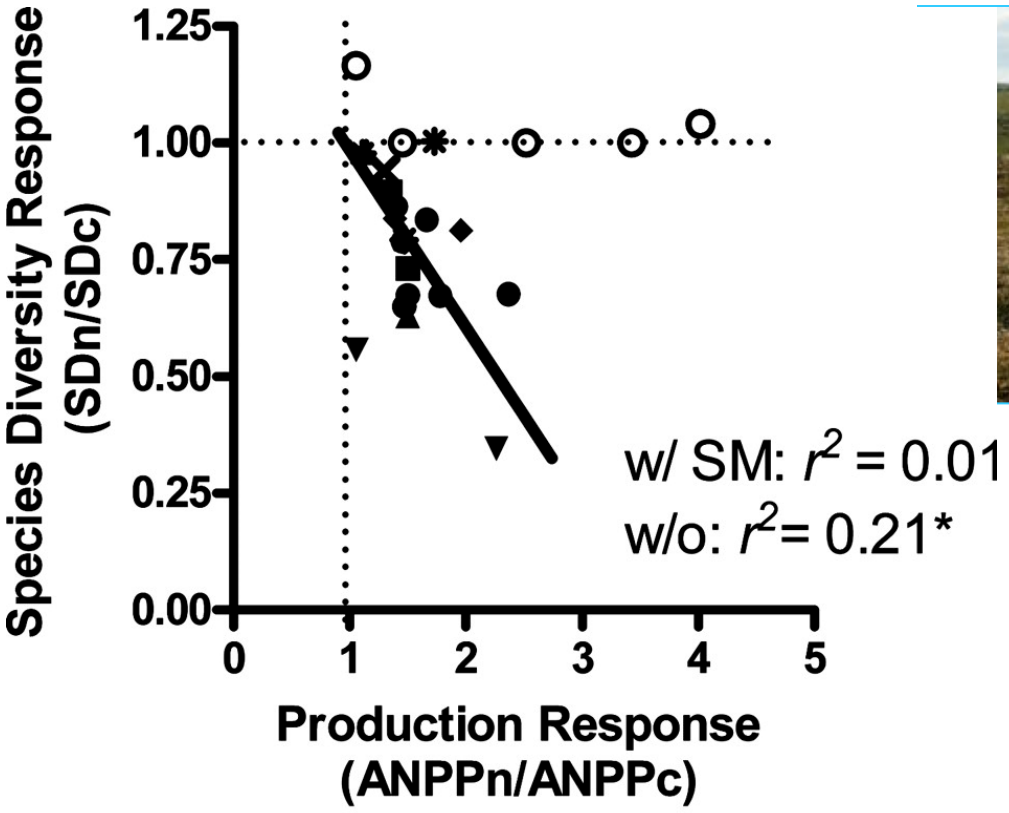
- Responses of 1000+ species records

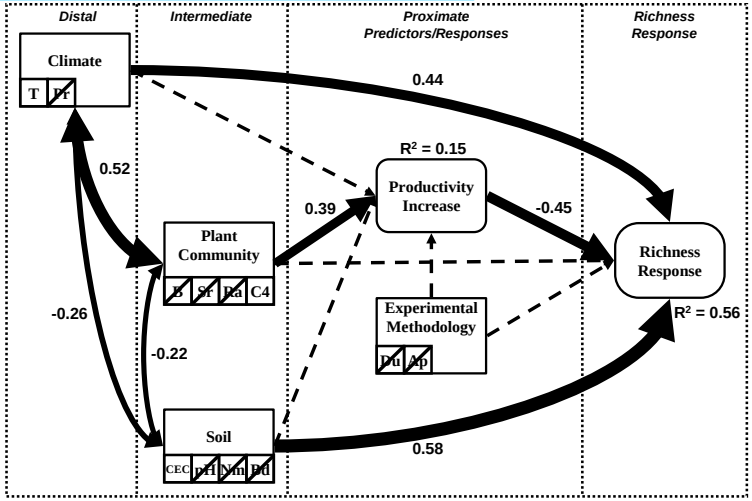
- Responses evaluated in relation to species traits

- Data compiled Cleland et al 2005 (and updated)

Suding et al. 2005 PNAS; Clark et al. 2008 Ecol Letters; Cleland et al 2011J Ecology; 2013 Ecology Gough et al 2012 Oecologia

N-addition decreases diversity



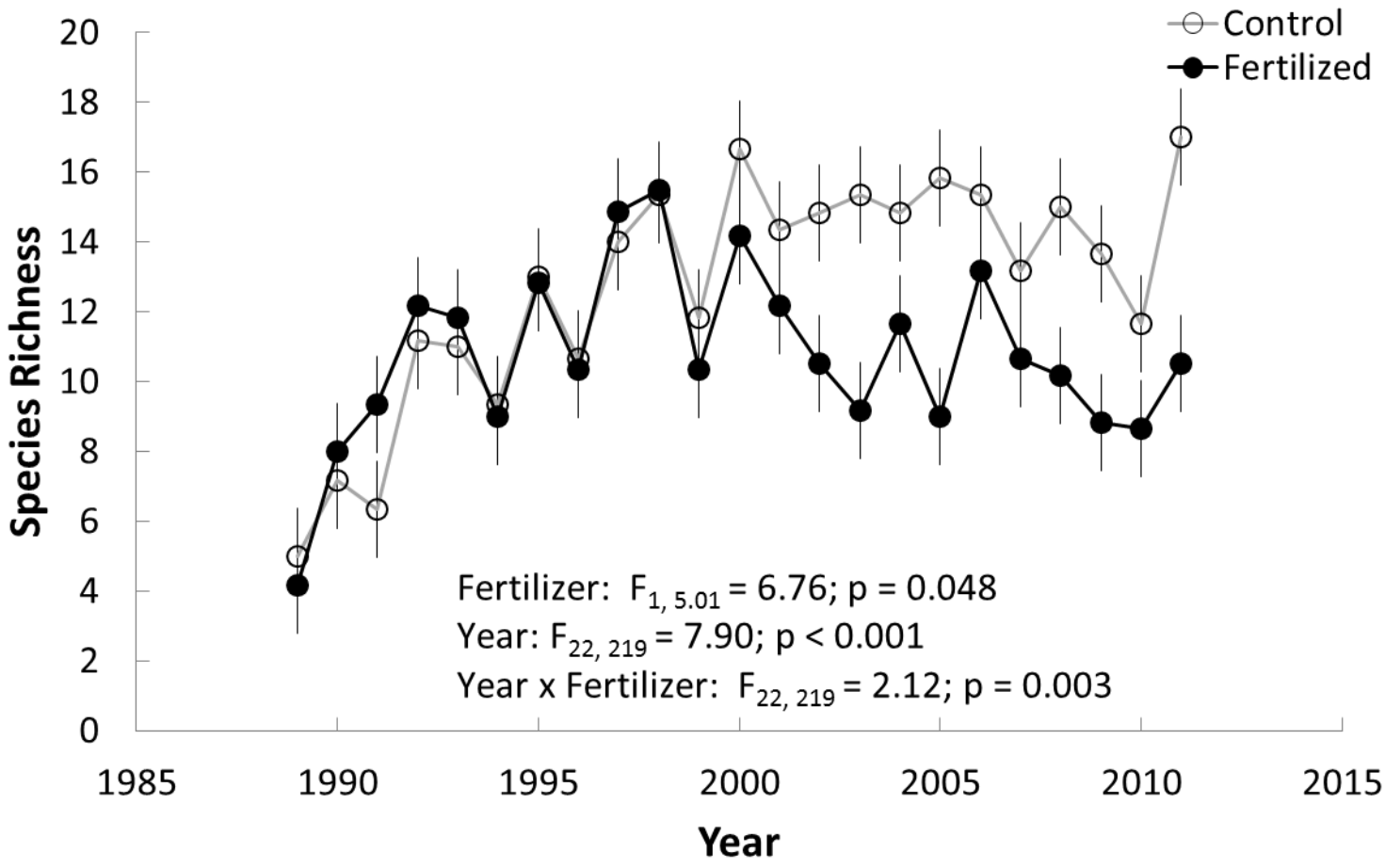


Suding et al. 2005 PNAS

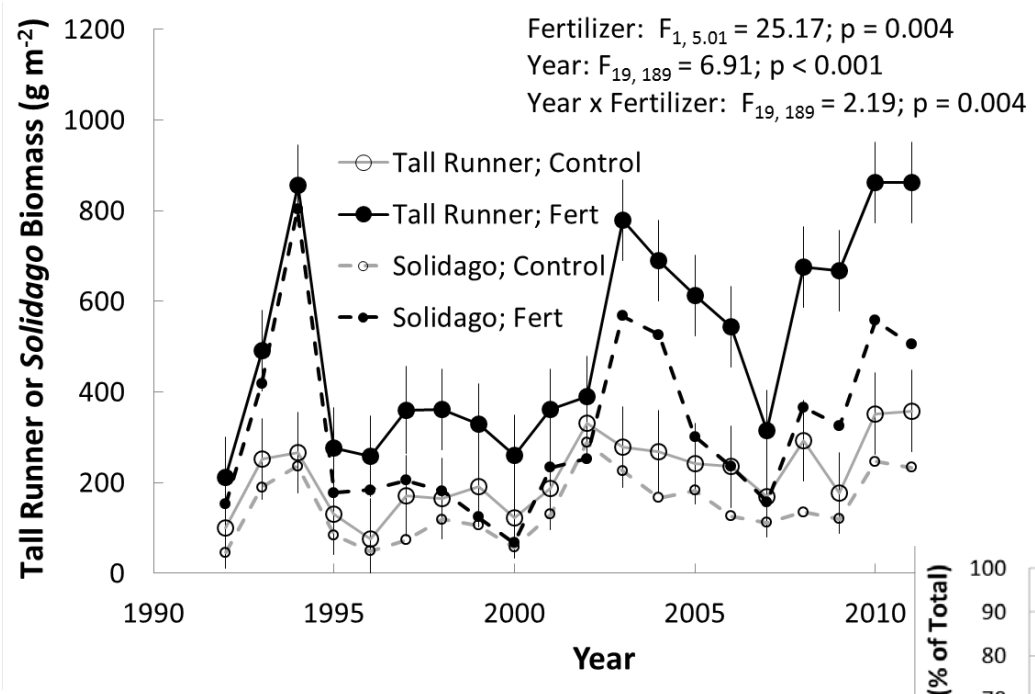
Clark et al. 2008 Ecol Letters

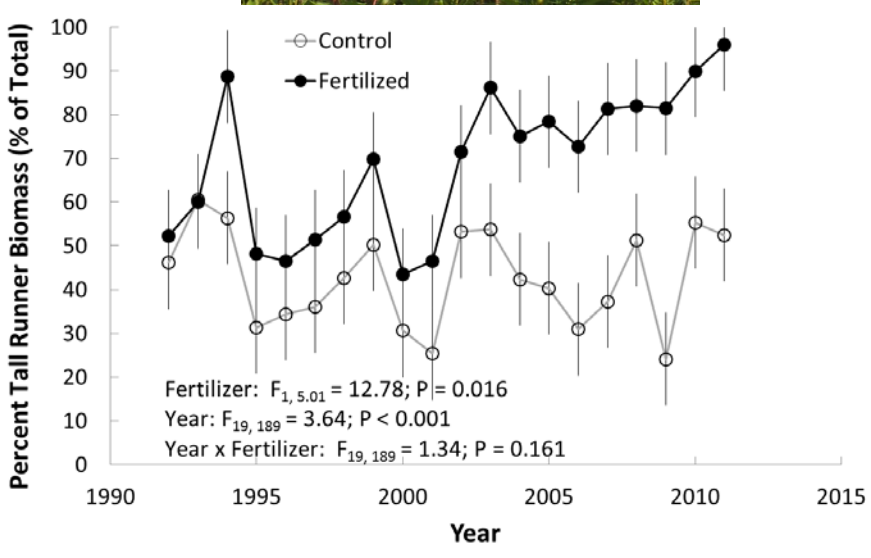
The "KBS Story" … did not fit follow the "pattern"

Species richness decline was 'delayed'… 14 years!

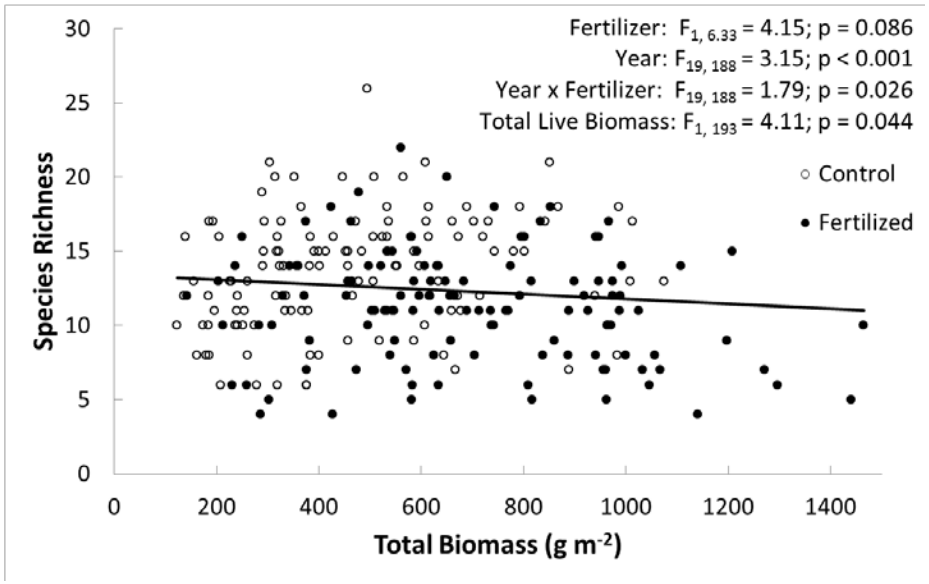


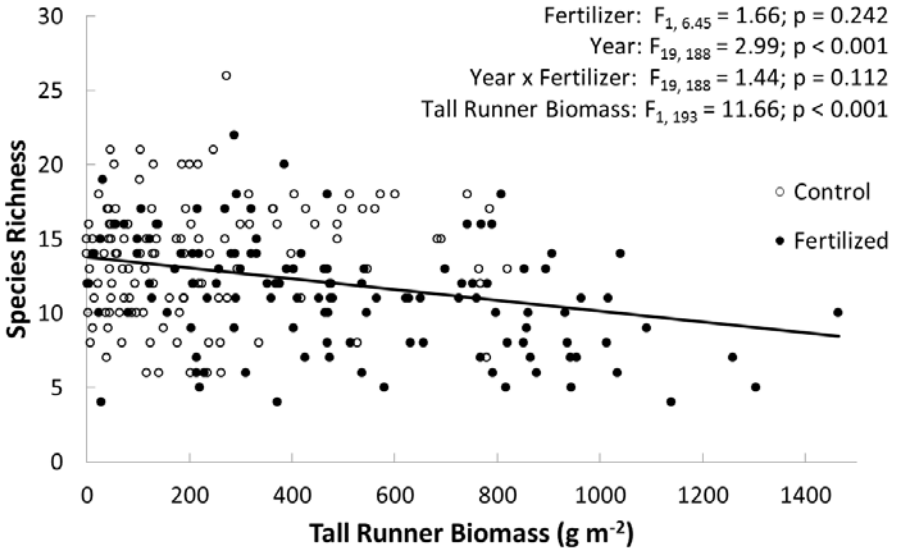
Changes in the abundance of ‘tall-runner’ species (goldenrod species) seems to drive this pattern

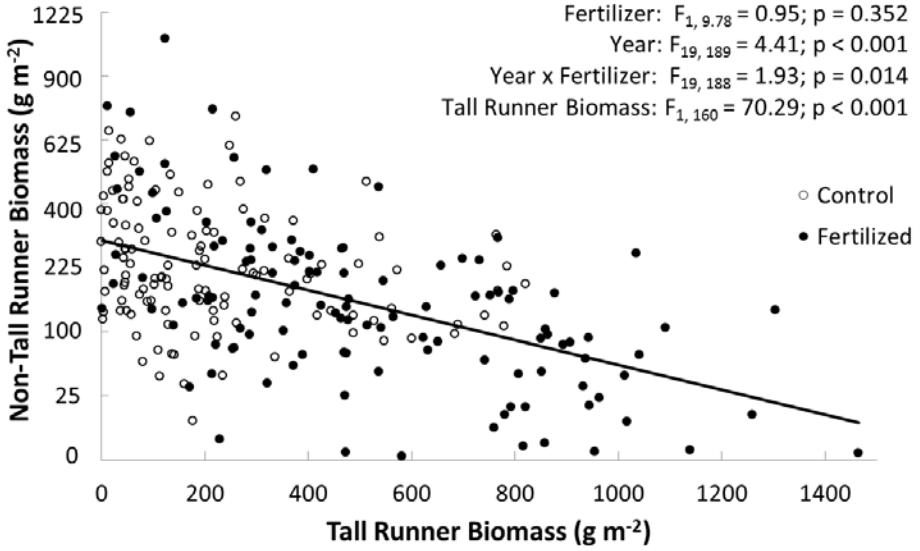




Dickson & Gross (in review)







When “tall-runner species” increase, “non-tall runners” decrease in abundance…
and species richness declines

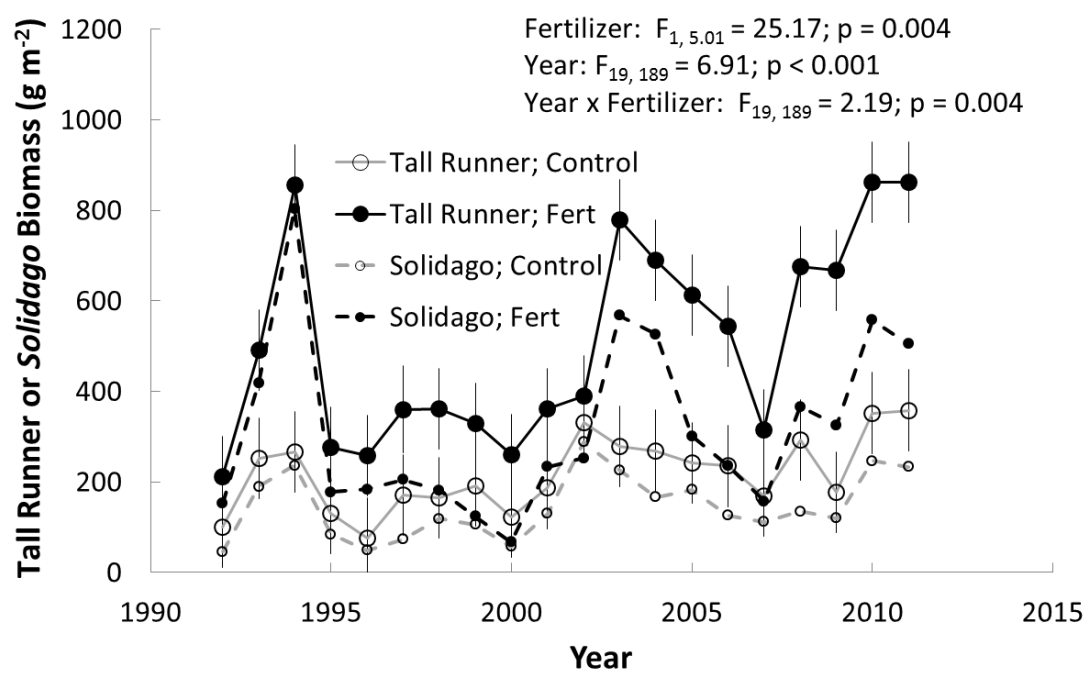
Dickson & Gross (in review)

What caused the delay?

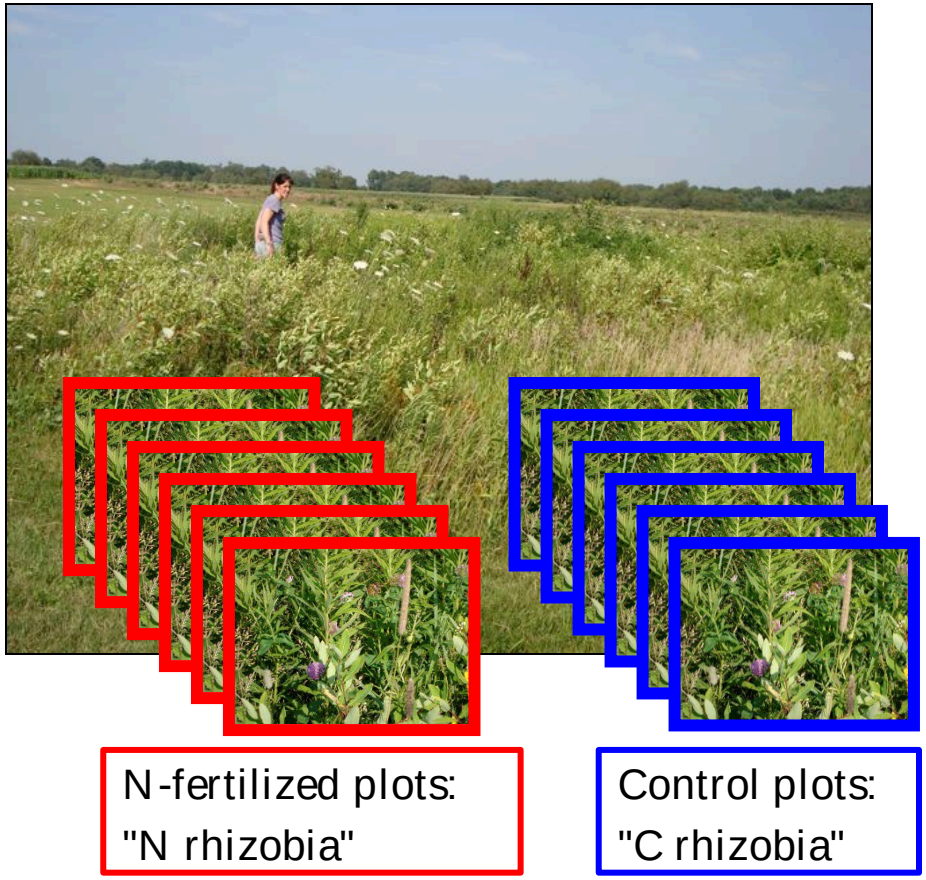
Disappearance of 'tall runners' such as Solidago species 3-4 years into the study

What caused the Solidago 'tall runners' to decline?

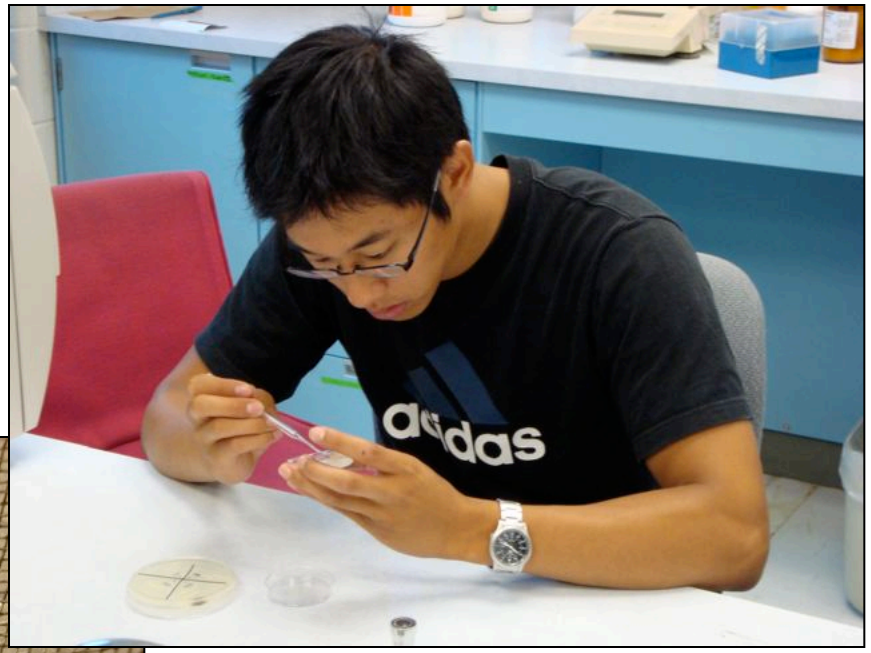
Hypothesis:
Emergence of species specific herbivore (e.g. *Trirhabda* spp) which controlled *Solidago* abundance and prevented losses of species due to fertilization

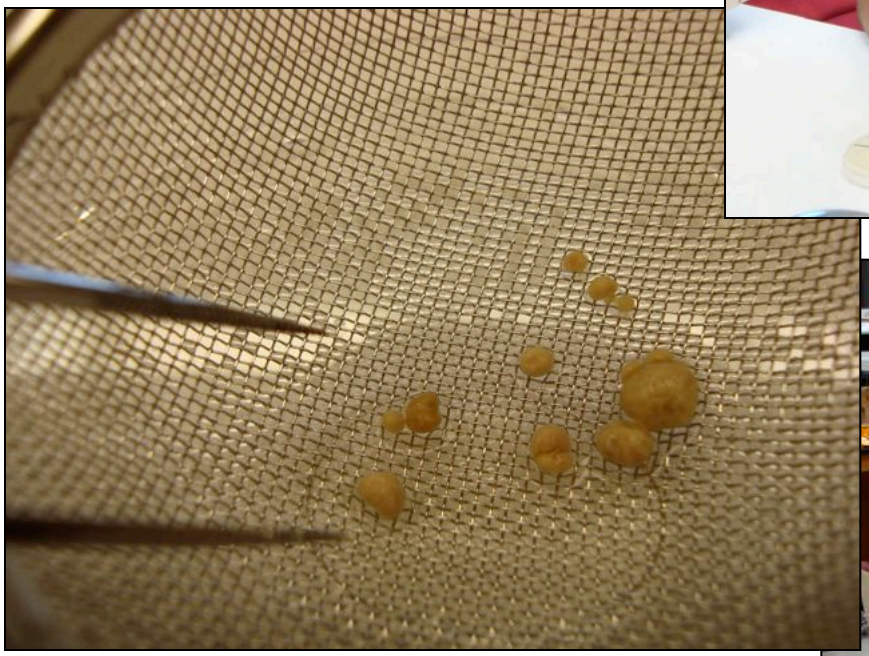


The Rip Van Winkle effect: How does N-deposition affect the evolution of the legume-rhizobium mutualism?

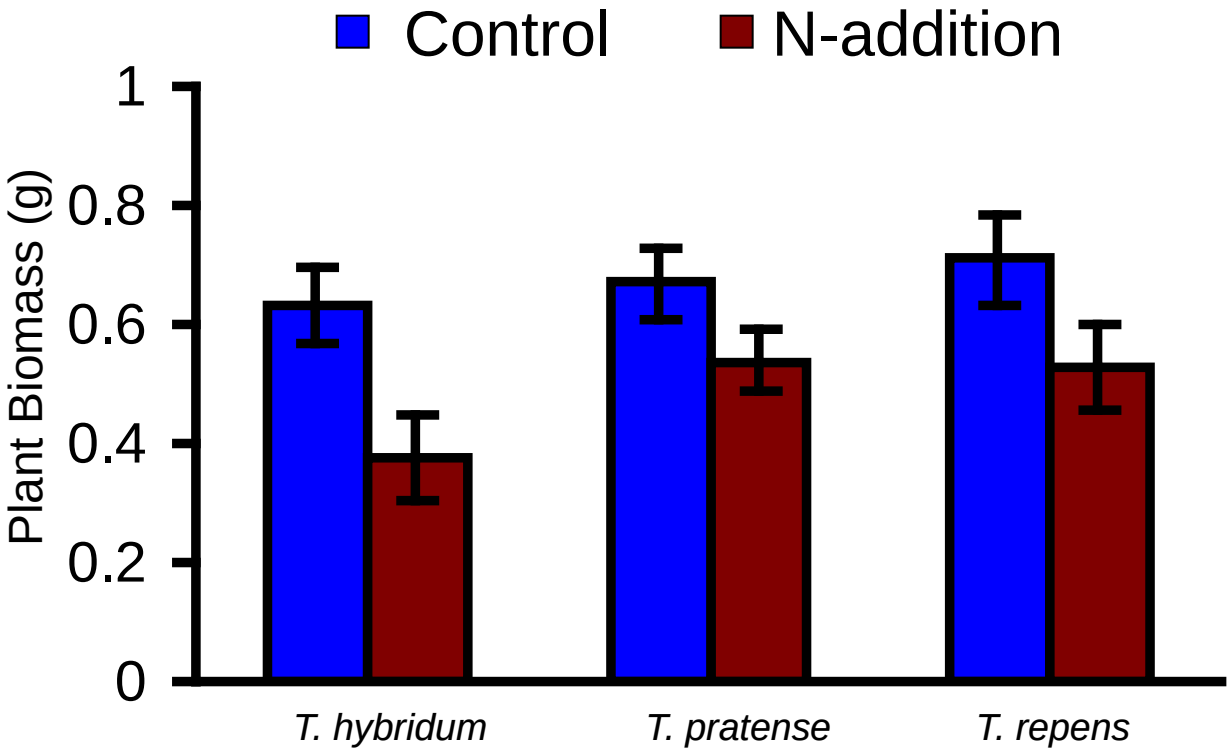


How study evolution in LTER?
Compare populations from N-addition and control plots.



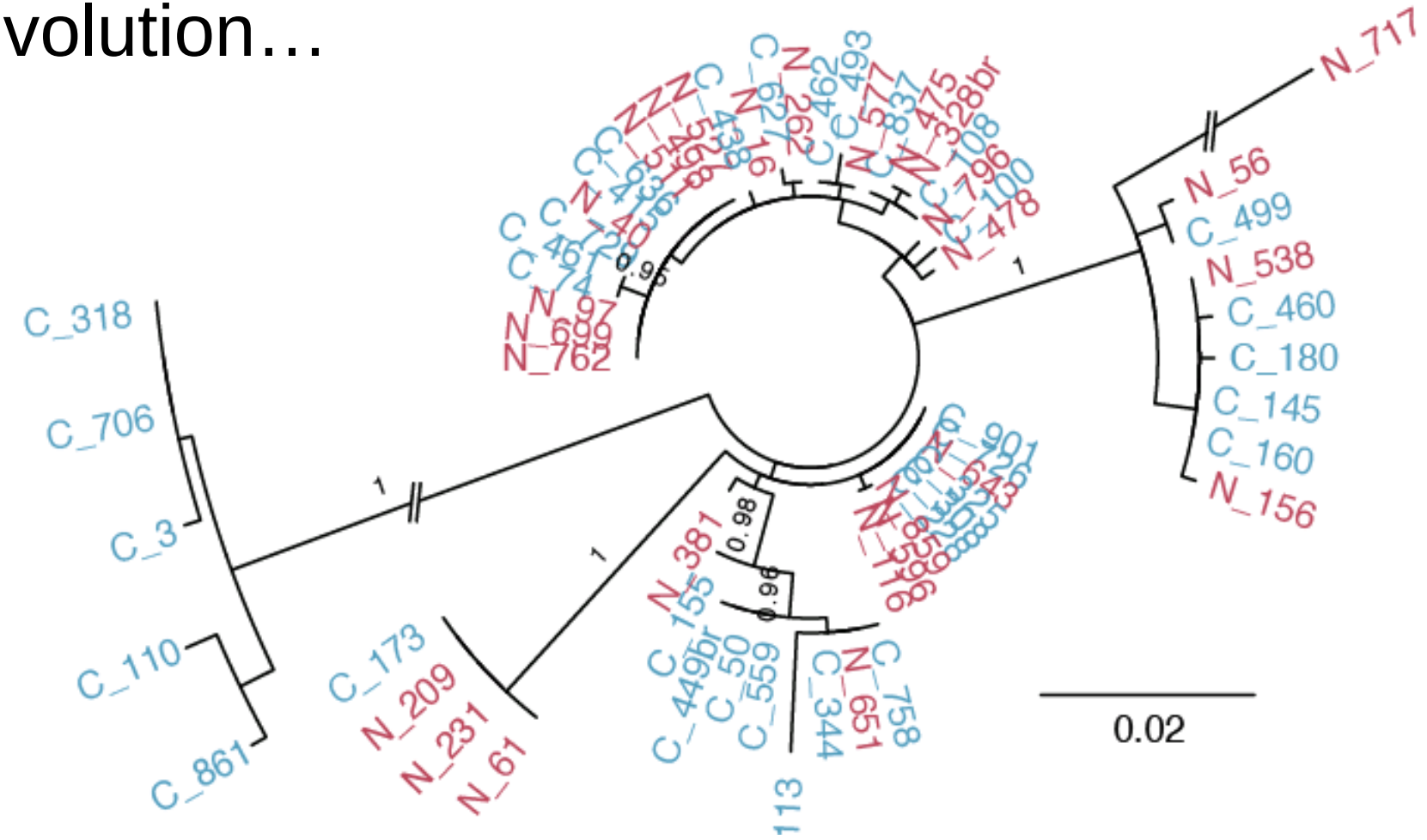


N-addition causes the evolution of less cooperative mutualists…



Weese et al. 2015 *Evolution*

Strains from N-fertilized and control plots are interspersed across the phylogeny suggesting evolution…

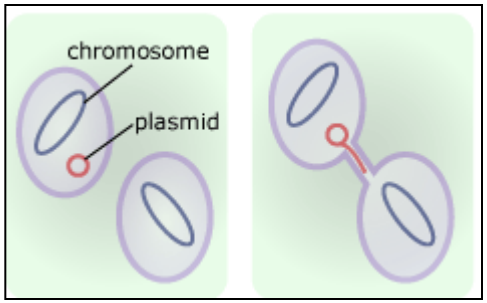


…rather than changes in community composition

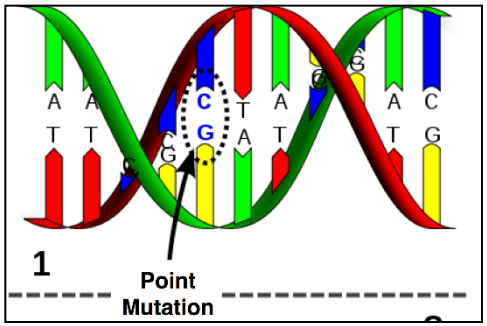
Weese et al. 2015

N-addition causes rhizobia to evolve to be less beneficial…

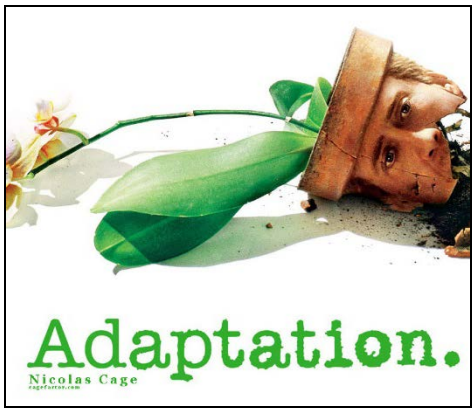
Genetic mechanisms



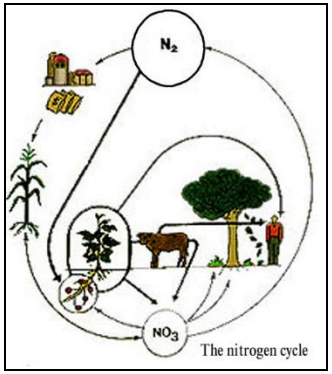
(http://evolution.berkeley.edu)



Evolutionary mechanisms

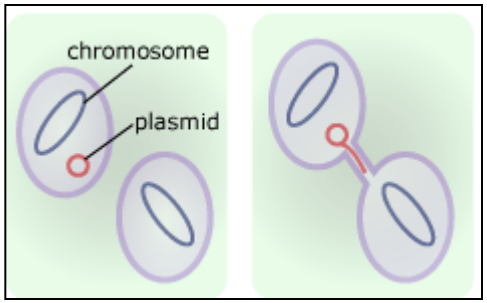


Ecological consequences



N-addition causes rhizobia to evolve to be less beneficial…

Genetic mechanisms



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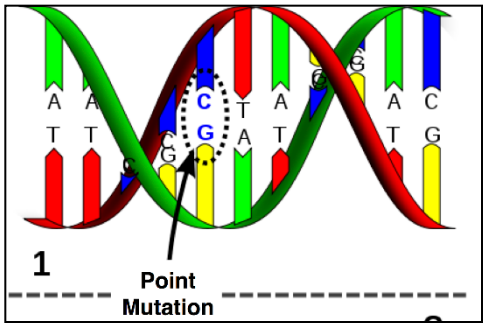
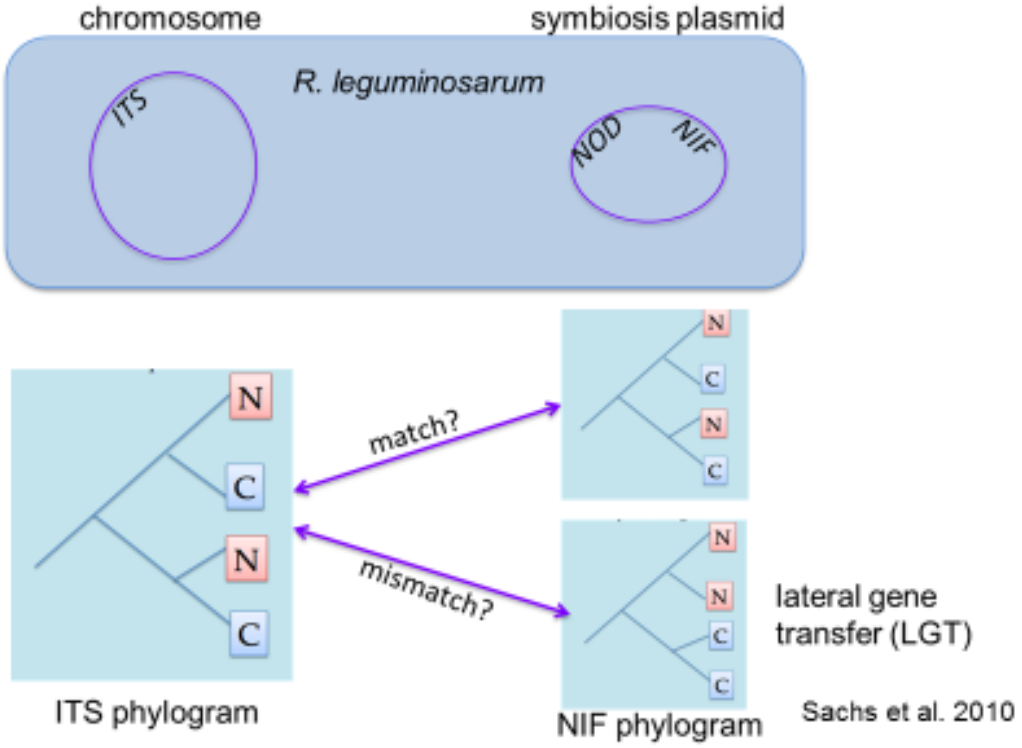


Is lateral gene transfer responsible for evolution of reduced cooperation?

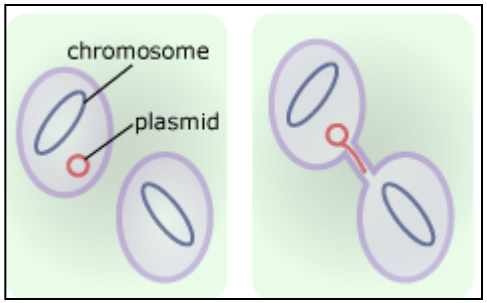


LGT is rampant and explains some, but not all, of our findings…

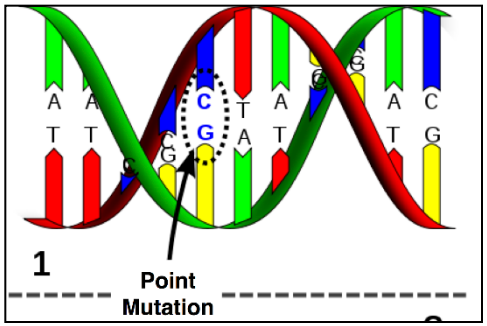
Gordon et al., in review

N-addition causes rhizobia to evolve to be less beneficial…

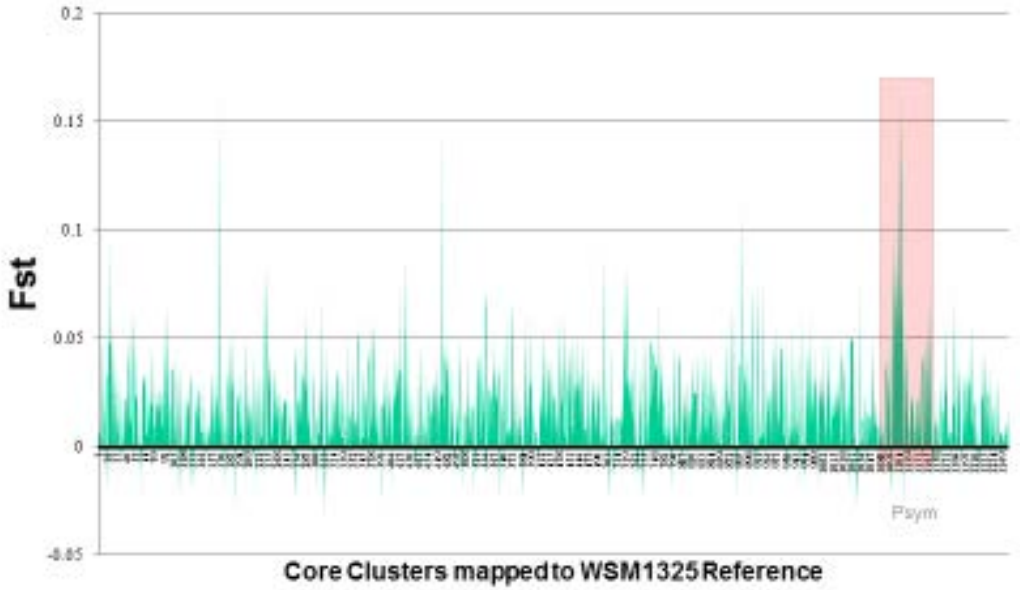
Genetic mechanisms



(http://evolution.berkeley.edu)



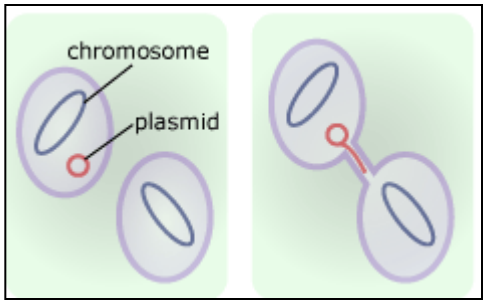
Are point mutations responsible for evolution of reduced cooperation?



A region on the symbiosis plasmid has significant structure.

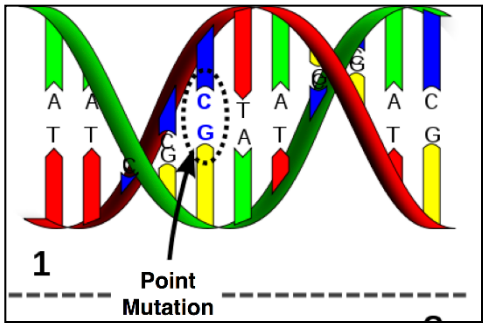
N-addition causes rhizobia to evolve to be less beneficial…

Genetic mechanisms



(http://evolution.berkeley.edu)

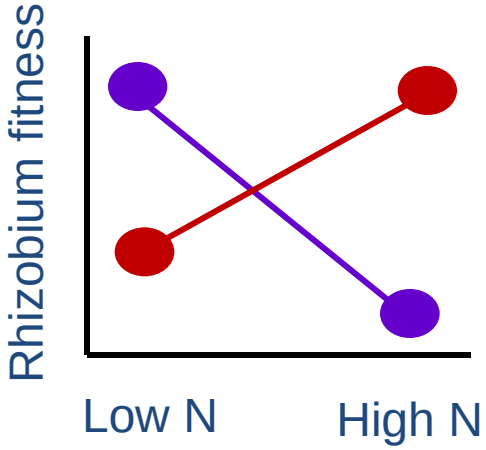
Lateral gene transfer is common. Explains some, but not all, of the evolution of reduced cooperation.



Evidence suggests point mutuations near known symbiosis genes differentiated in N vs. C rhizobia.

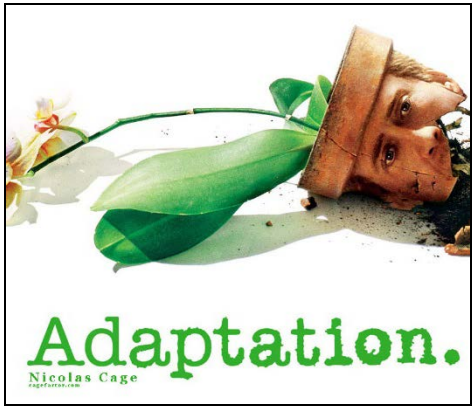
N-addition causes rhizobia to evolve to be less beneficial…

Adaptation?



High N selects for less cooperative rhizobia.

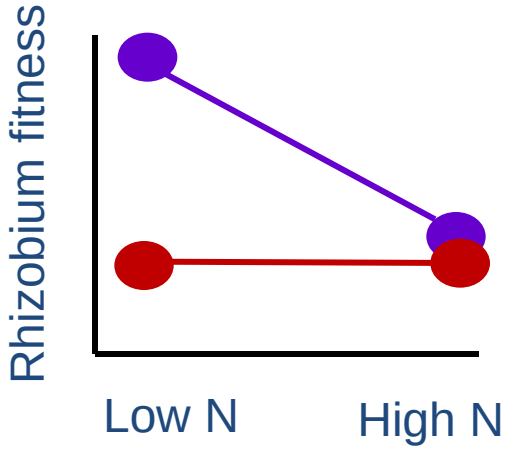
Evolutionary mechanisms



N Strains

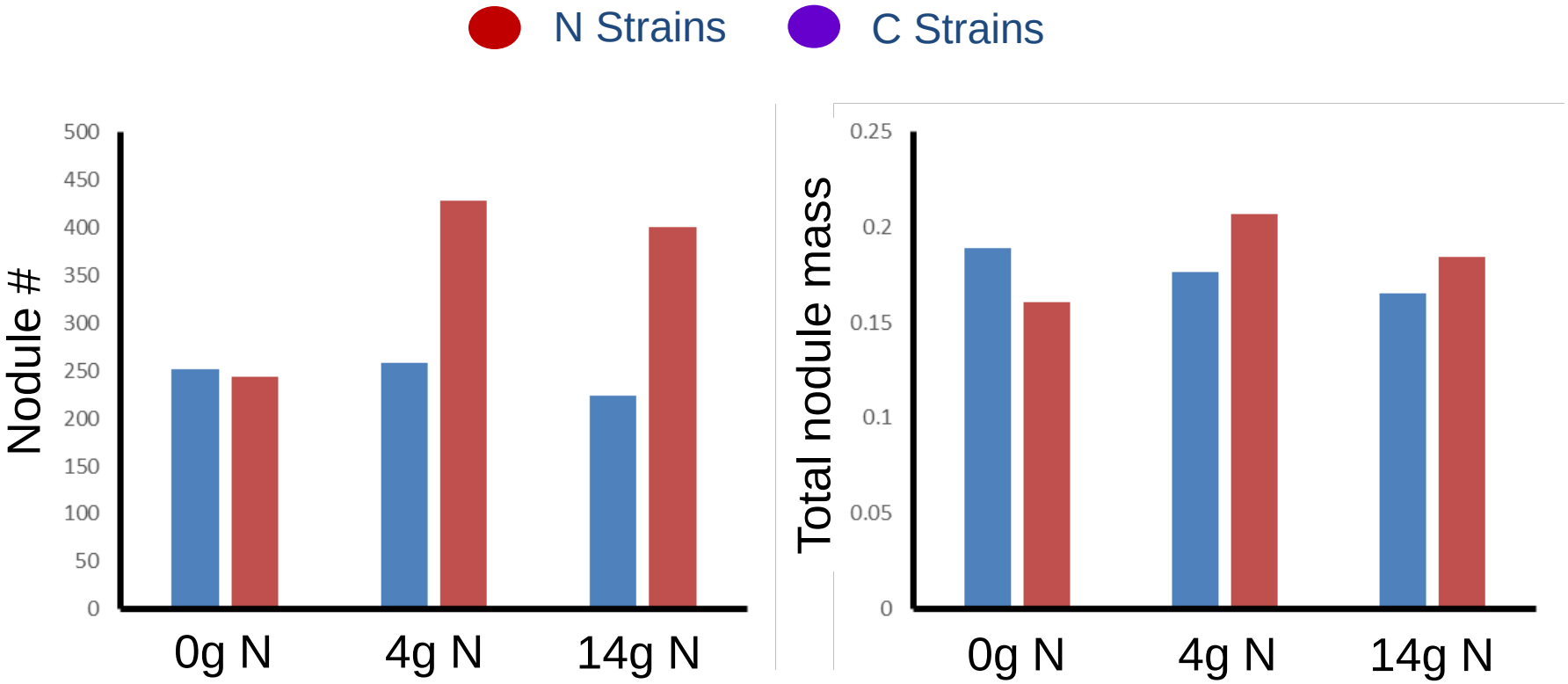
C Strains

Drift or relaxed selection?



High N reduces selection for more cooperative rhizobia.

N-addition causes rhizobia to evolve to be less beneficial…



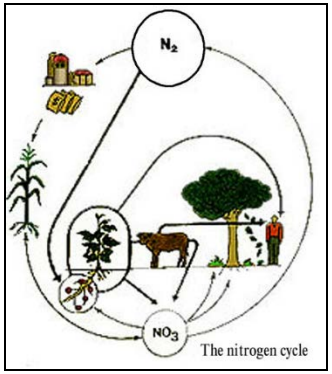
And these evolutionary changes appear to be adaptive!

N-addition causes rhizobia to evolve to be less beneficial…

Ecological consequences

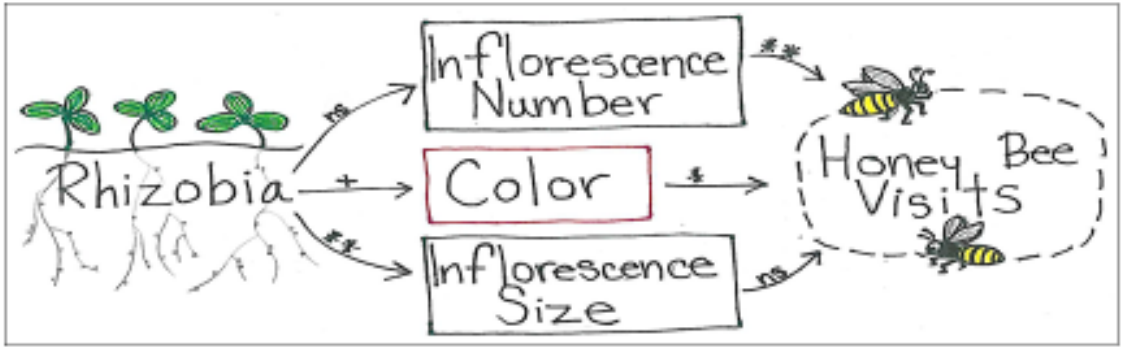
Does rhizobium evolution influence:

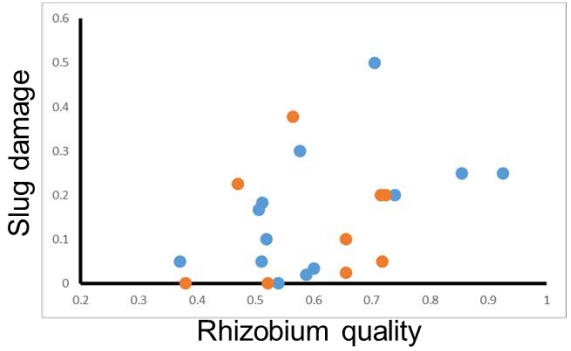
- Higher trophic levels?
- Plant communities?
- N availability?



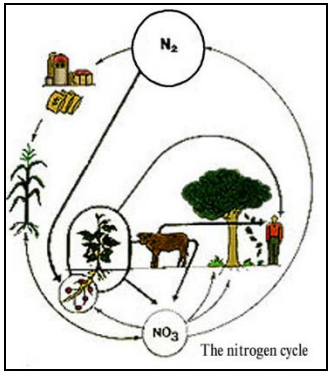
N-addition causes rhizobia to evolve to be less beneficial…

Does rhizobium evolution affect higher trophic levels?





Ecological consequences



N-addition causes rhizobia to evolve to be less beneficial…

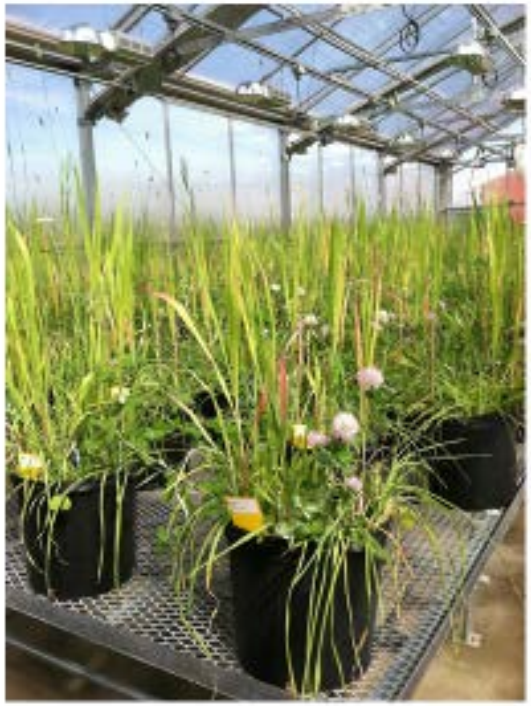
Does rhizobium evolution affect plant communities & nutrient availability?

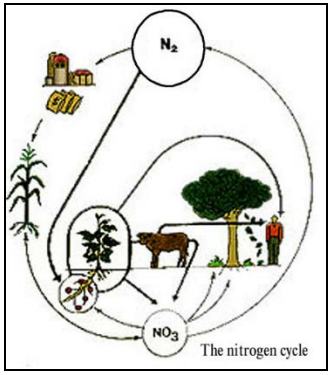
Ecological consequences

Each pot: 10 plant spp. & 18 rhizobium strains (either C or N rhizobia) + uninoculated control.

Measured:

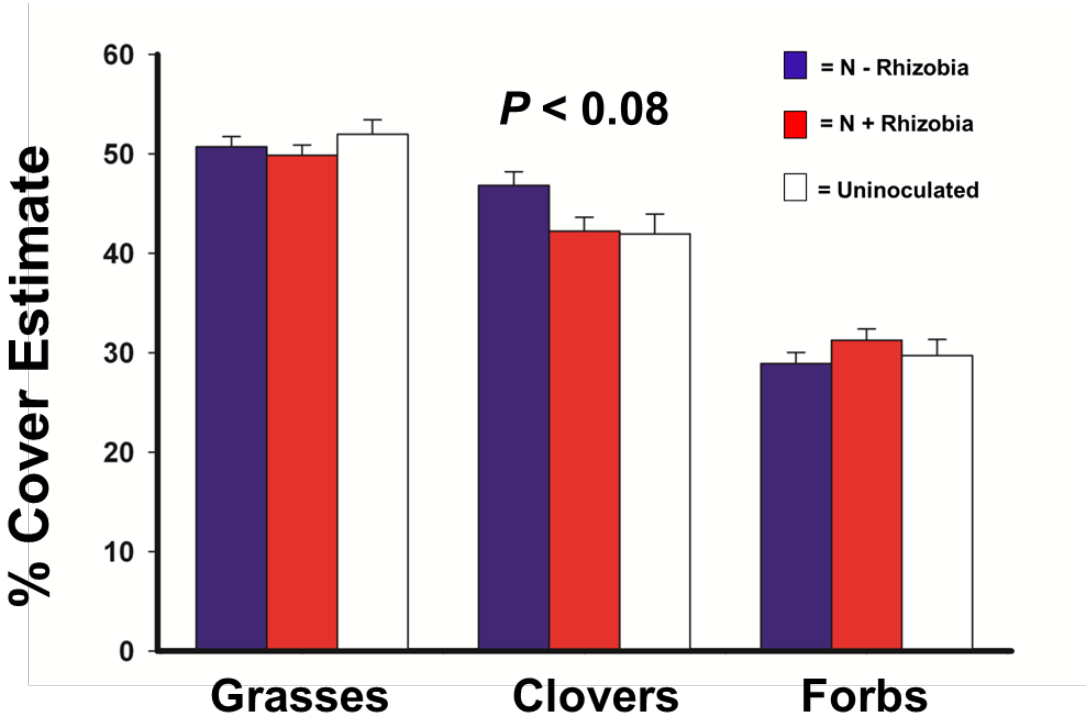
- % cover, community composition, productivity.
- Soil N, isotope analyses.



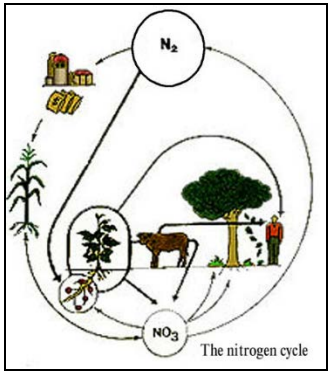


N-addition causes rhizobia to evolve to be less beneficial…

Evolutionary responses to high N reduce clover dominance…

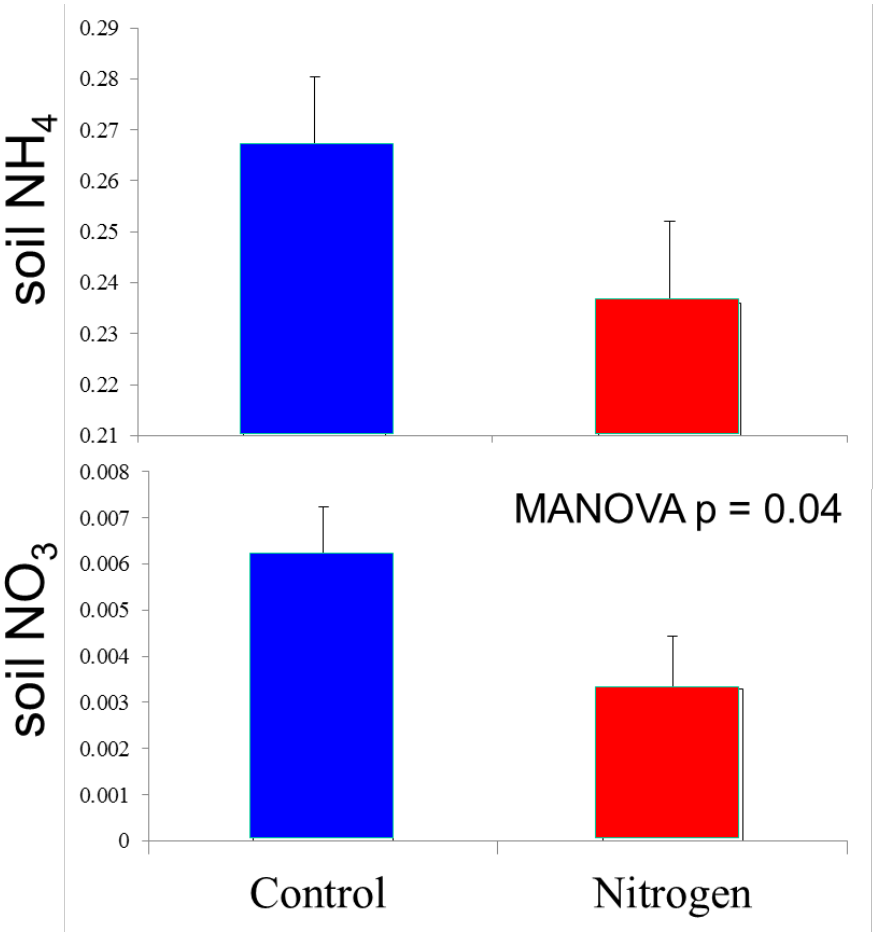


Ecological consequences

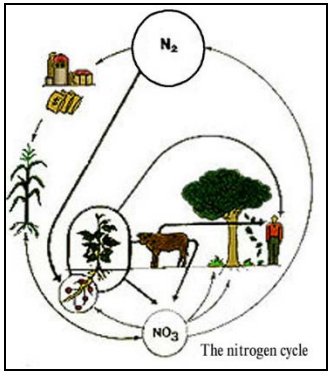


N-addition causes rhizobia to evolve to be less beneficial…

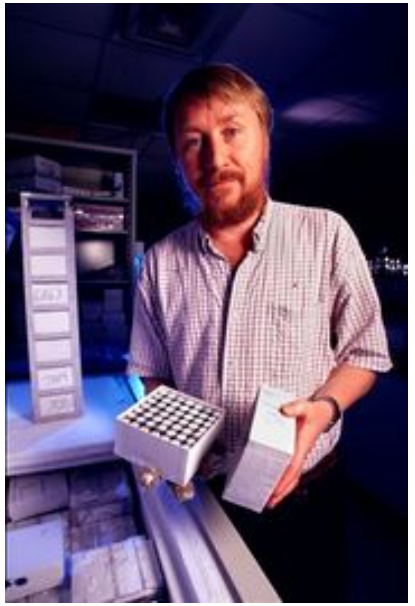
Evolutionary responses to high N reduce soil N…



Ecological consequences



Long-term experiments are useful in more ways than we ever imagined…

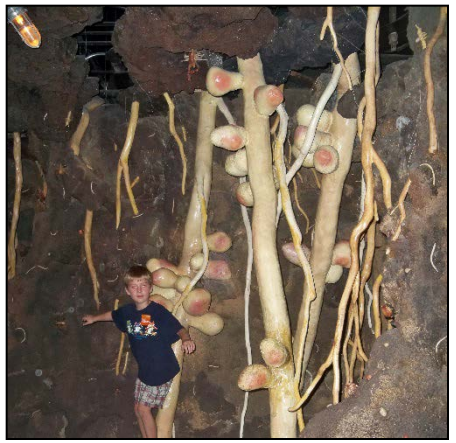


Thank you!

Tim Dickson

Katy Heath

Dylan Weese



Mark Hammond

C. Klinger & B. Gordon

2013 & 2014
Summer labbies

NSF

KBS LTER

Kellogg Biological Station

Long-term Ecological Research