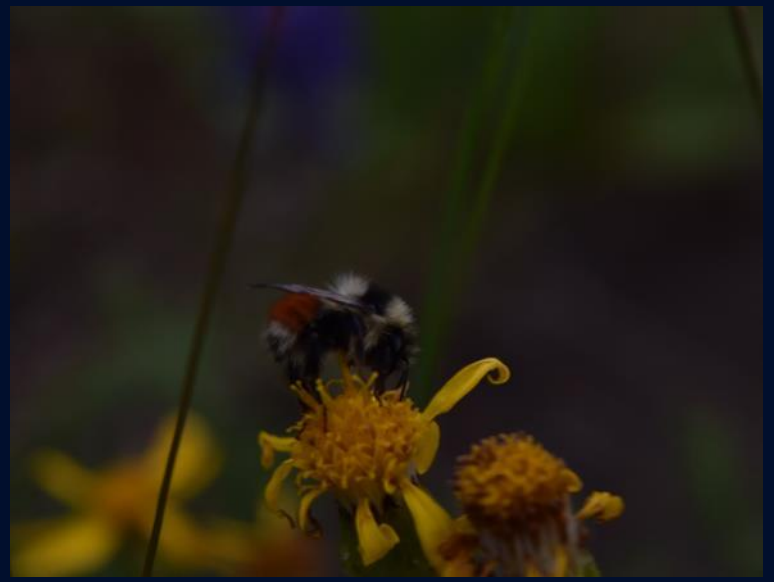
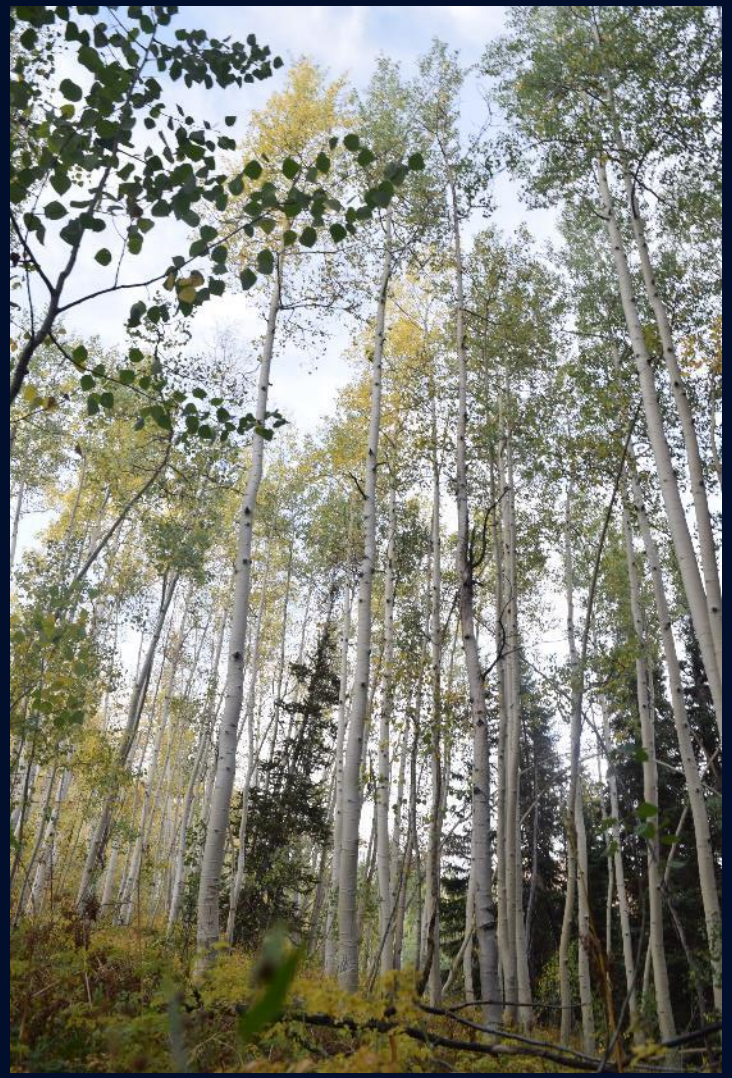
Biodiversity and ecosystem function

What does "ecosystem function" mean?





Enigmaticus

Kuttelvaserova Stuchelova

Diversity and stability of ecosystem functions

Stability ≈ Function maintained in the face of perturbations

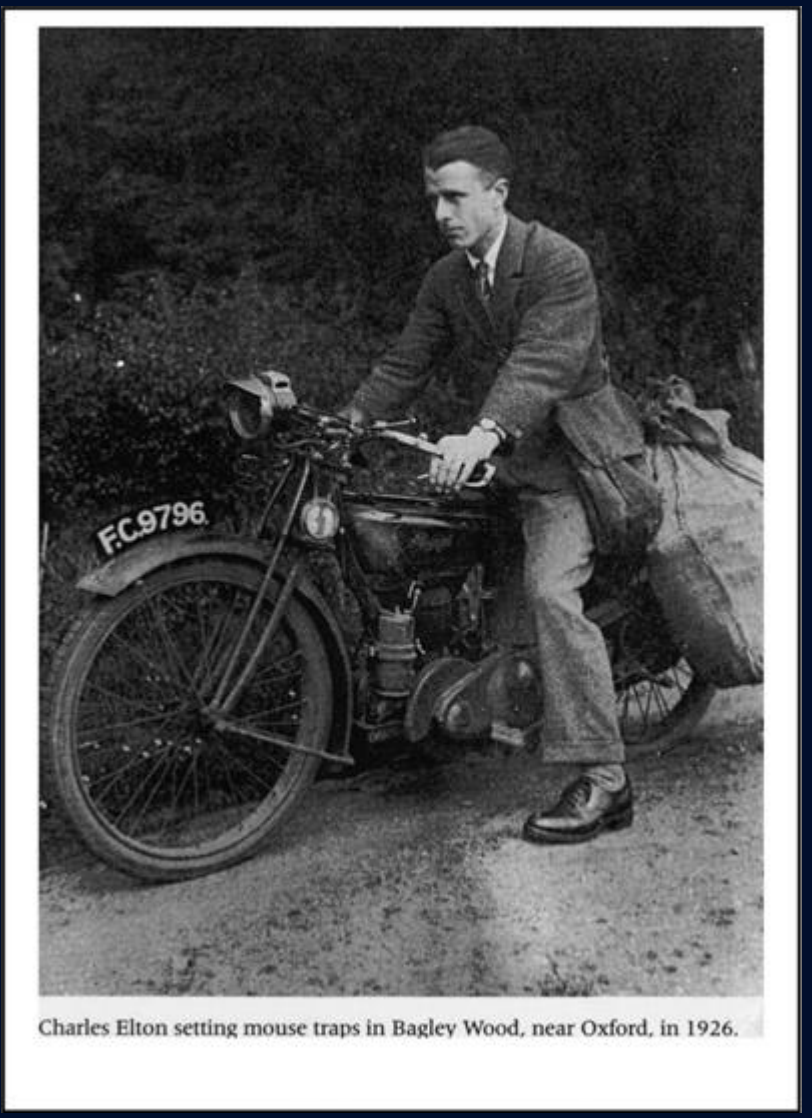
Diversity and stability

Stability ≈ Function maintained in the face of perturbations

Charles Elton (1950s) proposed:

higher diversity = higher ecosystem stability

Observed that higher diversity led to higher productivity, reduced invasions, lower severity of disease or pest outbreaks



Charles Elton setting mouse traps in Bagley Wood, near Oxford, in 1926.

What drives the relationship between diversity and stability?

Today, we will consider three main factors

Species diversity

Functional diversity

& Functional redundancy

Species diversity

Functional diversity:

"…a component of biodiversity that generally concerns the range of things that organisms do in communities and ecosystems"

Petchey & Gaston 2006

Functional diversity:

"…a component of biodiversity that generally concerns the range of things that organisms do in communities and ecosystems"

Petchey & Gaston 2006

Functional redundancy:

"…is based on the observation that some species perform similar roles in communities and ecosystem…"

Rosenfeld 2002

Functional redundancy:

"…is based on the observation that some species perform similar roles in communities and ecosystem…"

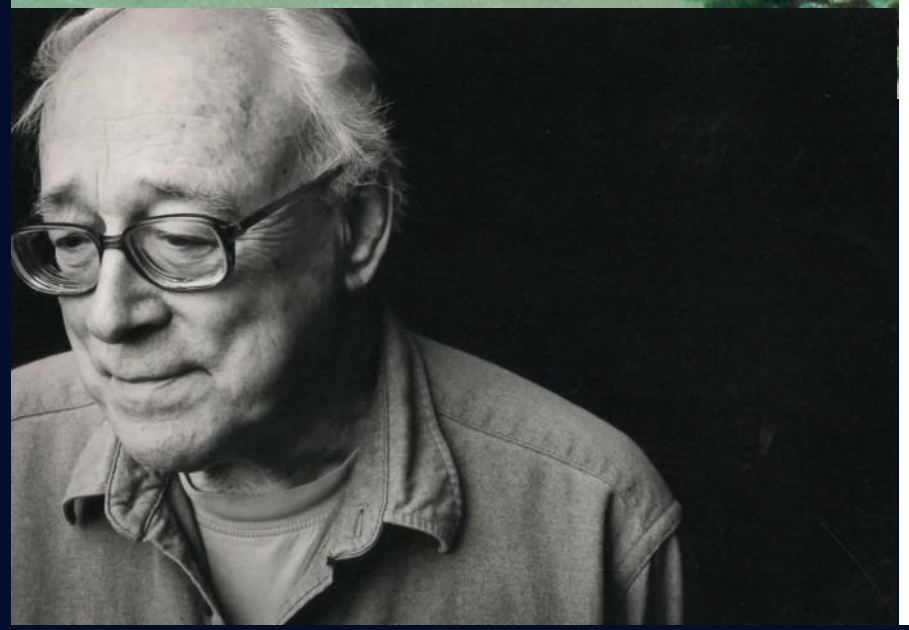
Rosenfeld 2002

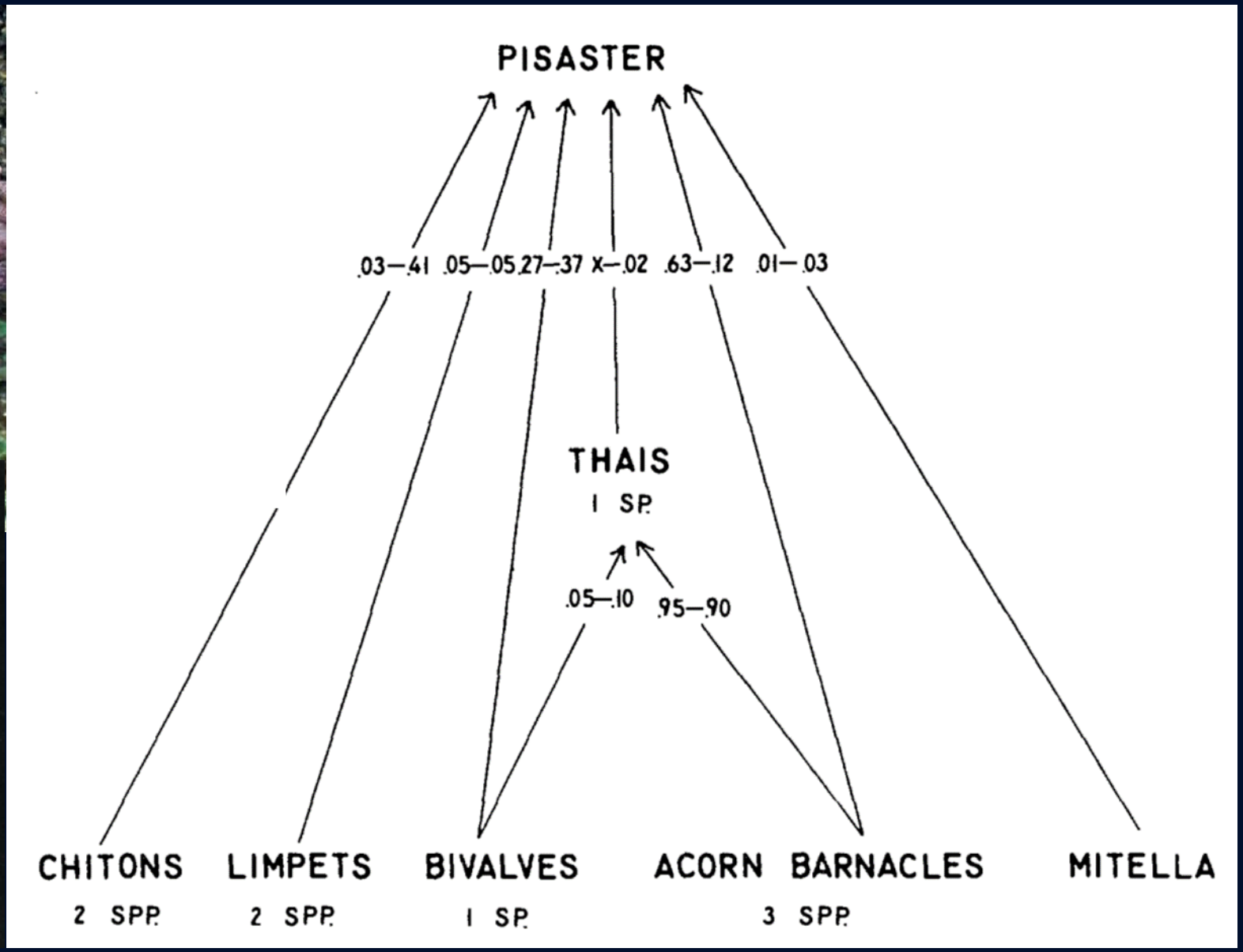
Case study: Rocky intertidal

Strong interactions

Functional diversity

Photo: Tarik C. Gouhier



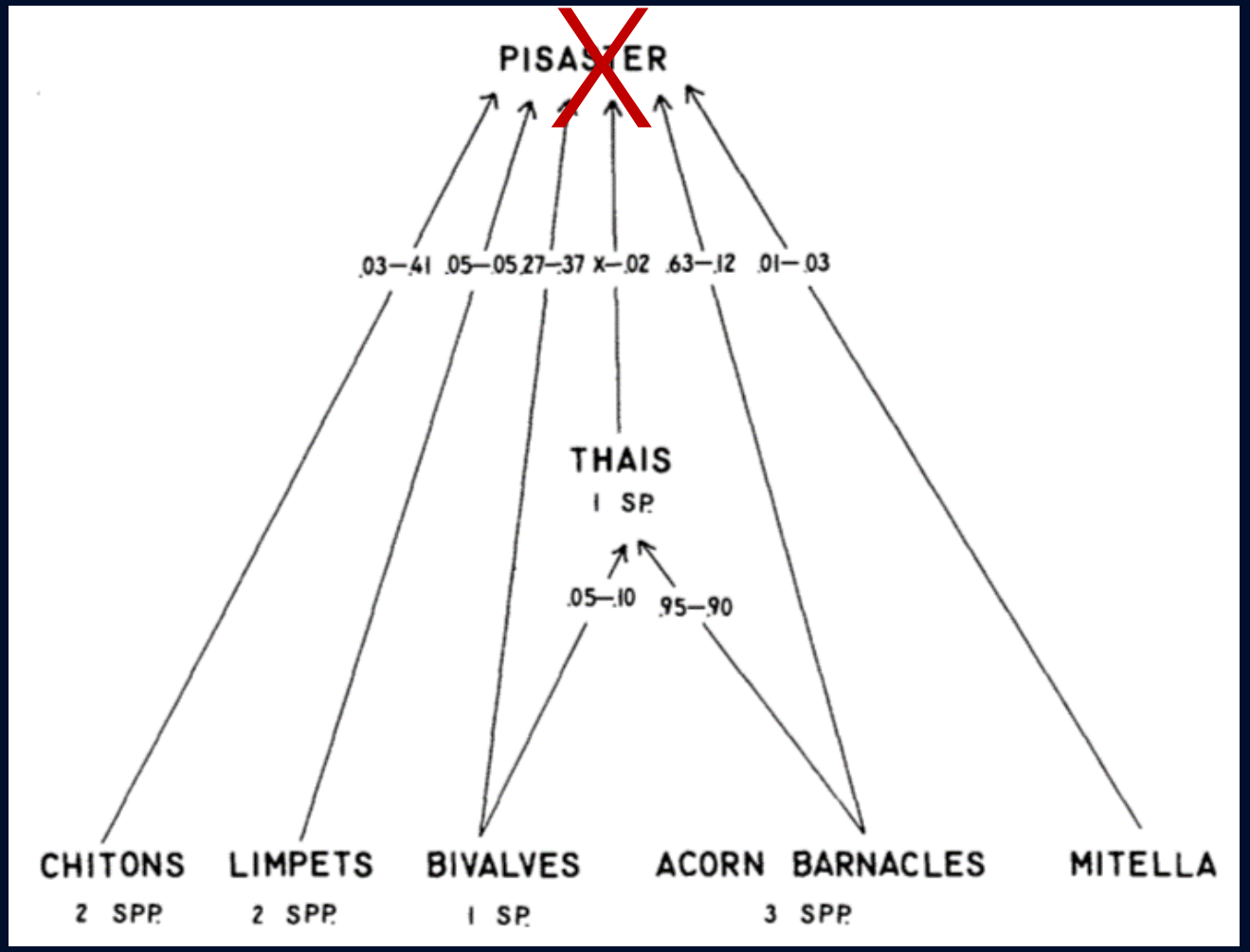


Robert Paine
1933 - 2016

biology.washington.edu

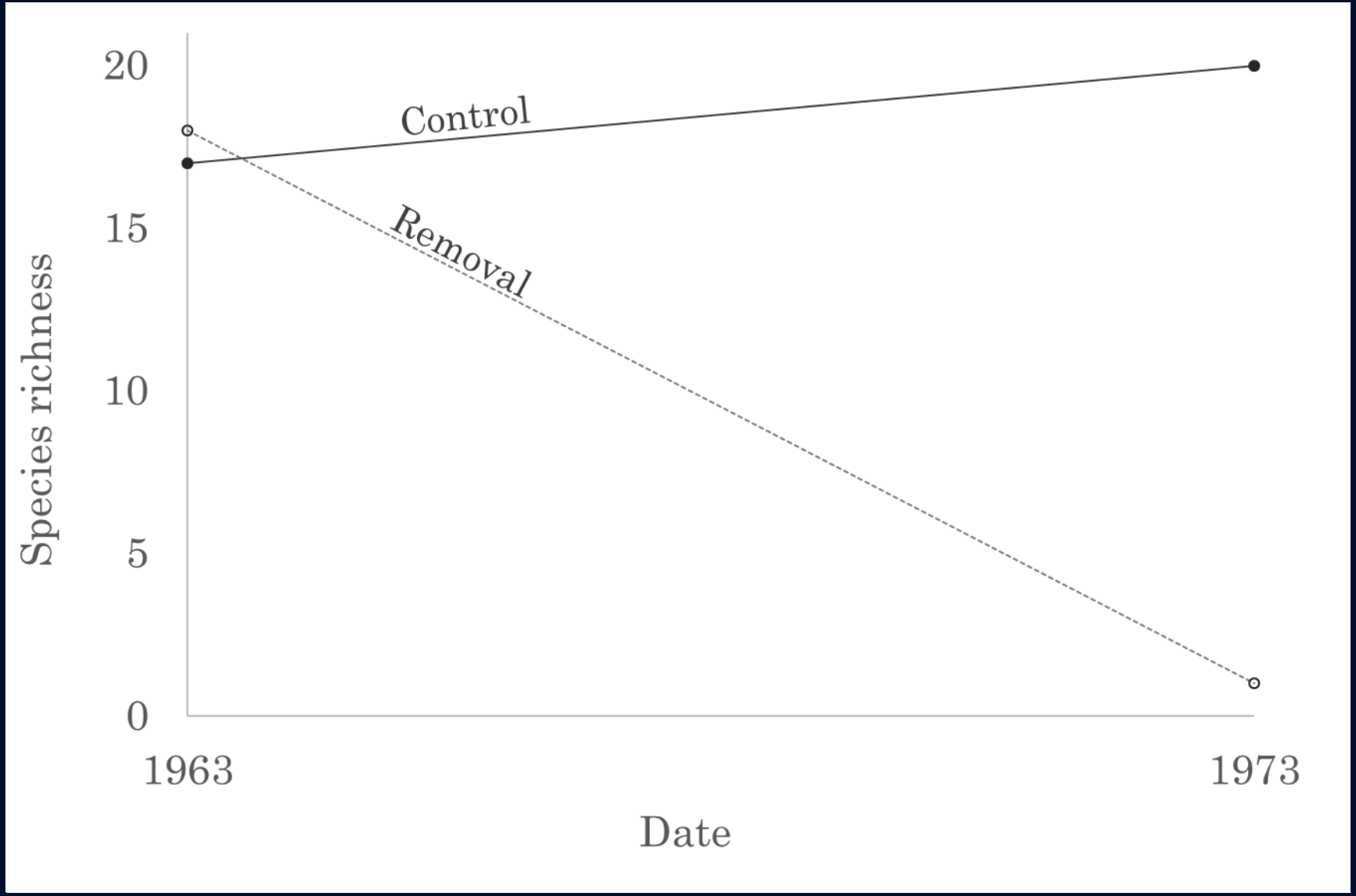
Paine 1966

Robert Paine in 1974



Paine 1966

Change in species richness in response to *Piaster ochraceus* removal



Data from Paine 1974

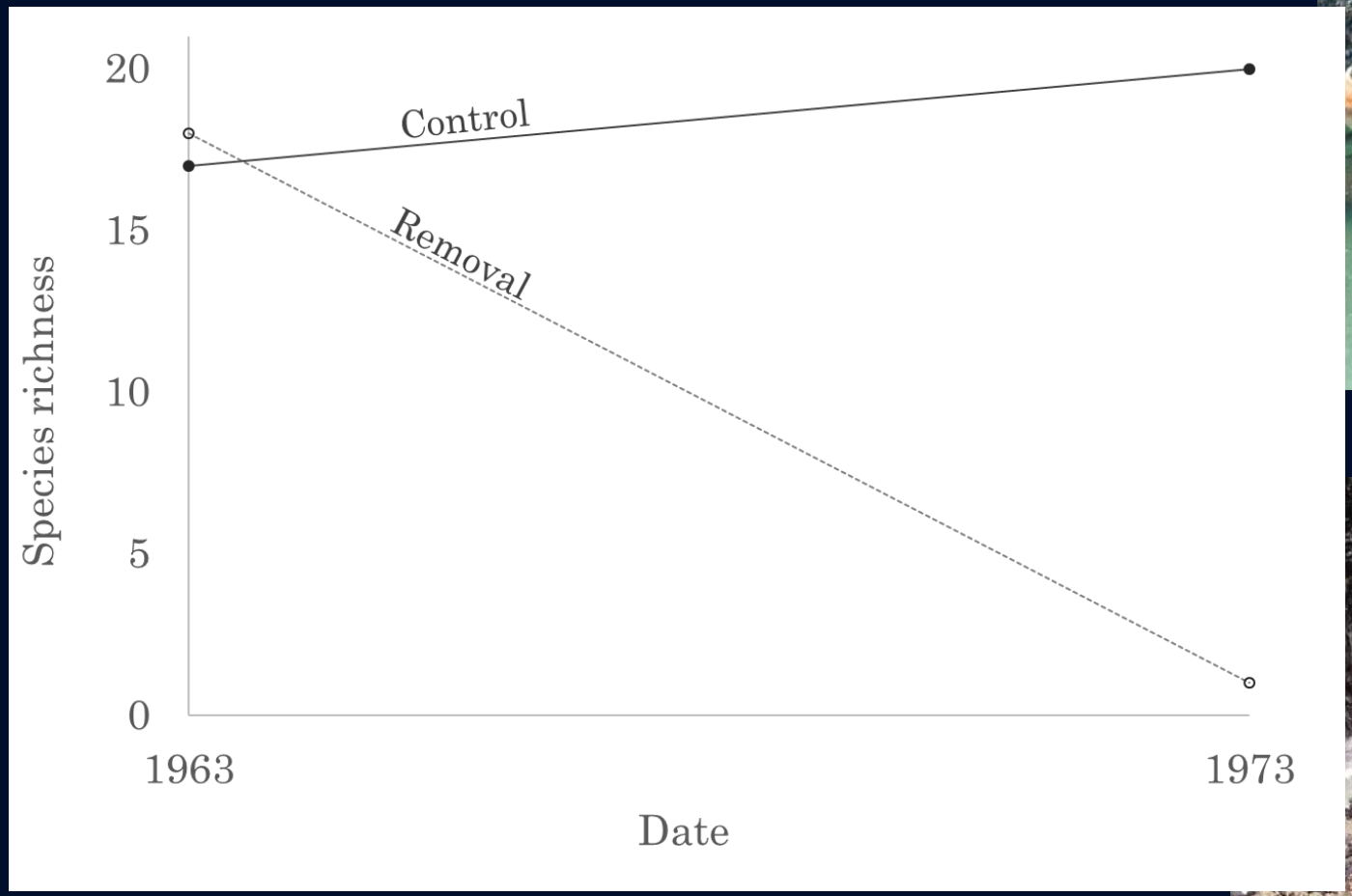
Mussels (*Mytilus sp.*) are superior competitors for space, but are a favorite prey of *Pisaster ochraceus*

Strong interactions

Photos: Wikimedia Commons

In absence of predation by *Pisaster*, mussels can completely dominate the rocky intertidal system

Strong interactions



Loss of **functional diversity** de-stabilizes the system

Case study: Grassland

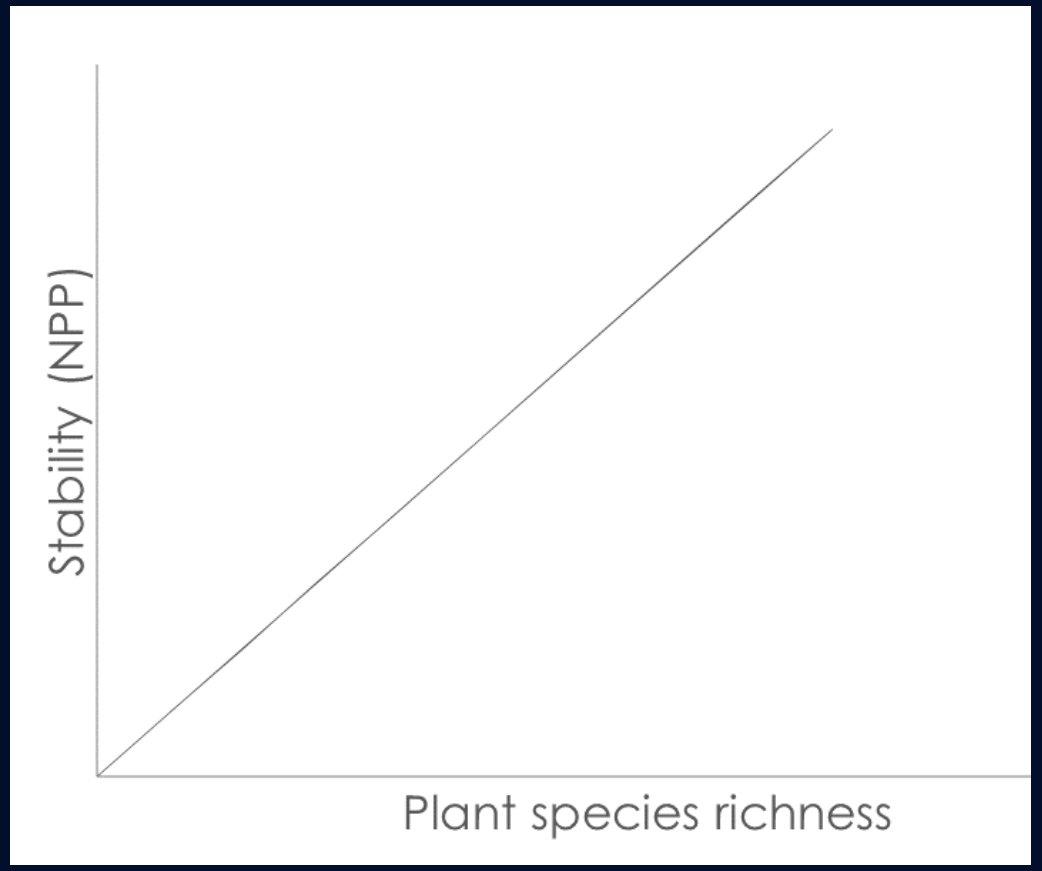
Weak interactions

Functional diversity

Functional redundancy

Following Elton's ideas – Tilman *et al.* hypothesized:

Positive relationship between number of plant species and stability of net-primary productivity (an ecosystem function)



Cedar Creek Ecosystem Science Reserve (University of Minnesota)

Photo: cbs.umn.edu

Field experiment

Photo: cbs.umn.edu

- Plots seeded with 1, 2, 4, 8, or 16 native species (n = 30 each)
- Species drawn at random from pool of 18 native species
- 4x each: C4 grasses, C3 grasses, leguminous forbes, non-leguminous forbes, and 2x woody species
- Allowed to grow for 10 years, measuring species pop sizes / productivity and overall productivity

Varied: Species diversity

Field experiment

- Plots seeded with 1, 2, 4, 8, or 16 native species (n = 30 each)
- Species drawn at random from pool of 18 native species
- 4x each: C4 grasses, C3 grasses, leguminous forbes, non-leguminous forbes, and 2x woody species
- Allowed to grow for 10 years, measuring species pop sizes / productivity and overall productivity

But what else?

Field experiment

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- Species drawn at random from pool of 18 native species
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functional diversity

Field experiment

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functional redundancy

Field experiment

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PAUSE & CONSIDER

Is species diversity independent from functional diversity and functional redundancy?

Field experiment

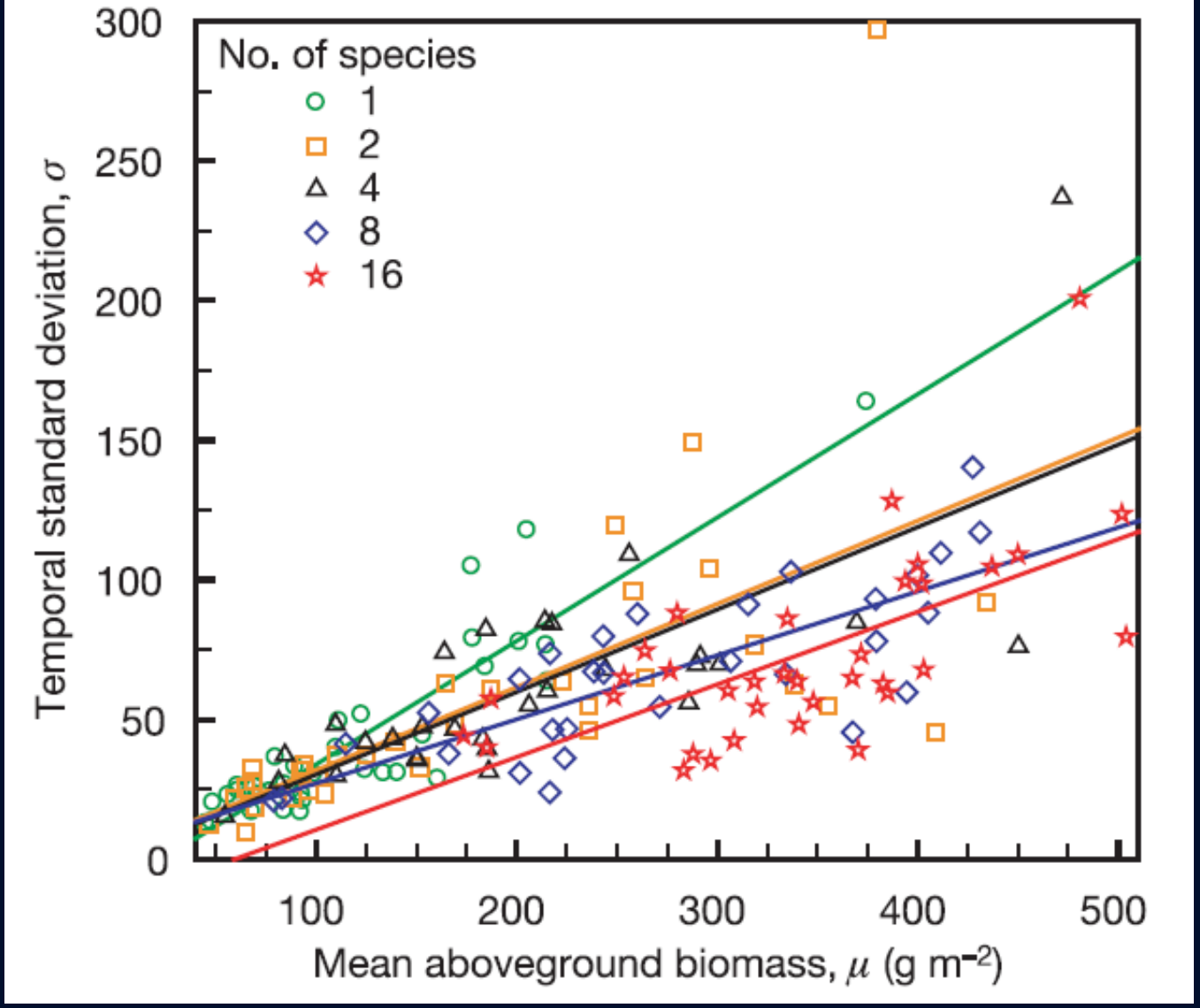
- Plots seeded with 1, 2, 4, 8, or 16 native species (n = 30 each)
- Species drawn at random from pool of 18 native species
- 4x each: C4 grasses, C3 grasses, leguminous forbes, non-leguminous forbes, and 2x woody species
- Allowed to grow for 10 years, measuring species pop sizes / productivity and overall productivity

What do you think they found?

Field experiment

- Plots seeded with 1, 2, 4, 8, or 16 native species (n = 30 each)
- Species drawn at random from pool of 18 native species
- 4x each: C4 grasses, C3 grasses, leguminous forbes, non-leguminous forbes, and 2x woody species
- Allowed to grow for 10 years, measuring species pop sizes / productivity and overall productivity

The more species rich a plot was

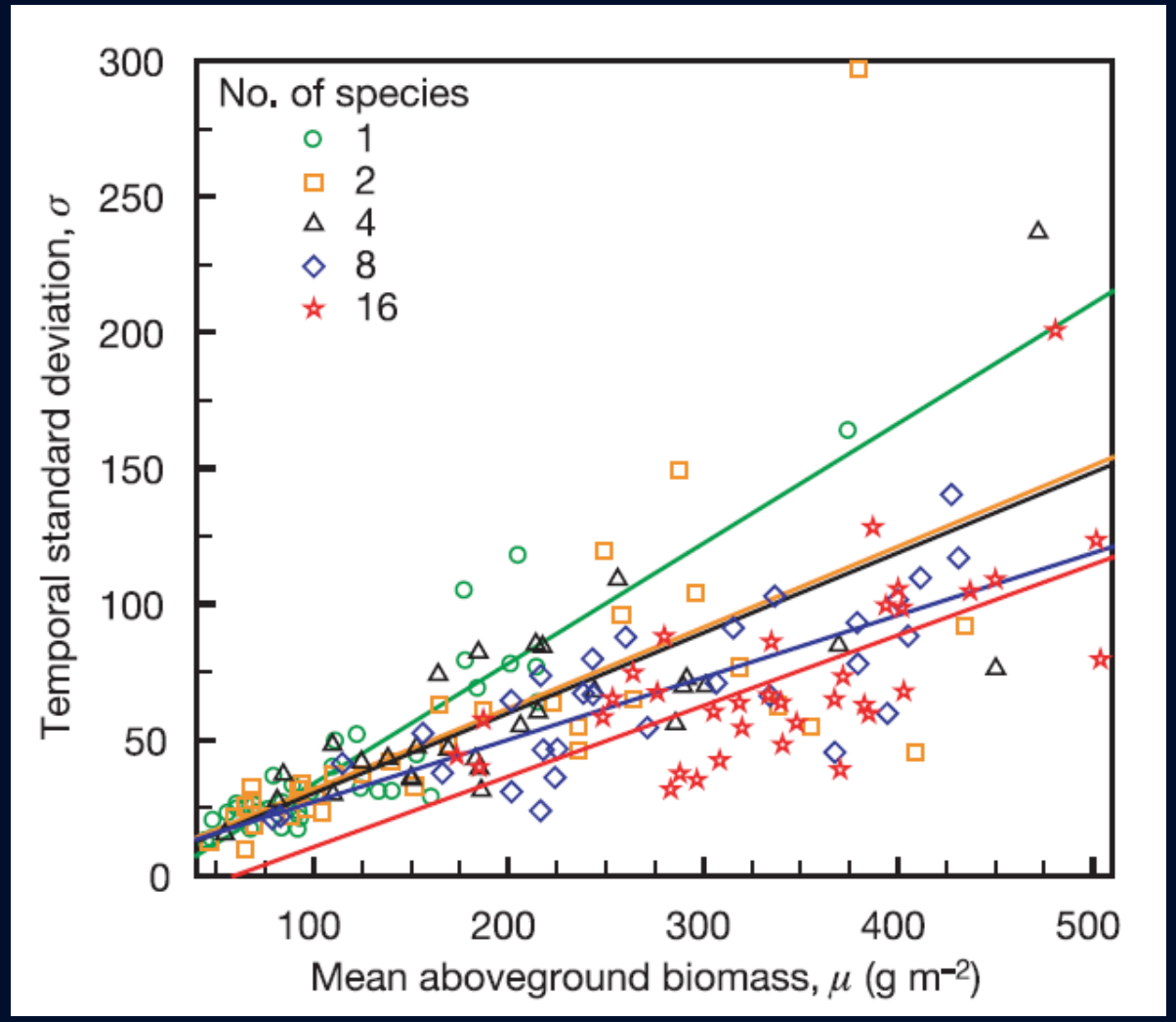


the more stable NPP was
(for a given level of biomass)

Tilman *et al* 2006

Why did they observe this relationship?

Many possible explanations:



Tilman *et al* 2006

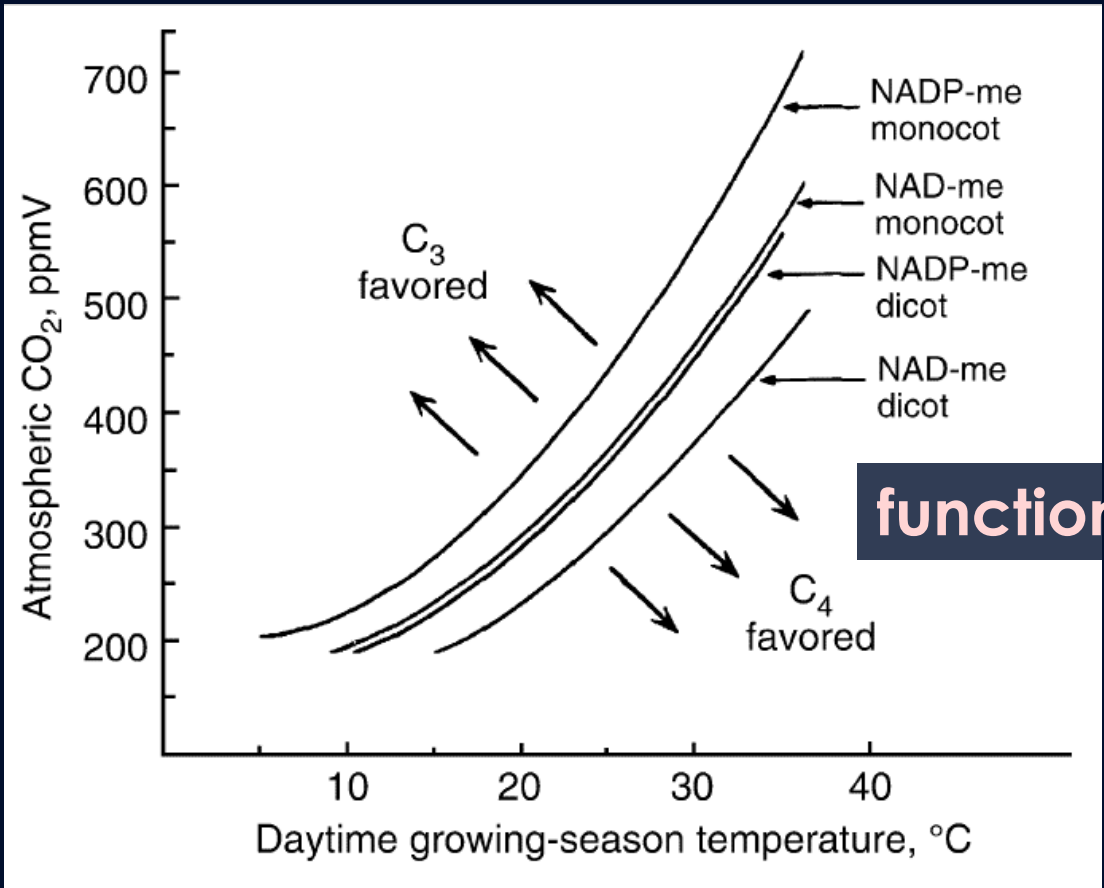
Why did they observe this relationship?

More species, more opportunity for facilitative interactions between species

awkwardbotany.com

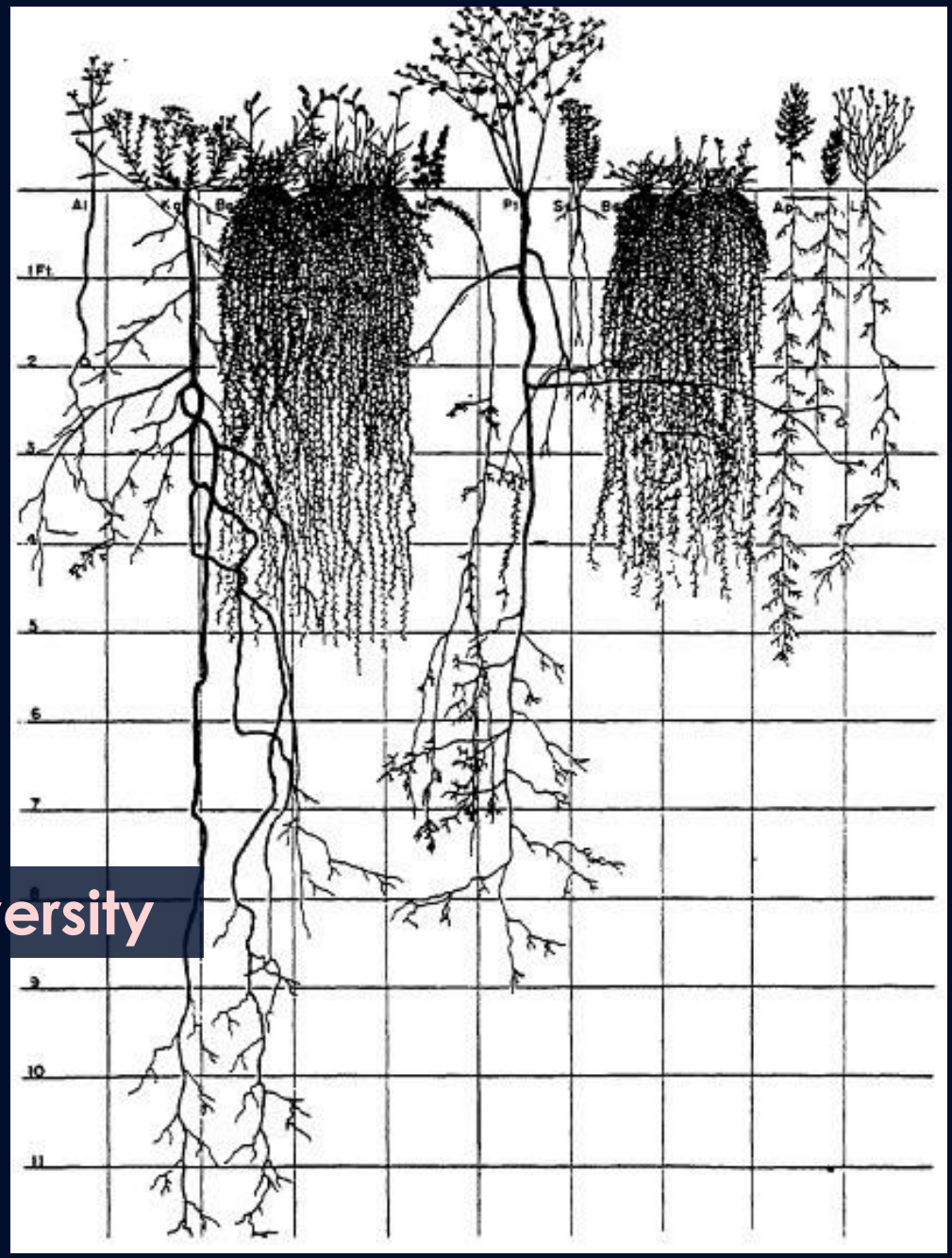
Why did they observe this relationship?

Different species take advantage of available resources in different ways
Complementarity /niche partitioning



Keeley & Rundel 2005

functional diversity



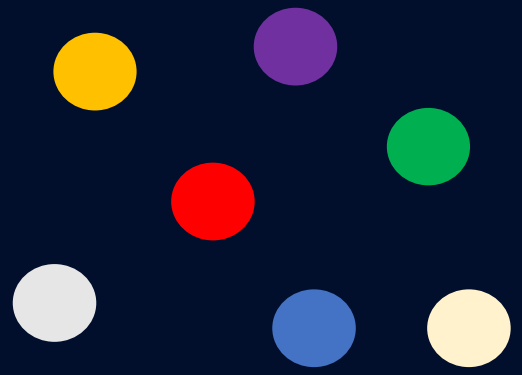
National Research Council

Why did they observe this relationship?

Sampling Effect:
The larger the number of species present → Strongest performers more likely to be present

Draw 2: Pr {Red} ≈ 0.28

Draw 6: Pr {Red} ≈ 0.86

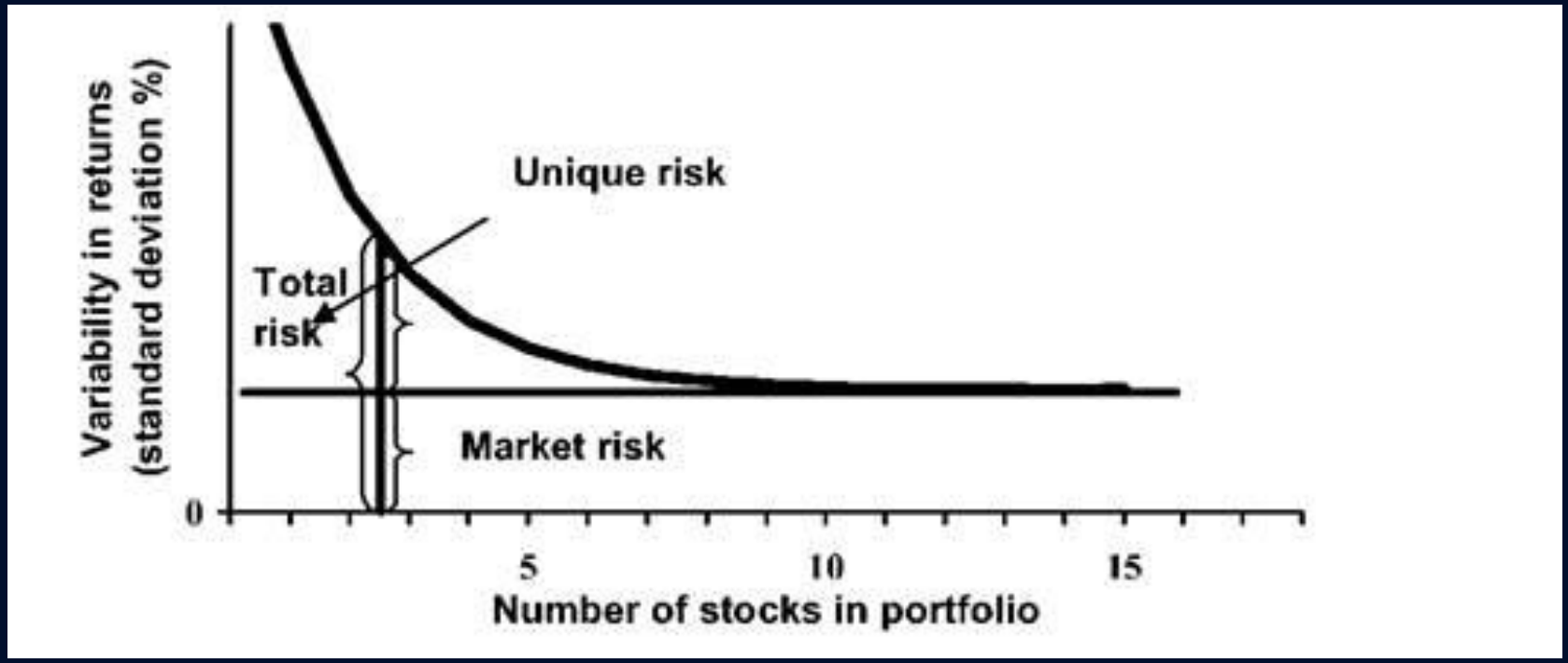


functional redundancy

Why did they observe this relationship?

Portfolio effect:

- Different species have different sensitivities to environmental variations
- More species present, more likely responses will be mixed
- More mixed response are, less the system changes overall (i.e. greater stability)



functional redundancy

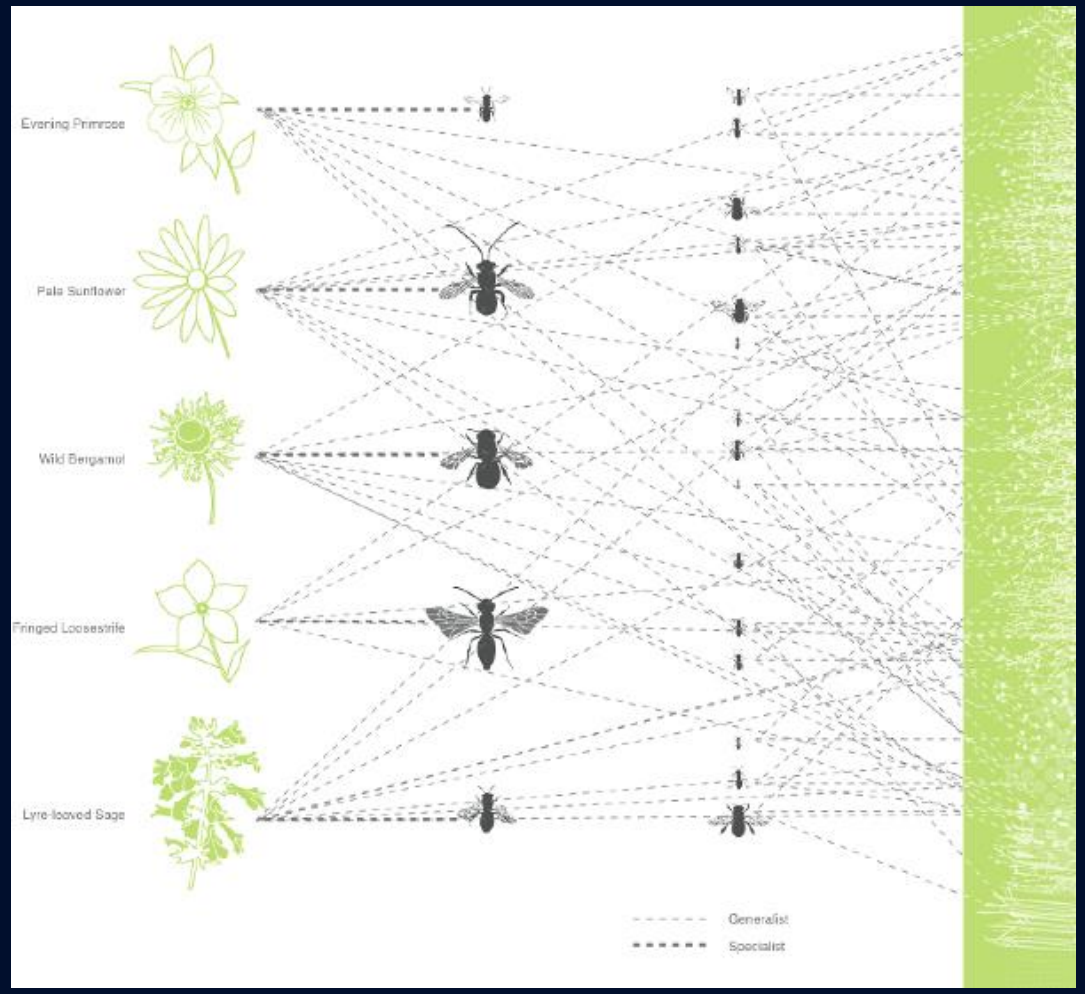
Case study: Crop pollination

Few strong interactions

Many weak interactions

Functional redundancy

Many weak interactions?



Few strong interactions?

Karen May: cargocollective.com/karenmaybe/Pollination-City

http://delvinfarms.com

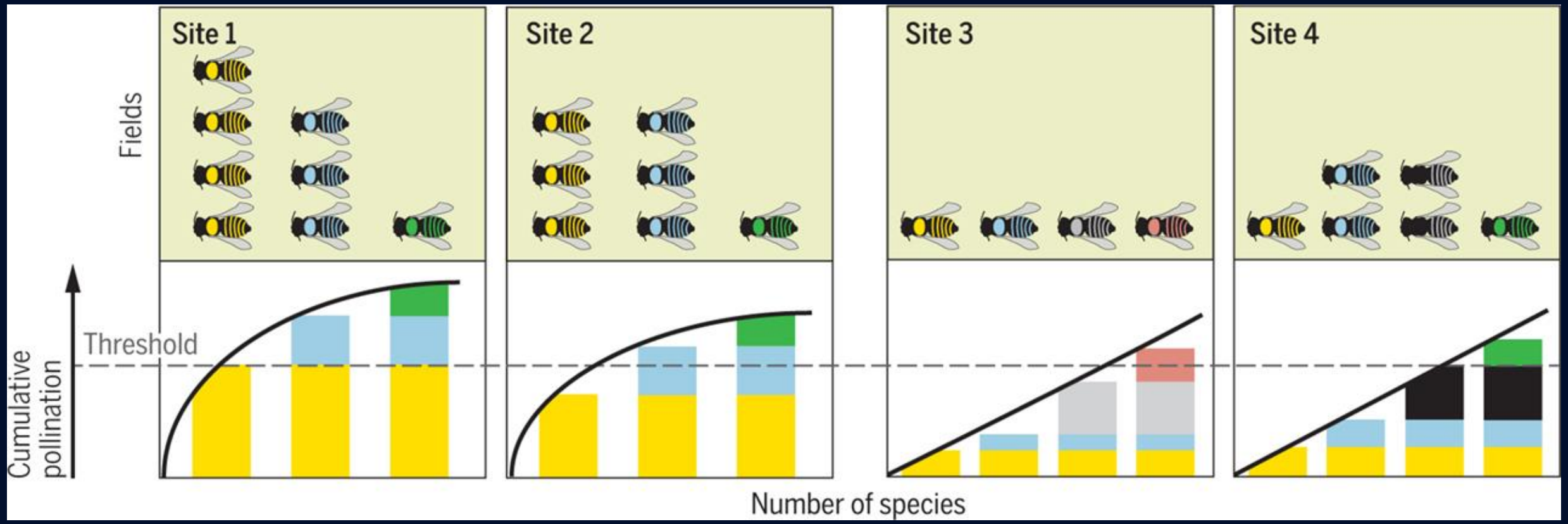
Stephen Ausmus

David DeCenzo

ag.umass.edu

sfgate.com

Blair Sampson



Kremen 2018, interpreting Winfree *et al.* 2018

Few strong interactions?

Yes, and…

Many weak interactions?

Abundance of common species, not species richness, drives delivery of a real-world ecosystem service

Rachael Winfree, Jeremy W. Fox, Neal M. Williams, James R. Reilly, Daniel P. Cariveau 2015

Species turnover promotes the importance of bee diversity for crop pollination at regional scales

Rachael Winfree, James R. Reilly1, Ignasi Bartomeus, Daniel P. Cariveau, Neal M. Williams, Jason Gibbs 2018

What have you learned today?

Give me 3 or 4 take-home messages

A few takeaways

Diversity does not generate stability, but does facilitate it

Species diversity ≠ functional diversity

Both strong and weak interactions are important

Functional diversity and functional redundancy are both critical