Community Ecology, Week 3, Day 2

Beyond interspecific competition

Takeaways from Lotka-Volterra competition model

Takeaways from Lotka-Volterra competition model

- When two similar species compete, coexistence on a shared limiting resource can be challenging

Takeaways from Lotka-Volterra competition model

- When two similar species compete, coexistence on a shared limiting resource can be challenging

- Isocline analysis helps us make sense of the conditions under which a pair of species can coexist

Takeaways from Lotka-Volterra competition model

- When two similar species compete, coexistence on a shared limiting resource can be challenging

- Isocline analysis helps us make sense of the conditions under which a pair of species can coexist

  (and the conditions that give rise to priority effects and to competitive exclusion)

Takeaways from Lotka-Volterra competition model

Through isocline analysis, we saw that only one arrangement of the pairwise competition coefficients α allow coexistence:

Takeaways from Lotka-Volterra competition model

Through isocline analysis, we saw that only one arrangement of the pairwise competition coefficients α allow coexistence:

$$\alpha_{11} > \alpha_{21} \quad \text{and} \quad \alpha_{22} > \alpha_{12}$$

Takeaways from Lotka-Volterra competition model

Through isocline analysis, we saw that only one arrangement of the pairwise competition coefficients α allow coexistence:

$$\alpha_{11} > \alpha_{21} \text{ and } \alpha_{22} > \alpha_{12}$$

Biological interpretation: each species competes more strongly with itself than it does with the other species.

Takeaways from Lotka-Volterra competition model

Through isocline analysis, we saw that only one arrangement of the pairwise competition coefficients α allow coexistence:

$$\alpha_{11} > \alpha_{21} \text{ and } \alpha_{22} > \alpha_{12}$$

Biological interpretation: each species competes more strongly with itself than it does with the other species.

In other words: Each species changes the environment in a way that limits conspecifics more than heterospecifics.

Takeaways from Lotka-Volterra competition model

Through isocline analysis, we saw that only one arrangement of the pairwise competition coefficients α allow coexistence:

$$\alpha_{11} > \alpha_{21} \text{ and } \alpha_{22} > \alpha_{12}$$

Biological interpretation: each species competes more strongly with itself than it does with the other species.

In other words: Each species changes the environment in a way that limits conspecifics more than heterospecifics.

Takeaways from Lotka-Volterra competition model

Biological interpretation: each species competes more strongly with itself than it does with the other species.

Takeaways from Lotka-Volterra competition model

Biological interpretation: each species competes more strongly with itself than it does with the other species.

When a pair of species overlaps strongly in their niches, there is little difference between intra- and interspecific competition.

Takeaways from Lotka-Volterra competition model

Biological interpretation: each species competes more strongly with itself than it does with the other species.

When a pair of species overlaps strongly in their niches, there is little difference between intra- and interspecific competition.

> *It doesn't matter whether you are competing with another individual of your same species, or an individual of the other: competition is equally strong*

Takeaways from Lotka-Volterra competition model

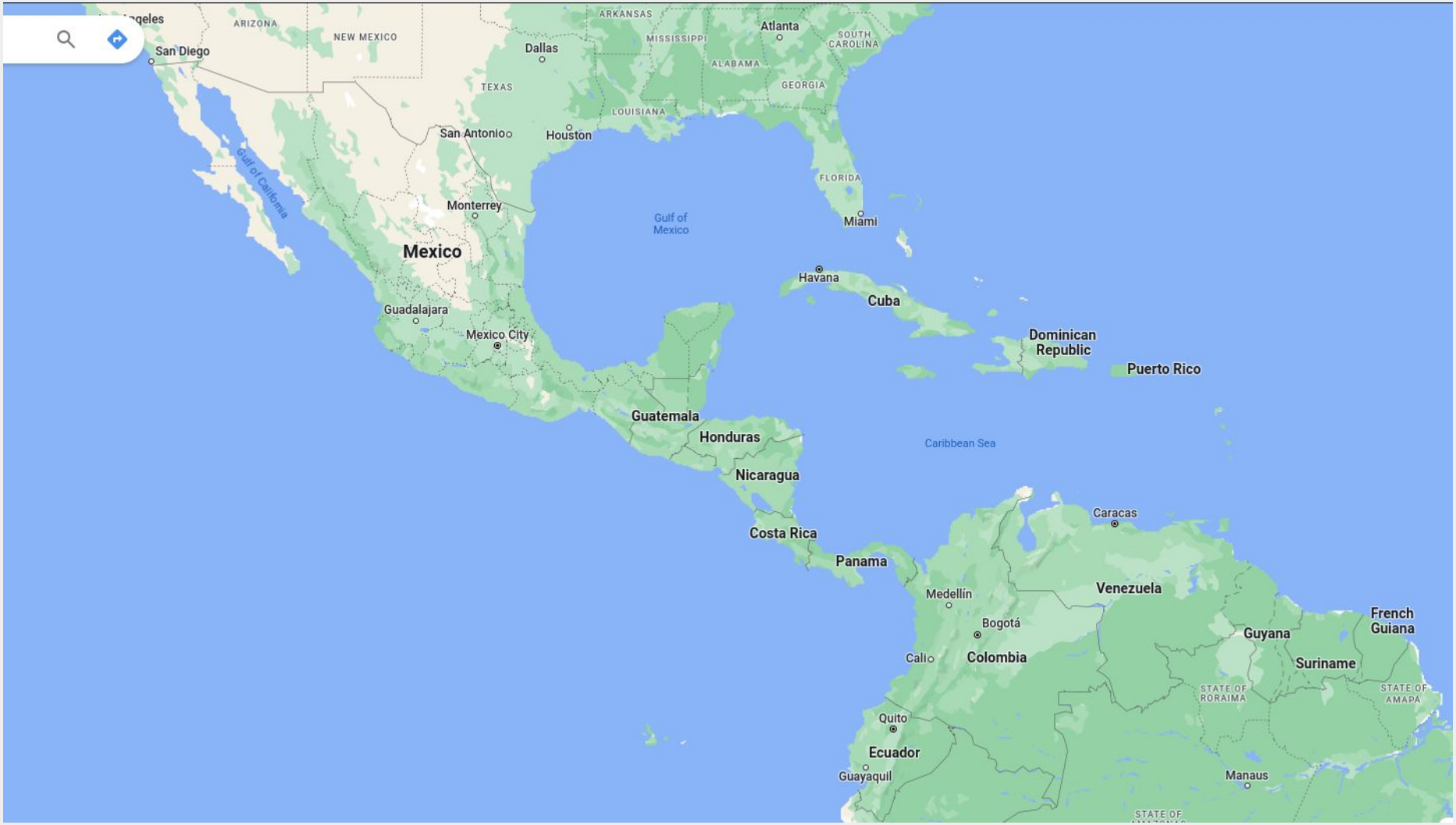
Biological interpretation: each species competes more strongly with itself than it does with the other species.

When a pair of species overlaps strongly in their niches, there is little difference between intra- and interspecific competition.

> *It doesn't matter whether you are competing with another individual of your same species, or an individual of the other: competition is equally strong*

But when niches are distinct, there is more competition within than between species.

Case study: Niche overlap and coexistence among finches on the Galapagos islands



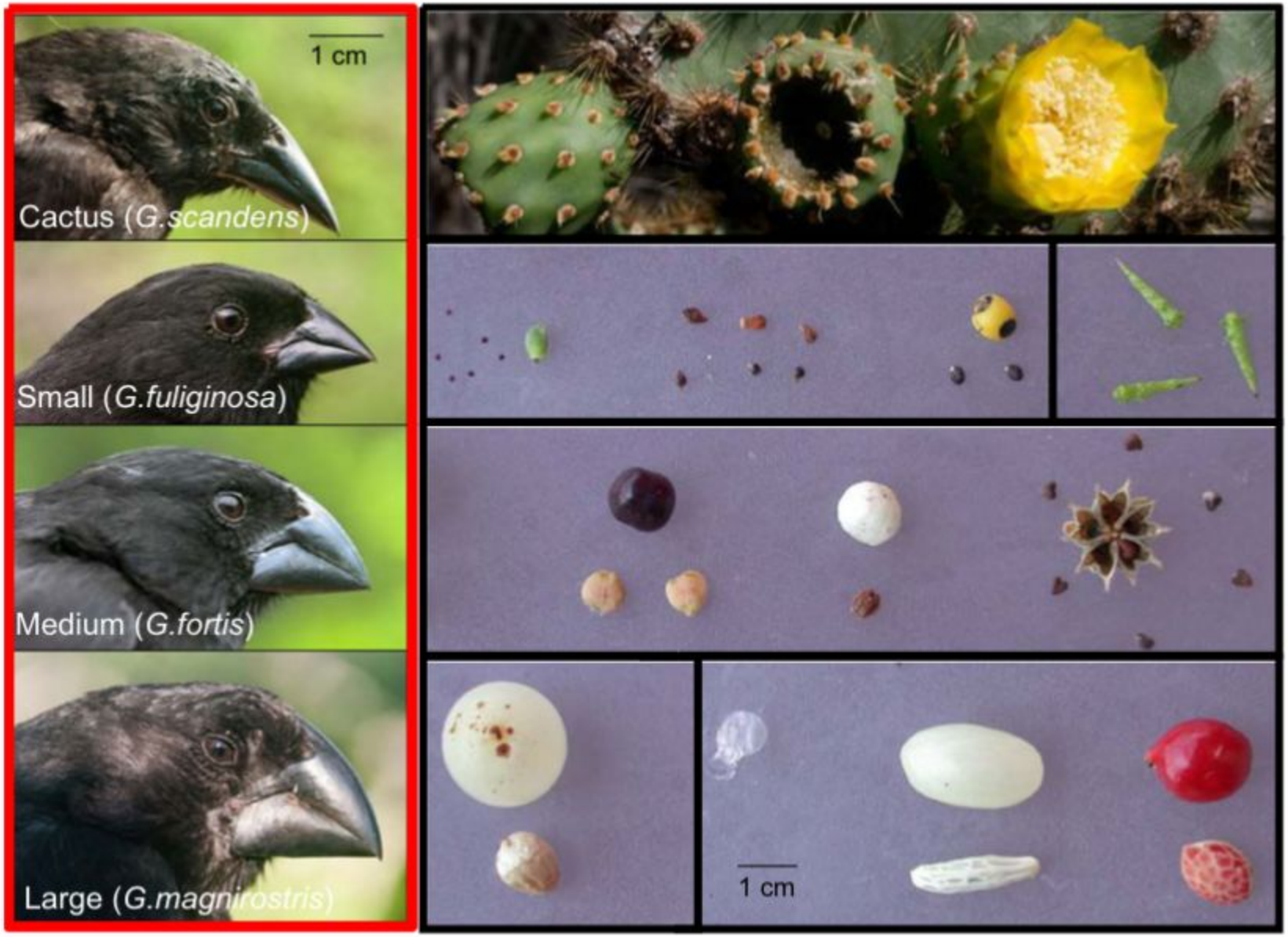
JOURNAL OF Evolutionary Biology

eseb European Society for Evolutionary Biology

doi: 10.1111/jeb.12383

Darwin's finches and their diet niches: the sympatric coexistence of imperfect generalists

L. F. DE LEÓN*†, J. PODOS‡, T. GARDEZI†, A. HERREL§ & A. P. HENDRY†


1 cm
Cactus (G.scandens)
Small (G.fuliginosa)
Medium (G.fortis)
Large (G.magnirostris)
1 cm

... Geospiza magnirostris, which has the largest beak and the highest bite force, was the only species to feed on the very large/hard seeds of Cordia lutea and it fed on these seeds regularly.

… Geospiza magnirostris, which has the largest beak and the highest bite force, was the only species to feed on the very large/hard seeds of Cordia lutea and it fed on these seeds regularly.

Geospiza scandens, which has the longest beak, was often seen probing the flowers of Optuntia cactus, whereas this behaviour was rare for the other species.

… Geospiza magnirostris, which has the largest beak and the highest bite force, was the only species to feed on the very large/hard seeds of Cordia lutea and it fed on these seeds regularly.

Geospiza scandens, which has the longest beak, was often seen probing the flowers of Optuntia cactus, whereas this behaviour was rare for the other species.

Geospiza fuliginosa, which has the smallest beak and the lowest bite force, often fed on the very small seeds of Cryptocarpus piryformis, whereas this behaviour was uncommon for the other species.

… Geospiza magnirostris, which has the largest beak and the highest bite force, was the only species to feed on the very large/hard seeds of Cordia lutea and it fed on these seeds regularly.

Geospiza scandens, which has the longest beak, was often seen probing the flowers of Optuntia cactus, whereas this behaviour was rare for the other species.

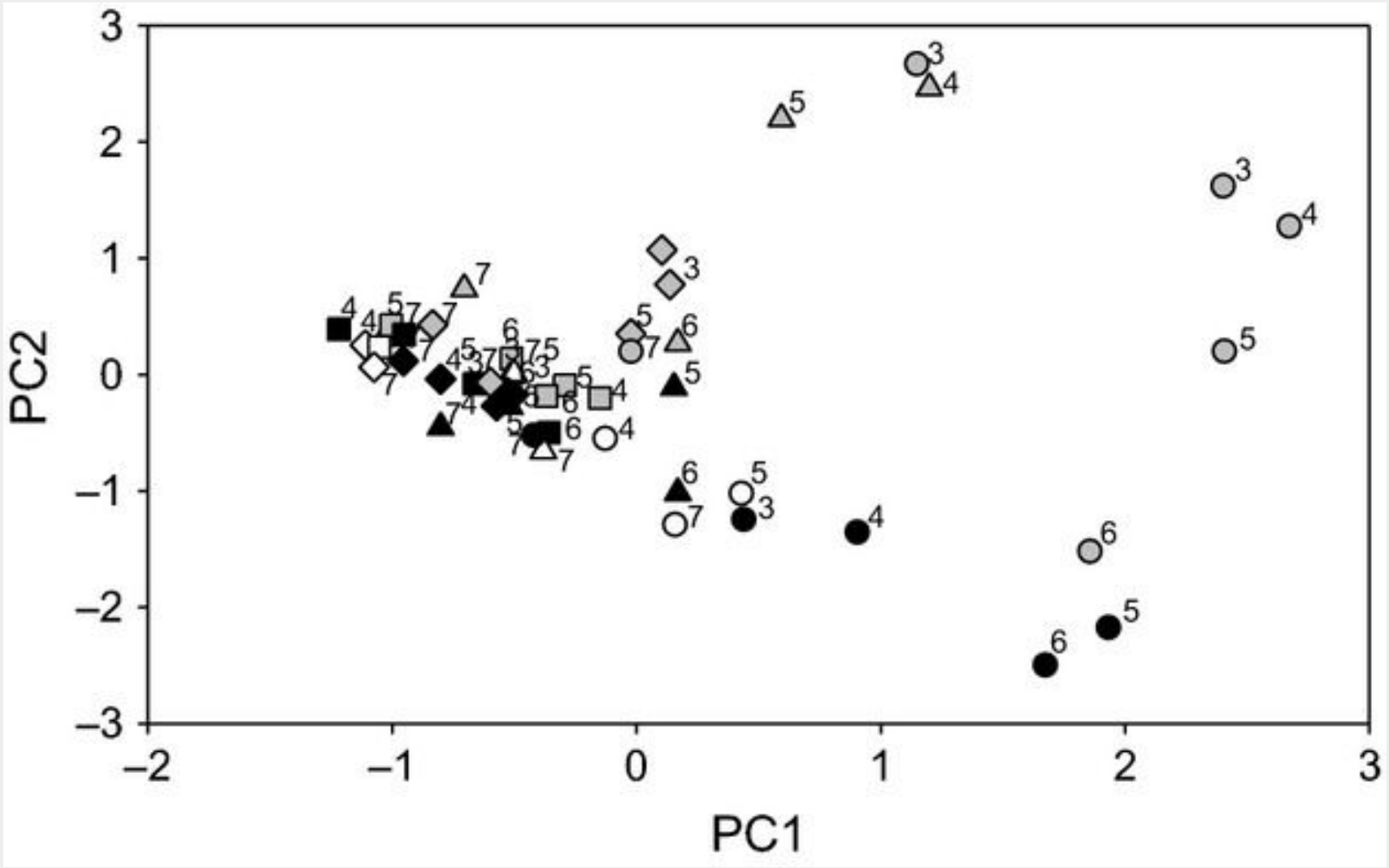
Geospiza fuliginosa, which has the smallest beak and the lowest bite force, often fed on the very small seeds of Cryptocarpus piryformis, whereas this behaviour was uncommon for the other species.

Geospiza fortis, which is intermediate in beak size and bite force, fed more often on the intermediate seed-sized Scutia spicata than did the other species…

But!

But!

Despite these unique food resources, the overall diet of the finch species is quite similar.


PC2
PC1
3
2
1
0
−1
−2
−3
−2
−1
0
1
2
3

The authors' conclusion:

"When conditions are favourable (e.g. high rainfall), all species converge on the best resources – often arthropods.

The authors' conclusion:

"When conditions are favourable (e.g. high rainfall), all species converge on the best resources – often arthropods.

When conditions deteriorate, multiple species might still prefer any abundant resources that remain, such as the fruits of Scutia spicata.

The authors' conclusion:

"When conditions are favourable (e.g. high rainfall), all species converge on the best resources – often arthropods.

When conditions deteriorate, multiple species might still prefer any abundant resources that remain, such as the fruits of Scutia spicata.

When conditions are very bad (e.g. drought) and food resources become rare overall, species increasingly use those resources for which their morphologies are best adapted: small seeds for G. fuliginosa, medium seeds for G. fortis, large seeds for G. magnirostris and cacti for G. scandens."

Takeaways from Lotka-Volterra competition model

Takeaways from Lotka-Volterra competition model

- Coexistence only becomes a problem when resources are limiting (which they often are - but not always)

Takeaways from Lotka-Volterra competition model

- Coexistence only becomes a problem when resources are limiting (which they often are - but not always)

- Under scarce resource conditions, coexistence possible when each species limit itself more than it limits other

Takeaways from Lotka-Volterra competition model

- Coexistence only becomes a problem when resources are limiting (which they often are - but not always)

- Under scarce resource conditions, coexistence possible when each species limit itself more than it limits other

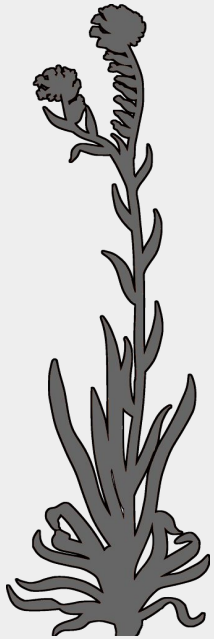
- ***More generally***: Coexistence requires that each species changes the environment in a way that limits conspecifics more than the other species.

Applying this insight more broadly:

A case study with plant-microbe interactions


Borneo, Malaysia

plant **1**



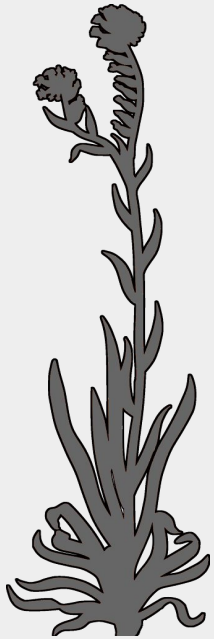
plant **2**

microbial
community **A**

microbial
community **B**

Bever et al. 1997 (J. Ecol)

plant **1**



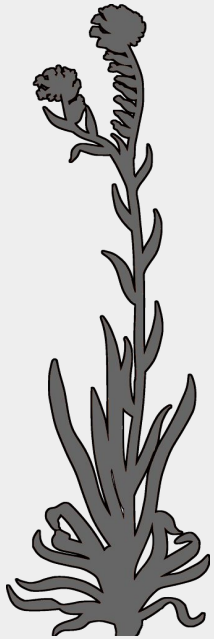
plant **2**

microbial community **A**

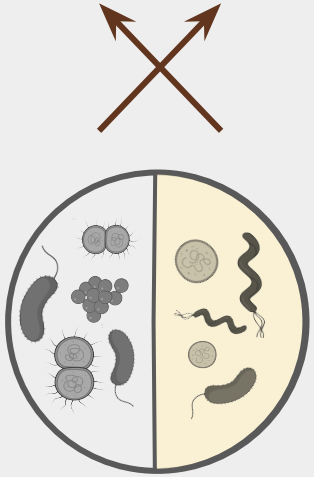
microbial community **B**

Bever et al. 1997 (J. Ecol)

plant **1**



plant **2**

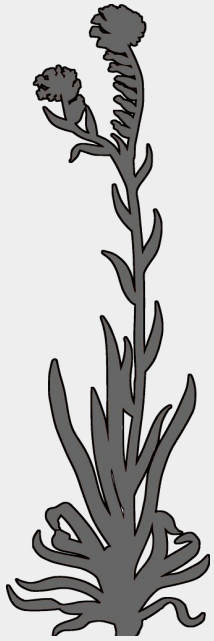


microbial
community **A**

microbial
community **B**

Bever et al. 1997 (J. Ecol)

plant **1**



m_{1A}

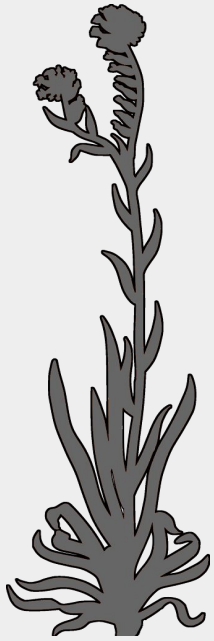
m_{1B}

microbial community **A**

microbial community **B**

plant **1**

plant **2**



m_{1A}

m_{1B} m_{2A}

m_{2B}

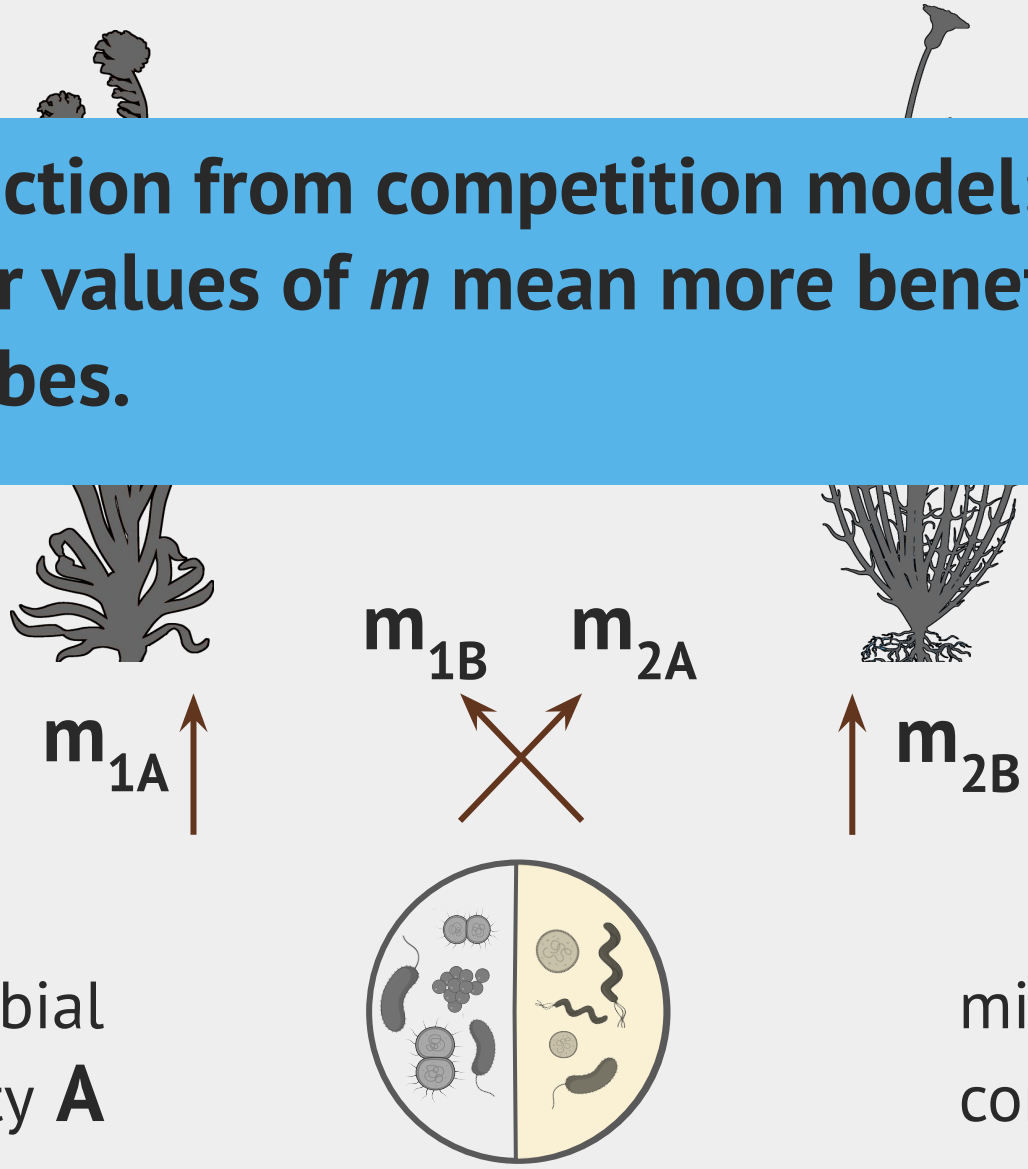
microbial community **A**

microbial community **B**

plant **1**

plant **2**

Distinction from competition model: Larger values of *m* mean more beneficial microbes.



microbial community **A**

microbial community **B**

Key insight from this model:

Plant-microbe interactions favor plant coexistence when microbes hurt the cultivating species more* than the other species

Bever et al. 1997 J. Ecol, Kandlikar et al. 2019

** or benefit it less*

Key insight from this model:

Plant-microbe interactions favor plant coexistence when microbes hurt the cultivating species more* than the other species

Bever et al. 1997 J. Ecol, Kandlikar et al. 2019

** or benefit it less*

Key insight from this model:

Plant-microbe interactions favor plant coexistence when microbes hurt the cultivating species more* than the other species

$$m_{1A} < m_{2A} \quad \textbf{and} \quad m_{2B} < m_{2A}$$

Bever et al. 1997 J. Ecol, Kandlikar et al. 2019

** or benefit it less*

Key insight from this model:

Plant-microbe interactions favor plant coexistence when microbes hurt the cultivating species more* than the other species

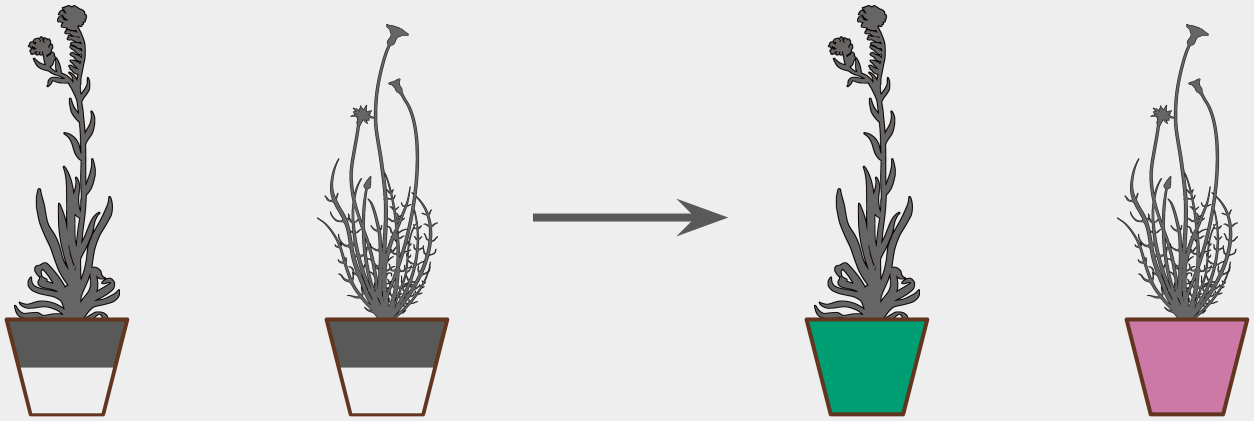
$$m_{1A} < m_{2A} \quad \textbf{and} \quad m_{2B} < m_{2A}$$

How do we measure m for real plant-microbe systems?

Bever et al. 1997 J. Ecol, Kandlikar et al. 2019

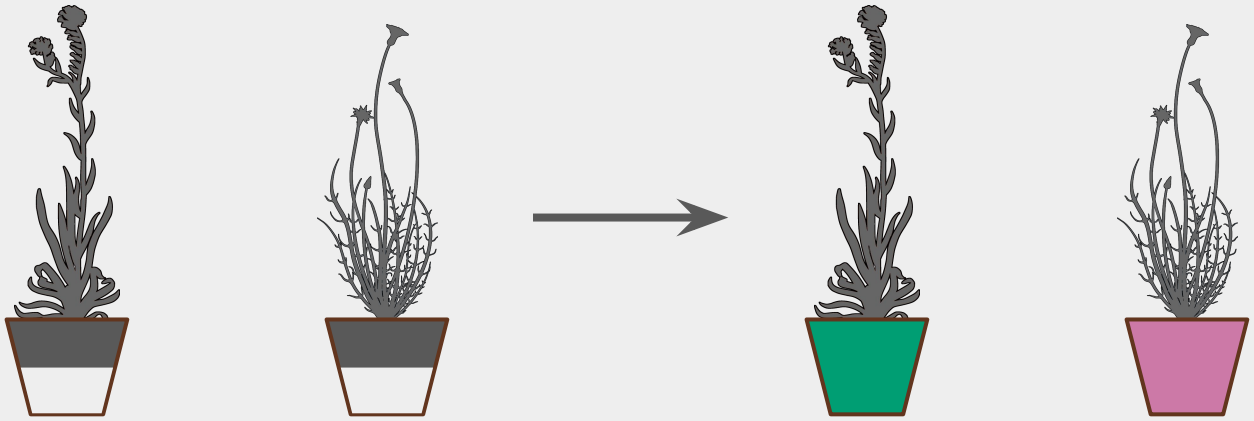
** or benefit it less*

Phase 1. **Cultivate** each plant's unique microbial community



Phase 2. Measure each plant's **response** to cultivated microbes

Phase 1. **Cultivate** each plant's unique microbial community



Phase 2. Measure each plant's **response** to cultivated microbes

Sedgwick Reserve (unceded territory of Chumash people)

Sedgwick Reserve (unceded territory of Chumash people)

Acmispon wrangelianus

Festuca microstachys

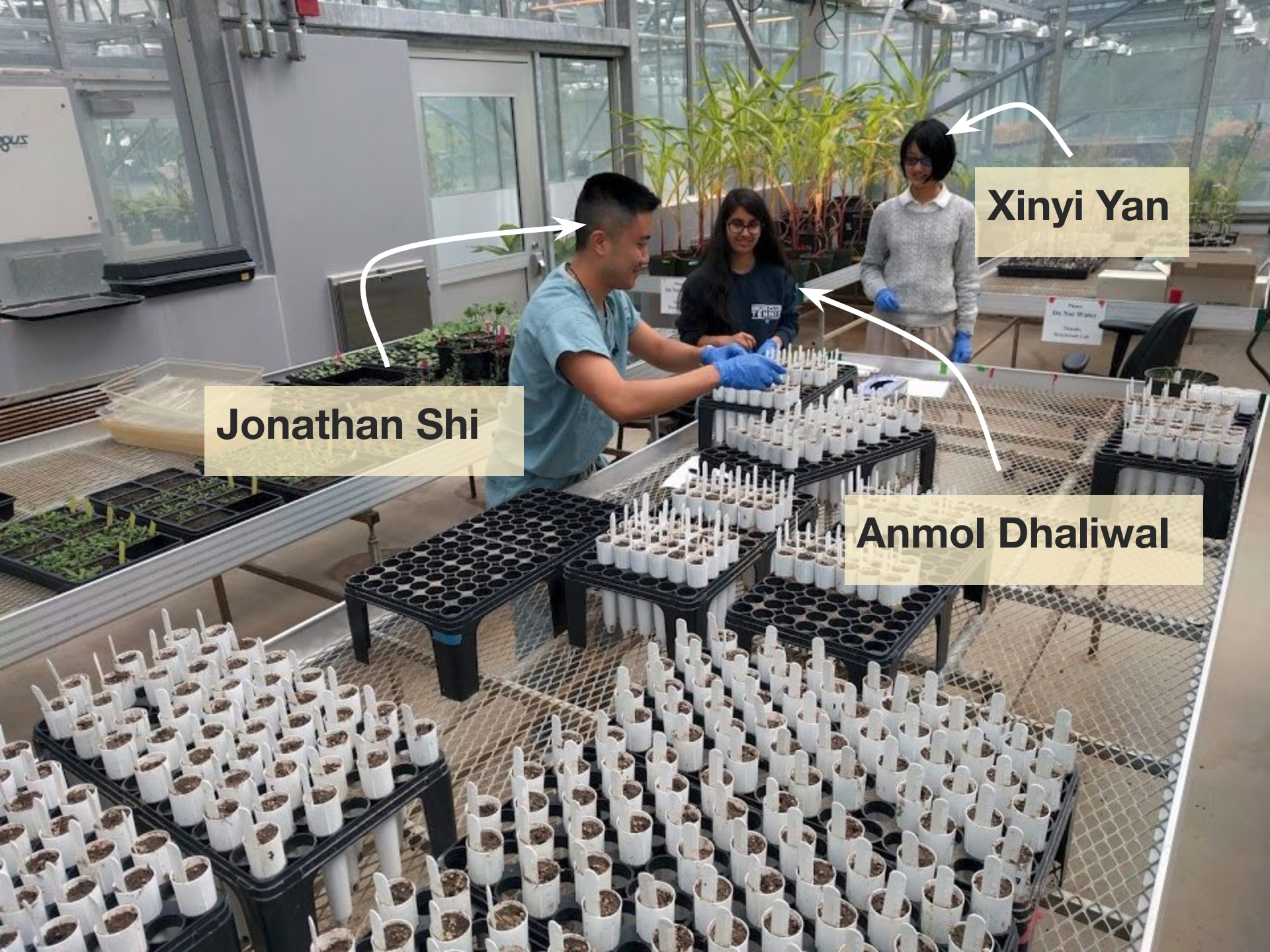
Hordeum murinum

Salvia columbariae

Plantago erecta

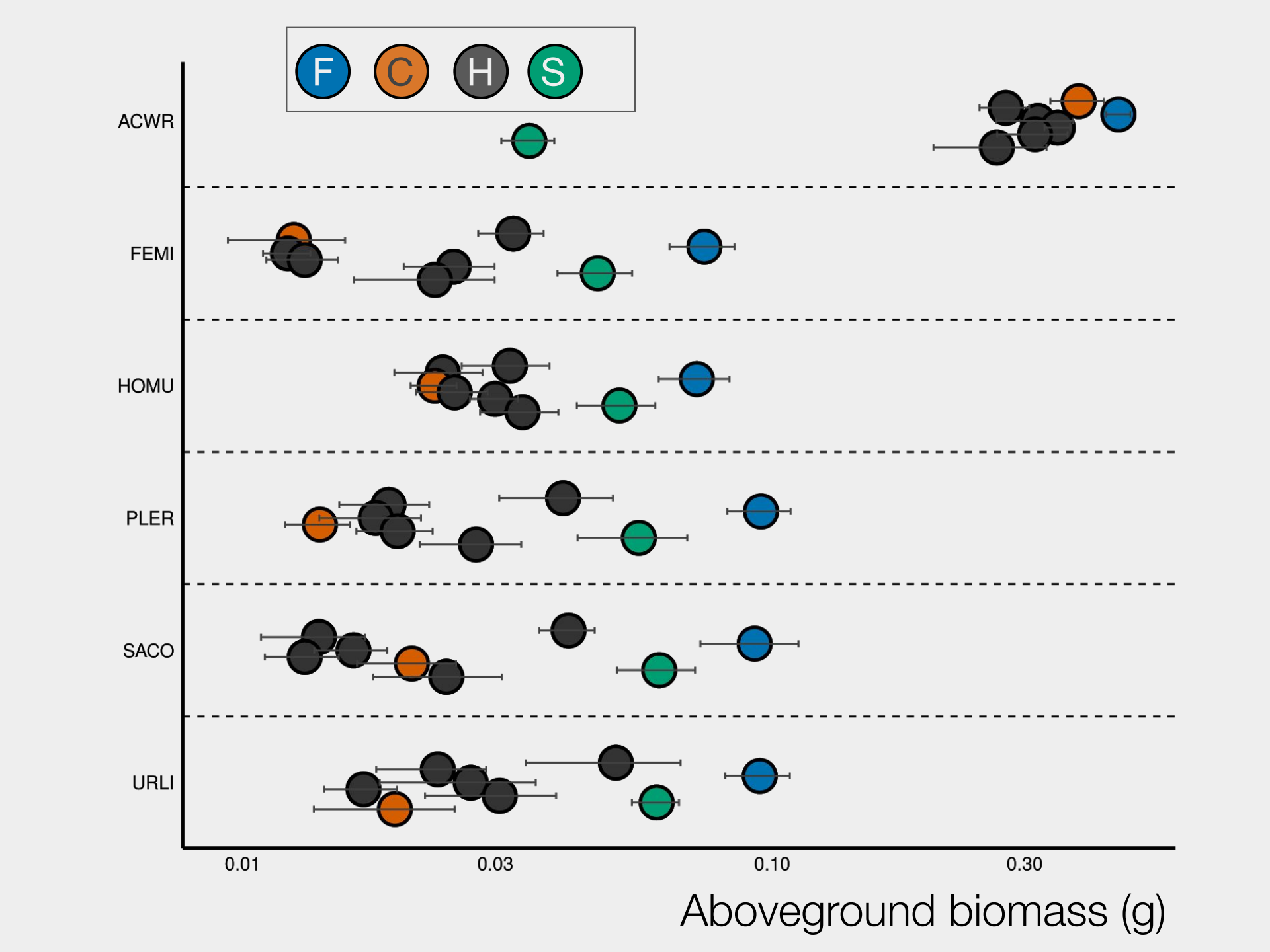
Uropappus lindleyi

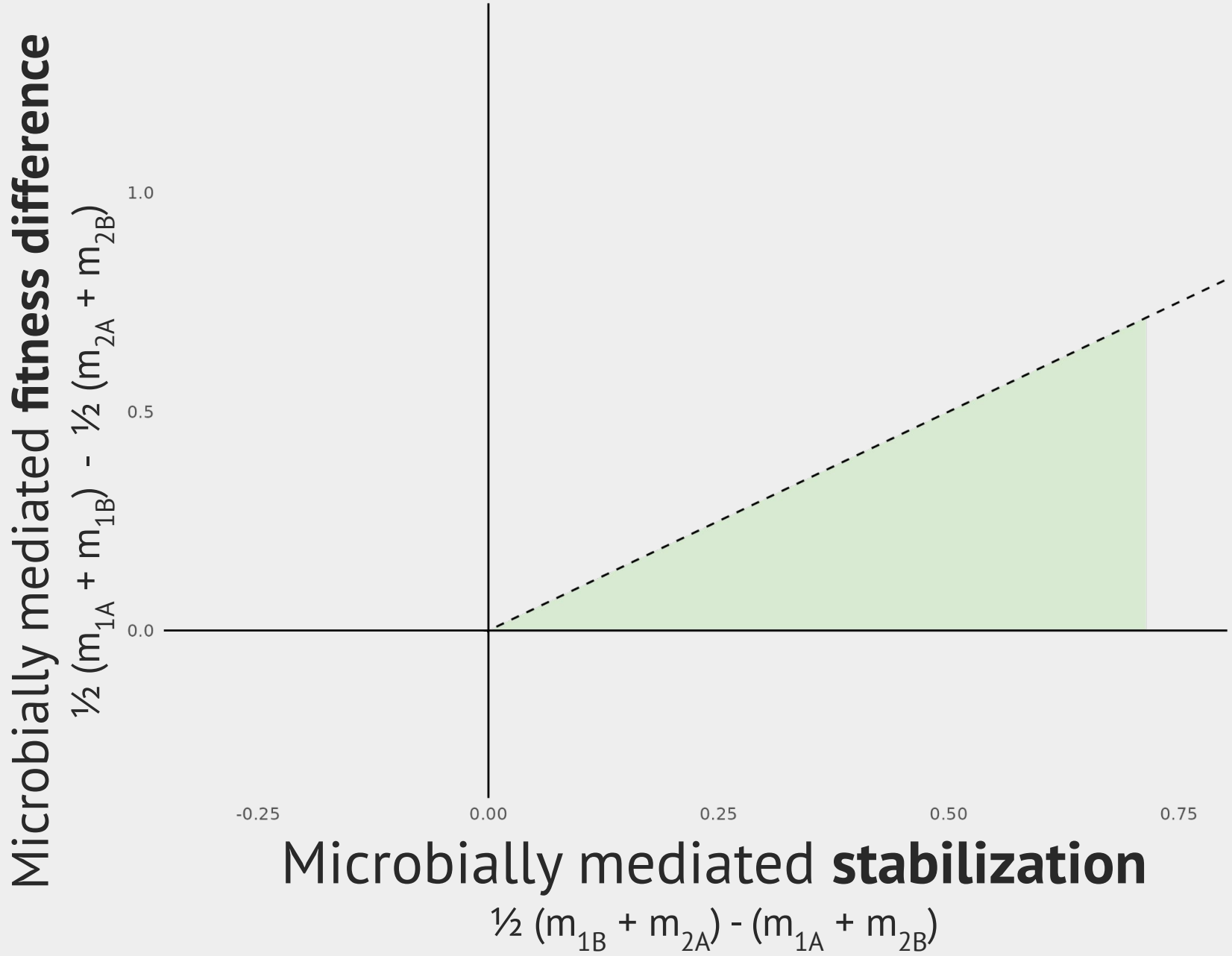
6 species → 15 pairwise comparisons

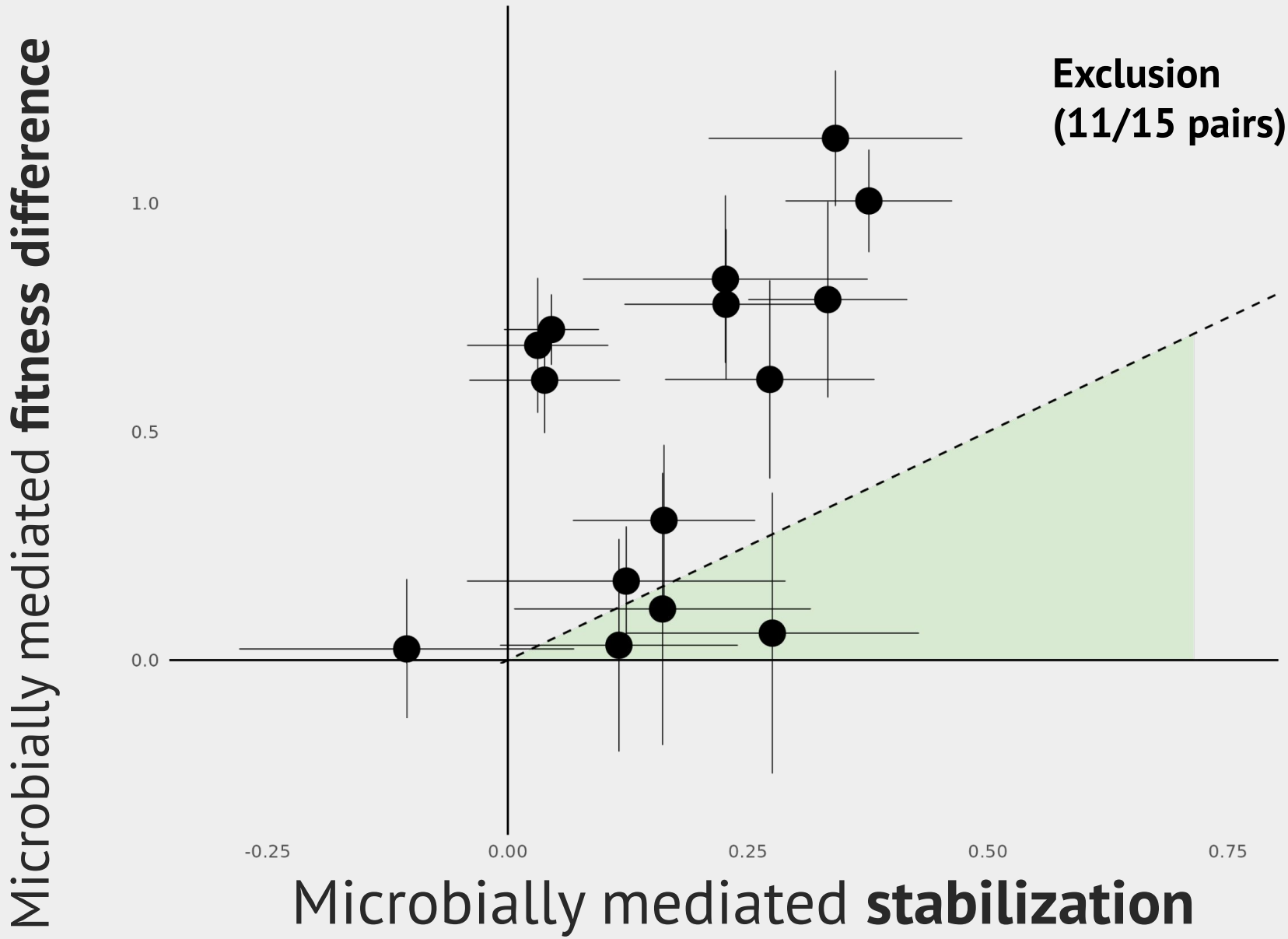

Xinyi Yan
Jonathan Shi
Anmol Dhaliwal


Pump Panel
Tab 1


4-14
SA_PLER_R10
4·15
PL_PLER_R10
4·14
str_FEMI_R1
4·18
fld_ACWR_R10


F
C
H
S
ACWR
FEMI
HOMU
PLER
SACO
URLI
0.01
0.03
0.10
0.30
Aboveground biomass (g)


Microbially mediated **fitness difference**
½ (m_{1A} + m_{1B}) - ½ (m_{2A} + m_{2B})
1.0
0.5
0.0
-0.25
0.00
0.25
0.50
0.75
Microbially mediated **stabilization**
½ (m_{1B} + m_{2A}) - (m_{1A} + m_{2B})



Kandlikar et al. 2021 American Naturalist

Do microbially mediated fitness differences matter in nature?

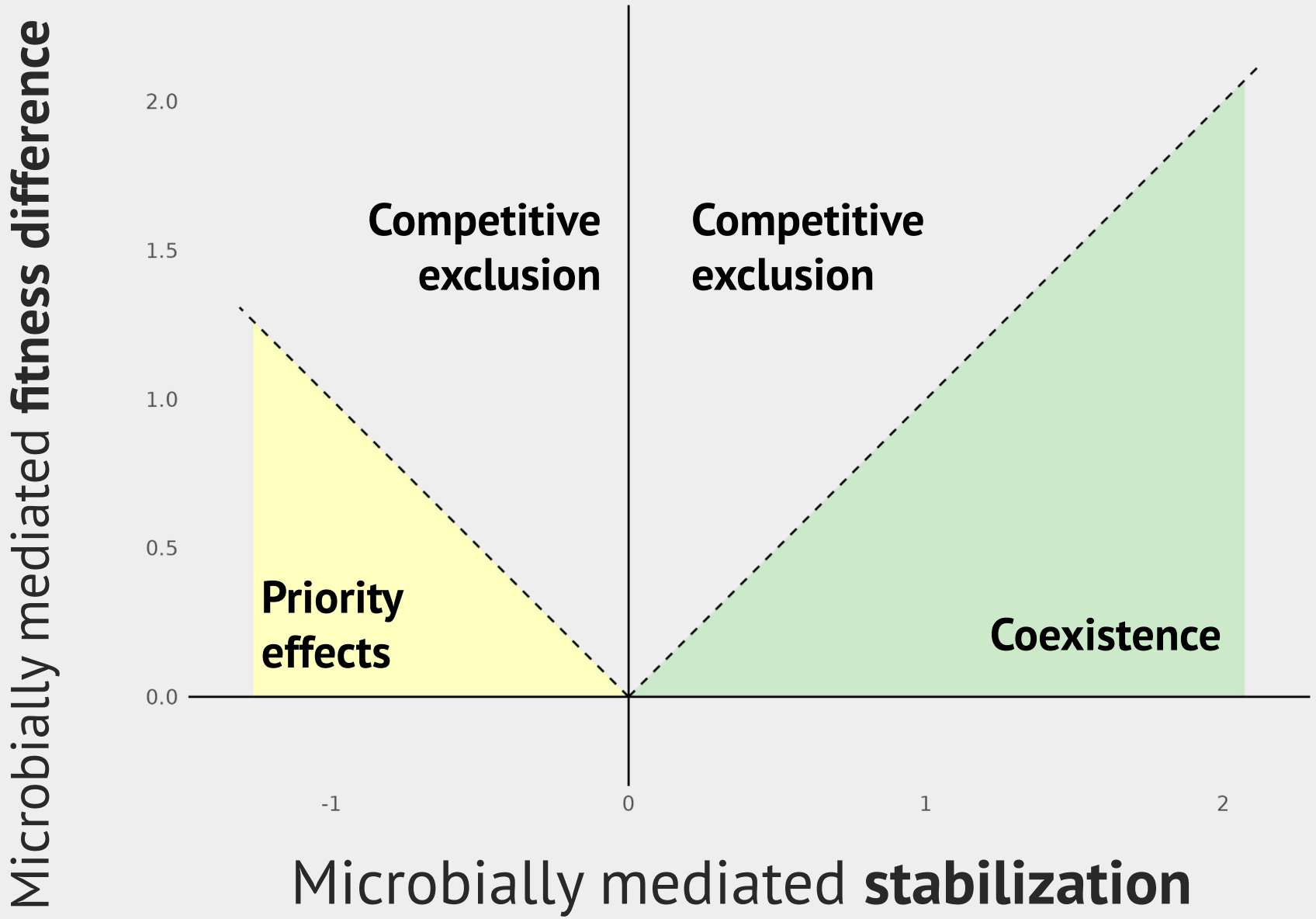
1. Experiment (Kandlikar *et al.* 2021, American Naturalist)

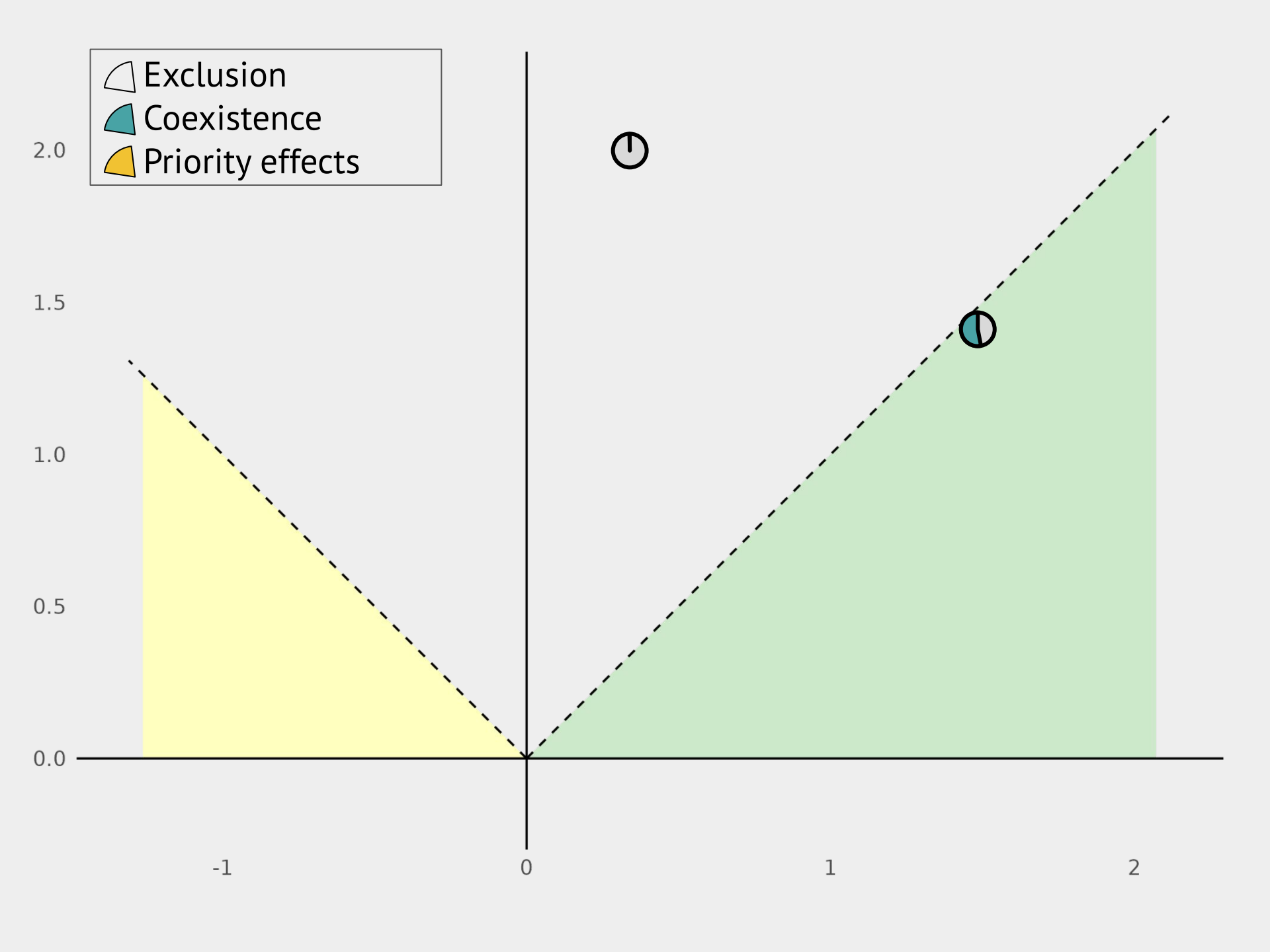
   Stronger fitness differences than stabilization among grassland annuals

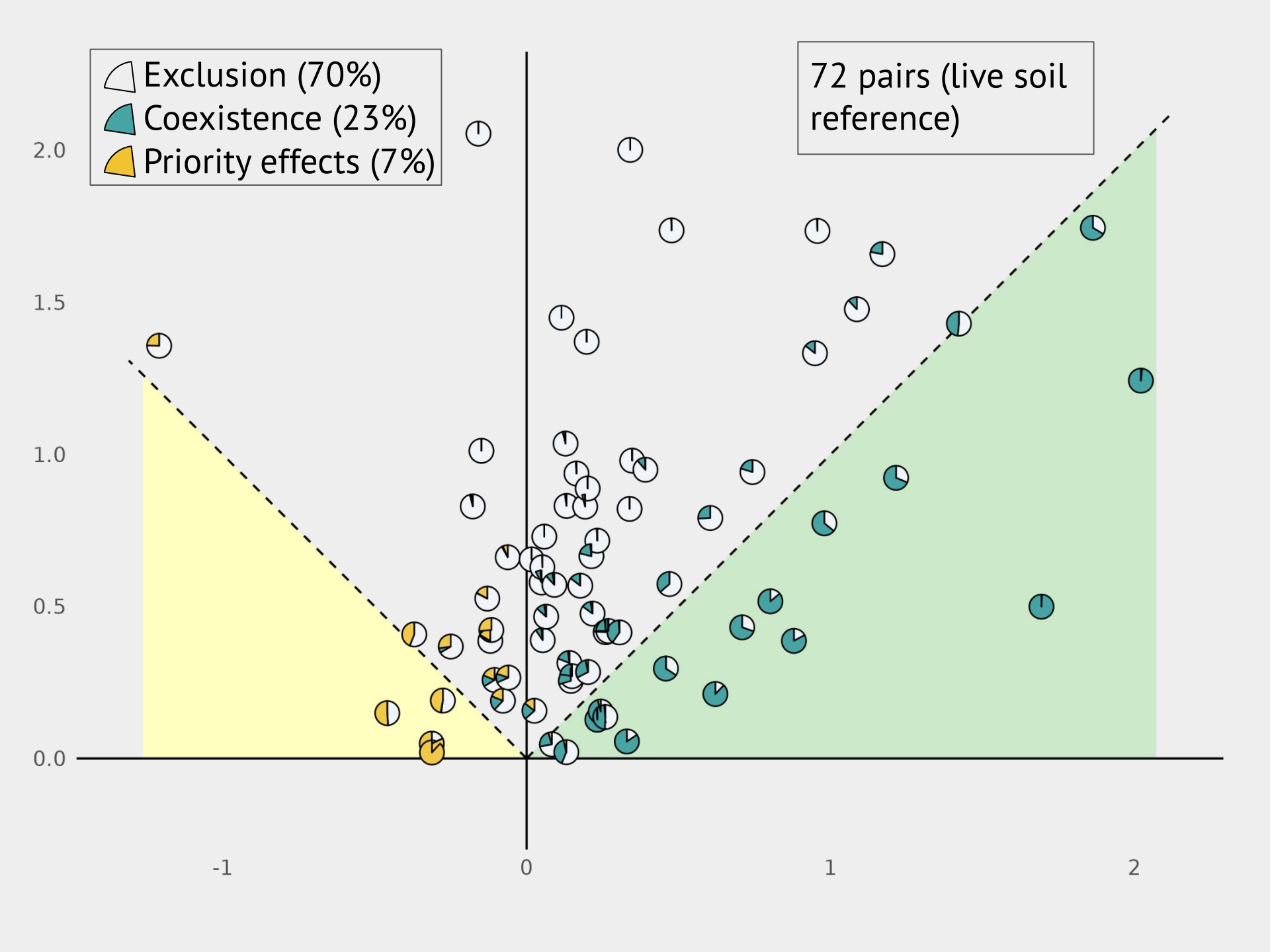
2. **Meta-analysis**

   (Yan, Levine, and Kandlikar 2022, PNAS)

Xinyi Yan


Microbially mediated fitness difference
2.0
1.5
1.0
0.5
0.0
Competitive exclusion
Competitive exclusion
Priority effects
Coexistence
-1
0
1
2
Microbially mediated stabilization


Exclusion
Coexistence
Priority effects
2.0
1.5
1.0
0.5
0.0
-1
0
1
2


Exclusion (70%)
Coexistence (23%)
Priority effects (7%)
72 pairs (live soil reference)
2.0
1.5
1.0
0.5
0.0
-1
0
1
2

Does this mean we should expect more plant species richness in a world without microbes?

Does this mean we should expect more plant species richness in a world without microbes?

no!

Does this mean we should expect more plant species richness in a world without microbes?

no!

But, these results show that if we want to better understand the dynamics of plant communities, incorporating soil microbes can be critical.


NATURE
BITES