

Biodiversity and Ecosystem Functioning

Today's Agenda:

- Quiz
- Ecosystem Functions and Services
- Biodiversity and Ecosystem Functioning
 - BEF examples

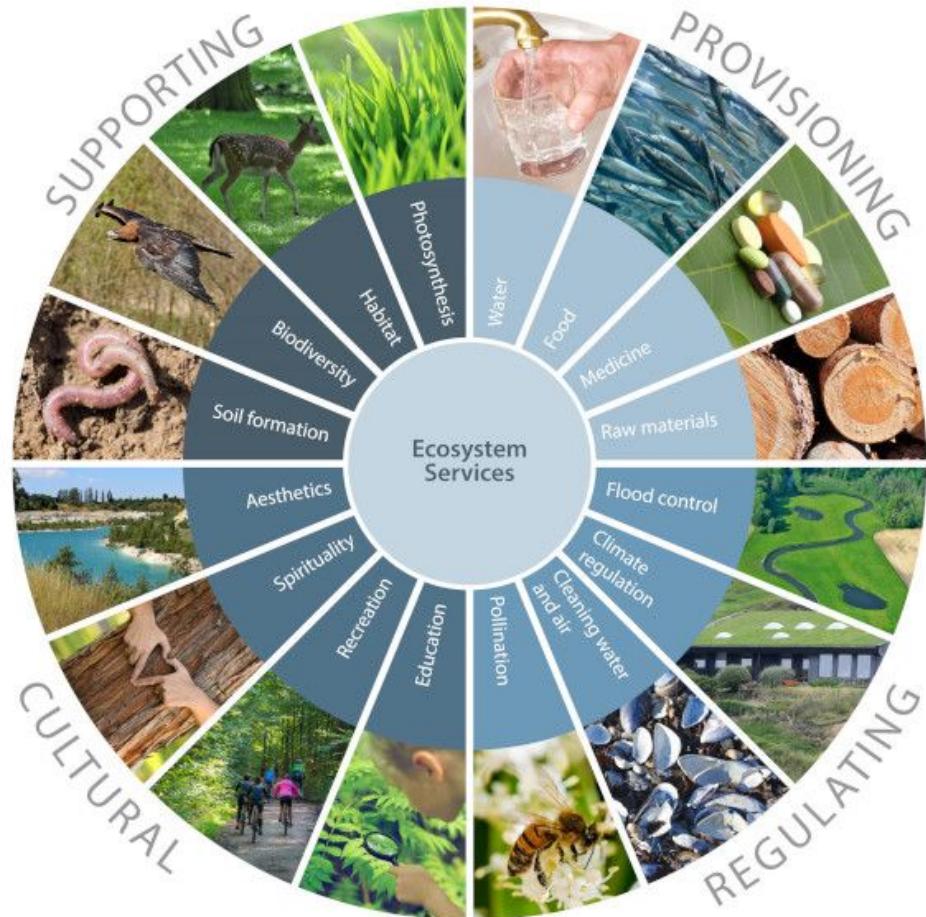
Ecosystem Functioning

- The biological and chemical processes that occur in ecosystems
- Functions that benefit people are called “ecosystem services”
 - Also referred to as “nature’s contributions to people”

Ecosystem Services

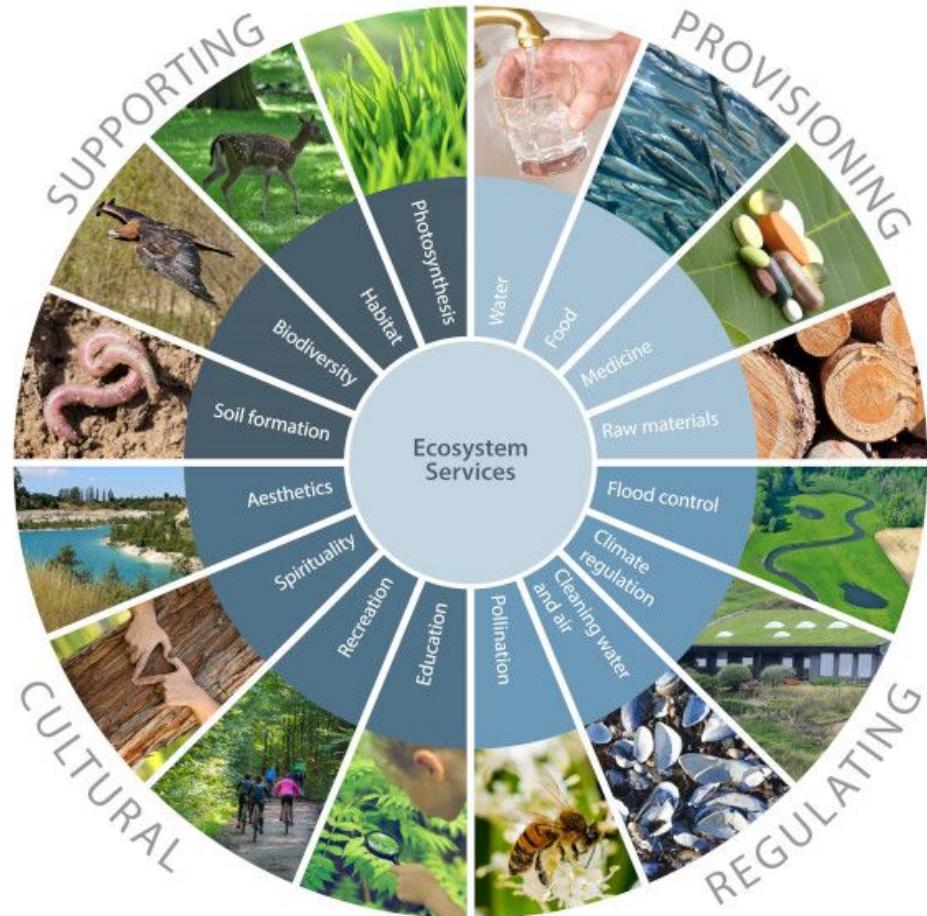
What examples can folks think of?

Ecosystem Services



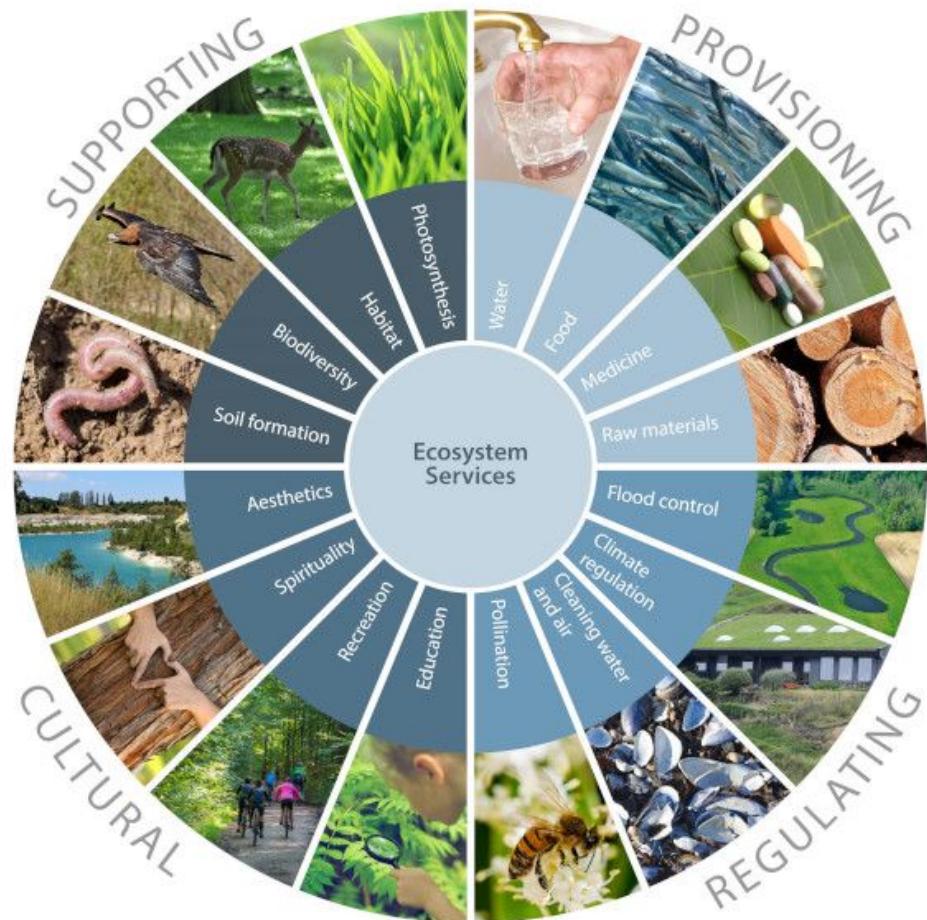
Ecosystem Services

- Supporting
 - maintain fundamental ecosystem processes



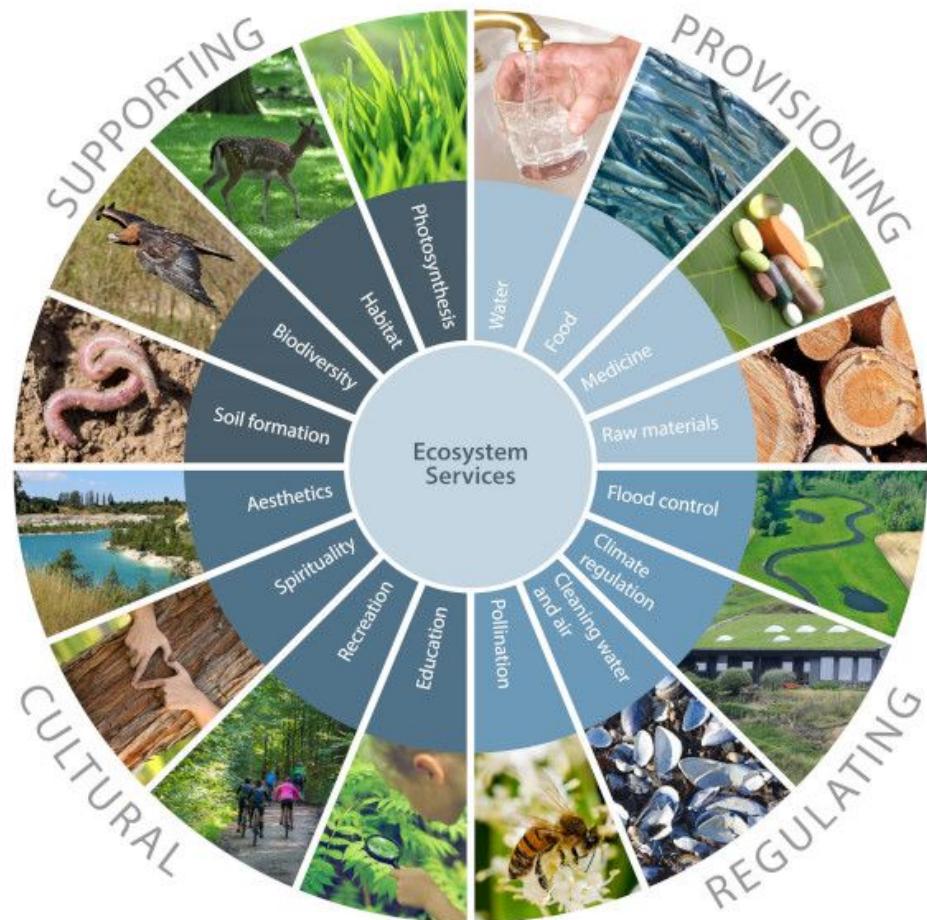
Ecosystem Services

- Supporting
 - maintain fundamental ecosystem processes
- Provisioning
 - Material and energy



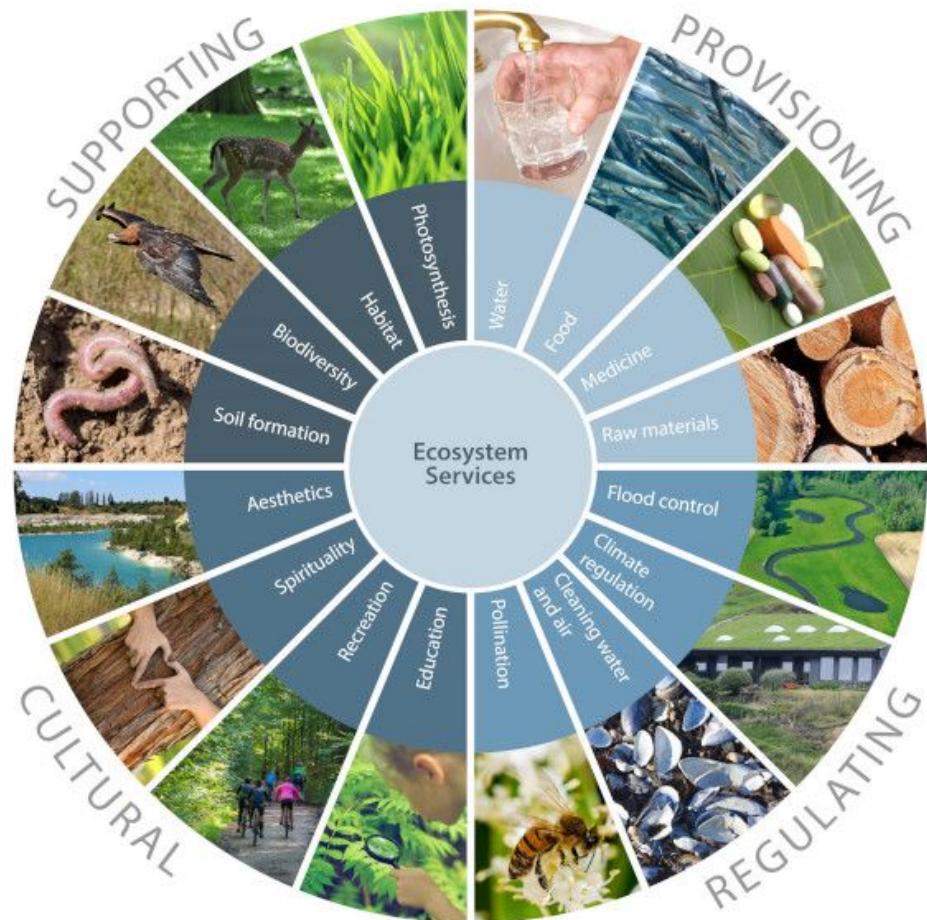
Ecosystem Services

- Supporting
 - maintain fundamental ecosystem processes
- Provisioning
 - Material and energy
- Regulating
 - moderation or control of ecosystem processes



Ecosystem Services

- Supporting
 - maintain fundamental ecosystem processes
- Provisioning
 - Material and energy
- Regulating
 - moderation or control of ecosystem processes
- Cultural
 - non-material/energy benefits to human societies



DRIVERS

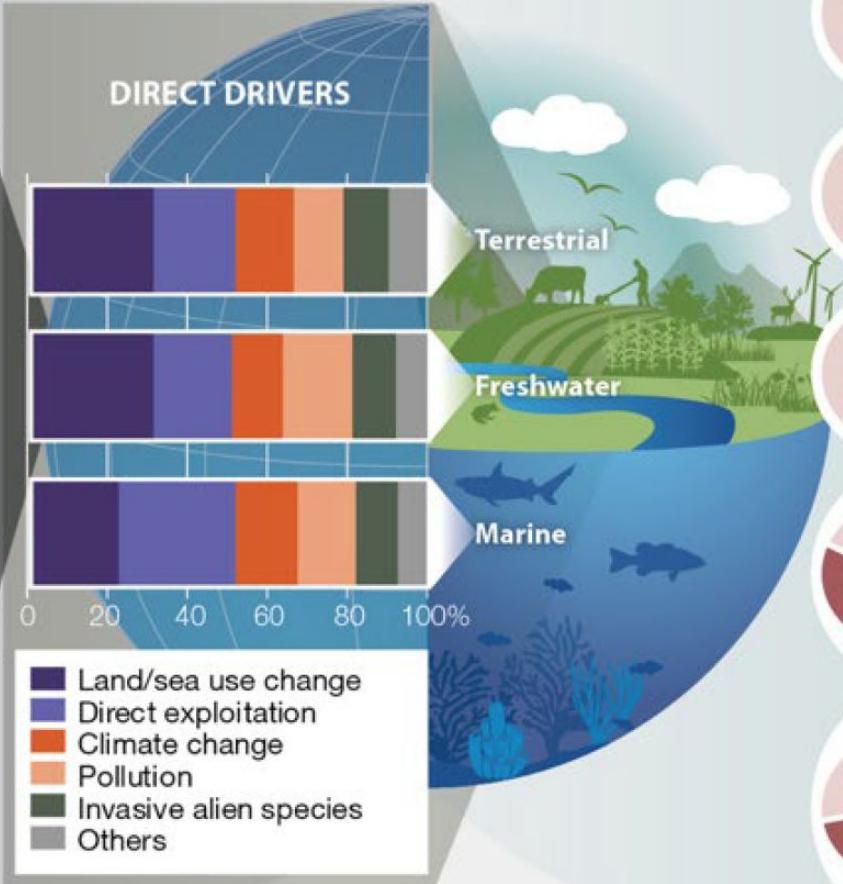
INDIRECT DRIVERS

Demographic
and
sociocultural

Economic
and
technological

Institutions
and
governance

Conflicts
and
epidemics



EXAMPLES OF DECLINES IN NATURE

ECOSYSTEM EXTENT AND CONDITION

47%

Natural ecosystems have **declined by 47 per cent** on average, relative to their earliest estimated states.

25%

SPECIES EXTINCTION RISK

Approximately **25 per cent of species are already threatened with extinction** in most animal and plant groups studied.

23%

ECOLOGICAL COMMUNITIES

Biotic integrity—the abundance of naturally-present species—has **declined by 23 per cent** on average in terrestrial communities.*

82%

BIOMASS AND SPECIES ABUNDANCE

The global biomass of wild mammals has **fallen by 82 per cent.*** Indicators of vertebrate abundance have declined rapidly since 1970

72%

NATURE FOR INDIGENOUS PEOPLES AND LOCAL COMMUNITIES

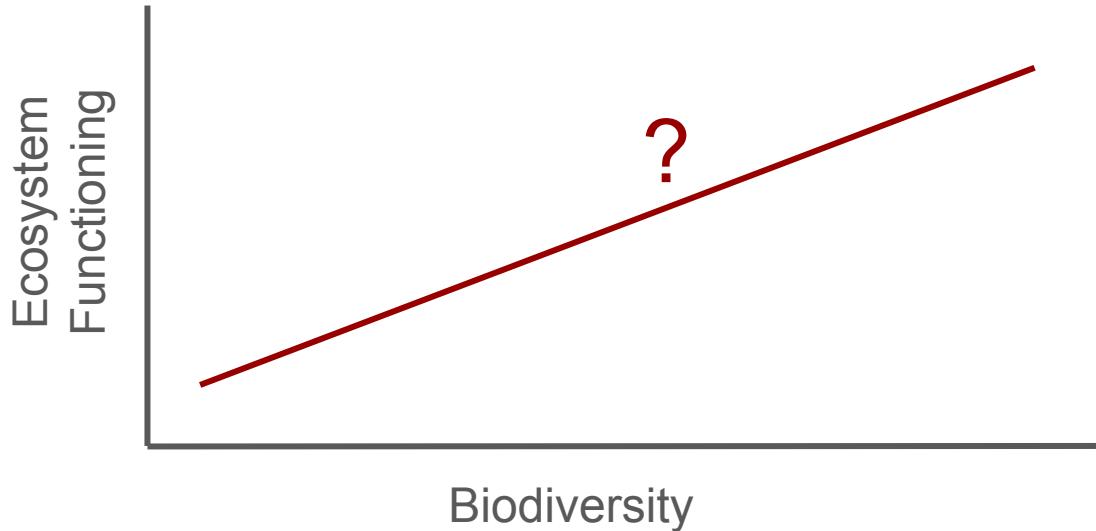
72 per cent of indicators developed by indigenous peoples and local communities show **ongoing deterioration** of elements of nature important to them

How much biodiversity do we need?

- Biodiversity provides things we need
- We're destroying nature at mass extinction rates
- Need to predict impacts of our actions

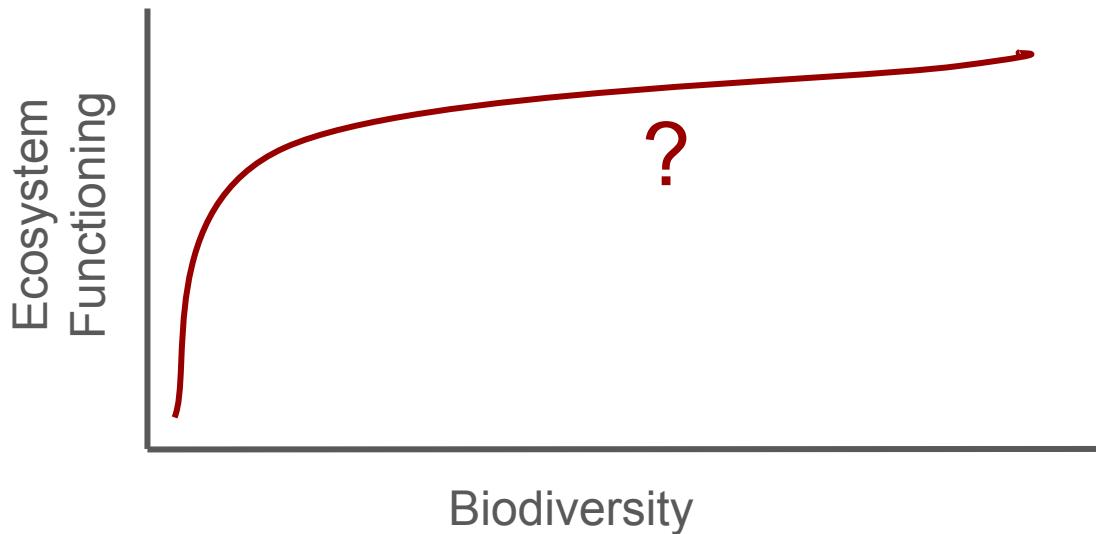
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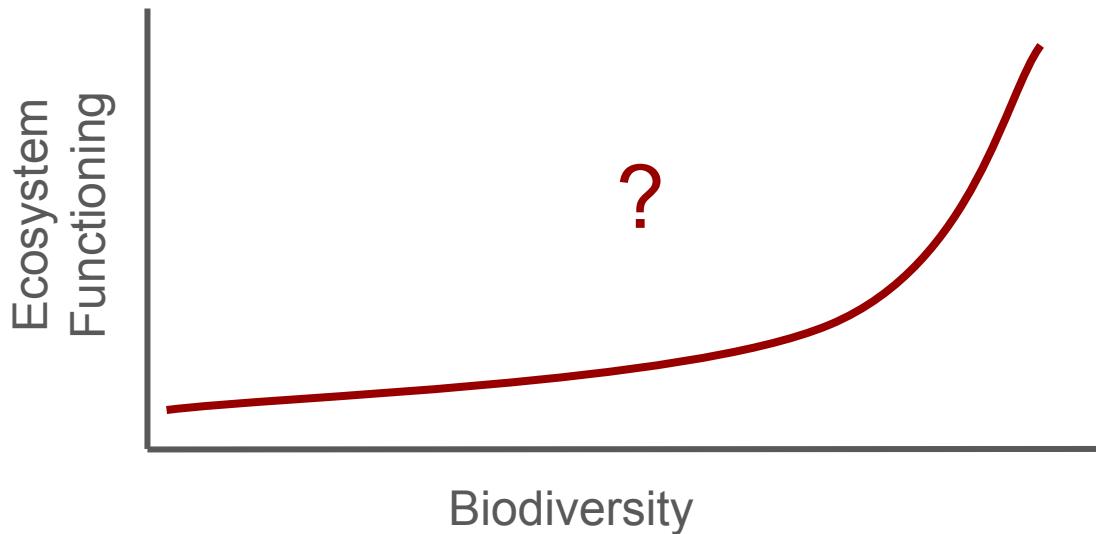
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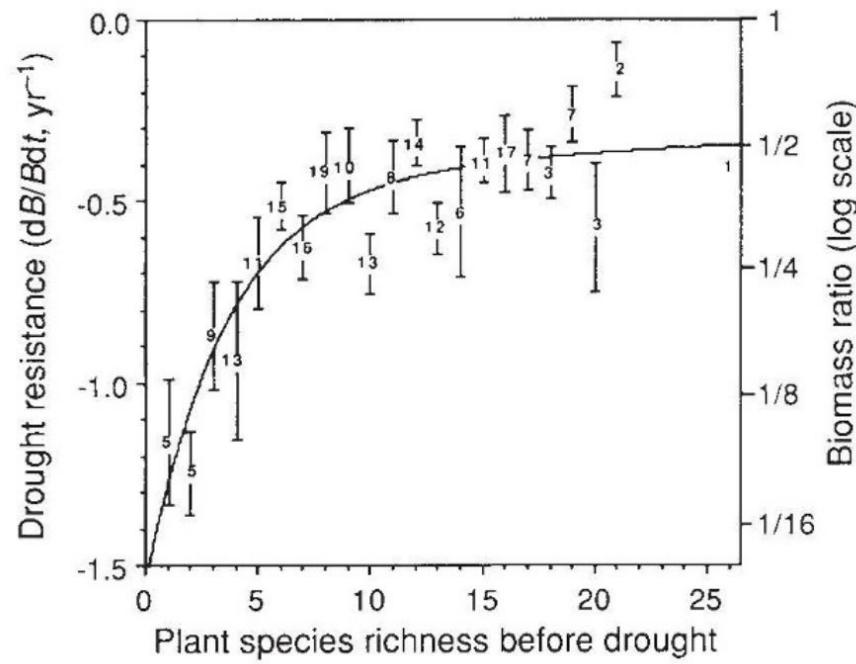
How much biodiversity do we need?

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Early Experimental Evidence

- Grassland system
- Suggestive, but diversity was altered by fertilizer, confounding things

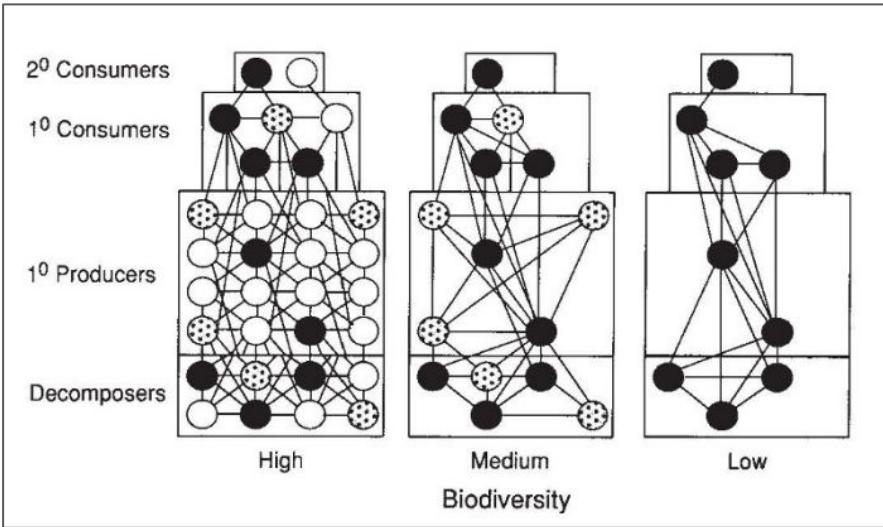


Biodiversity and stability in grasslands

David Tilman & John A. Downing

Early Experimental Evidence

- Fancy environmental chambers
- Manipulated species directly
- Manipulated multiple trophic levels



Declining biodiversity can alter the performance of ecosystems

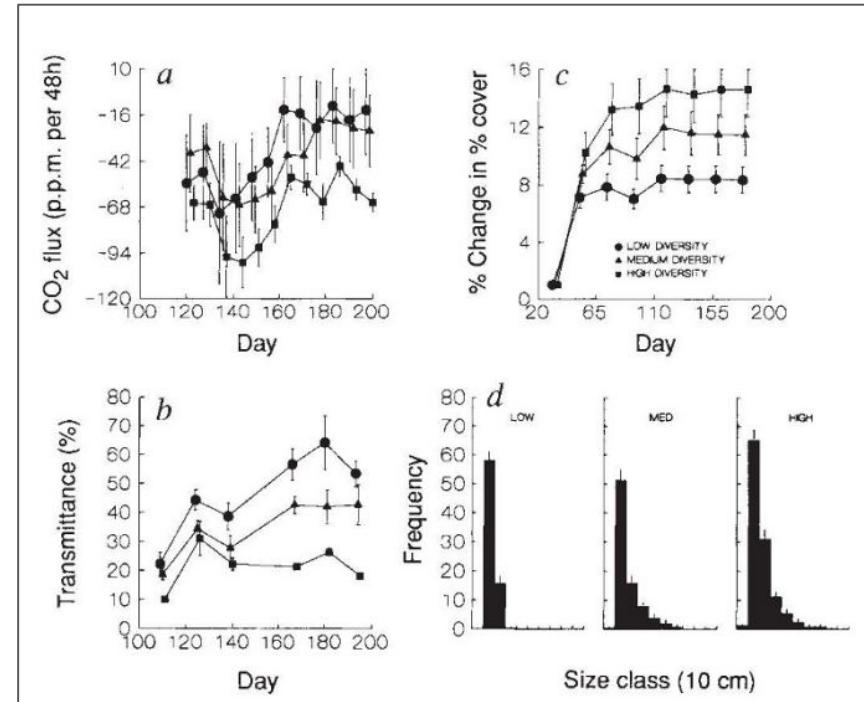
**Shahid Naeem, Lindsey J. Thompson,
Sharon P. Lawler, John H. Lawton
& Richard M. Woodfin**

Early Experimental Evidence

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Declining biodiversity can alter the performance of ecosystems

Shahid Naeem, Lindsey J. Thompson,
Sharon P. Lawler, John H. Lawton
& Richard M. Woodfin



Focal ecosystem functions

Your book focuses on four types of ecosystem functions:

- Productivity
- Nutrient cycling
- Community stability
- Invasibility

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Diversity and Productivity

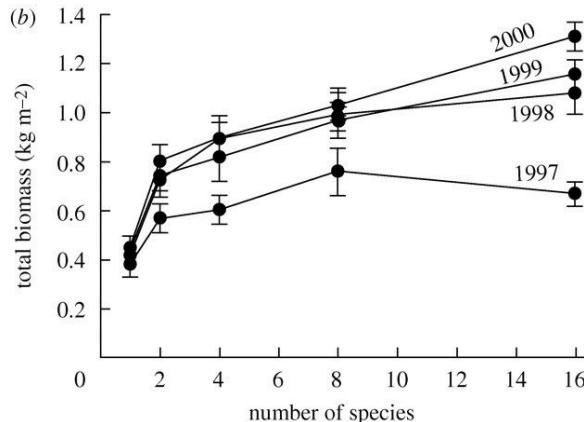
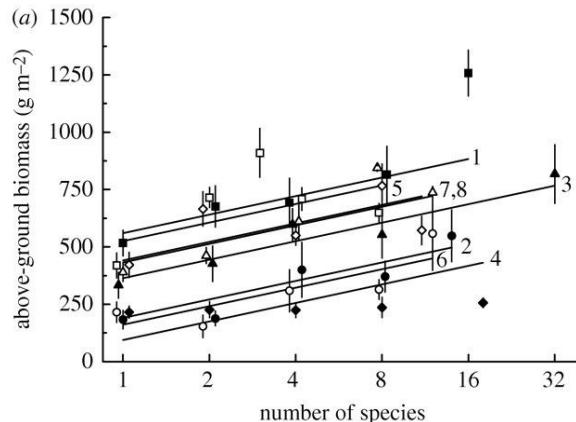
- Investigated by 3, high-profile, long-term, experiments
 - Cedar Creek (US)
 - Jena (Germany)
 - BIODEPTH (Europe)
- In all, species diversity was experimentally manipulated

Diversity and Productivity

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- In all, species diversity was experimentally manipulated
- Across all 3, **diversity was positively correlated with productivity**

Diversity and Productivity

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 - Cedar Creek (US)
 - Jena (Germany)
 - BIODEPTH (Europe)
- In all, species diversity was experimentally manipulated
- Across all 3, diversity was positively correlated with productivity



a: BIODEPTH,
b: Cedar Creek

Diversity and Productivity

- Strong evidence that diversity drives productivity...but why?

Why Does Diversity Impact Productivity?

Two main hypotheses:

- Niche complementarity
 - Species differ in resources, predators, impacts on environment, etc.
- Sampling Effect (aka species selection)
 - More species, more likely to include highly-productive species

Testing complementarity vs sampling effects

How can we tease apart these hypotheses that make similar predictions about diversity-productivity relationships?

Testing complementarity vs sampling effects

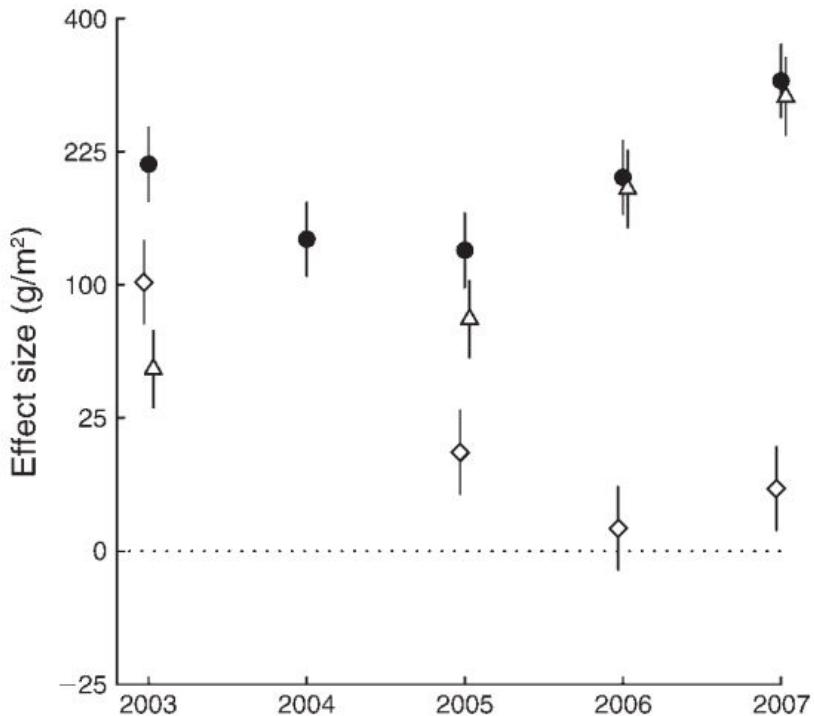
How can we tease apart these hypotheses that make similar predictions about diversity-productivity relationships?

Monoculture vs polyculture experiments!

Testing complementarity vs sampling effects

- Measure services provided by a species alone
- Measure services provided by different assemblages
- Sampling effect: polyculture results should equal monoculture results weighted by abundance
- Complementarity effect: polyculture results should be more than monoculture effects
- Can partition the relative composition of these

Complementarity vs sampling



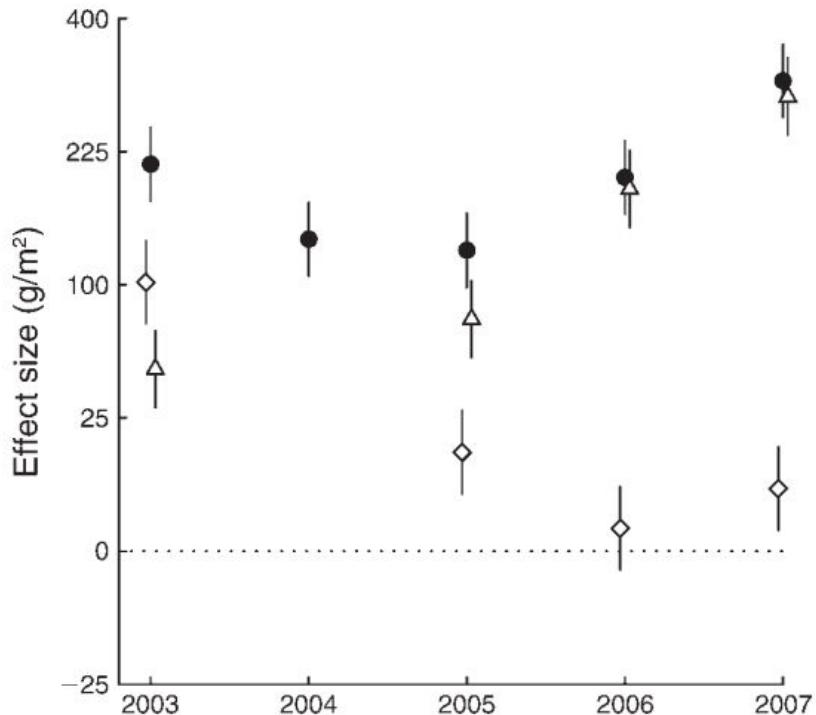
Ecology, 90(12), 2009, pp. 3290–3302
© 2009 by the Ecological Society of America

Plant species richness and functional composition drive overyielding
in a six-year grassland experiment

ELISABETH MARQUARD,^{1,2,6} ALEXANDRA WEIGELT,³ VICKY M. TEMPERTON,^{1,7} CHRISTIANE ROSCHER,¹
JENS SCHUMACHER,^{1,8} NINA BUCHMANN,⁴ MARKUS FISCHER,⁵ WOLFGANG W. WEISSE, ³ AND BERNHARD SCHMID²

Circles = Net Effect of Biodiversity
Diamonds = Selection
Triangles = Complementarity

Complementarity vs sampling



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Complementarity effects increase,
Selection effects decrease

Circles = Net Effect of Biodiversity
Diamonds = Selection
Triangles = Complementarity

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Focal ecosystem functions

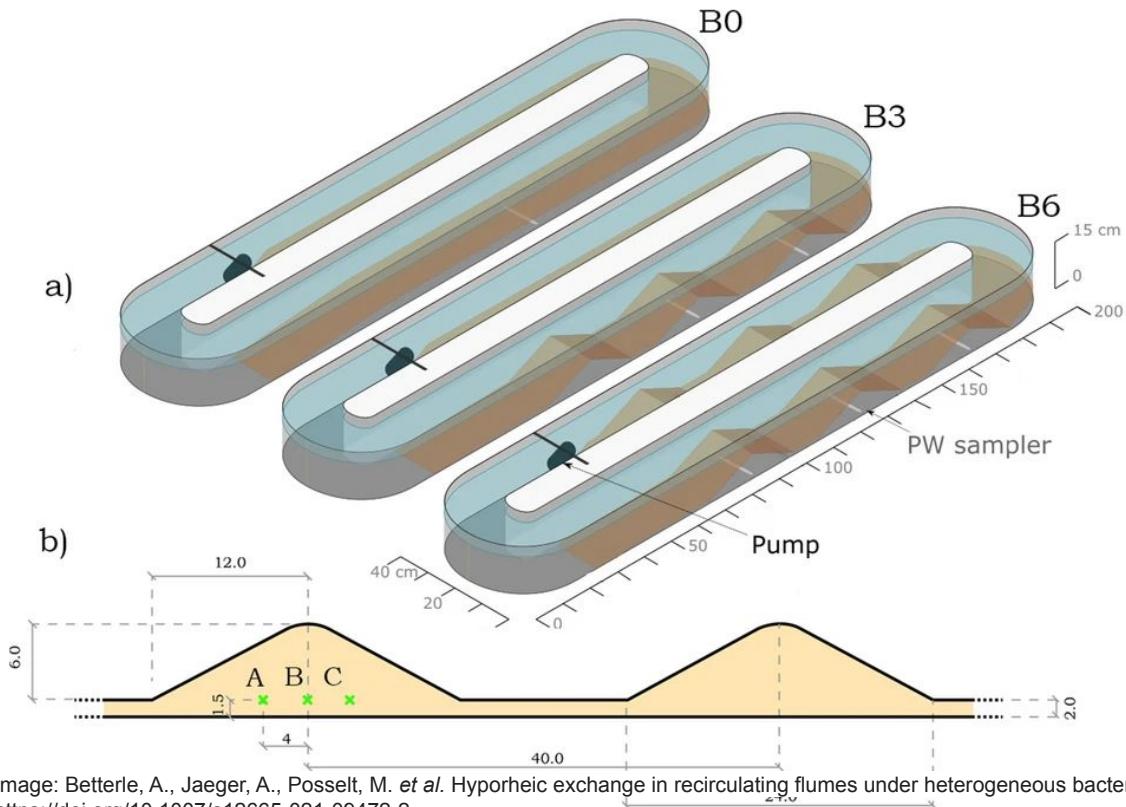
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Diversity and Nutrients

- If species have complementary niches, they should use more of the available resources
- More diverse communities are more likely to contain species that use resources more efficiently
- So again, sampling and complementarity effects

Diversity and Nutrients

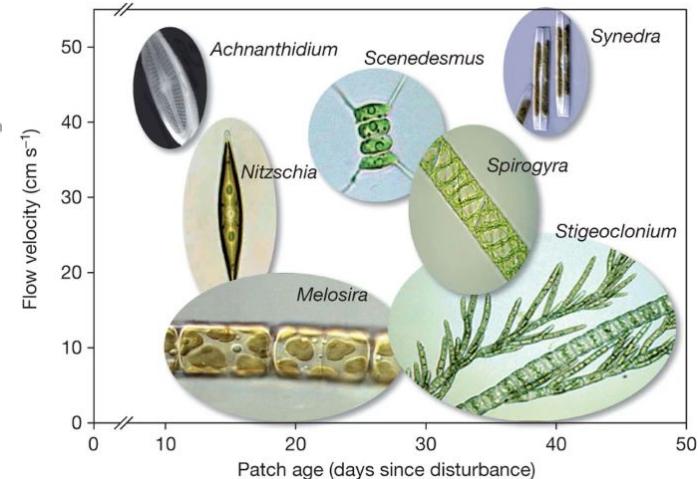


LETTER

doi:10.1038/nature09904

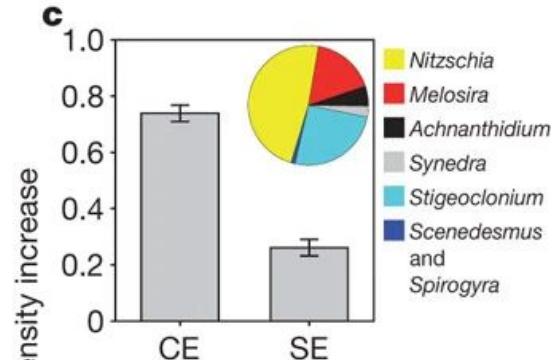
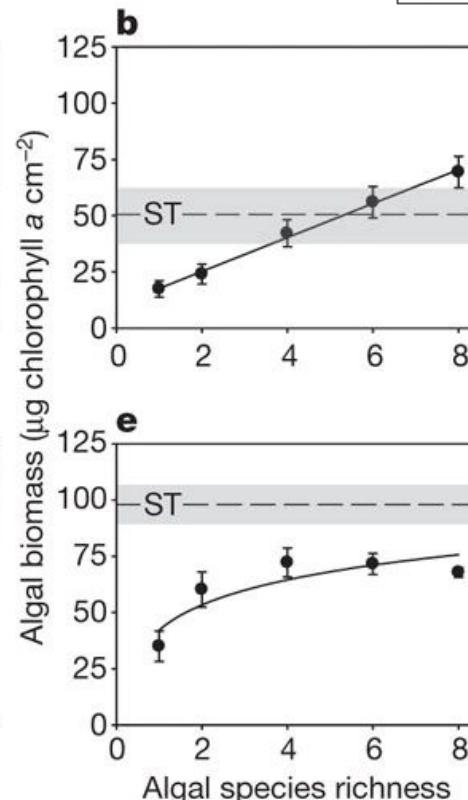
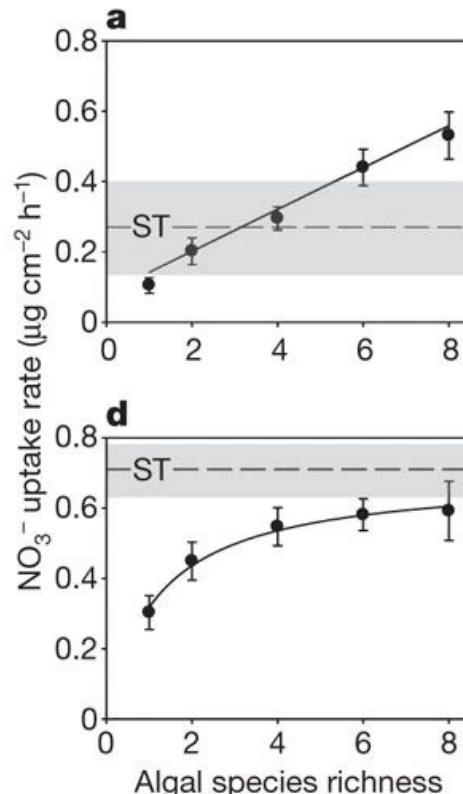
Biodiversity improves water quality through niche partitioning

Bradley J. Cardinale¹

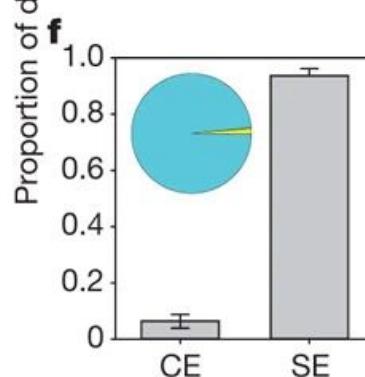
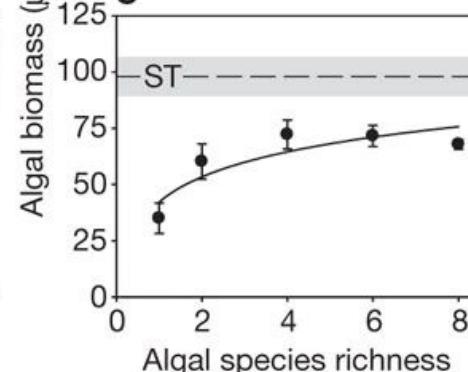
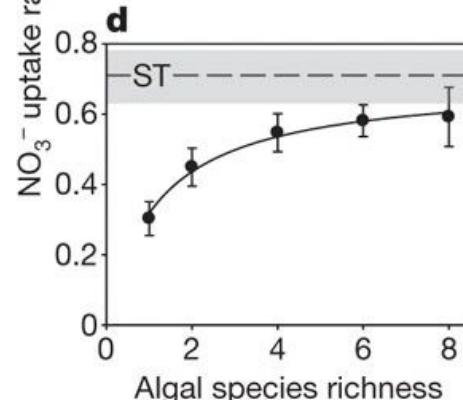


Diversity and Nutrients

Heterogeneous streams



Homogeneous streams



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Diversity and Stability

How do we quantify stability?

Variation in a quantity of interest over time

Usually measured as the inverse of the coefficient of variation (CV)

$CV = \text{Standard Deviation}/\text{Mean}$

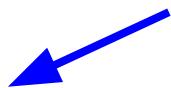
$\text{Stability} = 1/CV = \text{Mean}/\text{Standard Deviation}$

Diversity and Stability

$$\text{Stability} = \frac{\text{Mean Abundance}}{\text{SD Abundance}}$$

Diversity and Stability

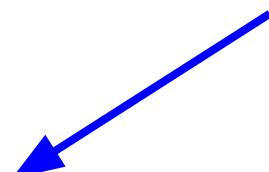
$$\text{Stability} = \frac{\text{Mean Abundance}}{\text{SD Abundance}}$$



More individuals,
more stability

Diversity and Stability

$$\text{Stability} = \frac{\text{Mean Abundance}}{\text{SD Abundance}}$$



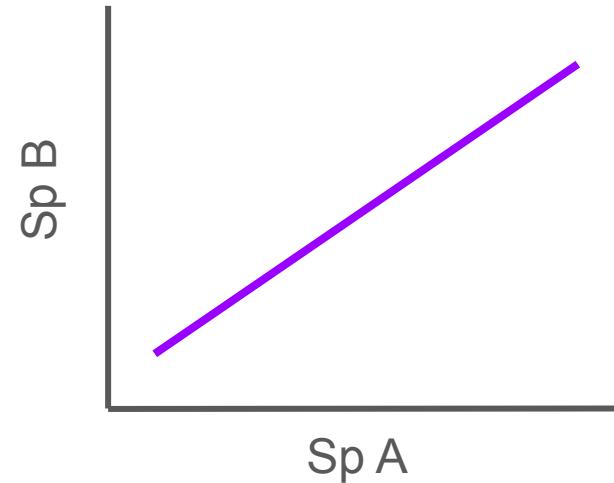
Less variation in abundance,
more stability

Diversity and Stability

$$\text{Stability} = \frac{\text{Mean Abundance}}{\text{SD Abundance}}$$

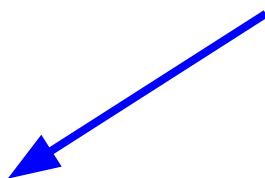
Positive covariance INCREASES SD

Less variation in abundance,
more stability

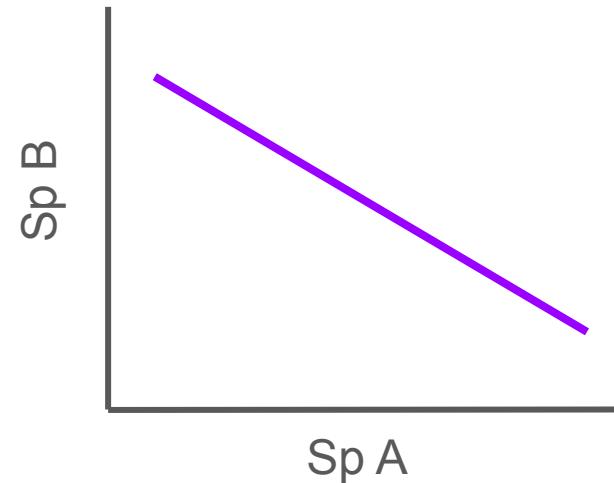


Diversity and Stability

$$\text{Stability} = \frac{\text{Mean Abundance}}{\text{SD Abundance}}$$

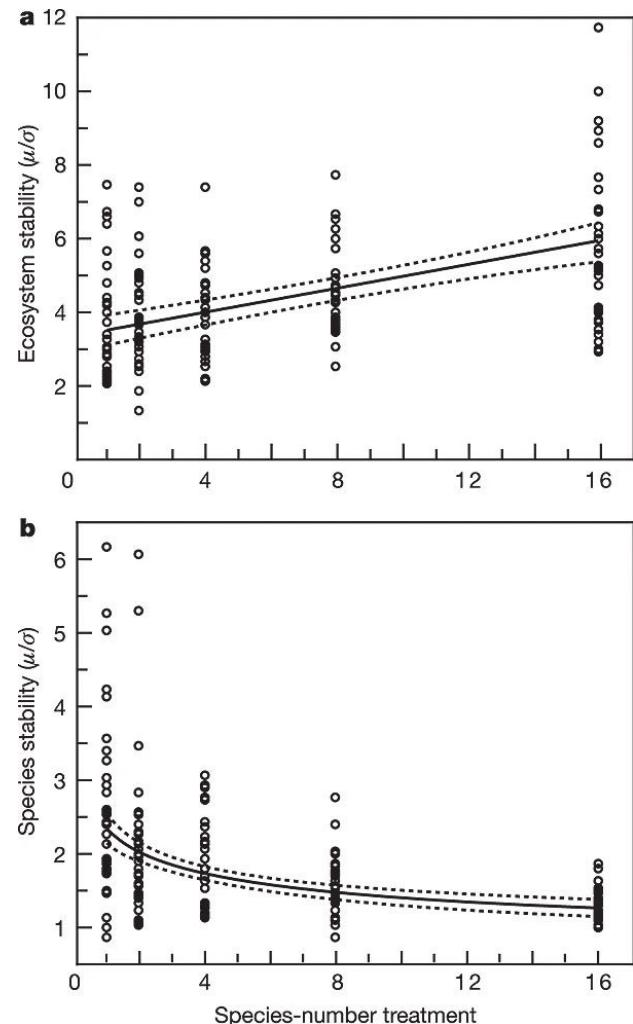


Less variation in abundance,
more stability



Negative covariance DECREASES SD

Diversity and Stability



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Focal ecosystem functions

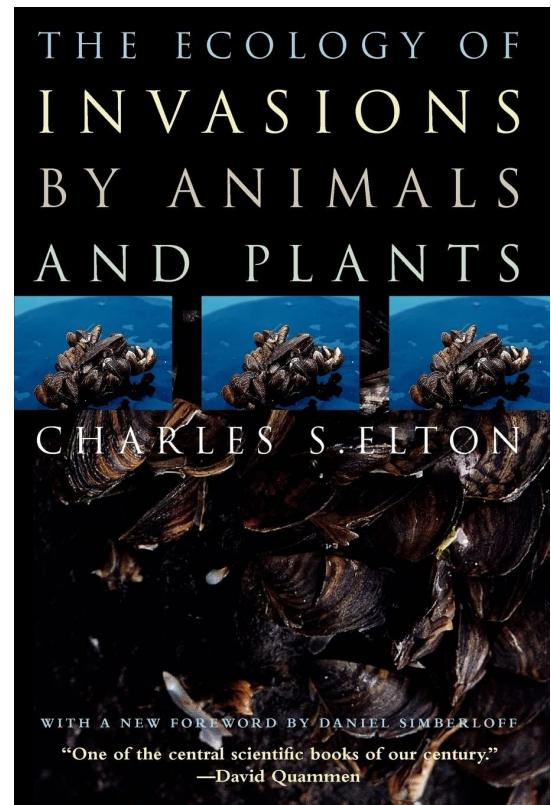
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Diversity and Invasibility

Diversity and Invasibility

- More diverse = more competitors, niche overlap
- Selection effects possible - more diverse communities more likely to contain species that resist invasion



Diversity and Invasibility

nature communications

Article

<https://doi.org/10.1038/s41467-024-48876-z>

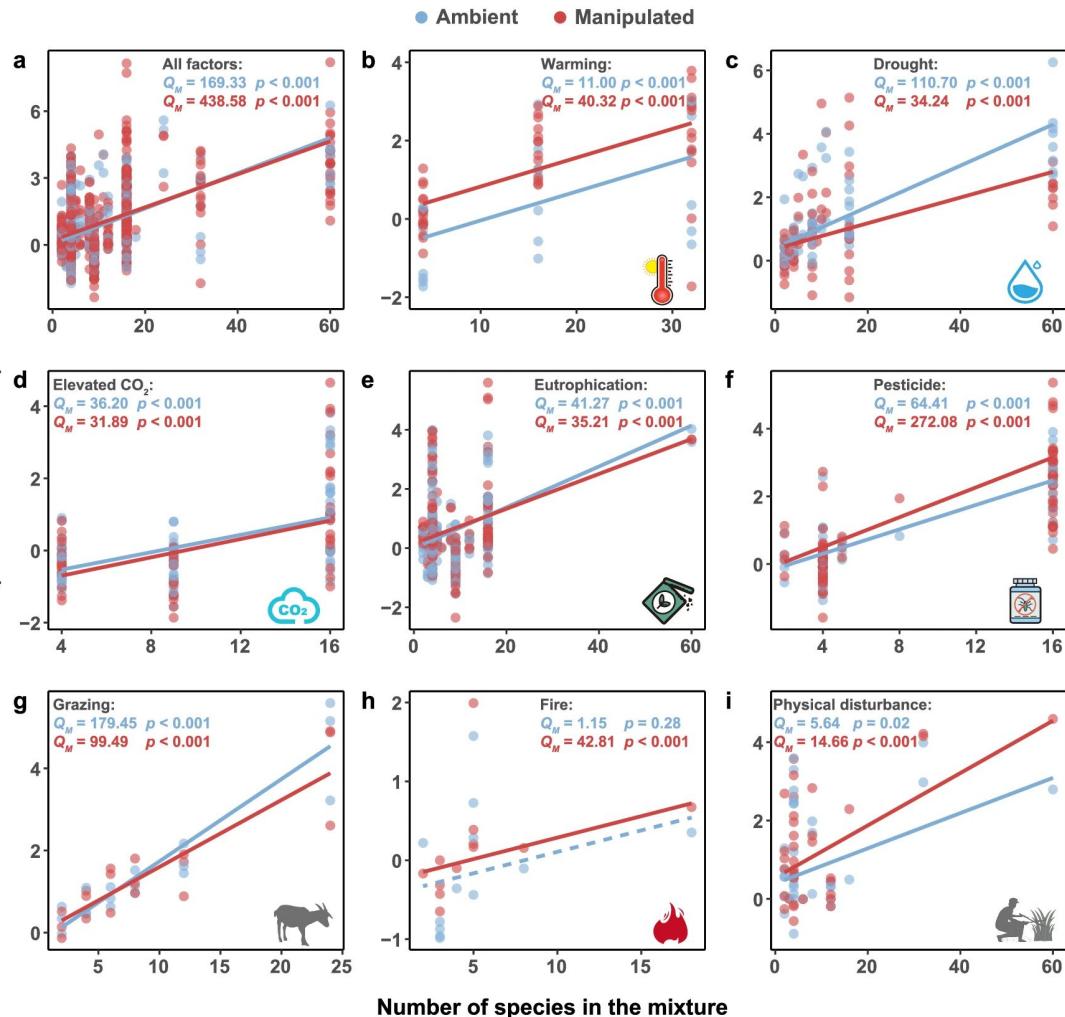
Biodiversity increases resistance of grasslands against plant invasions under multiple environmental changes

Received: 7 January 2024

Cai Cheng  ^{1,2}, Zekang Liu  ², Wei Song ², Xue Chen ², Zhijie Zhang  ³, Bo Li  ⁴, Mark van Kleunen  ^{3,5} & Jihua Wu  ¹

Accepted: 15 May 2024

Meta-analysis of 25 studies



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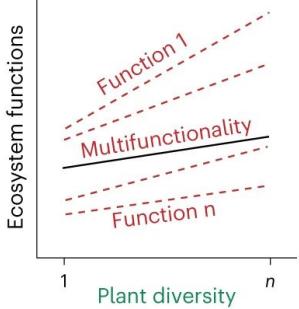
... but ecosystems provide MANY services at once...

Ecosystem Multifunctionality

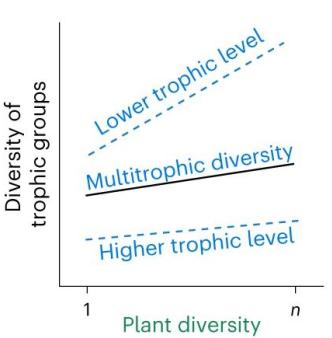
- Provision of multiple functions/services by ecosystems
- Different ways of calculating
 - Standardized averages
 - Number of functions that exceed some threshold value (e.g., 50% of max functioning)

Ecosystem Multifunctionality

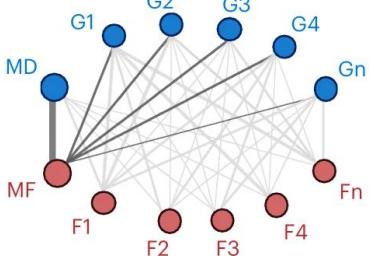
H1-1



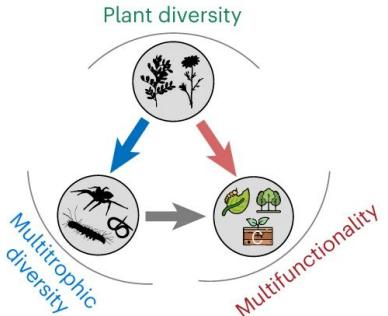
H1-2



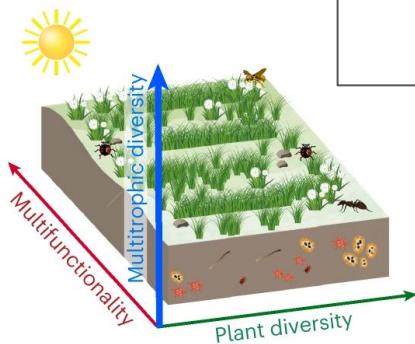
H2



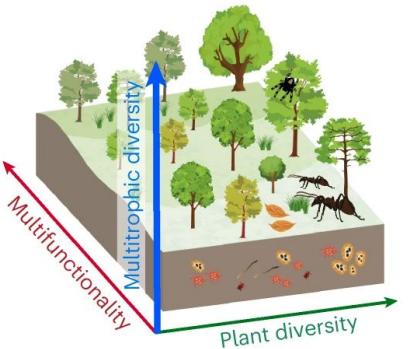
H3



Grassland



Forest



Plant diversity enhances ecosystem multifunctionality via multitrophic diversity

Received: 25 March 2024

Accepted: 24 July 2024

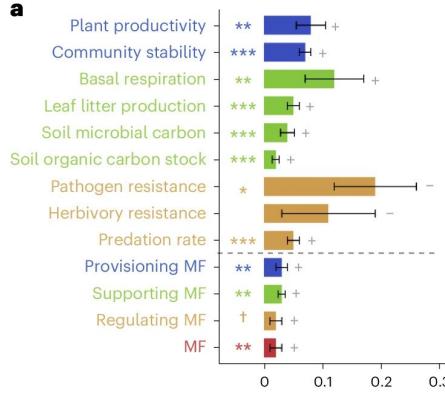
Published online: 29 August 2024

Check for updates

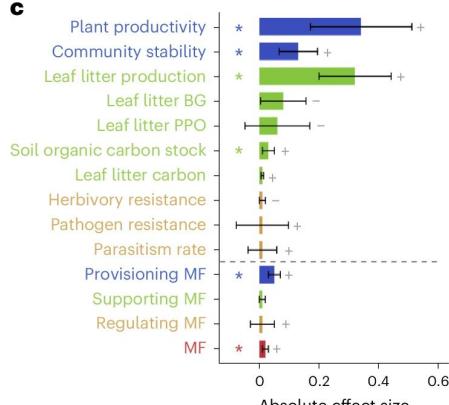
Yi Li^①, Andreas Schulte^②, Anne Ebeling^③, Nico Eisenhauer^{④,5}, Yuanyuan Huang^{④,6}, Georg Albert^⑥, Cynthia Abramt^⑦, Angelos Amynatas^⑧, Michael Bonkowski^⑨, Helge Bräuerheide^{⑩,9}, Maximilian Bräuerheide^⑩, Douglas Chivers^⑩, Jun Chen^{⑪,10}, Yannan Chen^{⑫,11}, Jing-Tianeng Chen^{⑬,11}, Meng Gobanova^{⑭,12}, Xiangling Guo^{⑮,13}, Felix Forstner^{⑯,14}, Gerd Grünauer^⑯, Lianggong He^{⑯,16}, Pengfei Guo^⑯, Anna Heintz-Buschart^⑯, Alexandra-Maria Klein^{⑯,14}, Markus Lange^{⑯,15}, Shan Li^⑯, Qi Li^{⑯,19}, Yingbin Liu^⑯, Arong Luo^⑯, Sebastian T. Meyer^{⑯,20}, Goddert von Ohem^⑯, Gemma Rutten^⑯, Thomas Scholten^{⑯,21}, Marco D. Selbach^⑯, Michael Staub^{⑯,22}, Ming-Qiang Wang^{⑯,23,24}, Neili Zhang^⑯, Chao-Dong Zhu^{⑯,25,26}, Bernhard Schmid^{⑯,27}, Keping Ma^{⑯,1} and Xiaojun Liu^{⑯,11,28}

Ecosystem Multifunctionality - Plant diversity effects

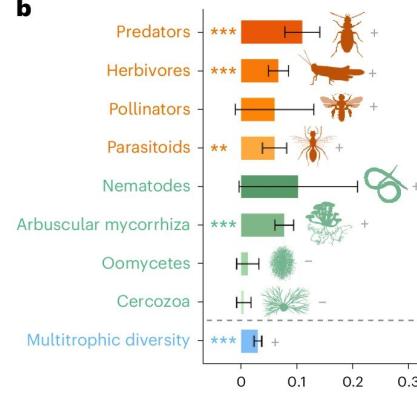
Grassland



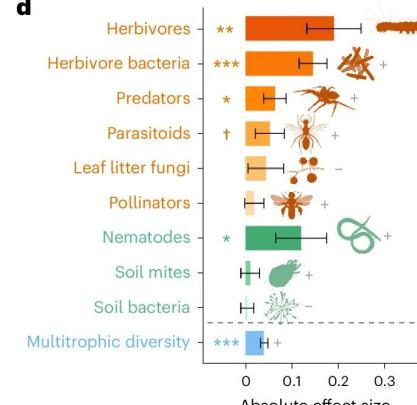
Forest



b



d



nature ecology & evolution

Article

<https://doi.org/10.1038/s41559-024-02517-2>

Plant diversity enhances ecosystem multifunctionality via multitrophic diversity

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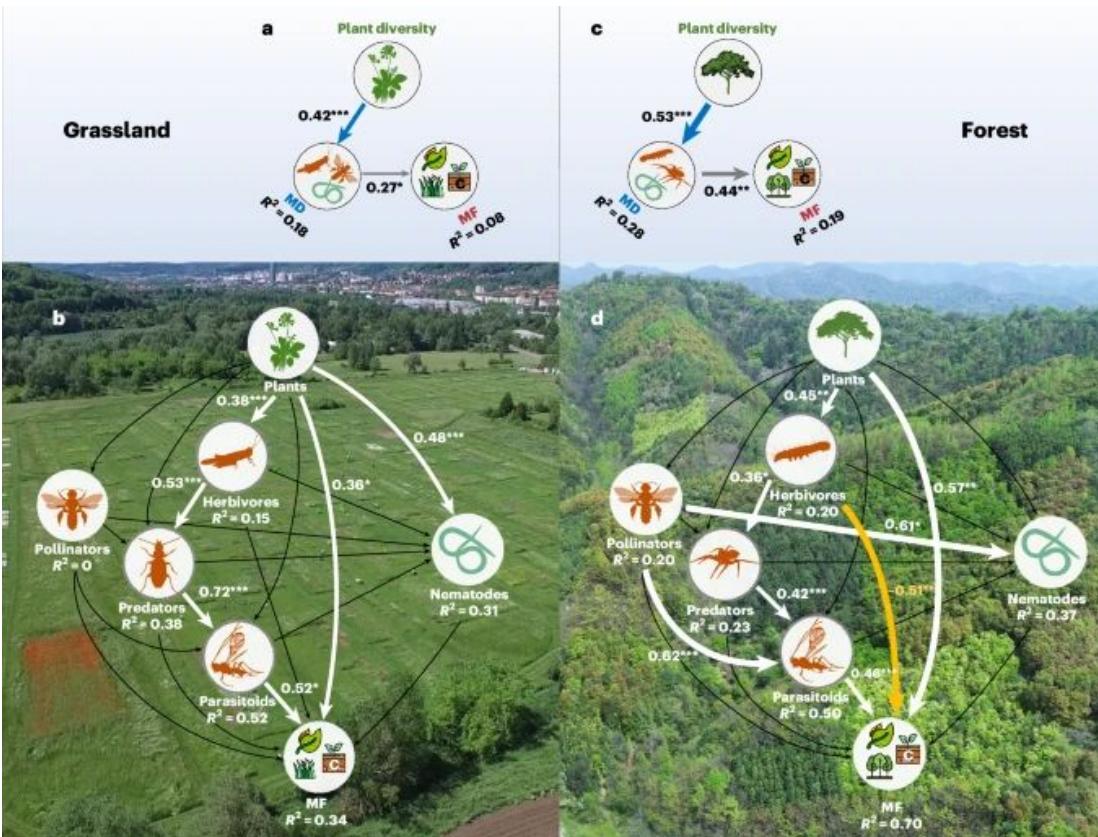
Accepted: 24 July 2024

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Yi Li¹, Andreas Schuldt², Anne Ebeling³, Nico Eisenhauer^{4,5}, Yuanyuan Huang^{4,5}, Georg Albert², Cynthia Albracht⁶, Angelos Amyntas⁷, Michael Bonikowski⁸, Helge Brueheide^{9,8}, Maximilian Bröcher¹⁰, Douglas Chester¹⁰, Jun Chen¹⁰, Yanran Chen^{10,11}, Jing-Ting Chen^{10,12}, Marcel Cobane^{10,12}, Xianglu Deng^{10,12}, Felix Fornoff^{10,14}, Gerd Glixner^{9,10}, Liangdong Guo^{10,14}, Peng Fei Guo¹⁰, Anna Heintz-Buschart¹⁰, Alexandra-Maria Klein^{10,14}, Markus Lange^{10,15}, Shuai Liu¹⁰, Qian Li^{10,14}, Yingjie Liu^{10,14}, Xiong Lu^{10,14}, Sebastian T. Maaß^{10,16}, Gudrun Oehl^{10,14}, Camilla Rumpf^{10,12}, Philipp Schulot^{10,17}, Marcel Solsbach¹⁰, Michael Strub^{10,12}, Ming-Qiang Wan^{10,18}, NaiLi Zhang¹⁰, Chao-Dong Zhu^{10,19}, Bernhard Schmid^{10,20}, Keping Ma¹⁰ & Xiaojuan Liu^{10,12,21}

Ecosystem Multifunctionality - Trophic effects



nature ecology & evolution

<https://doi.org/10.1038/s41559-024-02517-2>

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Next class: More Biodiversity and Ecosystem Functioning!