Biodiversity and Ecosystem Functioning

Today's Agenda:

- Quiz
- BEF: Unanswered Questions

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

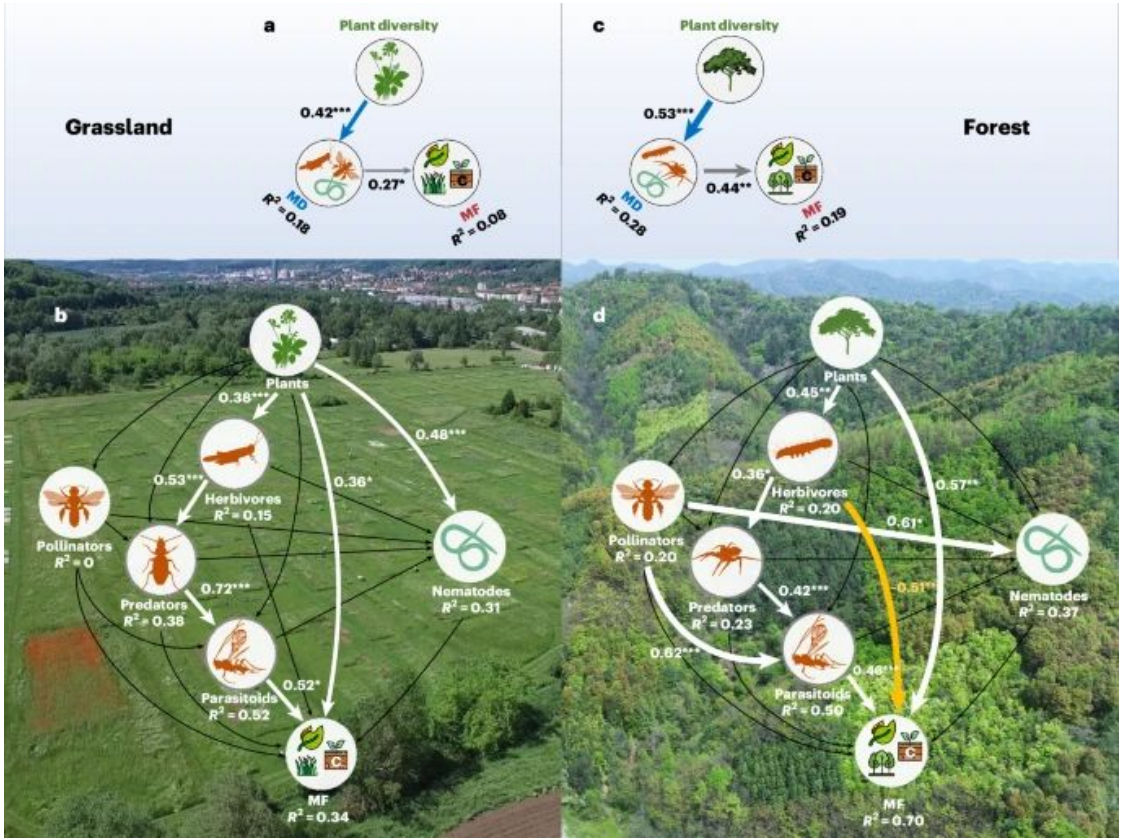
- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Effects across trophic levels

Most BEF experiments only manipulate plant diversity

- While many monitor diversity of other groups, they don’t often manipulate it

Effects across trophic levels



nature ecology & evolution

Article

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

Plant diversity enhances ecosystem multifunctionality via multitrophic diversity

Received: 25 March 2024

Accepted: 24 July 2024

Published online: 29 August 2024

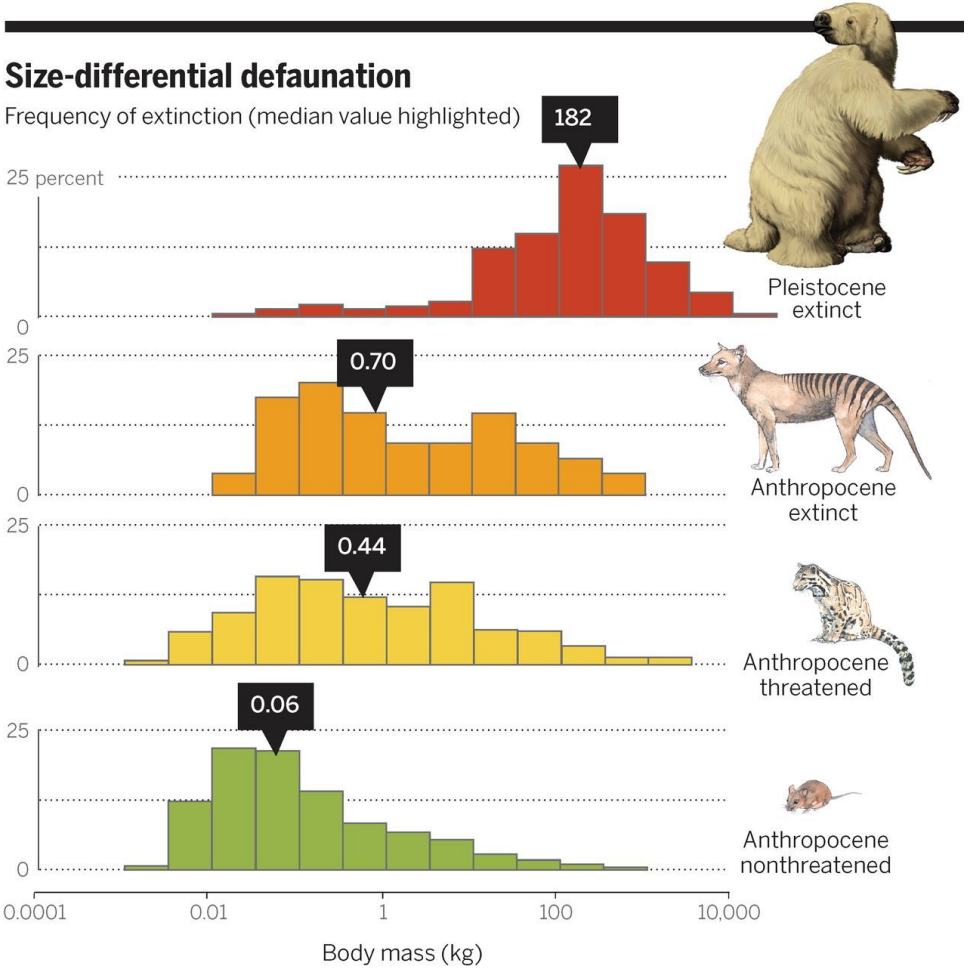
Check for updates

Yi Li[1], Andreas Schuldt[2,3], Anne Ebeling[3], Nico Eisenhauer[4,5], Yuanyuan Huang[6,7], Georg Albert[2,3], Cynthia Albracht[8], Angelos Amyntas[4,7], Michael Bonkowski[8], Helge Bruelheide[4,9], Maximilian Bröcher[2,3], Douglas Chesters[10], Jun Chen[10], Yannan Chen[10,11], Jing-Ting Chen[10,11], Marcel Ciobanu[12], Xianglu Deng[1,13], Felix Fornoff[14], Gerd Gleixner[15], Liangdong Guo[11,16], Peng-Fei Guo[17], Anna Heintz-Buschart[6], Alexandra-Maria Klein[14,18], Markus Lange[15], Shan Li[1], Qi Li[19], Yingbin Li[19], Arong Luo[10], Sebastian T. Meyer[20], Goddert von Oheimb[21], Gemma Rutten[22], Thomas Scholten[23], Marcel D. Solbach[8], Michael Staab[24], Ming-Qiang Wang[10,25], Naili Zhang[26], Chao-Dong Zhu[10,11], Bernhard Schmid[27], Keping Ma[1] & Xiaojuan Liu[1,13,28]

This paper we discussed yesterday is a step in the right direction!

Why is it important?

We're losing trophic complexity
E.g., top predators, large herbivores



REVIEW

Defaunation in the Anthropocene

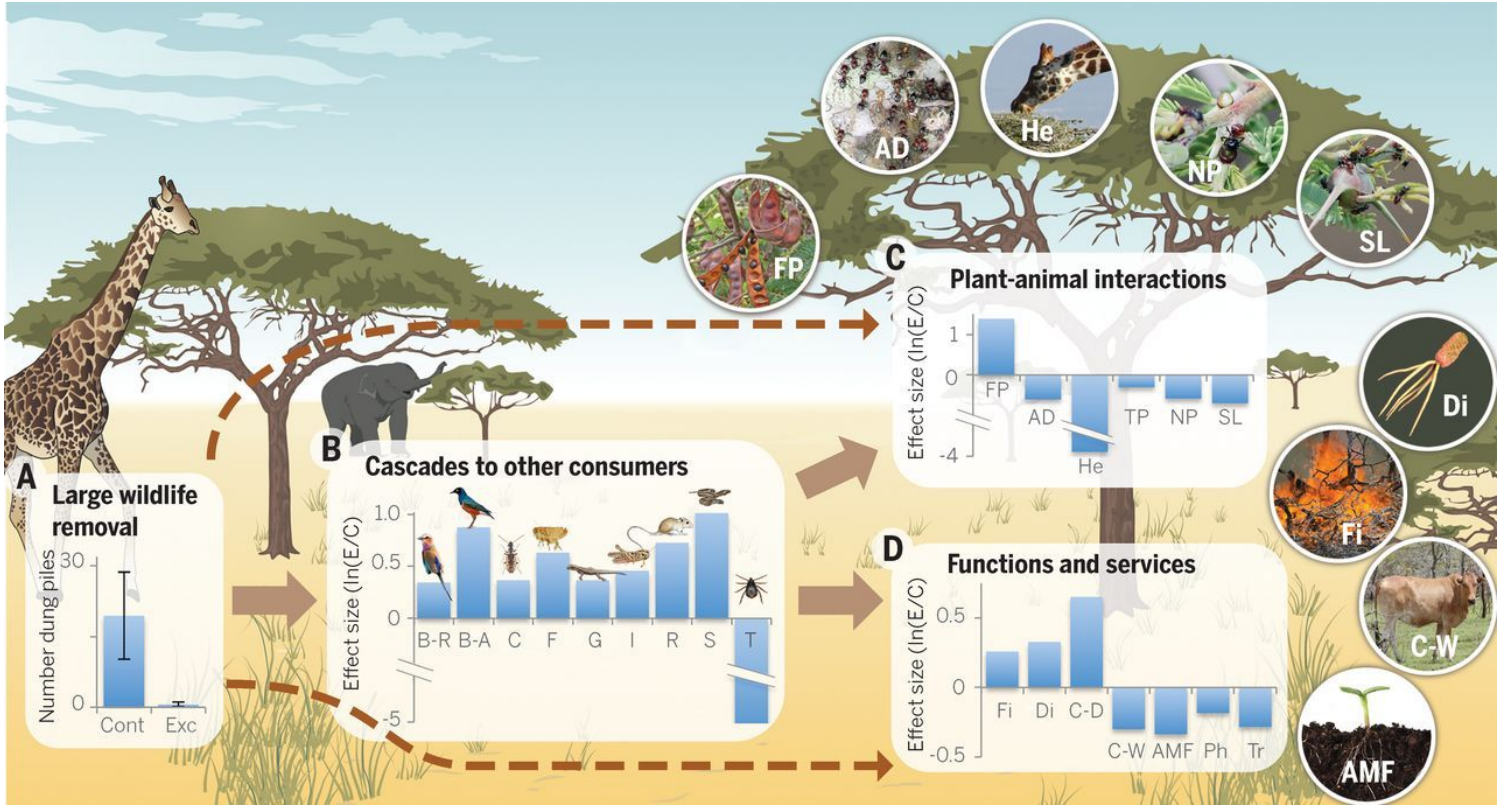
Rodolfo Dirzo,[1]* Hillary S. Young,[2] Mauro Galetti,[3] Gerardo Ceballos,[4] Nick J. B. Isaac,[5] Ben Collen[6]

Why is it important?

REVIEW

Defaunation in the Anthropocene

Rodolfo Dirzo,[1]* Hillary S. Young,[2] Mauro Galetti,[3] Gerardo Ceballos,[4] Nick J. B. Isaac,[5] Ben Collen[6]



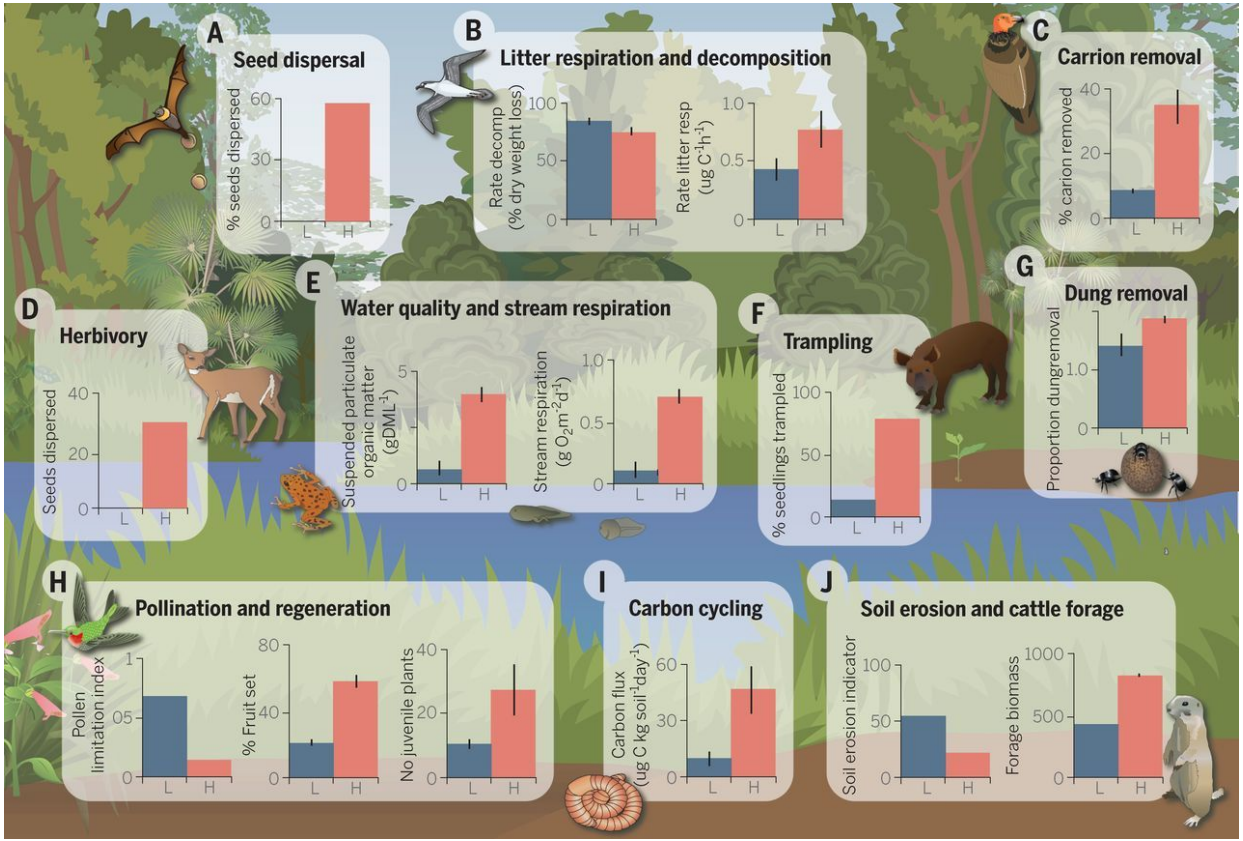
Removing large wildlife can have large impacts!

Why is it important?

REVIEW

Defaunation in the Anthropocene

Rodolfo Dirzo,[1]* Hillary S. Young,[2] Mauro Galetti,[3] Gerardo Ceballos,[4] Nick J. B. Isaac,[5] Ben Collen[6]



Removing consumers in general can also have impacts, even the smaller consumers!

Effects across trophic levels

- We know the higher trophic levels matter for functioning
- Unclear how *diversity* in higher trophic levels impacts things
- Also unclear how diversity interacts across trophic levels
    - (e.g., do herbivore diversity effects depend on plant diversity?)

Effects across trophic levels

- We know the higher trophic levels matter for functioning
- Unclear how *diversity* in higher trophic levels impacts things
- Also unclear how diversity interacts across trophic levels
    - (e.g., do herbivore diversity effects depend on plant diversity?)

- Algal or microbial systems in the lab are probably a good place to test!

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Species loss vs introduction

Most BEF experiments focus on assembling species

- Individuals of selected species are added to an unoccupied environment

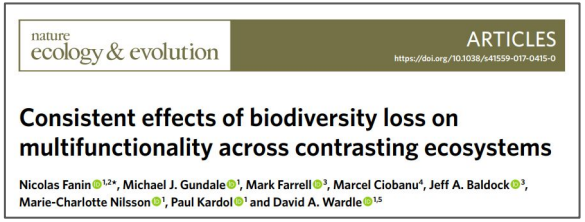
Species loss vs introduction

Most BEF experiments focus on assembling species

Individuals of selected species are added to an unoccupied environment

Adding species to an empty area == removing species from an occupied area?

Testing BEF with removal



Island experiment in Sweden

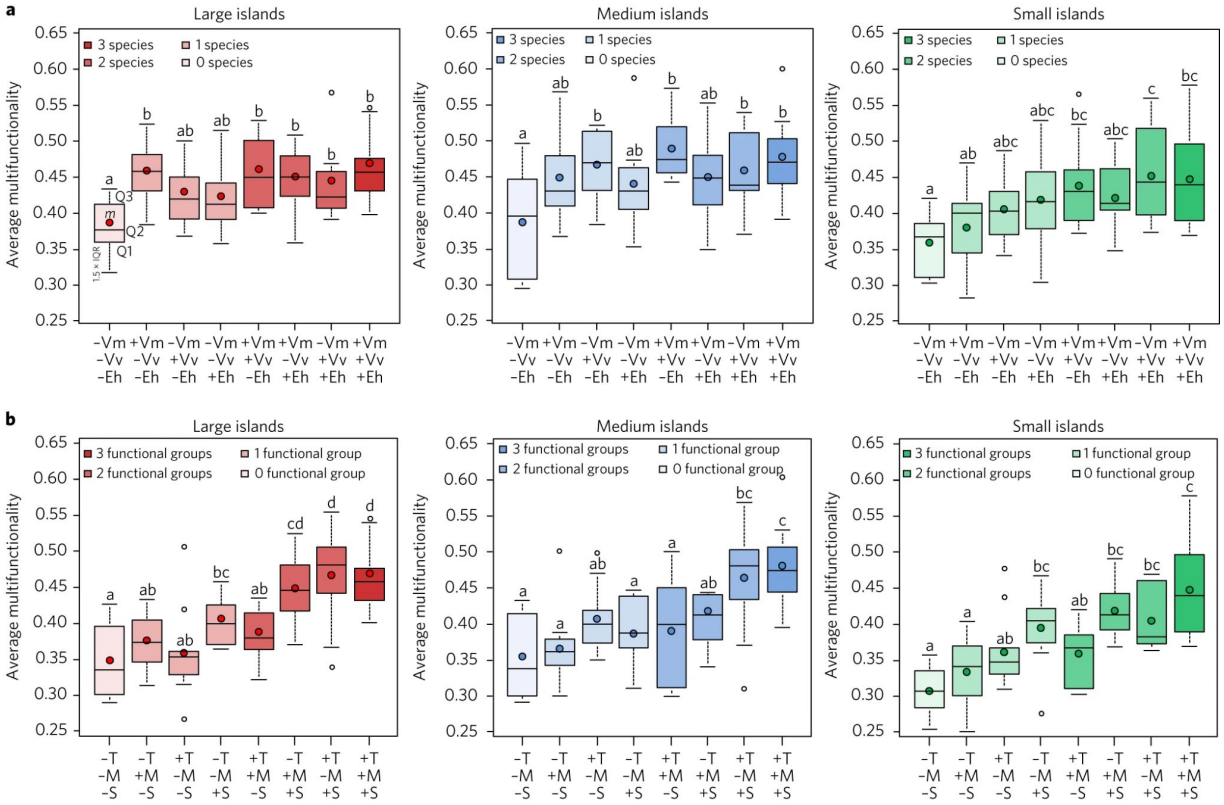
- 30 islands, 14 plots each (n = 420 total)
- Removed 0 to 3 functional groups (tree, shrub, moss)
- Removed 0 to 3 species of shrub
- Measured 15 ecosystem functions

Testing BEF with removal

nature ecology & evolution
ARTICLES
https://doi.org/10.1038/s41559-017-0415-0

Consistent effects of biodiversity loss on multifunctionality across contrasting ecosystems

Nicolas Fanin[1,2*], Michael J. Gundale[1], Mark Farrell[3], Marcel Ciobanu[4], Jeff A. Baldock[3], Marie-Charlotte Nilsson[1], Paul Kardol[1] and David A. Wardle[1,5]



BEF and removal

Need for experiments that use both addition and removal

- Relatively fast systems probably most amenable (e.g. algae)
- Some experiments suggest that order of arrival matters

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

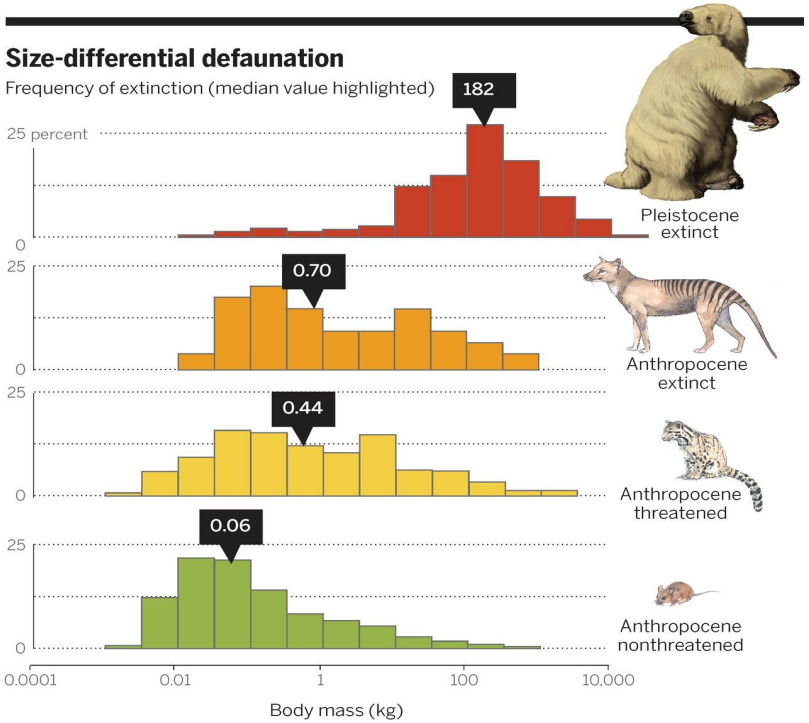
- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Extinction is global, functions are local

Strong evidence that humans are causing lots of extinctions

Extinction is global, functions are local

Strong evidence that humans are causing lots of extinctions



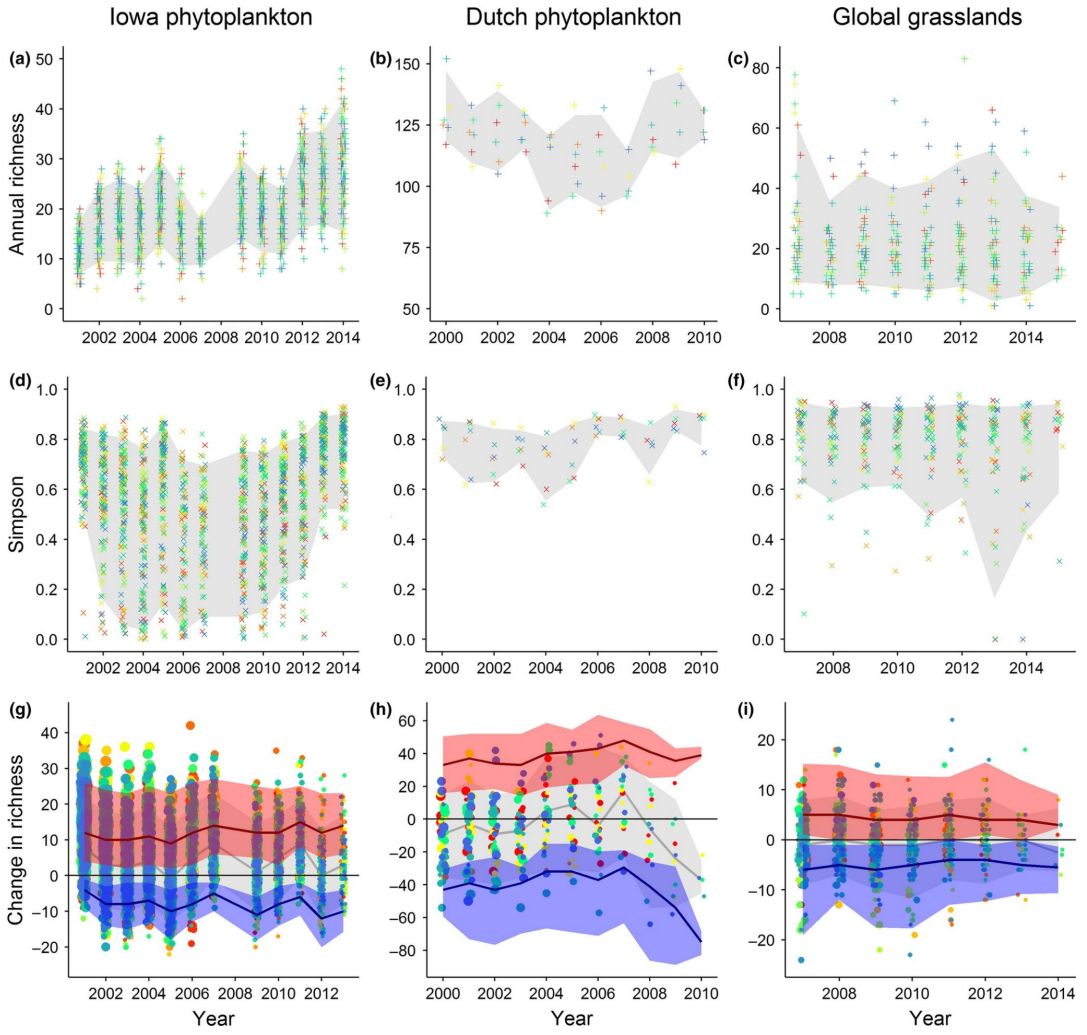
REVIEW

Defaunation in the Anthropocene

Rodolfo Dirzo,[1]* Hillary S. Young,[2] Mauro Galetti,[3] Gerardo Ceballos,[4] Nick J. B. Isaac,[5] Ben Collen[6]

Net local change

But species introductions can balance out local extirpations



Received: 15 March 2017 | Accepted: 13 June 2017
DOI: 10.1111/1365-2664.12959

RESEARCH ARTICLE*

Journal of Applied Ecology

Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring

Helmut Hillebrand[1,2] | Bernd Blasius[2,3] | Elizabeth T. Borer[4] | Jonathan M. Chase[5,6] | John A. Downing[7] | Britas Klemens Eriksson[8] | Christopher T. Filstrup[7] | W. Stanley Harpole[5,9,10] | Dorothee Hodapp[1] | Stefano Larsen[5] | Aleksandra M. Lewandowska[1] | Eric W. Seabloom[4] | Dedmer B. Van de Waal[11] | Alexey B. Ryabov[3]

Net local change

But species introductions can balance out local extirpations

$$SER_r = \frac{S_{imm} + S_{ext}}{S_{tot}}$$

$$SER_a = \frac{\sum_i (p_i - p_i')^2}{\sum p_i^2 + \sum p_i'^2 - \sum p_i p_i'}$$

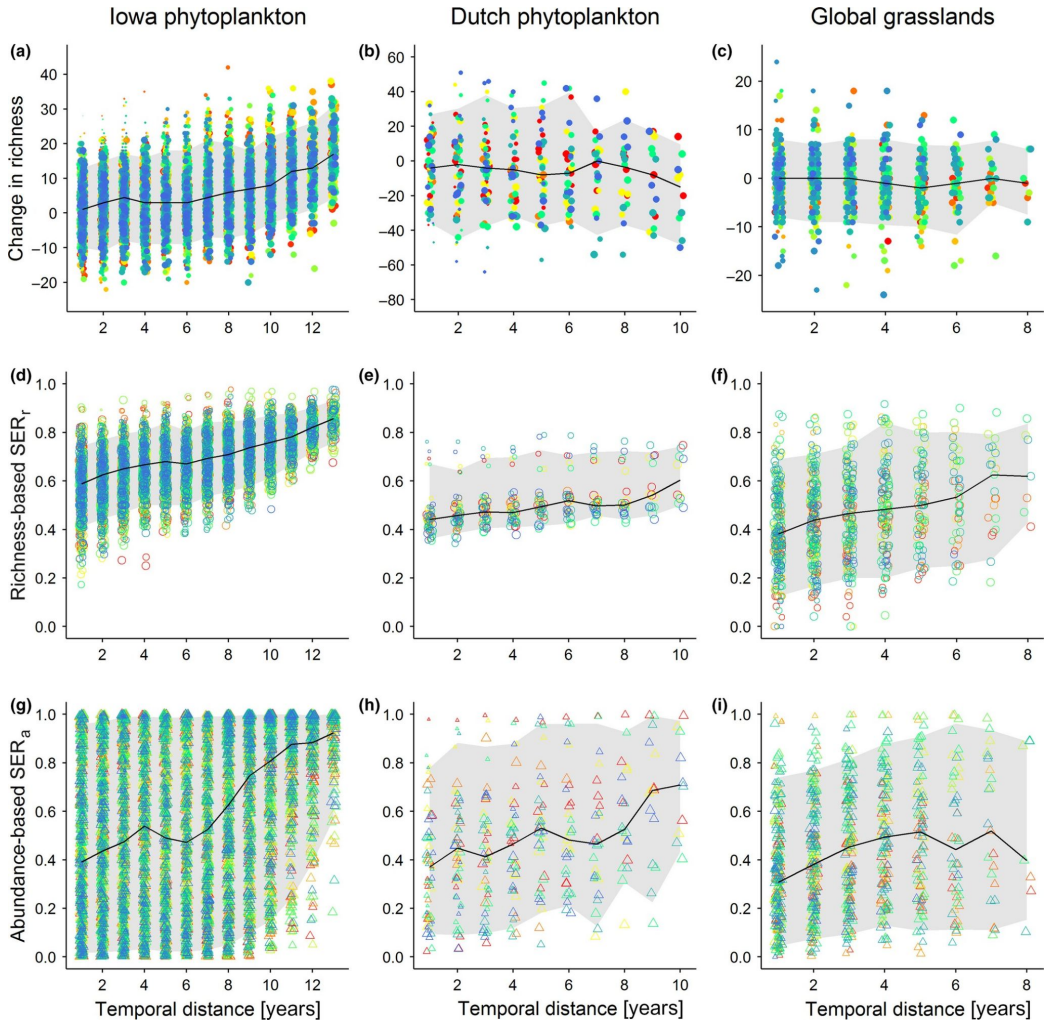
Received: 15 March 2017 | Accepted: 13 June 2017
DOI: 10.1111/1365-2664.12959

RESEARCH ARTICLE*

Journal of Applied Ecology

Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring

Helmut Hillebrand[1,2] | Bernd Blasius[2,3] | Elizabeth T. Borer[4] | Jonathan M. Chase[5,6] | John A. Downing[7] | Britas Klemens Eriksson[8] | Christopher T. Filstrup[7] | W. Stanley Harpole[5,9,10] | Dorothee Hodapp[1] | Stefano Larsen[5] | Aleksandra M. Lewandowska[1] | Eric W. Seabloom[4] | Dedmer B. Van de Waal[11] | Alexey B. Ryabov[3]



Need to go beyond species richness

Species richness only gets us so far

- Richness can stay constant despite major changes in species
- Moving to a trait-based approach may help



vs



Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

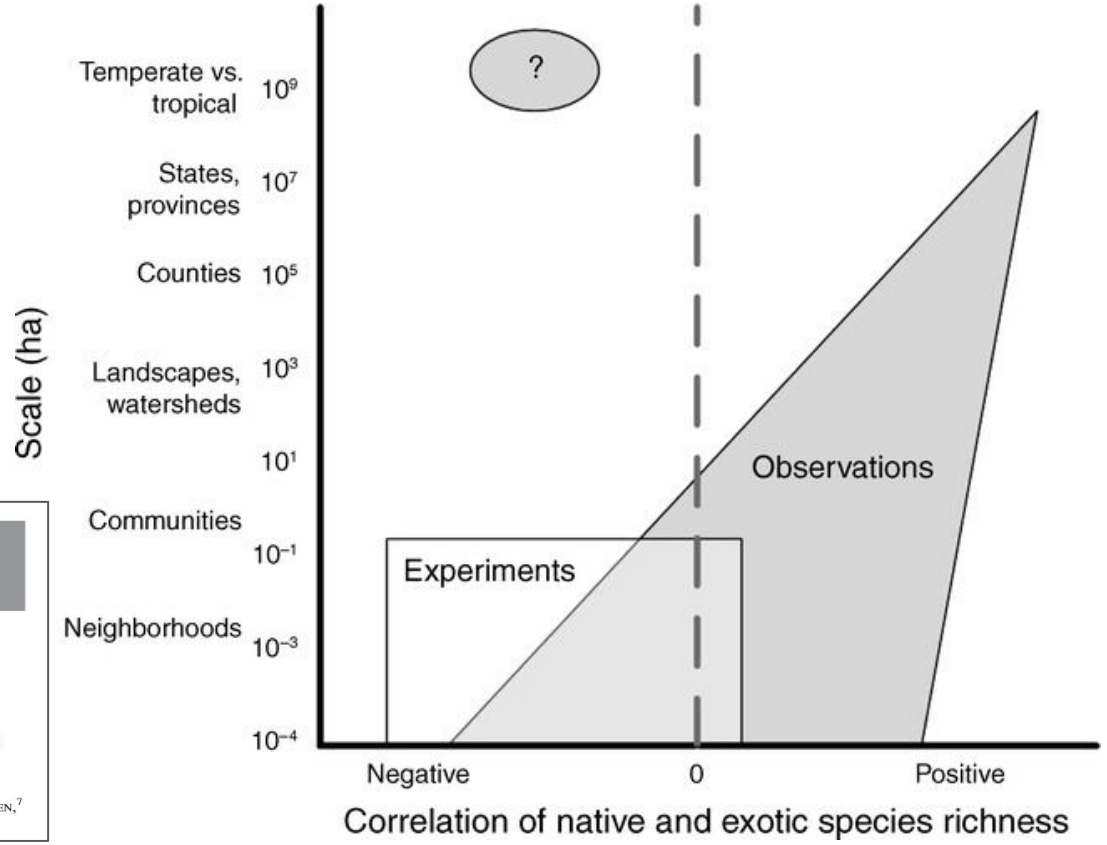
The Invasion Paradox

CONCEPTS & SYNTHESIS
EMPHASIZING NEW IDEAS TO STIMULATE RESEARCH IN ECOLOGY

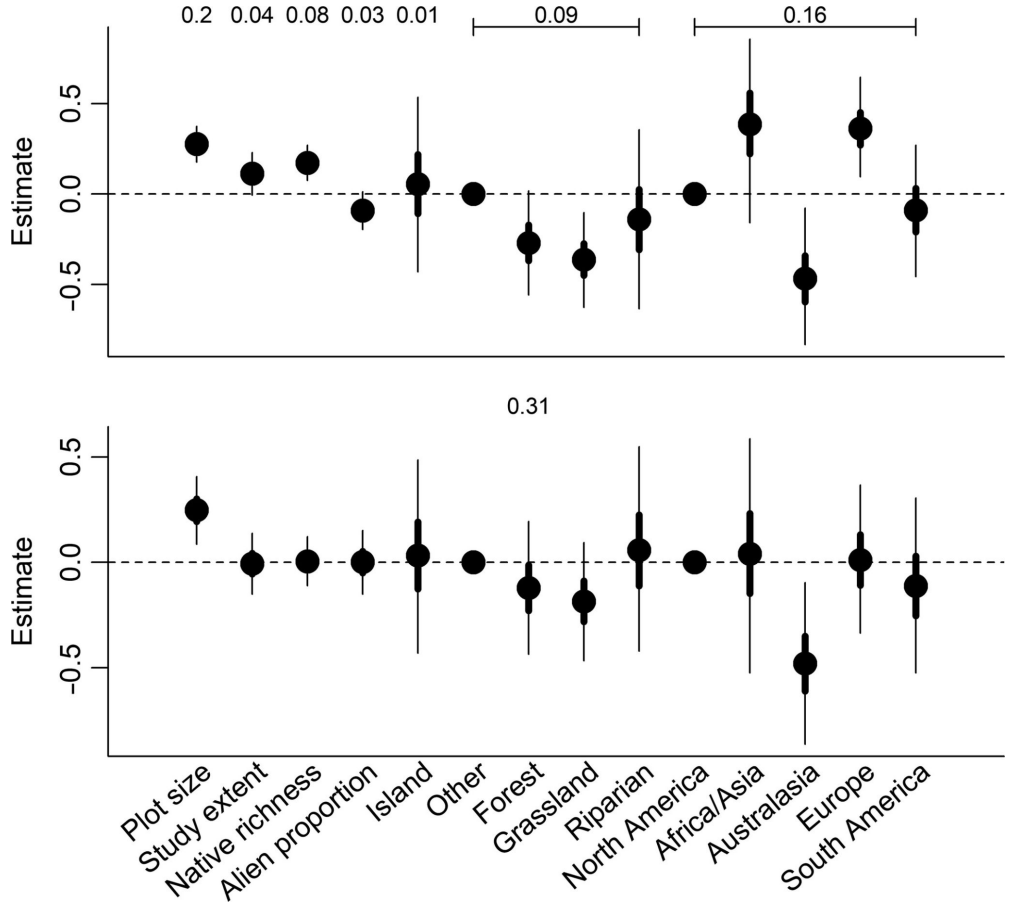
Ecology, 88(1), 2007, pp. 3–17

THE INVASION PARADOX: RECONCILING PATTERN AND PROCESS IN SPECIES INVASIONS

J. D. Fridley,[1,10] J. J. Stachowicz,[2] S. Naeem,[3] D. F. Sax,[4] E. W. Seabloom,[5] M. D. Smith,[6] T. J. Stohlgren,[7] D. Tilman,[8] and B. Von Holle[9]



The Invasion Paradox



ECOLOGY LETTERS

Ecology Letters, (2019) **22**: 1038–1046 doi: 10.1111/ele.13261

REVIEW AND SYNTHESIS

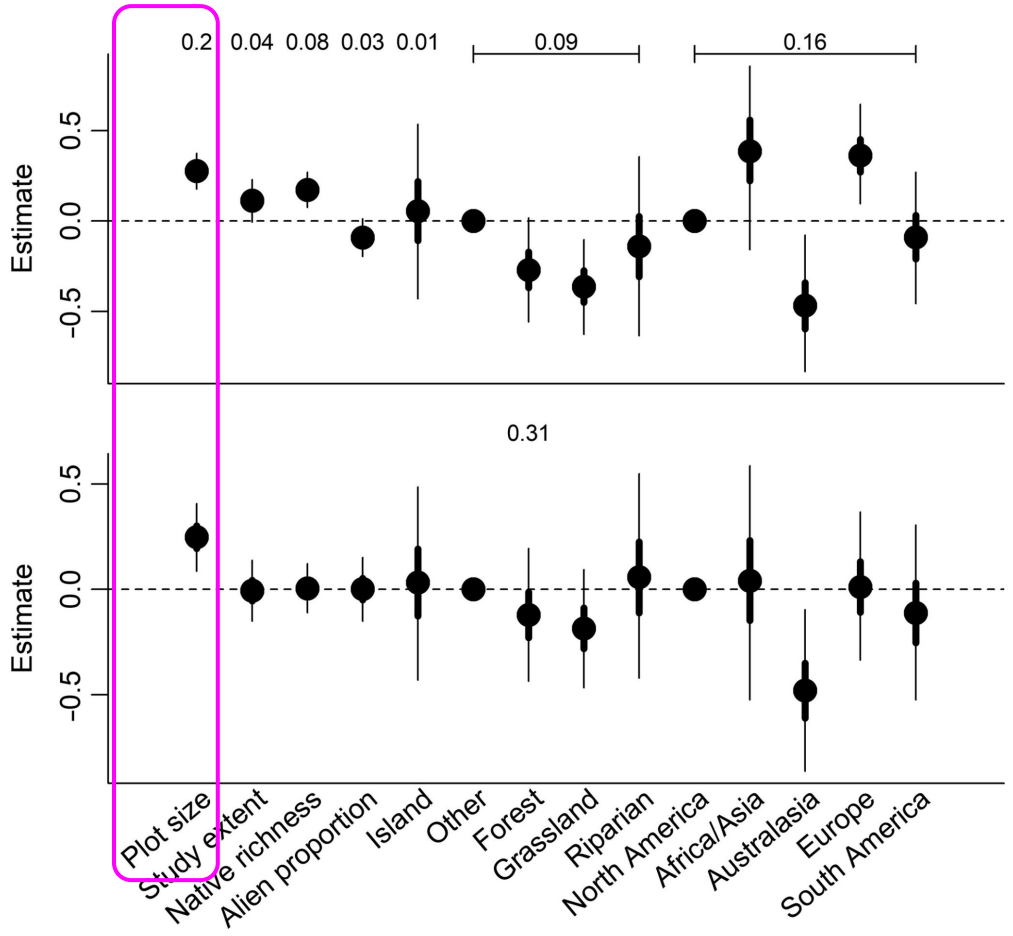
Resolving the invasion paradox: pervasive scale and study dependence in the native-alien species richness relationship

Federico Tomasetto,[1]* Richard P. Duncan[2,3] and Philip E. Hulme[2]

Abstract

The degree to which plant communities are vulnerable to invasion by alien species has often been assessed using the relationship between native and alien plant species richness (NAR). Variation in the direction and strength of the NAR tends to be negative for small plot sizes and study

The Invasion Paradox



ECOLOGY LETTERS

Ecology Letters, (2019) **22**: 1038–1046 doi: 10.1111/ele.13261

REVIEW AND SYNTHESIS

Resolving the invasion paradox: pervasive scale and study dependence in the native-alien species richness relationship

Federico Tomasetto,[1]* Richard P. Duncan[2,3] and Philip E. Hulme[2]

Abstract

The degree to which plant communities are vulnerable to invasion by alien species has often been assessed using the relationship between native and alien plant species richness (NAR). Variation in the direction and strength of the NAR tends to be negative for small plot sizes and study

The Invasion Paradox

Why?

- Same factors that drive native species richness drive introduced species richness?

- Experiments often relatively homogeneous, as opposed to more natural systems

- More work needs to be done

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

BEF in natural systems

- Much of what we know is from experimental systems
- How important are these effects in natural systems?

BEF in natural systems

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499
1220

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany

				Observed relationships			
						Non-experimental studies	
Category of function	Ecosystem function	Ecosystem type	Focal group	Theory	Experiments	N	
Biomass	Tree biomass stock	Temperate forests	Trees	↗ a,b,c	↗ m	38	↗
	Tree biomass production	Temperate forests	Trees	↗ a,b,c		61	↗
	Tree biomass stock	Tropical forests	Trees	↗ a,b,c	↗ m	44	→
	Tree biomass production	Tropical forests	Trees	↗ a,b,c		17	→
	Plant biomass*	Grasslands	Plants	↗ a,b,c	↗ n	102	↗
	Plant biomass*	Aquatic systems	Plants	↗ a,b,c	↗ n	21	↗
	Consumer biomass	All	Consumers	↗ a,b,c		24	↗
Decomposition	Decomposition	All	Plants	↘ d	↗ o	33	↗
	Decomposition	All	Decomposers	↗ d	↗ p	20	→
Soil carbon storage	Soil organic carbon stock	All	Plants		↗ o	35	→
Biomass stability	Plant biomass stability	All	Plants	↗ e,f,g	↗ q,r	27	↗
	Consumer biomass stability	All	Consumers	↗ e,f,g		13	↗
Pathogen / herbivore damage	Overall pathogen damage	All	Hosts		↘ o	17	→
	Damage by specialist pathogen	All	Hosts	↘ h		18	↘
	Herbivore damage	All	Plants	↘ h,i	↘ o	45	→
	Herbivore damage	All	Herbivores	↗ j,k		10	→
	Herbivore damage	All	Predators	↘ k	→ o	11	→
Pollination	Fruit or seed set	All	Plants			8	→
	Fruit or seed set	All	Pollinators	↗ l		36	↗
Ecosystem multi-functionality	Ecosystem multifunctionality	All	All		↗ s	111	↗
	Ecosystem multifunctionality	Temperate forests**	All			16	↗
	Ecosystem multifunctionality	Tropical forests**	All			17	→
	Ecosystem multifunctionality	Grasslands**	All			55	→

*In grasslands and aquatic systems, distinguishing between biomass stocks and production is challenging, hence I pooled biomass stock and production BEF relationships in grasslands.
**These analyses rely on a subset of the data (and are therefore not independent) of the analysis on ecosystem multifunctionality across all ecosystem types.

BEF in natural systems

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany

				Observed relationships		
						Non-experimental studies
Category of function	Ecosystem function	Ecosystem type	Focal group	Theory	Experiments	N
Biomass	Tree biomass stock	Temperate forests	Trees	↗ a,b,c	↗ m	38
	Tree biomass production	Temperate forests	Trees	↗ a,b,c		61
	Tree biomass stock	Tropical forests	Trees	↗ a,b,c	↗ m	44
	Tree biomass production	Tropical forests	Trees	↗ a,b,c		17
	Plant biomass*	Grasslands	Plants	↗ a,b,c	↗ n	102
	Plant biomass*	Aquatic systems	Plants	↗ a,b,c	↗ n	21
	Consumer biomass	All	Consumers	↗ a,b,c		24
Decomposition	Decomposition	All	Plants	↘ d	↗ o	33
	Decomposition	All	Decomposers	↗ d	↗ p	20
Soil carbon storage	Soil organic carbon stock	All	Plants		↗ o	35
Biomass stability	Plant biomass stability	All	Plants	↗ e,f,g	↗ q,r	27
	Consumer biomass stability	All	Consumers	↗ e,f,g		13
Pathogen / herbivore damage	Overall pathogen damage	All	Hosts		↘ o	17
	Damage by specialist pathogen	All	Hosts	↘ h		18
	Herbivore damage	All	Plants	↘ h,i	↘ o	45
	Herbivore damage	All	Herbivores	↗ j,k		10
	Herbivore damage	All	Predators	↘ k	→ o	11
Pollination	Fruit or seed set	All	Plants			8
	Fruit or seed set	All	Pollinators	↗ l		36
Ecosystem multi-functionality	Ecosystem multifunctionality	All	All		↗ s	111
	Ecosystem multifunctionality	Temperate forests**	All			16
	Ecosystem multifunctionality	Tropical forests**	All			17
	Ecosystem multifunctionality	Grasslands**	All			55

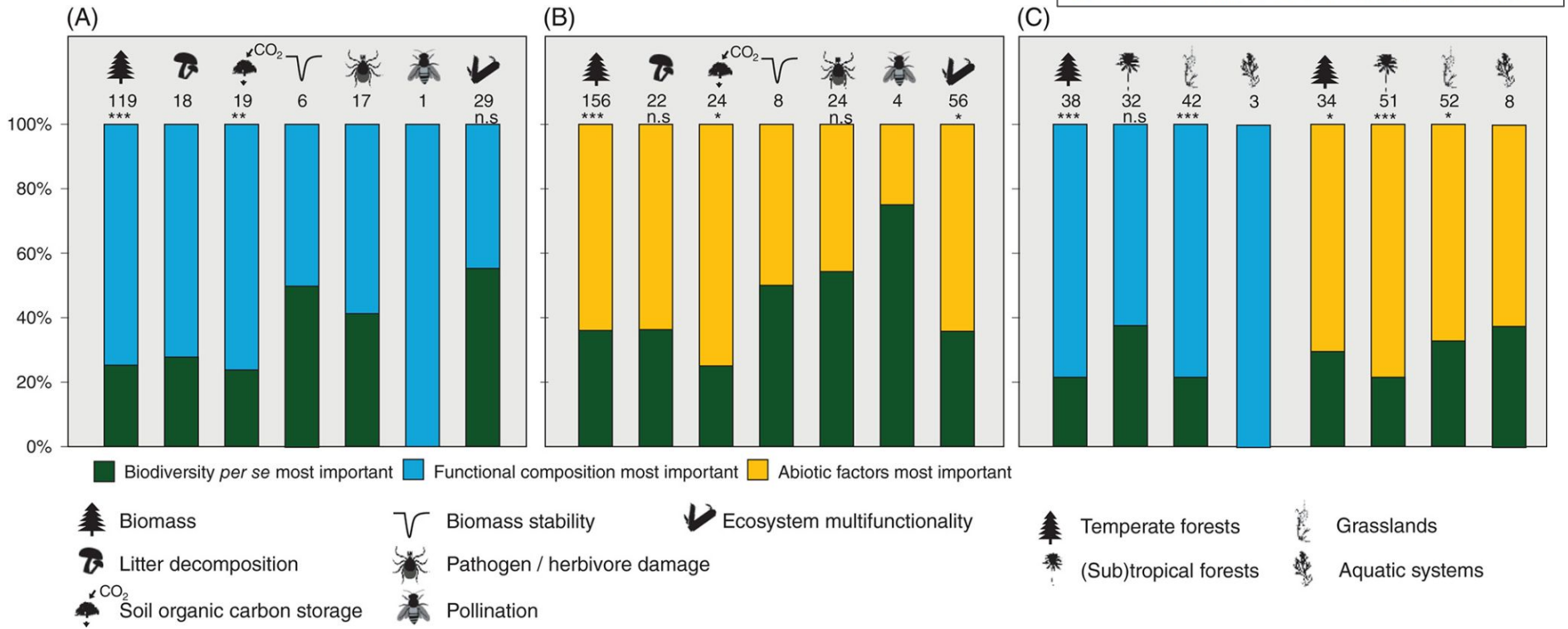
*In grasslands and aquatic systems, distinguishing between biomass stocks and production is challenging, hence I pooled biomass stock and production BEF relationships in grasslands.
**These analyses rely on a subset of the data (and are therefore not independent) of the analysis on ecosystem multifunctionality across all ecosystem types.

BEF in natural systems

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499
1220

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany



BEF in natural vs experimental systems

- Some relationships seems consistent, others differ
- Richness isn’t usually the main factor - functional composition matters more

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

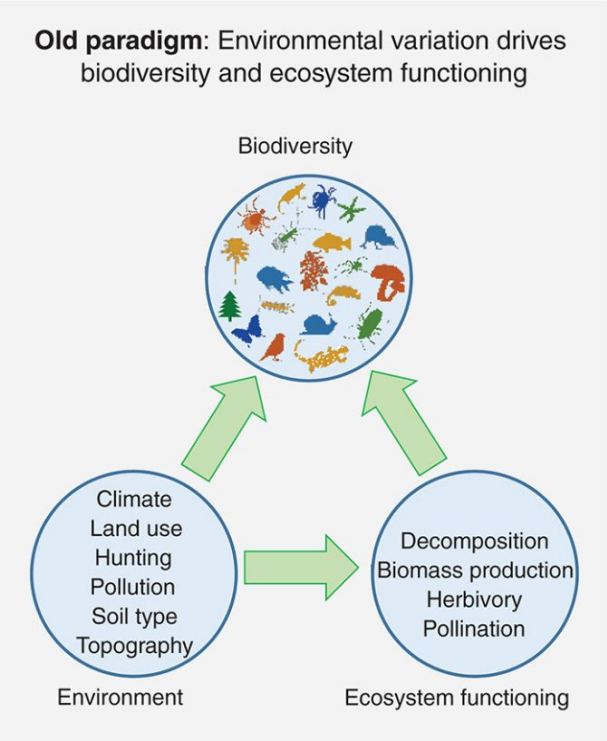
BEF: It's complicated

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany

(A)



BEF: It's complicated

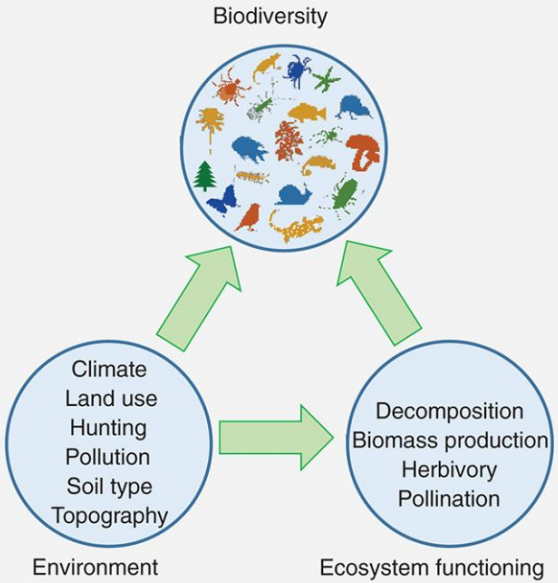
BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499
1220

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany

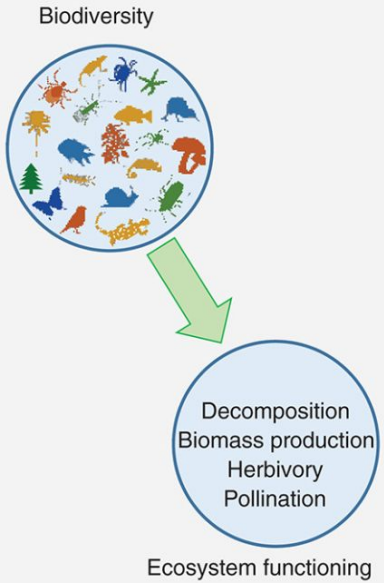
(A)

Old paradigm: Environmental variation drives biodiversity and ecosystem functioning



(B)

Focus of early BEF work: isolating the effects of biodiversity on ecosystem functioning

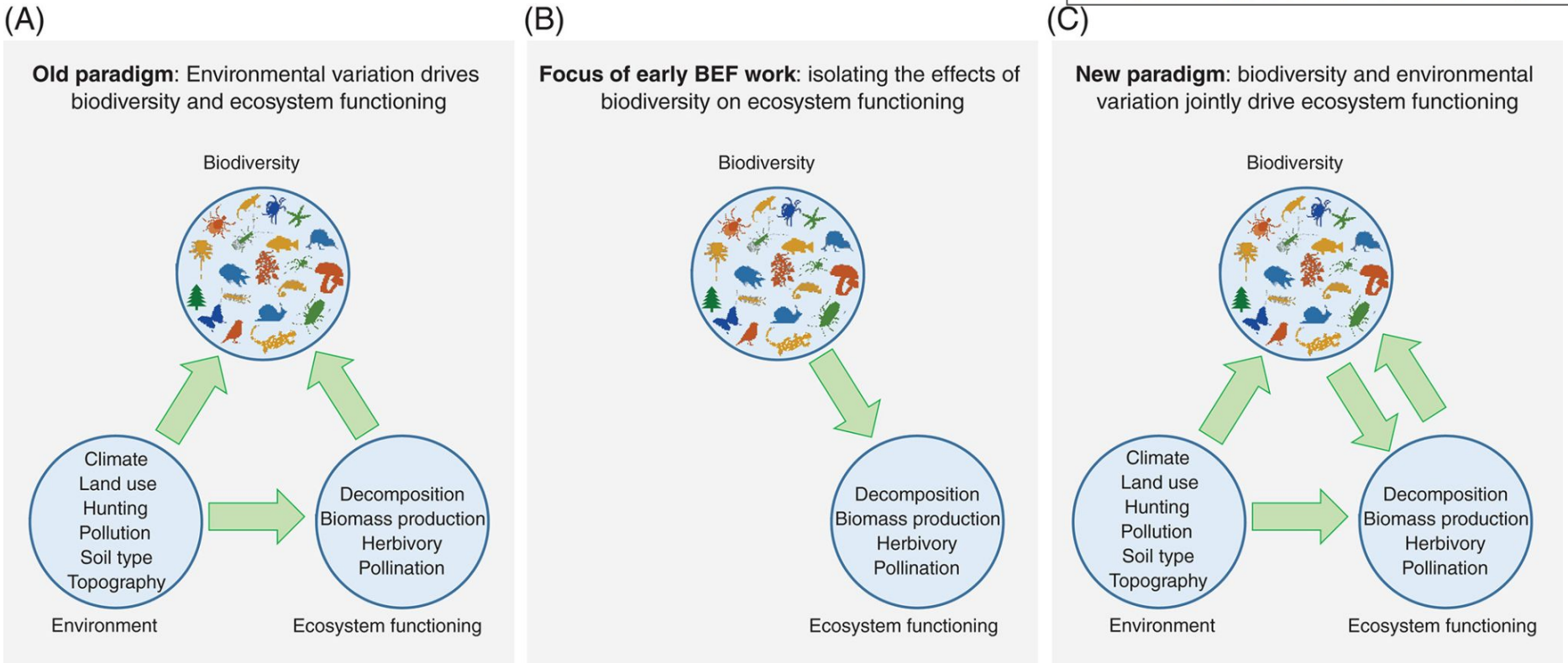


BEF: It's complicated

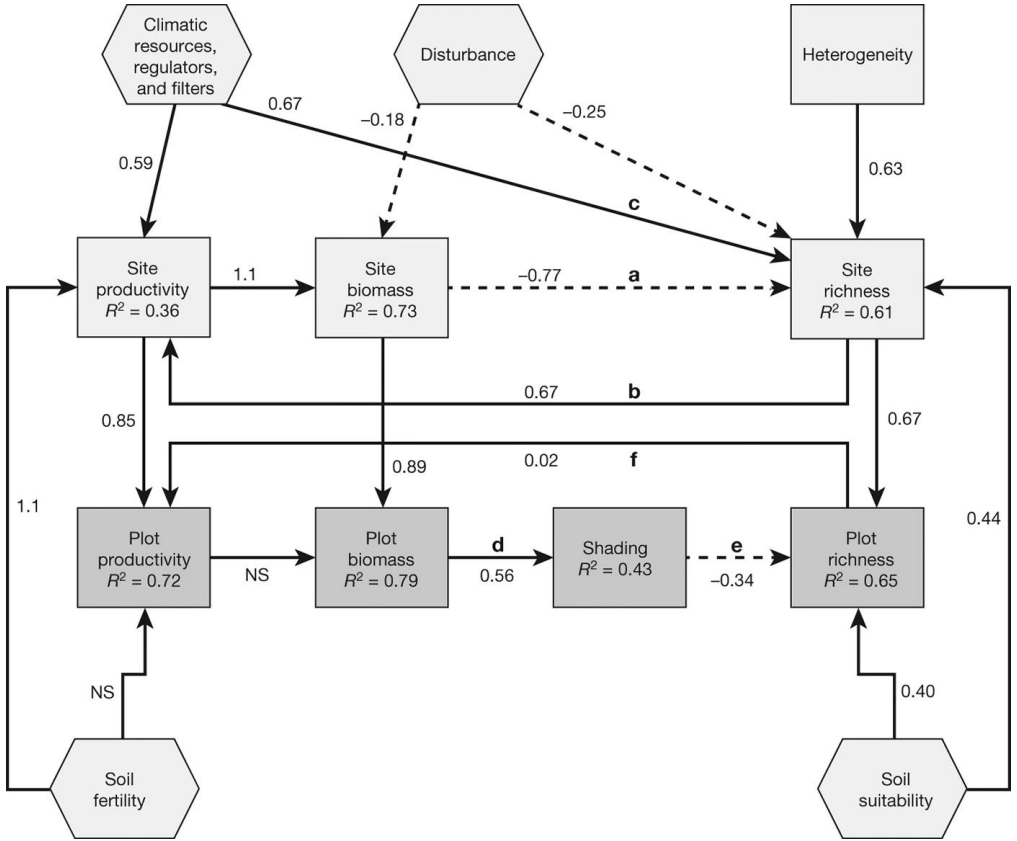
BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2019), **94**, pp. 1220–1245.
doi: 10.1111/brv.12499
1220

Biodiversity and ecosystem functioning in naturally assembled communities

Fons van der Plas*
Systematic Botany and Functional Biodiversity, Institute of Biology, Leipzig University, Johannisallee 21-23, 04103 Leipzig, Germany



BEF: It's complicated



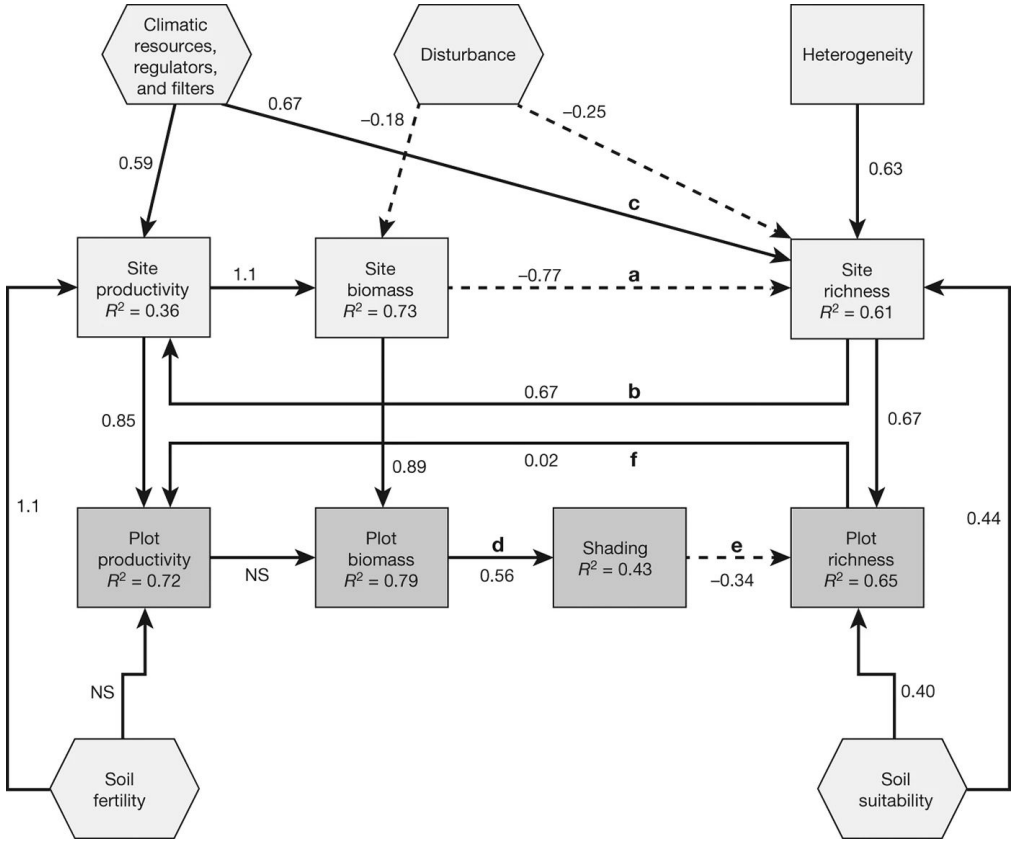
LETTER

doi:10.1038/nature16524

Integrative modelling reveals mechanisms linking productivity and plant species richness

James B. Grace[1], T. Michael Anderson[2], Eric W. Seabloom[3], Elizabeth T. Borer[3], Peter B. Adler[4], W. Stanley Harpole[5,6,7], Yann Hautier[8], Helmut Hillebrand[9], Eric M. Lind[3], Meelis Pärtel[10], Jonathan D. Bakker[11], Yvonne M. Buckley[12], Michael J. Crawley[13], Ellen I. Damschen[14], Kendi F. Davies[15], Philip A. Fay[16], Jennifer Firn[17], Daniel S. Gruner[18], Andy Hector[19], Johannes M. H. Knops[20], Andrew S. MacDougall[21], Brett A. Melbourne[15], John W. Morgan[22], John L. Orrock[14], Suzanne M. Prober[23] & Melinda D. Smith[24]

BEF: It's complicated



LETTER

doi:10.1038/nature16524

Integrative modelling reveals mechanisms linking productivity and plant species richness

James B. Grace[1], T. Michael Anderson[2], Eric W. Seabloom[3], Elizabeth T. Borer[3], Peter B. Adler[4], W. Stanley Harpole[5,6,7], Yann Hautier[8], Helmut Hillebrand[9], Eric M. Lind[3], Meelis Pärtel[10], Jonathan D. Bakker[11], Yvonne M. Buckley[12], Michael J. Crawley[13], Ellen I. Damschen[14], Kendi F. Davies[15], Philip A. Fay[16], Jennifer Firn[17], Daniel S. Gruner[18], Andy Hector[19], Johannes M. H. Knops[20], Andrew S. MacDougall[21], Brett A. Melbourne[15], John W. Morgan[22], John L. Orrock[14], Suzanne M. Prober[23] & Melinda D. Smith[24]

Complicated relationships might also explain differences between experiments and nature!

Or variation among systems!

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Unanswered Questions in BEF

Your book highlight some important areas where work is still needed:

- Effects across multiple trophic levels
- Species loss vs introduction
- Extinction is global, functions are local
- The invasion paradox
- The importance of diversity in natural systems
- Complicated relationship between diversity and productivity

Next class: Density Dependence!