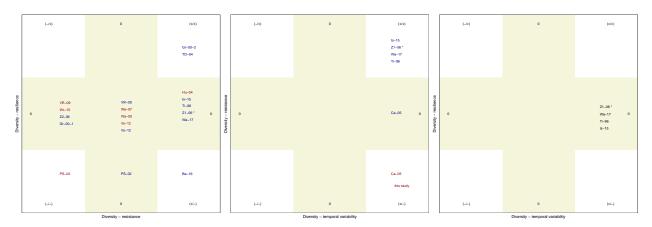
Reproducible report II for 'Biodiversity increases and decreases ecosystem stability'

Analysis of covariation in diversity-stability relationships $Frank\ Pennekamp$ $July\ 5,\ 2018$

Review of relevant literature

Based on the review by Donohue et al. (2016) we obtained a set of studies of resilience, resistance, and temporal variability of ecosystem functions in response to direct or indirect experimental manipulations of diversity. Direct manipulations were defined as changing diversity by adding different sets of species to an experimental plot, jar, or other unit, whereas indirect manipulations induced variation in diversity via the experimental treatment, such as fertilization. We only included studies that performed experimental manipulations. To analyse whether specific mechanisms lead to covariation, we noted the type of mechanism proposed for each of the individual diversity-stability components. Furthermore, we assessed whether a quantitative or verbal argument was provided (or the mechanisms were not addressed at all).

Visual summary of diversity-stability relationships



Positive, negative and neutral relationships among resistance, resilience and temporal variability in empirical studies with diversity manipulation. Detailed information about individual studies (e.g. code VR-09) is provided in extended data table 3 & 4. Beige regions indicate no covariation. Relative positions within regions are arbitrary and do not indicate relative strengths of relationships. Different colours indicate the effect of diversity on absolute (red) and relative resistance (blue). We restricted our analysis to the most commonly used stability components: temporal stability, resistance and resilience.

Table with all studies used in the analysis

Code	Description	Abbreviated reference
Ba-16	Diversity manipulation of diatoms, analysing resistance and	Baert et al (2016)
	resilience to perturbation (chemical stressor, atrazine) of biomass	Ecology, 97, 3433
	production.	
Ca-05	Diversity manipulation of grassland plants (Portuguese BIODEPTH	Caldeira et al (2005)
	site) analysing temporal variability and resistance to natural	Oikos, 110, 115
	perturbation (frost and low precipitation) of biomass production.	
Gr-00-1	Diversity manipulation by fumigation of soil microorganisms,	Griffiths et al (2000)
	analysing resilience to perturbation (heating) and resistance to	Oikos, 2, 279
	perturbation (heating or chemical stress, CuSO4) of respiration.	
Gr-00-2	Diversity manipulation by fumigation of soil microorganisms,	Griffiths et al (2000)
	analysing resilience to perturbation (heating) and resistance to	Oikos, 2, 279
	perturbation (heating or chemical stress, CuSO4) of respiration.	
Hu-04	Analysis of diverse studies of marine ecosystems, some of which	Hughes & Stachwicz
	examined diversity-resistance and some diversity-resilience	(2004), PNAS, 101, 24
	relationships for various ecosystem functions.	
Is-15	Forty-six diversity manipulations of grassland plants analysing	Isbell et al (2015)
	temporal variability, resistance, and resilience to natural	Nature, 526, 574
	perturbations (drought and wet events) of biomass production.	
PS-02	Diversity manipulation of grassland plants (Swiss BIODEPTH site)	Pfister & Schmid
	analysing resistance and resilience of biomass production to	(2002) Nature, 416, 84
	experimental drought perturbation.	
TD-94	Diversity manipulation by fertilisation of plants, analysing	Timan & Downing
	resistance and resilience of biomass production to natural	(1994) Nature, 367,
	perturbation (drought).	363
Ti-96	Diversity manipulation of grassland plants via fertilisation. Analysis	Tilman (1996)
	of temporal variability, resilience and resistance of biomass	Ecology, 77, 350
	production to natural drought perturbation.	
Vo-12	Diversity manipulation of grassland plants. Analysis of resistance	Vogel et al (2012)
	and resilience of biomass production to drought perturbation.	PLoS One, 7, e36992
VR-09	Diversity manipulation of plants, analysing resistance and resilience	Van Ruijven &
	to natural perturbation (drought) of biomass production.	Berendse (2009)
		Journal of Ecology, 98,
*** **		81
Wa-00	Diversity manipulation of plants, analysing resistance and resilience	Wardle et al (2000)
	to experimental perturbation (drought) of various ecosystem	Oikos, 98, 11
***	functions.	
Wa-17	Diversity manipulation of grassland plants. Analysis of temporal	Waag et al (2017)
	variability and resilience of biomass production to drought	Ecology, DOI:
TT7 0=	perturbation.	10.1002/ecy.2003
We-07	Manipulation of soil microbial diversity by serial dilution. Analysis	Wertz et al (2007)
	of resistance and resilience of denitrification and nitrite oxidisation	Environmental
***	to a temperature perturbation.	Microbiology, 9, 2211
Wr-15	Diversity manipulation of grassland plants. Analysis of temporal	Wright et al (2015)
	variability and resilience of biomass production to drought	Nature
	perturbation.	Communications, 6,
Z1-06 *	Diversity manipulation of unicellular alone analysing terms and	7hang & 7hang (2006)
∠1-00 "	Diversity manipulation of unicellular algae analysing temporal	Zhang & Zhang (2006)
	variability and resistance to experimental cold perturbation of	Oikos, 114, 385
Z2-06	biomass production.	Thong & Thong (2006)
22-00	Diversity manipulation of unicellular algae analysing resistance and	Zhang & Zhang (2006)
	resilience of biomass production to experimental cold perturbation.	Oikos, 112, 218

Breakdown of results

How many individual diversity-stability relationships of each type?

direction	Freq
negative	8
neutral	19
positive	15

How many reported relationships are accomanpanied by which type of evidence of mechanism?

type of evidence	Freq
missing	14
signals of mechanisms	16
verbal	12

How often do we find covariation?

stability comp 1	stability comp 2	Freq
negative	negative	1
neutral	negative	1
positive	negative	1
negative	neutral	4
neutral	neutral	5
positive	neutral	5
negative	positive	1
neutral	positive	5
positive	positive	6

How many studies have quantitative analysis of mechanisms?

type of evidence 1	type of evidence 2	Freq
missing	missing	6
signals of mechanisms	missing	4
verbal	missing	3
missing	signals of mechanisms	2
signals of mechanisms	signals of mechanisms	6
verbal	signals of mechanisms	2
missing	verbal	0
signals of mechanisms	verbal	0
verbal	verbal	6

Summary of reported mechanisms

There were 29 bivariate diversity-stability relationships (not including our own, hence a total of 30 is referred to in the main text). Some studies occur multiple times, as they report both absolute and relative resistance values. Of the 29 pairs of stability components, about half were accompanied by quantitative analyses of diversity-stability relationships. Mechanisms included selection / composition effects, high / low response diversity, abundance evenness, insurance effect, synchrony / asynchrony, statistical averaging, and trade-offs in response diversity among stressors.

List of studies with positive covariation

Code	diversity_stability_relation	direction	mechanism1	mechanism2	evidence1	evidence2
Gr-00-2	resistance/resilience	positive/positive	insurance	insurance	verbal	verbal
			effect	effect		
Is-15	resistance/temporal_var	positive/positive	not stated	not stated	missing	missing
PS-02	resistance/resilience	negative/negative	high	species	signals of	signals of
			response	composi-	mecha-	mecha-
			diversity;	tion	nisms	nisms
			evenness			
TD-94	resistance/resilience	positive/positive	high	not stated	verbal	missing
			response			
			diversity			
Ti-96	resistance/temporal_var	positive/positive	high	high	verbal	signals of
			response	response		mecha-
			diversity	diversity;		nisms
				competi-		
				tion		
Wa-17	resistance/temporal_var	positive/positive	insurance	insurance	verbal	verbal
			effect	effect		
Z1-06 *	resistance/temporal_var	positive/positive	high	statistical	verbal	signals of
			response	averaging		mecha-
			diversity			nisms

List of studies with negative covariation

Code	diversity_stability_relation	direction	mechanism1	mechanism2	evidence1	evidence2
Ba-16	resistance/resilience	positive/negative	low	selection	signals of	signals of
			response	effect	mecha-	mecha-
			diversity		nisms	nisms
Ca-05	resistance/temporal_var	negative/positive	selection	increased	signals of	signals of
			effect	evenness,	mecha-	mecha-
				synchrony,	nisms	nisms
				statistical		
				averaging		

List of studies that did not find covariation:

Code	diversity_stability_relation	direction	mechanism1	mechanism2	evidence1	evidence2
Ca-05	resistance/temporal_var	neutral/positive	selection	increased	signals of	signals of
			effect	evenness,	mecha-	mecha-
				synchrony,	nisms	nisms
				statistical		
				averaging		
Gr-00-1	resistance/resilience	negative/neutral	not stated	not stated	missing	missing
Hu-04	resistance/resilience	positive/neutral	trade-offs	not a	signals of	signals of
			in response	sampling	mecha-	mecha-
			diversity	effect	nisms	nisms
			among			
			stressors			
Is-15	resistance/resilience	positive/neutral	not stated	not stated	missing	missing
Is-15	resilience/temporal_var	neutral/positive	not stated	not stated	missing	missing
PS-02	resistance/resilience	neutral/negative	high	species	signals of	signals of
	,	, 9	response	composi-	mecha-	mecha-
			diversity;	tion	nisms	nisms
			evenness			
Ti-96	resistance/resilience	positive/neutral	high	not stated	verbal	missing
	- I Simoneo	Positive/ neutral	response	100 554004		
			diversity			
Ti-96	resilience/temporal var	neutral/positive	not stated	high	missing	signals of
-100	var	lication, positive	100 000000	response		mecha-
				diversity;		nisms
				competi-		IIISIIIS
				tion		
Vo-12	resistance/resilience	neutral/neutral	not stated	not stated	missing	missing
Vo-12 Vo-12	resistance/resilience	neutral/neutral	not stated	not stated	missing	missing
VR-09	resistance/resilience	negative/neutral	high	not stated	signals of	missing
V 11-09	resistance/resinence	negative/neutrai	response	not stated	mecha-	missing
			_		nisms	
VR-09	resistance/resilience	neutral/neutral	diversity high	not stated	signals of	
v n-09	resistance/resinence	neutrai/neutrai		not stated	_	missing
			response		mecha-	
III 00	. , / .1:	1 1/ 1 1	diversity		nisms	1 1
Wa-00	resistance/resilience	neutral/neutral	species .	species .	verbal	verbal
			composi-	composi-		
			tion	tion		
Wa-17	resistance/resilience	positive/neutral	insurance	insurance	verbal	verbal
			effect	effect		
Wa-17	resilience/temporal_var	neutral/positive	insurance	insurance	verbal	verbal
	resinence, temporar_var	/ P				
			effect	effect		
We-07	resistance/resilience	neutral/neutral	effect high	effect high	verbal	verbal
We-07					verbal	verbal
We-07			high	high	verbal	verbal
We-07 Wr-15			high response	high response	verbal signals of	verbal
	resistance/resilience	neutral/neutral	high response diversity	high response diversity		
	resistance/resilience	neutral/neutral	high response diversity selection	high response diversity	signals of	
	resistance/resilience	neutral/neutral	high response diversity selection effect;	high response diversity	signals of mecha-	
	resistance/resilience	neutral/neutral	high response diversity selection effect; community	high response diversity	signals of mecha-	
Wr-15	resistance/resilience	neutral/neutral	high response diversity selection effect; community composi-	high response diversity	signals of mecha-	
	resistance/resilience resistance/resilience	neutral/neutral	high response diversity selection effect; community composi- tion	high response diversity not stated	signals of mecha- nisms	missing
Wr-15	resistance/resilience resistance/resilience	neutral/neutral	high response diversity selection effect; community composition high response	high response diversity not stated	signals of mecha- nisms	missing
Wr-15 Z1-06 *	resistance/resilience resistance/resilience resistance/resilience	neutral/neutral negative/neutral positive/neutral	high response diversity selection effect; community composition high response diversity	high response diversity not stated	signals of mecha- nisms	missing
Wr-15 Z1-06 *	resistance/resilience resistance/resilience	neutral/neutral	high response diversity selection effect; community composition high response	high response diversity not stated not stated statistical	signals of mecha- nisms	missing missing signals of
Wr-15 Z1-06 *	resistance/resilience resistance/resilience resistance/resilience	neutral/neutral negative/neutral positive/neutral	high response diversity selection effect; community composition high response diversity	high response diversity not stated	signals of mecha- nisms	missing missing signals of mecha-
Wr-15 Z1-06 * Z1-06 *	resistance/resilience resistance/resilience resistance/resilience resilience/resilience	neutral/neutral negative/neutral positive/neutral neutral/positive	high response diversity selection effect; community composition high response diversity not stated	high response diversity not stated not stated statistical averaging	signals of mechanisms verbal missing	missing missing signals of mechanisms
Wr-15	resistance/resilience resistance/resilience resistance/resilience	neutral/neutral negative/neutral positive/neutral	high response diversity selection effect; community composition high response diversity	high response diversity not stated not stated statistical	signals of mecha- nisms	missing missing signals of mecha-

Which pairs of diversity-stability relationships have a quantitative analysis of both relationships.

Positive covariation

Code	diversity_stability_relation	direction	mechanism1	mechanism2	evidence1	evidence2
PS-02	resistance/resilience	negative/negative	high	species	signals of	signals of
			response	composi-	mecha-	mecha-
			diversity;	tion	nisms	nisms
			evenness			

Negative covariation

Code	diversity_stability_relation	direction	mechanism1	mechanism2	evidence1	evidence2
Ba-16	resistance/resilience	positive/negative	low	selection	signals of	signals of
			response	effect	mecha-	mecha-
			diversity		nisms	nisms
Ca-05	resistance/temporal_var	negative/positive	selection	increased	signals of	signals of
			effect	evenness,	mecha-	mecha-
				synchrony,	nisms	nisms
				statistical		
				averaging		

No covariation

Code	diversity stability relation	direction	mechanism1	mechanism2	evidence1	evidence2
	0- 0-					
Ca-05	resistance/temporal_var	neutral/positive	selection	increased	signals of	signals of
			effect	evenness,	mecha-	mecha-
				synchrony,	nisms	nisms
				statistical		
				averaging		
Hu-04	resistance/resilience	positive/neutral	trade-offs	not a	signals of	signals of
			in response	sampling	mecha-	mecha-
			diversity	effect	nisms	nisms
			among			
			stressors			
PS-02	resistance/resilience	neutral/negative	high	species	signals of	signals of
			response	composi-	mecha-	mecha-
			diversity;	tion	nisms	nisms
			evenness			

References

Donohue, I. et al. 2016. Navigating the complexity of ecological stability. - Ecology letters 19: 1172–1185.