

Reproducible report II for ‘Biodiversity increases and decreases ecosystem stability’

Analysis of covariation in diversity-stability relationships

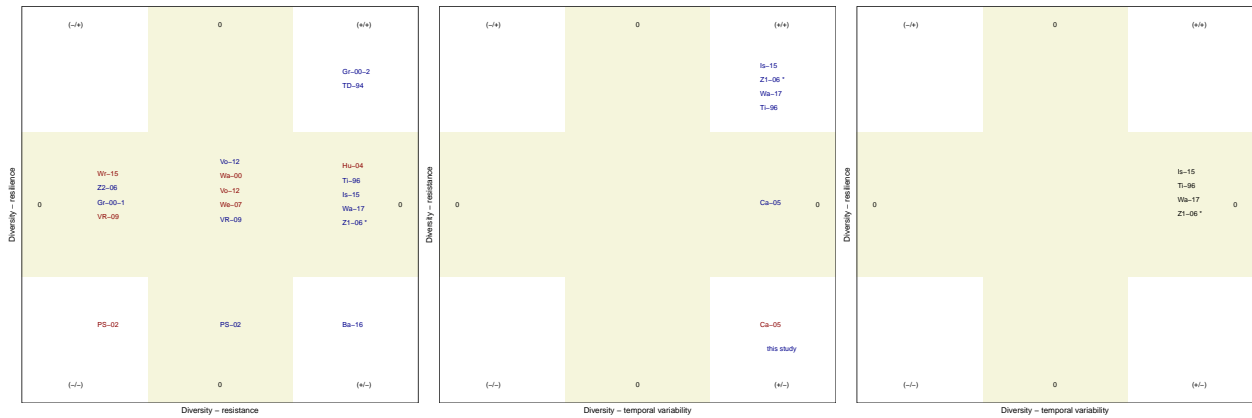
Frank Pennekamp

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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 resilience to perturbation (chemical stressor, atrazine) of biomass production.	Baert et al (2016) Ecology, 97, 3433
Ca-05	Diversity manipulation of grassland plants (Portuguese BIODDEPTH site) analysing temporal variability and resistance to natural perturbation (frost and low precipitation) of biomass production.	Caldeira et al (2005) Oikos, 110, 115
Gr-00-1	Diversity manipulation by fumigation of soil microorganisms, analysing resilience to perturbation (heating) and resistance to perturbation (heating or chemical stress, CuSO ₄) of respiration.	Griffiths et al (2000) Oikos, 2, 279
Gr-00-2	Diversity manipulation by fumigation of soil microorganisms, analysing resilience to perturbation (heating) and resistance to perturbation (heating or chemical stress, CuSO ₄) of respiration.	Griffiths et al (2000) Oikos, 2, 279
Hu-04	Analysis of diverse studies of marine ecosystems, some of which examined diversity-resistance and some diversity-resilience relationships for various ecosystem functions.	Hughes & Stachwicz (2004), PNAS, 101, 24
Is-15	Forty-six diversity manipulations of grassland plants analysing temporal variability, resistance, and resilience to natural perturbations (drought and wet events) of biomass production.	Isbell et al (2015) Nature, 526, 574
PS-02	Diversity manipulation of grassland plants (Swiss BIODDEPTH site) analysing resistance and resilience of biomass production to experimental drought perturbation.	Pfister & Schmid (2002) Nature, 416, 84
TD-94	Diversity manipulation by fertilisation of plants, analysing resistance and resilience of biomass production to natural perturbation (drought).	Timan & Downing (1994) Nature, 367, 363
Ti-96	Diversity manipulation of grassland plants via fertilisation. Analysis of temporal variability, resilience and resistance of biomass production to natural drought perturbation.	Tilman (1996) Ecology, 77, 350
Vo-12	Diversity manipulation of grassland plants. Analysis of resistance and resilience of biomass production to drought perturbation.	Vogel et al (2012) PLoS One, 7, e36992
VR-09	Diversity manipulation of plants, analysing resistance and resilience to natural perturbation (drought) of biomass production.	Van Ruijven & Berendse (2009) Journal of Ecology, 98, 81
Wa-00	Diversity manipulation of plants, analysing resistance and resilience to experimental perturbation (drought) of various ecosystem functions.	Wardle et al (2000) Oikos, 98, 11
Wa-17	Diversity manipulation of grassland plants. Analysis of temporal variability and resilience of biomass production to drought perturbation.	Waag et al (2017) Ecology, DOI: 10.1002/ecy.2003
We-07	Manipulation of soil microbial diversity by serial dilution. Analysis of resistance and resilience of denitrification and nitrite oxidation to a temperature perturbation.	Wertz et al (2007) Environmental Microbiology, 9, 2211
Wr-15	Diversity manipulation of grassland plants. Analysis of temporal variability and resilience of biomass production to drought perturbation.	Wright et al (2015) Nature Communications, 6, 6092
Z1-06 *	Diversity manipulation of unicellular algae analysing temporal variability and resistance to experimental cold perturbation of biomass production.	Zhang & Zhang (2006) Oikos, 114, 385
Z2-06	Diversity manipulation of unicellular algae analysing resistance and resilience of biomass production to experimental cold perturbation.	Zhang & Zhang (2006) 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 effect	insurance effect	verbal	verbal
Is-15	resistance/temporal_var	positive/positive	not stated	not stated	missing	missing
PS-02	resistance/resilience	negative/negative	high response diversity; evenness	species composition	signals of mechanisms	signals of mechanisms
TD-94	resistance/resilience	positive/positive	high response diversity	not stated	verbal	missing
Ti-96	resistance/temporal_var	positive/positive	high response diversity	high response diversity; competition	verbal	signals of mechanisms
Wa-17	resistance/temporal_var	positive/positive	insurance effect	insurance effect	verbal	verbal
Z1-06 *	resistance/temporal_var	positive/positive	high response diversity	statistical averaging	verbal	signals of mechanisms

List of studies with negative covariation

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

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 effect	increased evenness, synchrony, statistical averaging	signals of mechanisms	signals of mechanisms
Gr-00-1	resistance/resilience	negative/neutral	not stated	not stated	missing	missing
Hu-04	resistance/resilience	positive/neutral	trade-offs in response diversity among stressors	not a sampling effect	signals of mechanisms	signals of mechanisms
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 response diversity; evenness	species composition	signals of mechanisms	signals of mechanisms
Ti-96	resistance/resilience	positive/neutral	high response diversity	not stated	verbal	missing
Ti-96	resilience/temporal_var	neutral/positive	not stated	high response diversity; competition	missing	signals of mechanisms
Vo-12	resistance/resilience	neutral/neutral	not stated	not stated	missing	missing
Vo-12	resistance/resilience	neutral/neutral	not stated	not stated	missing	missing
VR-09	resistance/resilience	negative/neutral	high response diversity	not stated	signals of mechanisms	missing
VR-09	resistance/resilience	neutral/neutral	high response diversity	not stated	signals of mechanisms	missing
Wa-00	resistance/resilience	neutral/neutral	species composition	species composition	verbal	verbal
Wa-17	resistance/resilience	positive/neutral	insurance effect	insurance effect	verbal	verbal
Wa-17	resilience/temporal_var	neutral/positive	insurance effect	insurance effect	verbal	verbal
We-07	resistance/resilience	neutral/neutral	high response diversity	high response diversity	verbal	verbal
Wr-15	resistance/resilience	negative/neutral	selection effect; community composition	not stated	signals of mechanisms	missing
Z1-06 *	resistance/resilience	positive/neutral	high response diversity	not stated	verbal	missing
Z1-06 *	resilience/temporal_var	neutral/positive	not stated	statistical averaging	missing	signals of mechanisms
Z2-06	resistance/resilience	negative/neutral	low response diversity	not stated	signals of mechanisms	missing

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 response diversity; evenness	species composition	signals of mechanisms	signals of mechanisms

Negative covariation

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

No covariation

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

References

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