Community Diversity and Stability

1. Biogeography: Observed patterns of community diversity
2. What processes promote community diversity?
   - Productivity
   - Disturbance (IDH)
   - Balance (PDB)
3. Definitions of stability (resistance vs. resilience, structure vs. function)
4. Does diversity increase stability?

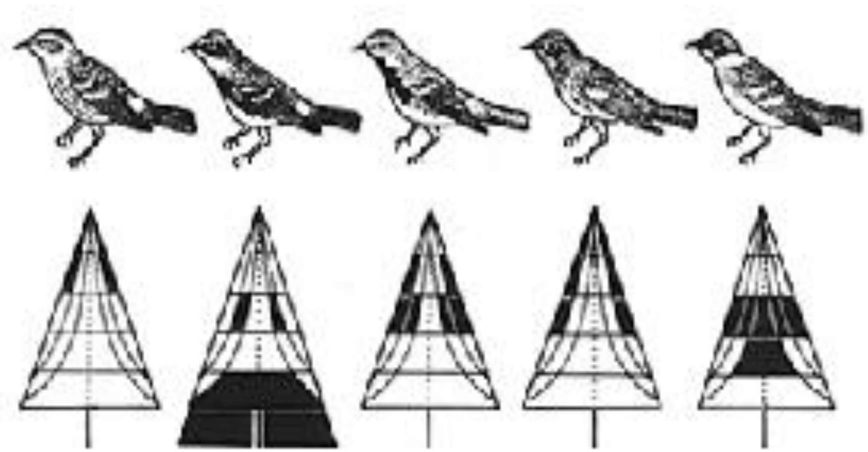
Community Diversity and Stability

Geographical Ecology → **Conservation Biology**

Cape May

Black Throated Green

Bay Breasted

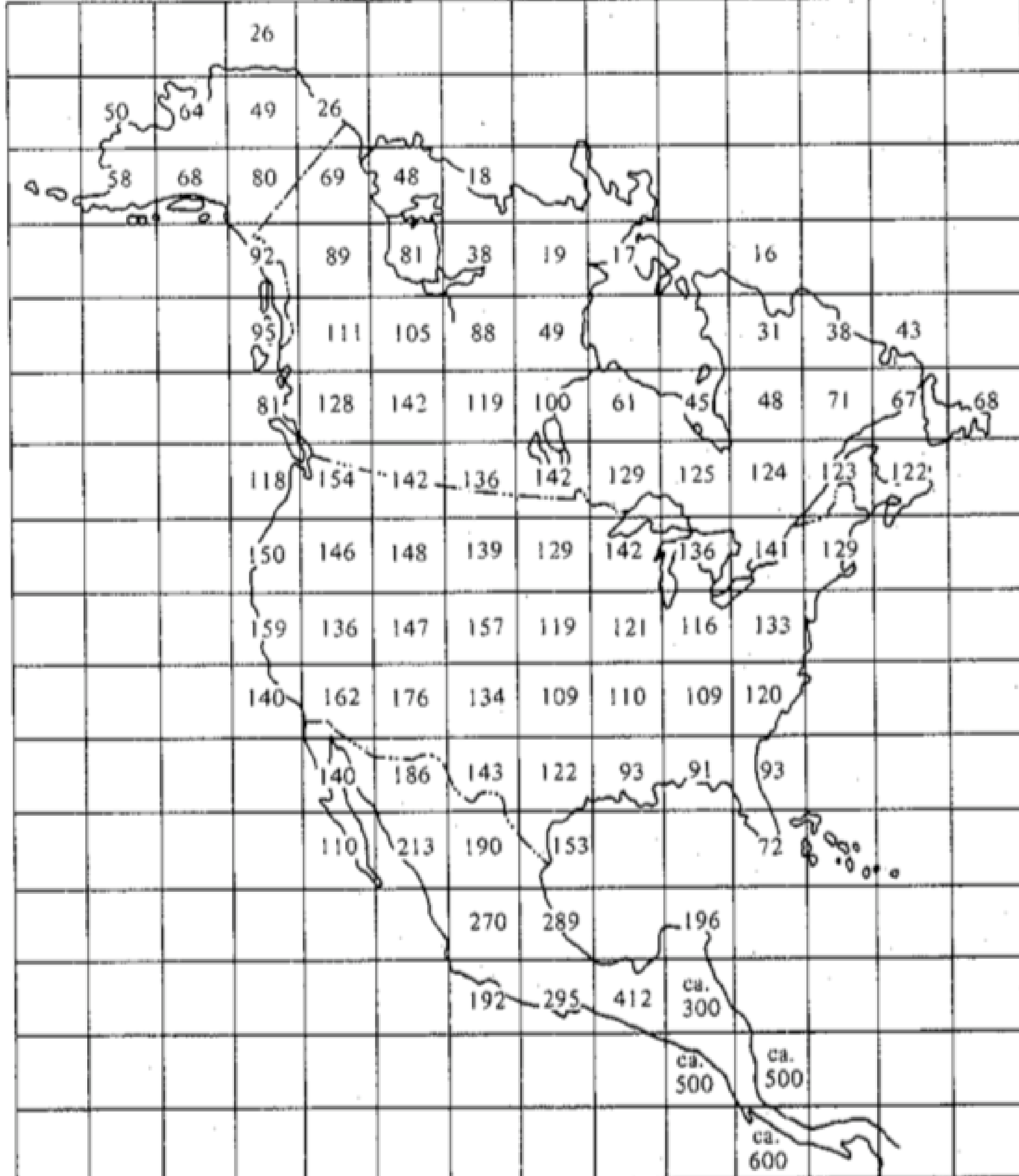


Yellow Rumped

Blackburnian

North and Central America

Bird Species Richness



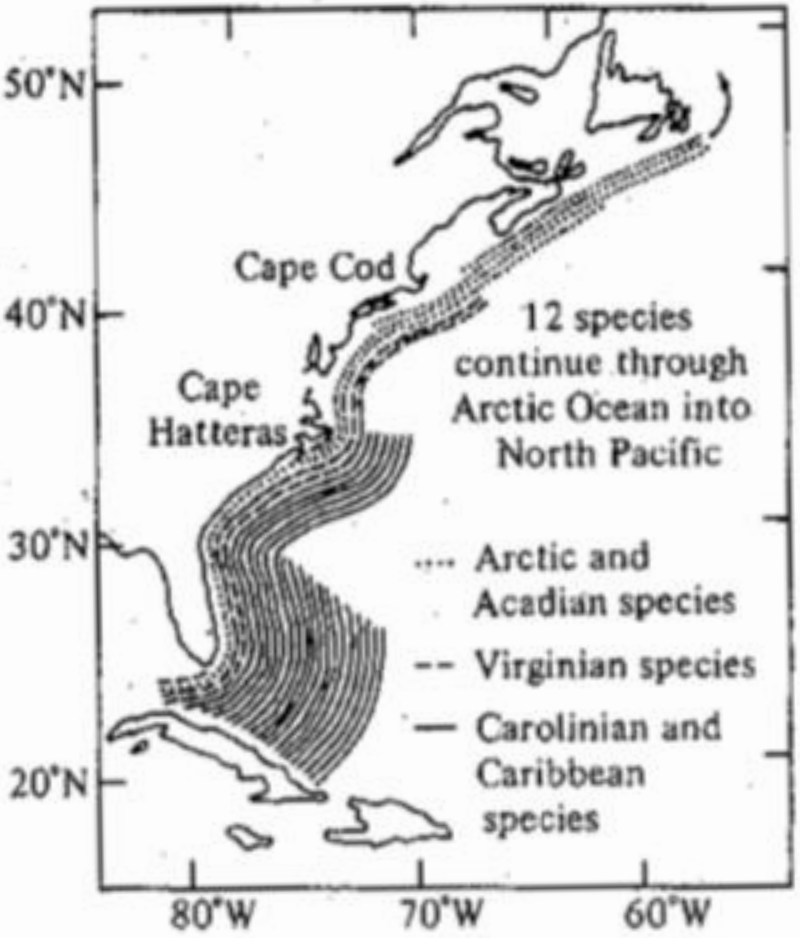
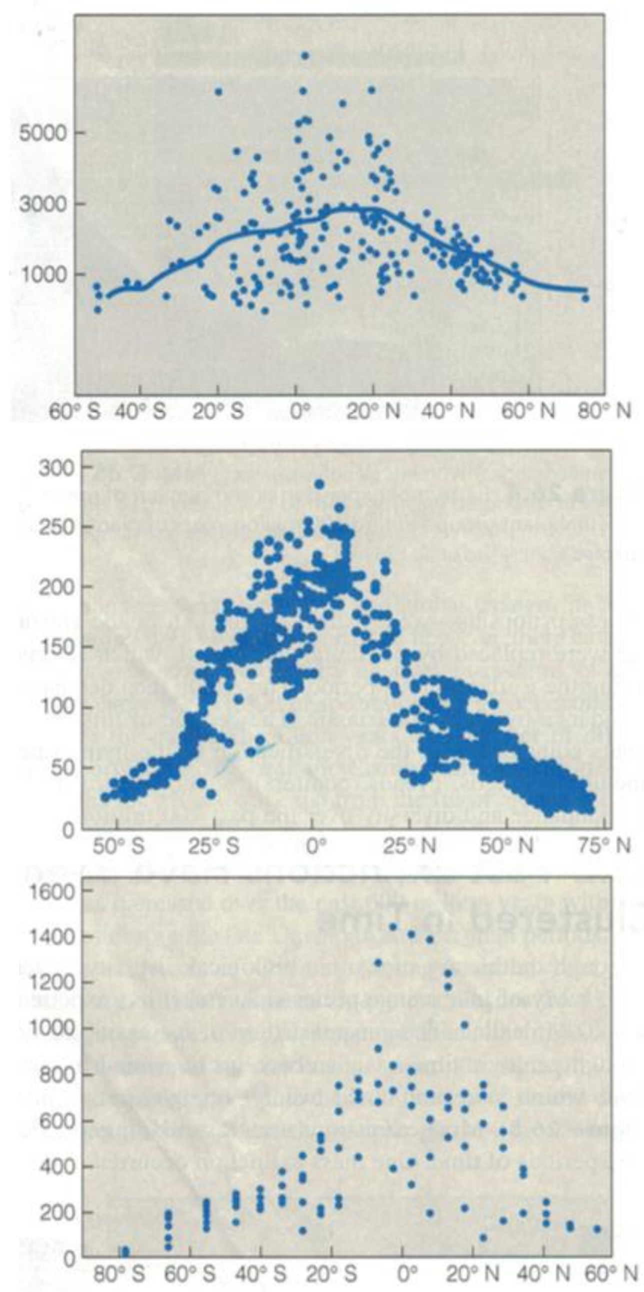


Fig. 8-9

Diversity gradient of gastropods along the eastern coast of the United States and Canada. Each line stands for ten species. (From Fischer, 1960, after Abbott.)

Latitudinal gradients in species richness

Explanations for this pattern have guided hypotheses about the drivers of biodiversity



Vascular plants

Mammals

Birds

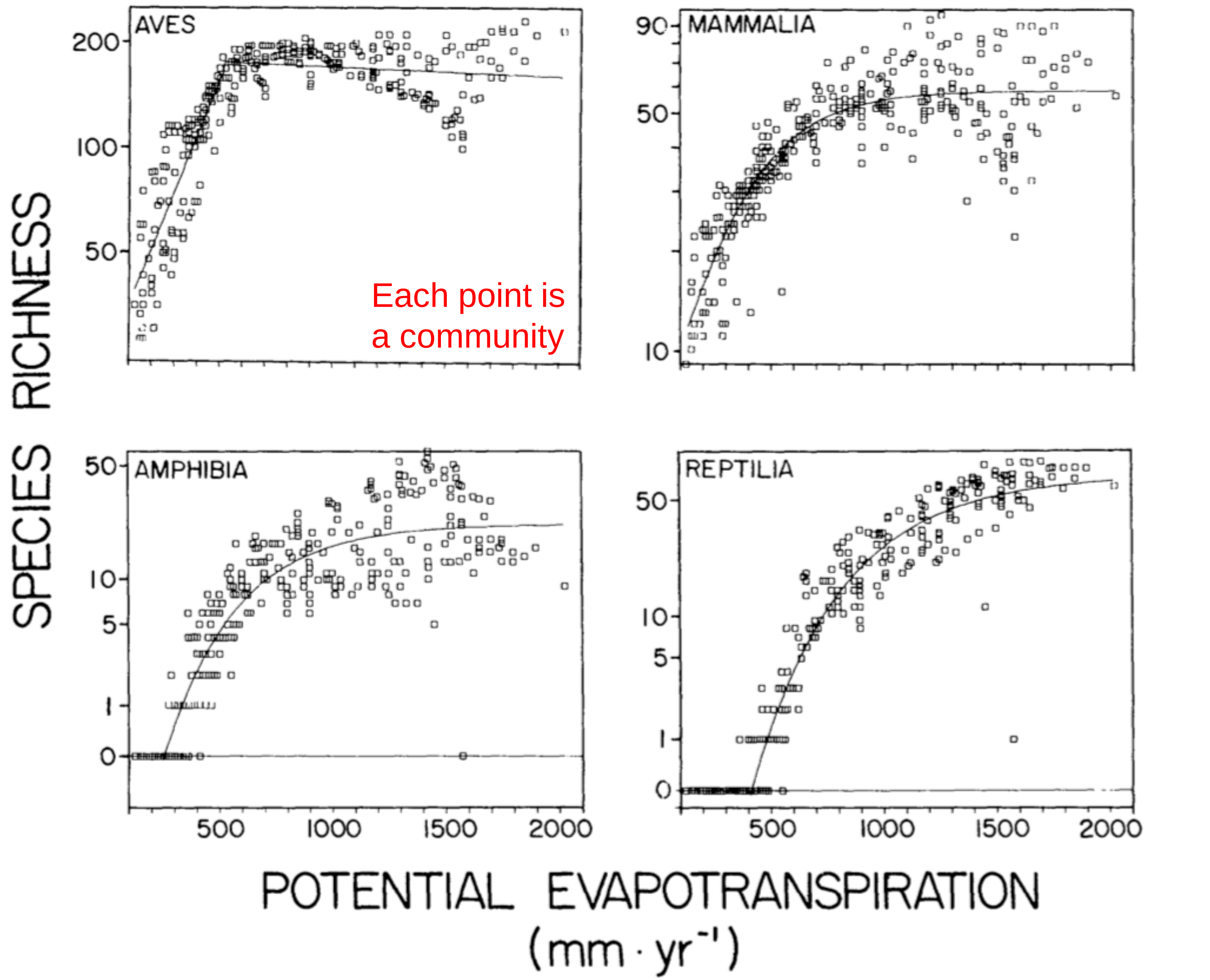
Species richness

Latitude

Hypothesis 1: Productivity drives diversity

High productivity
allows specialization:
narrow niches

High productivity
Reduces competition:
high niche overlap



Currie, D. J. (1991). Energy and large-scale patterns of animal-and plant-species richness. *The American Naturalist*, *137*(1), 27-49.

Productivity = rate of biomass production (g/m^2/yr)

Dodson et al. 2000. Ecology.

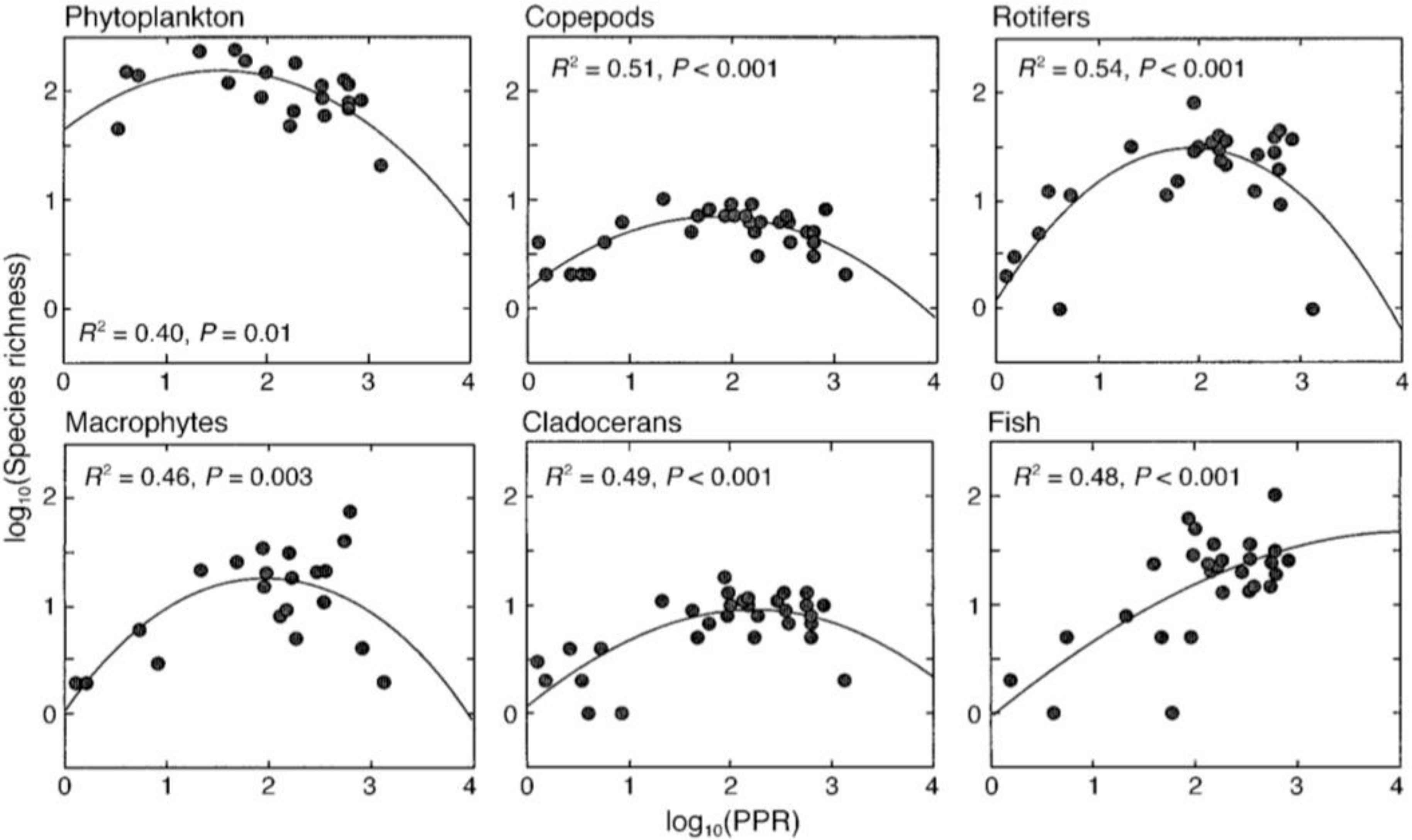
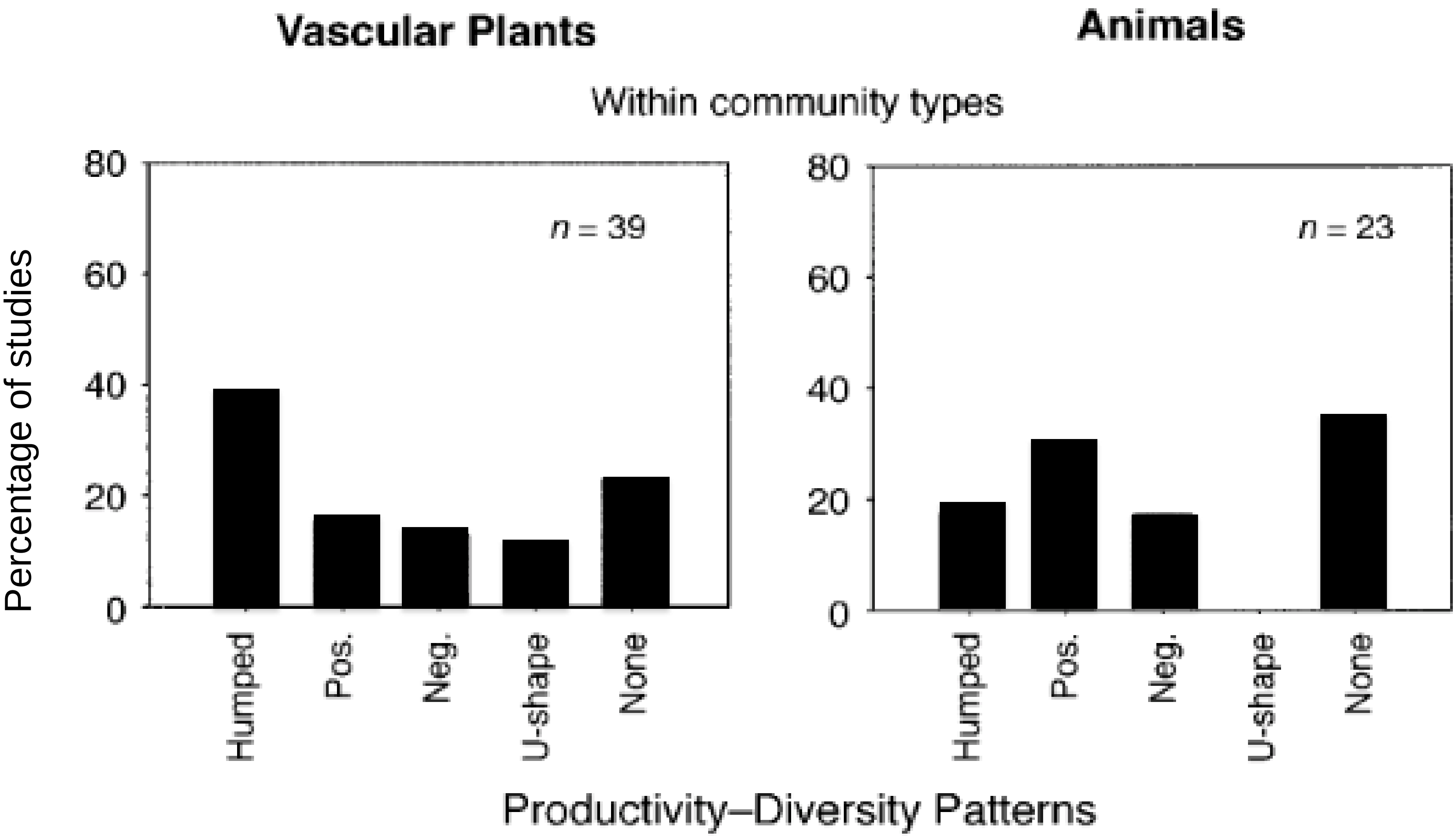


FIG. 3. A regression analysis of log(species richness) as a function of log(PPR), with the fitted quadratic model assuming no effect of area on the richness–productivity relationship. Panels are as in Fig. 2.

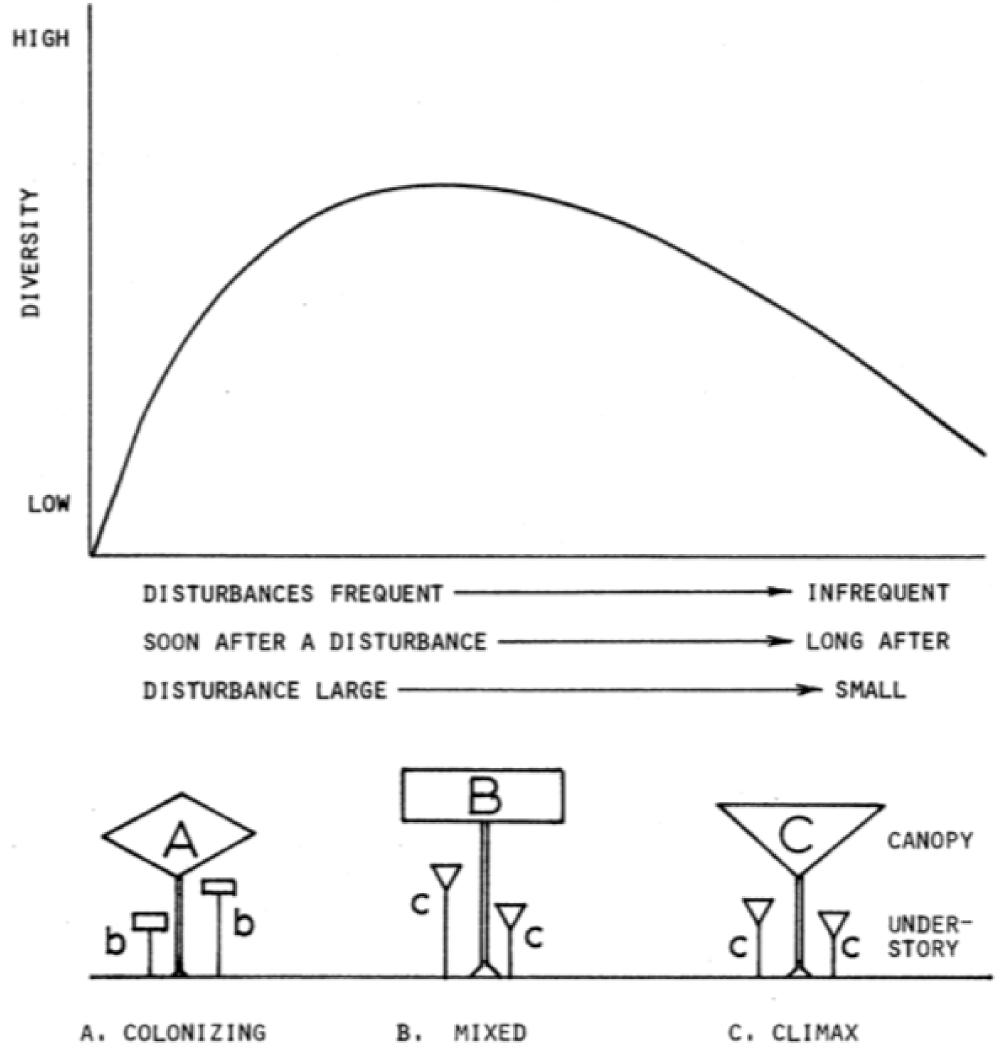


Mittelbach, G. et al. (2001). What is the observed relationship between species richness and productivity?. *Ecology*, *82*(9), 2381-2396.

Hypothesis 2: Disturbance drives diversity

Intermediate Disturbance Hypothesis

Fig. 1. The "intermediate disturbance" hypothesis. The patterns in species composition of adults and young proposed by Eggeling (*8*) for the different successional stages of the Budongo forest are shown diagrammatically at the bottom.



Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. *Science*, *199*(4335), 1302-1310.

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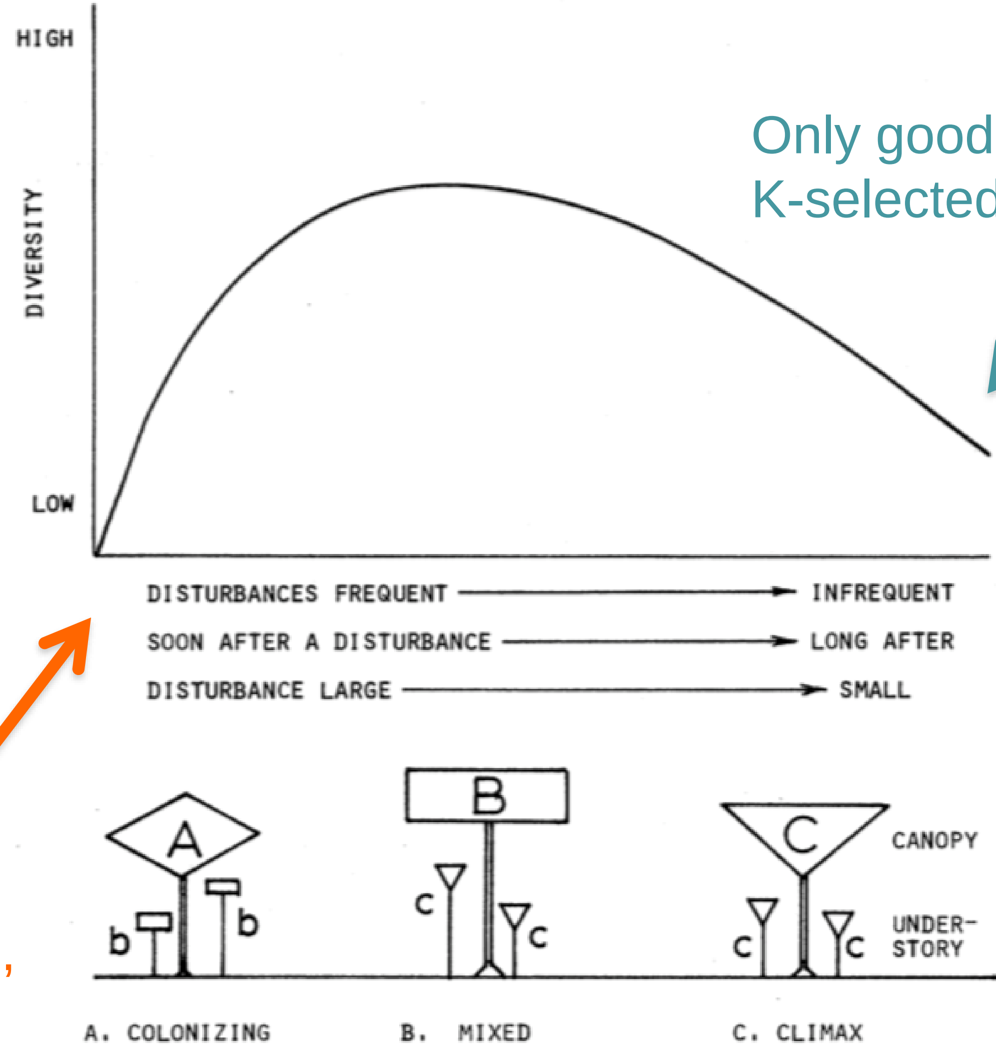


Only good competitors, K-selected species

Only good colonizers, r-selected species

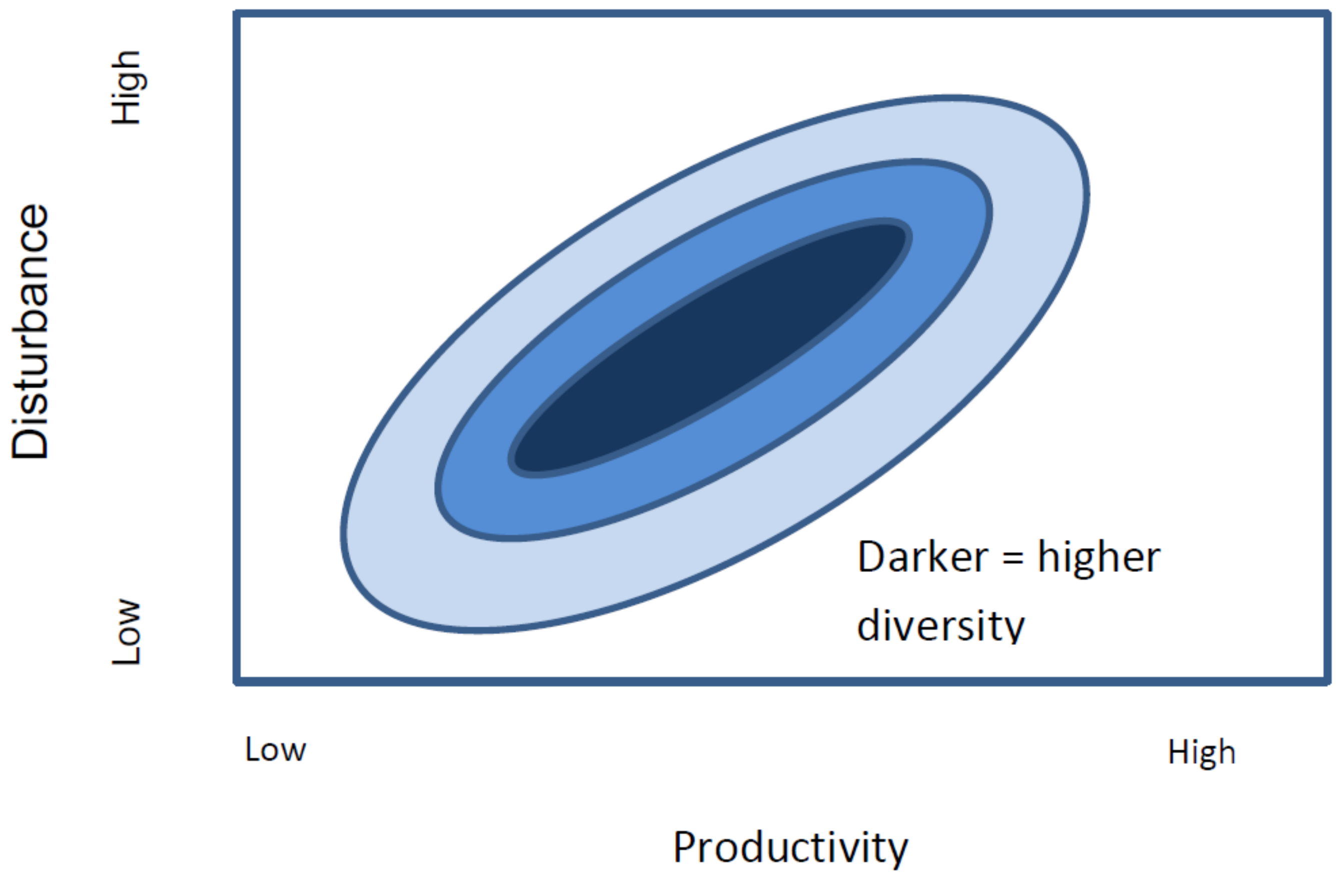
Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. *Science*, *199*(4335), 1302-1310.

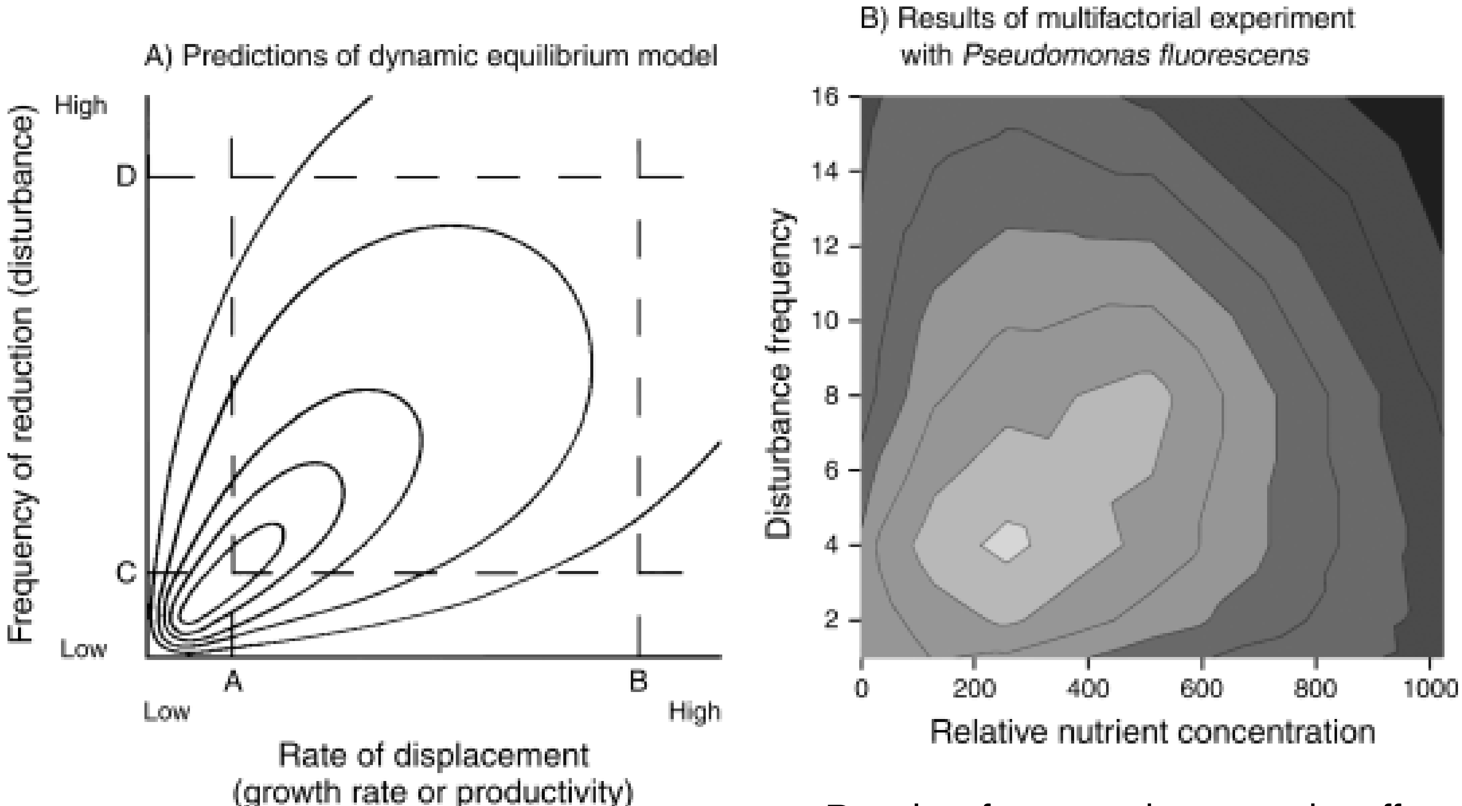
Table 21.2 Seasonal patterns in bare space and species richness on boulders in each of three classes, categorized according to the force (in newtons) required to move them. (After Sousa, 1979b.)

Census date	Boulder class (N)	Percentage bare space	Species richness		
			Mean	Standard error	Range
November 1975	< 49	78.0	1.7	0.18	1–4
	50–294	26.5	3.7	0.28	2–7
	> 294	11.4	2.5	0.25	1–6
May 1976	< 49	66.5	1.9	0.19	1–5
	50–294	35.9	4.3	0.34	2–6
	> 294	4.7	3.5	0.26	1–6
October 1976	< 49	67.7	1.9	0.14	1–4
	50–294	32.2	3.4	0.40	2–7
	> 294	14.5	2.3	0.18	1–6
May 1977	< 49	49.9	1.4	0.16	1–4
	50–294	34.2	3.6	0.20	2–5
	> 294	6.1	3.2	0.21	1–5

Sousa, W. P. (1979). Disturbance in marine intertidal boulder fields: the nonequilibrium maintenance of species diversity. *Ecology*, *60*(6), 1225-1239.

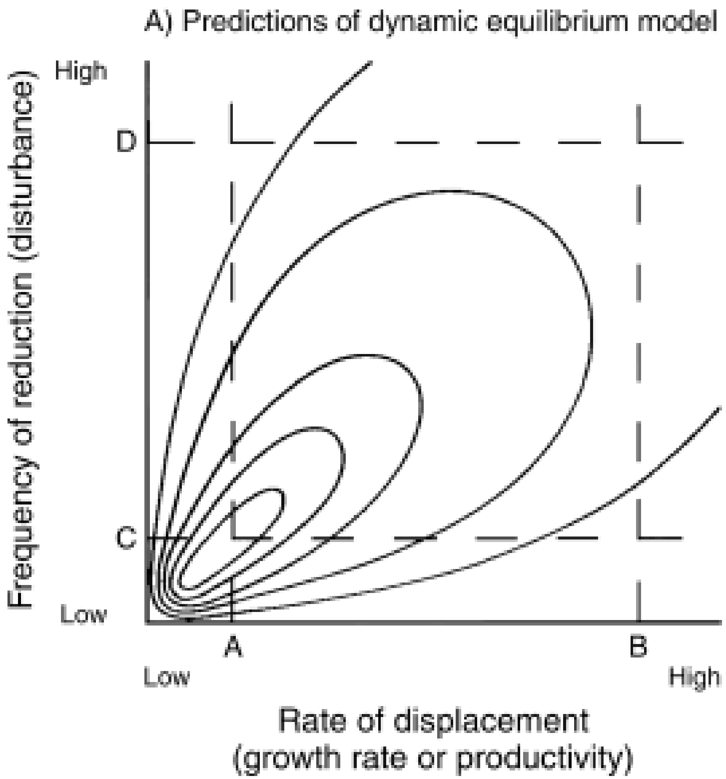
Hypothesis 3: Productivity Disturbance Balance

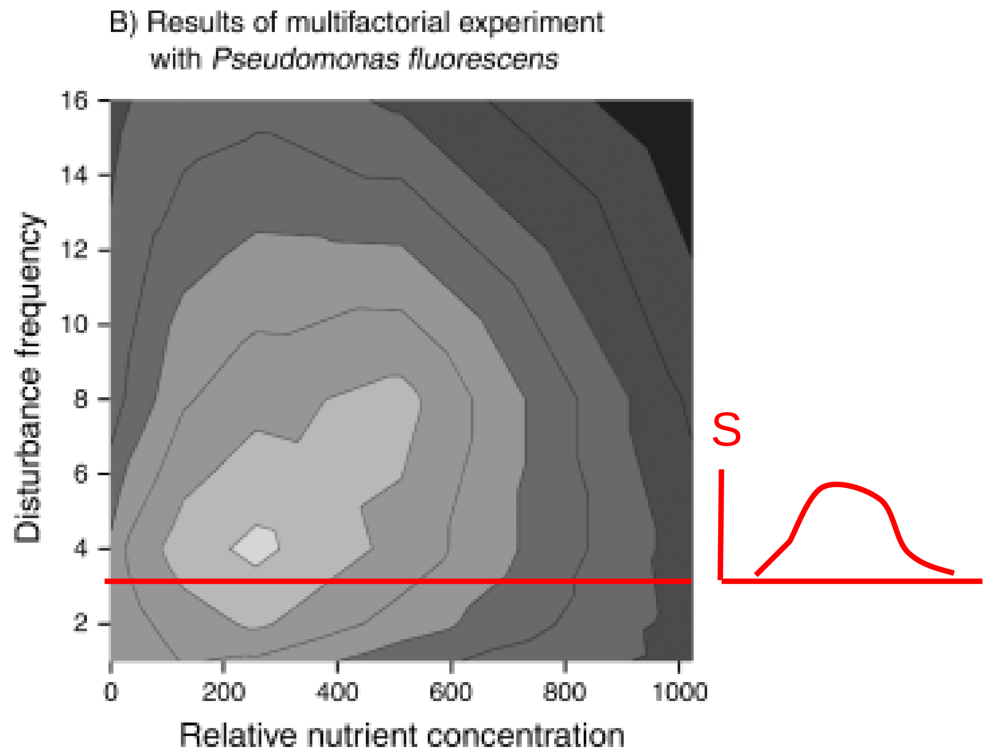




Results of an experiment on the effects of disturbance and productivity on microbial diversity. The contour map shows diversity of colony forms of *Pseudomonas fluorescens* that developed with five frequencies of disturbance (every 1, 2, 4, 8, or 16 days) and eight levels of productivity. High-diversity regions are shown in lighter shades and low-diversity regions in darker shades.

Huston, M. A. (2014). Disturbance, productivity, and species diversity: empiricism vs. logic in ecological theory. *Ecology*, *95*, 2382-2396.





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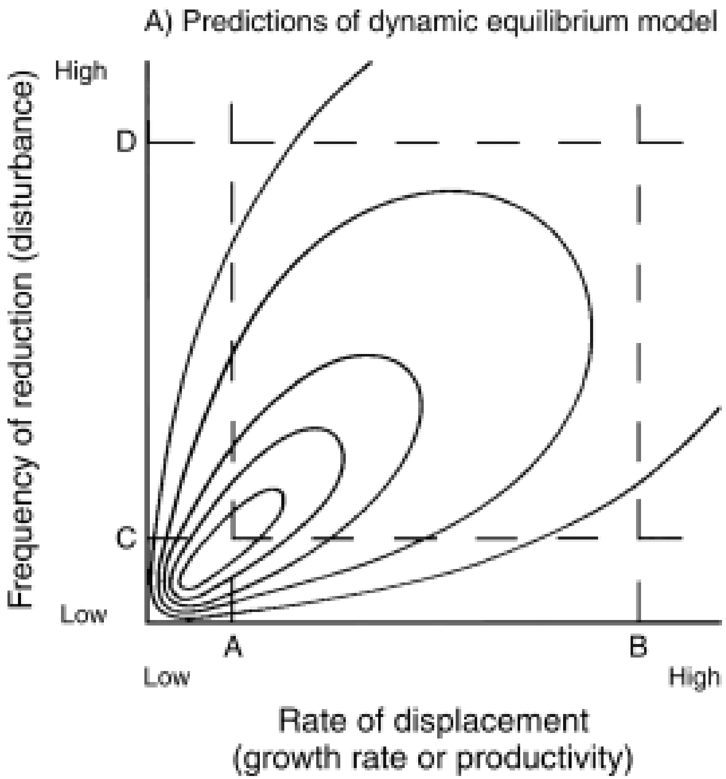

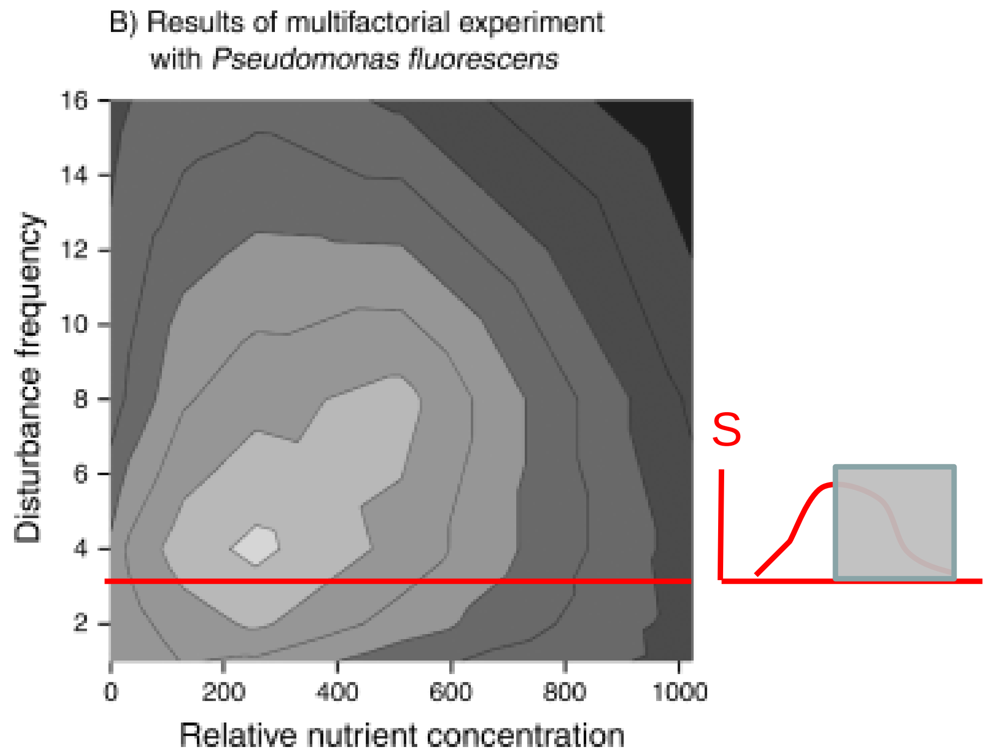

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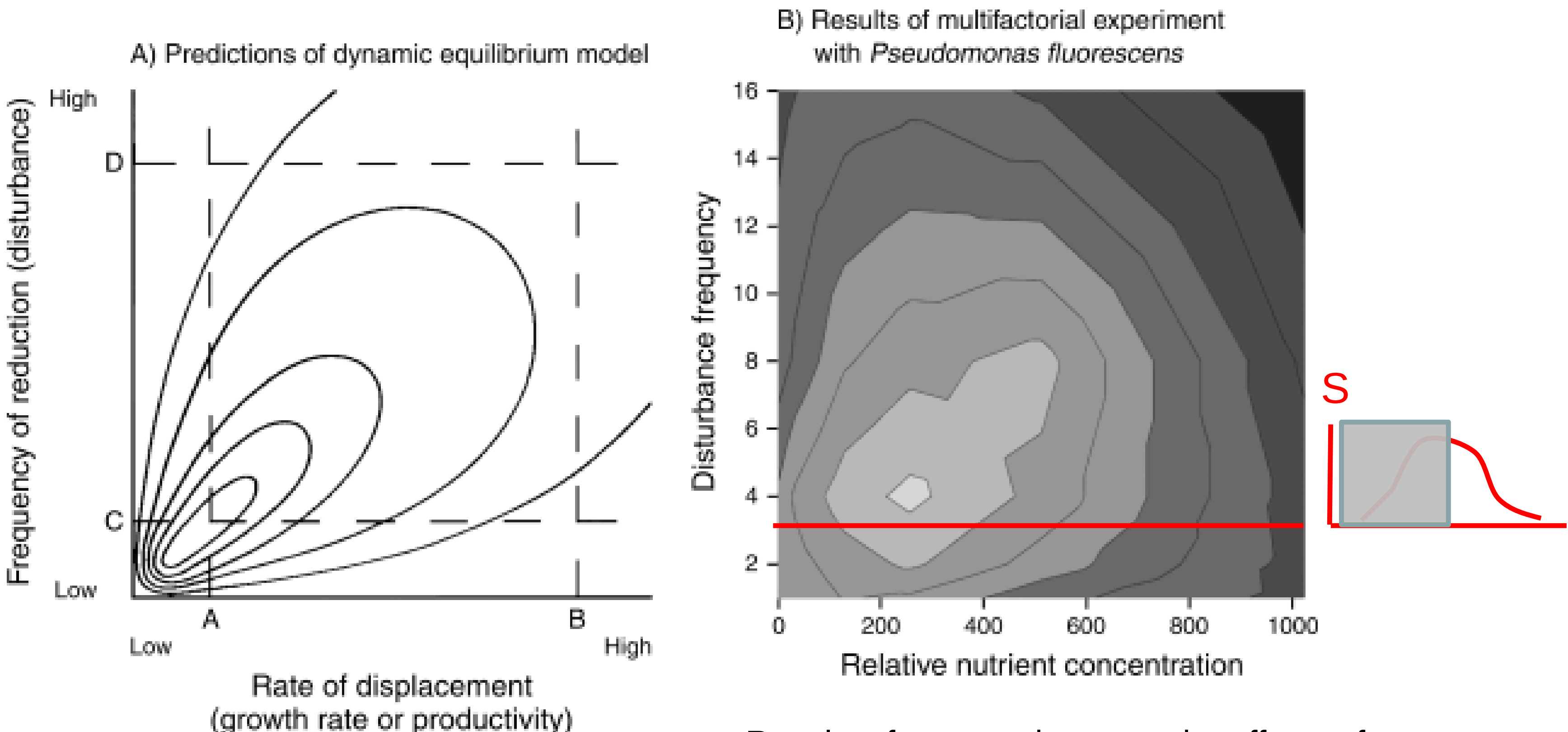

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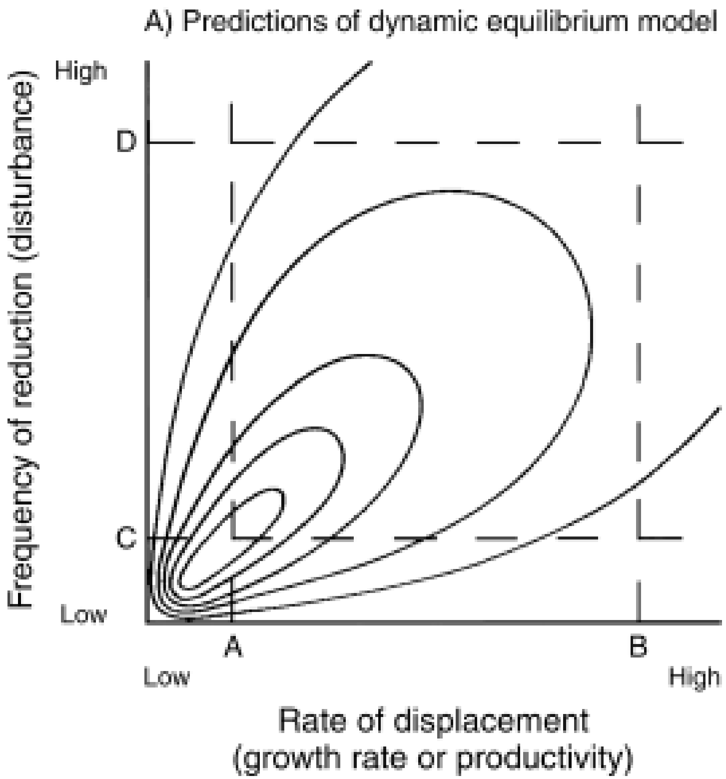

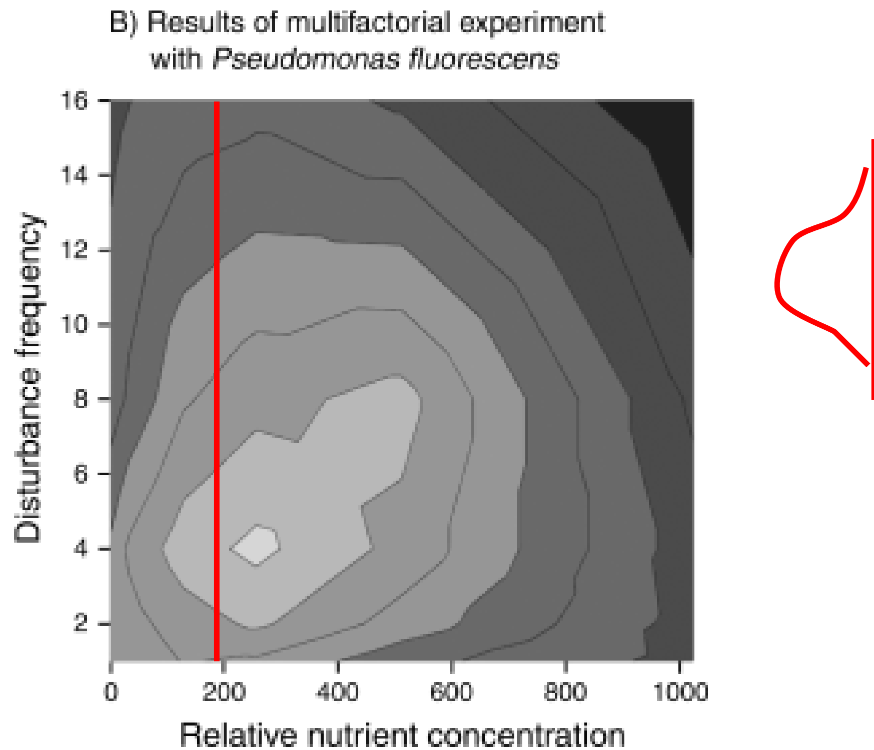

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Community Diversity and Stability

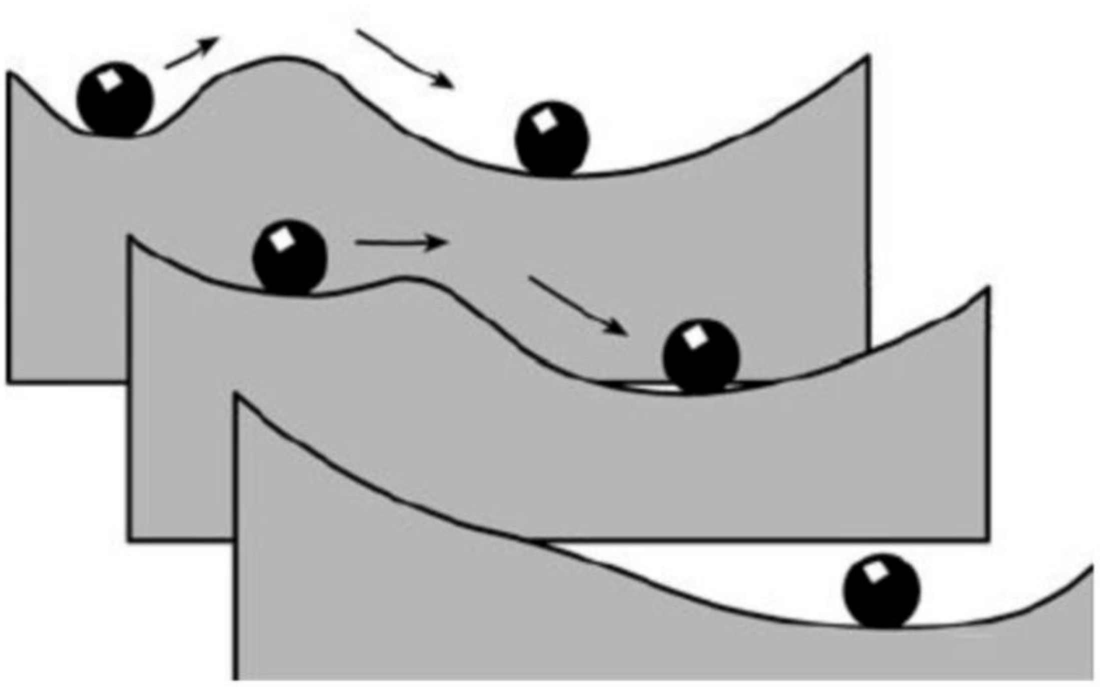
1. Diversity and stability of community STRUCTURE
2. Diversity and stability of community FUNCTION

Stability of Community Structure

Stability = Resistance + Resilience

Resistance measures the magnitude of disruption required to cause change

Resiliance measures the tendency to return to original state if change does occur



High resistance,
Low resilience

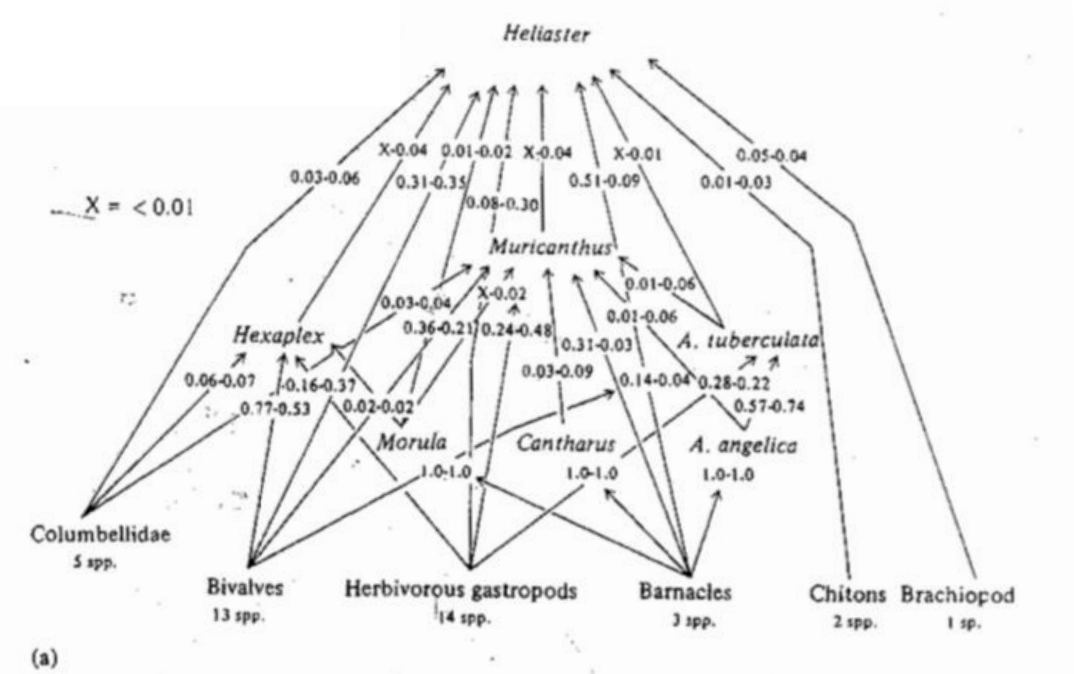
Low resistance,
Low resilience

High resistance,
High resilience

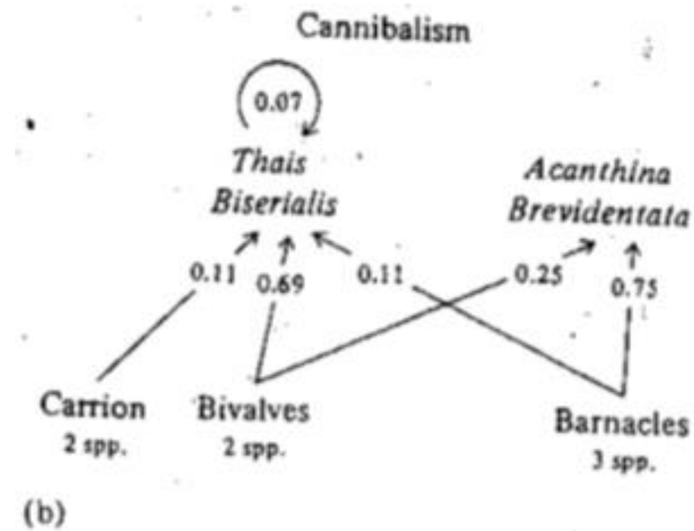
Conventional View: High species richness INCREASES stability

Functional redundancy

Complex, species-rich web



Simple, species-poor web

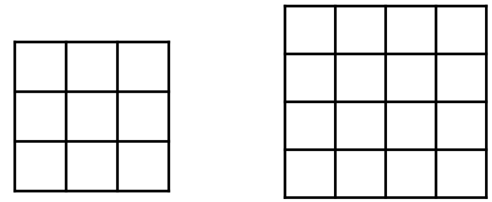


MacArthur, R. (1955). Fluctuations of animal populations and a measure of community stability. *Ecology*, *36*, 533-536.

Challenging View: High species richness could DECREASE stability

Models with randomly assembled food webs, systematically varying:

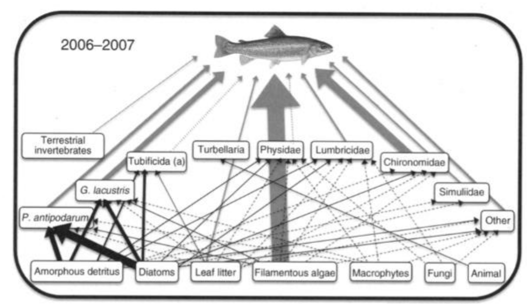
S = Species richness



C = Connectance (links/species²)
(links per possible link)

	1	2	3	4	
		x	x		1
	x			x	2
	x			x	3
	x		x		4

β = Mean interaction strength



May, R. M. (2019). *Stability and complexity in model ecosystems.* Princeton University Press.

Challenging View: High species richness could DECREASE stability

$$\boldsymbol{\beta\sqrt{SC} < 1}$$ **Stable**

$$\boldsymbol{\beta\sqrt{SC} > 1}$$ **Unstable**

May, R. M. (2019). *Stability and complexity in model ecosystems.* Princeton University Press.

Resolution with empirical data: High species richness INCREASES stability

Fig. 2 Relationship between connectance and number of species in African grassland samples.

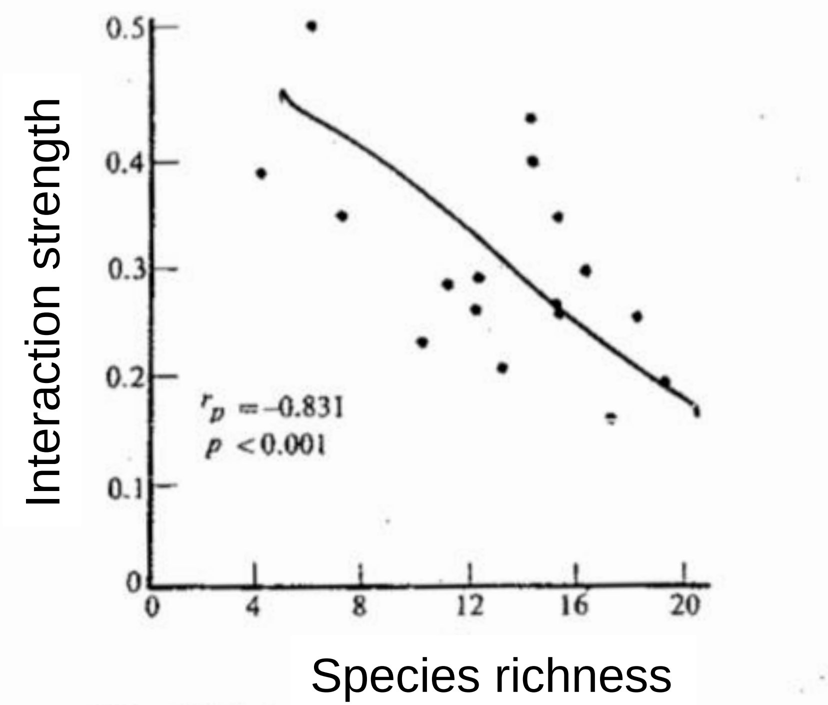
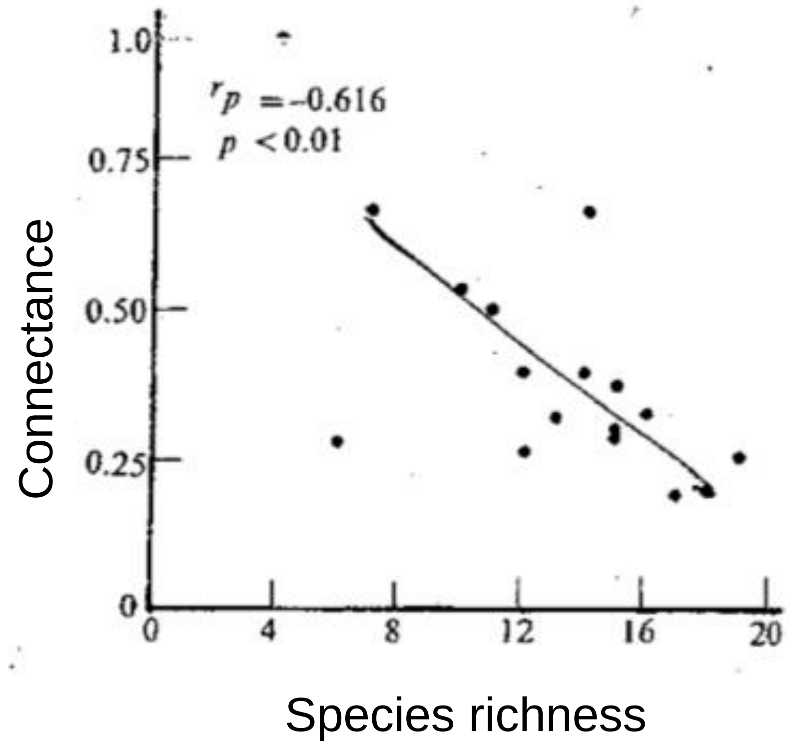
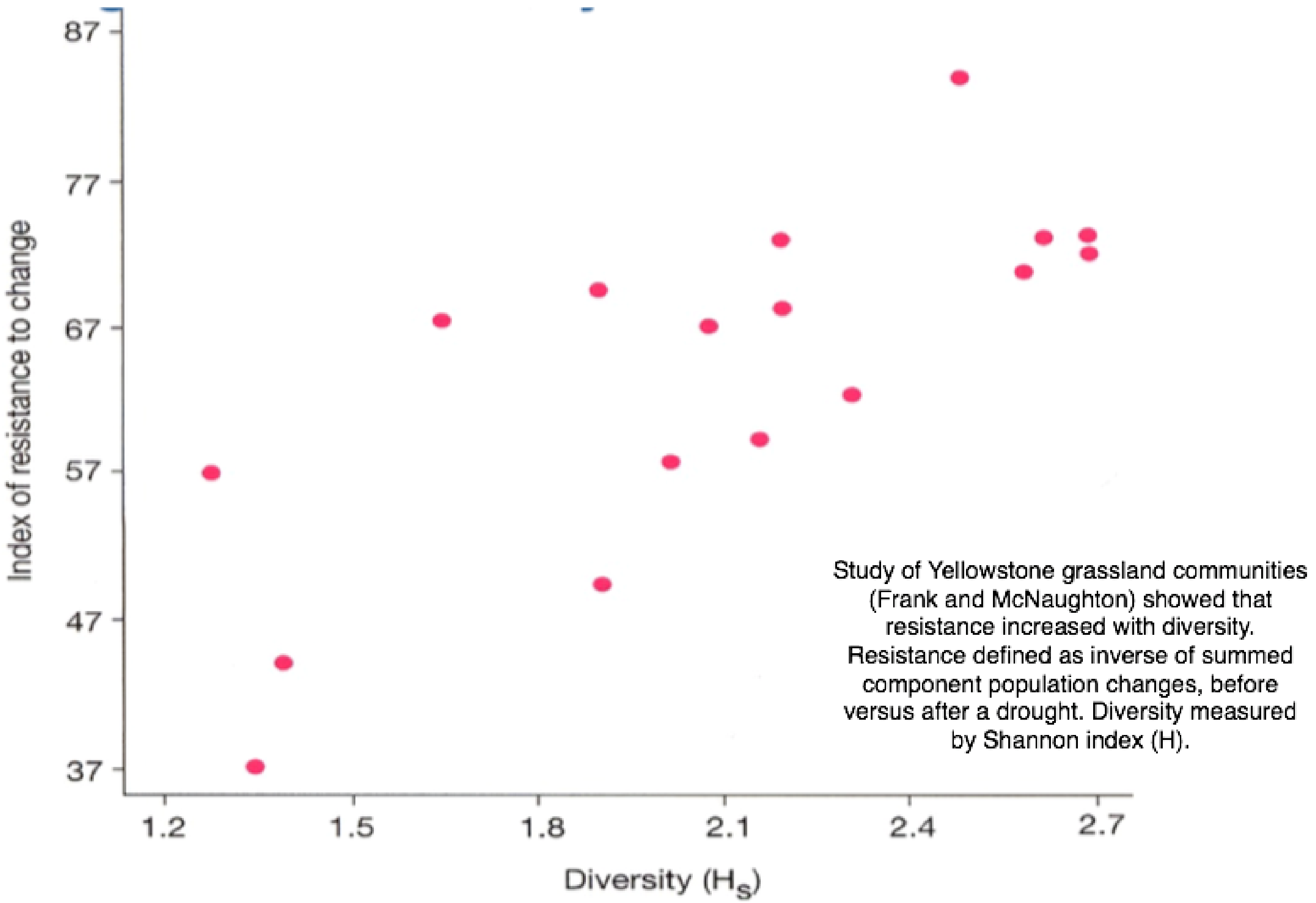


Fig. 1 relationship between average interaction strength among species and number of species in African grassland samples. r_p is the partial correlation coefficient with sample size held constant.



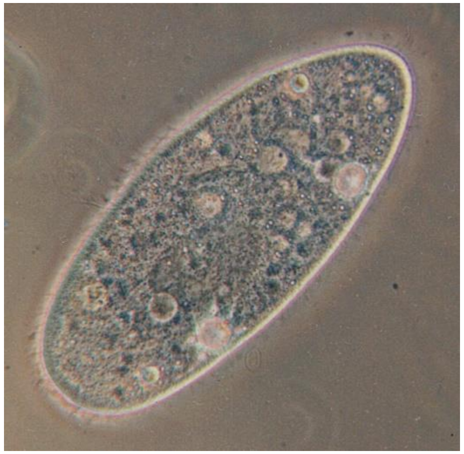
MCNAUGHTON, S. Stability and diversity of ecological communities. *Nature* 274, 251–253

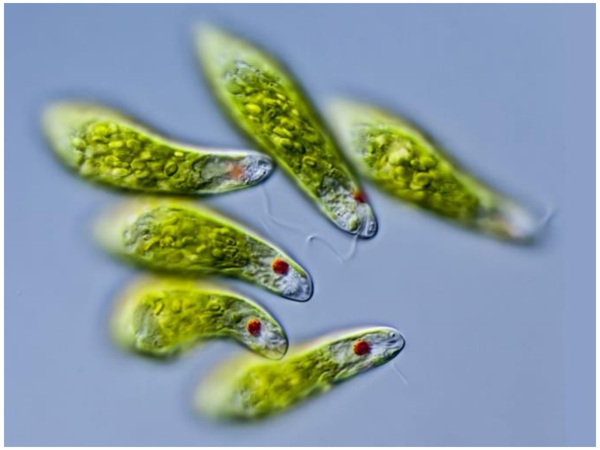
Resolution with empirical data: High species richness INCREASES stability

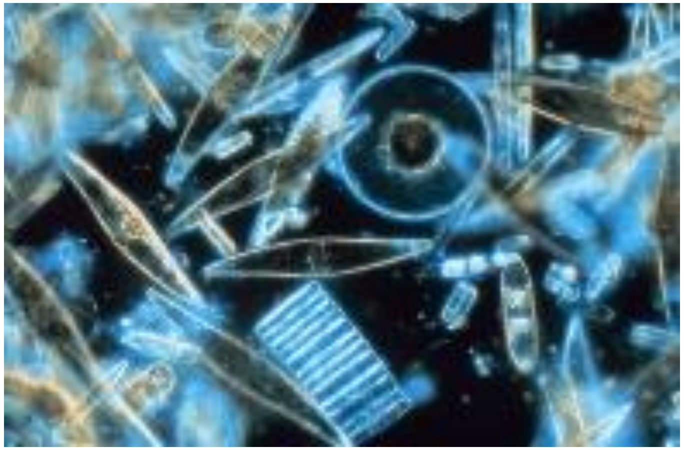


Frank and McNaughton. 1991. Stability Increases with Diversity in Plant Communities: Empirical Evidence from the 1988 Yellowstone Drought. Oikos *62*, 360 - 362.

High species richness increases stability of ecosystem FUNCTION





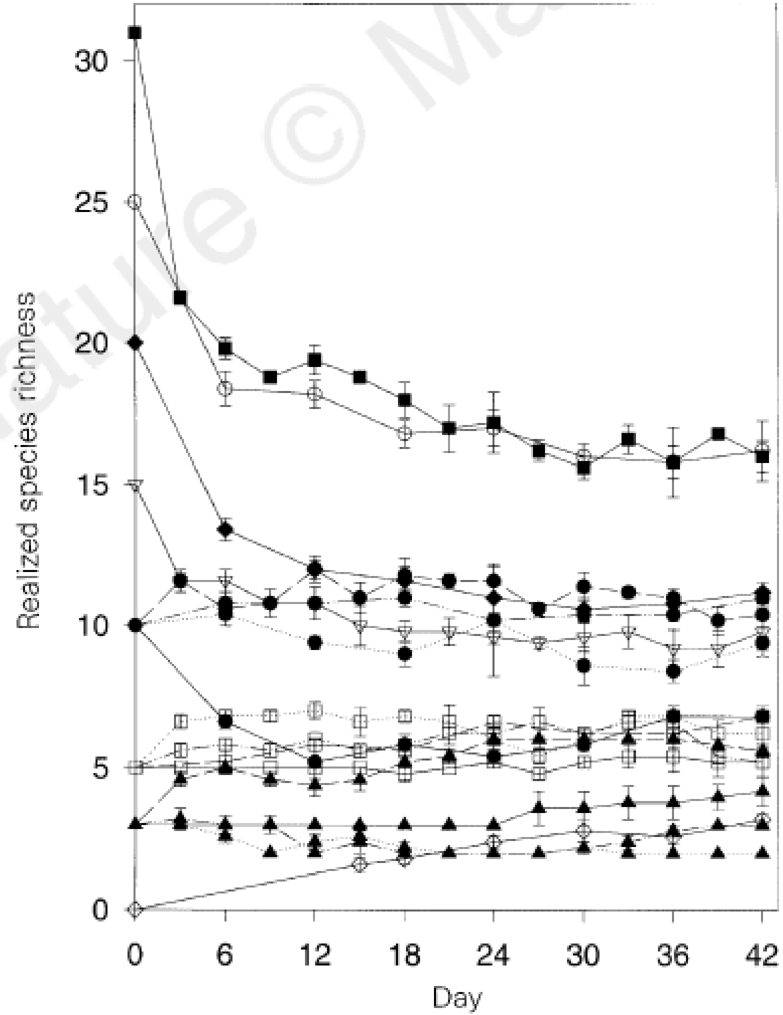


McGrady-Steed, J., Harris, P. M., & Morin, P. J. (1997). Biodiversity regulates ecosystem predictability. *Nature*, *390*, 162-165.

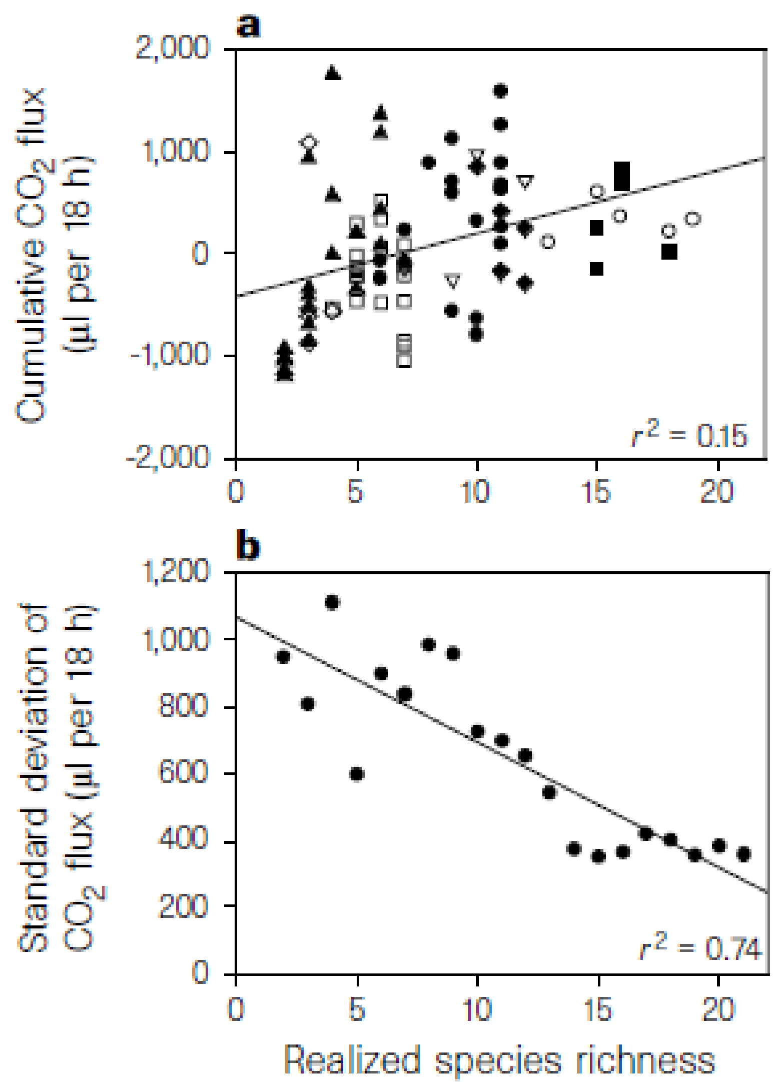
Table 1 Species combinations used to create a biodiversity gradient

Trophic position	Organism	Initial species richness 0	3	5	10	15	20	25	31
Producers	*Ankistrodesmus* 1	(a)	c		a, c	a	a	a	a
	Chlamydomonas	(a)	a, b	a–c	a–d	a	a	a	a
	Diatom sp.			c, d	b, d				
	Euglena					a	a	a	a
	Netrium					a	a		a
	(*Phacus*)				a			a	a
	(*Peridinium*)				a		a	a	a
	Scenedesmus		d	a, d	b–d	a		a	a
	Staurastrum			b	b–d		a	a	a
Herbivores	*Brachionus*		c		c	a			a
	Frontonia		d		a, d		a	a	a
	Hypostome sp.		b	c	b		a	a	a
	Stentor 1			b	b		a	a	a
	Stylonychia			a, d	c		a	a	a
Bacterivores	*Aspidisca*							a	a
	(*Amoeba*)						a		a
	(*Coleps*)						a		a
	Colpidium			c	a, c	a	a	a	a
	Colpoda sm.							a	a
	Colpoda lg.							a	a
	Halteria		a		d	a	a	a	a
	Gastrotrich sp.				a, d	a			a
	Microflagellates	(a)	a–d	a–d	a–d	a	a	a	a
	Monostyla			a	b		a	a	a
	P. bursaria				b		a	a	a
	Paramecium 2			d	a, d	a		a	a
	Rotaria			b	c	a		a	a
	Spirostomum				d	a		a	a
Predators	Heliozoa sp.				b			a	a
	(*Oxytricha*)				a		a	a	a
	Stentor 2				c	a	a	a	a
	(*Urostyla*)					a	a		a

Letters a, b, c and d indicate the species composition of up to four different communities within each level of biodiversity. Taxa in parentheses failed to become established. Letters in parentheses in the 0 species treatment indicate organisms that contaminated microcosms originally containing only bacteria. Three other contaminants occurred sporadically in other treatments (2 amoebae and *Ankistrodesmus* 2).



Replicated microcosms – able to separate effects of species richness and the set of species present


a
2,000
1,000
0
-1,000
-2,000
Cumulative CO_2 flux (µl per 18 h)
r^2 = 0.15
0
5
10
15
20
b
1,200
1,000
800
600
400
200
0
Standard deviation of CO_2 flux (µl per 18 h)
r^2 = 0.74
0
5
10
15
20
Realized species richness