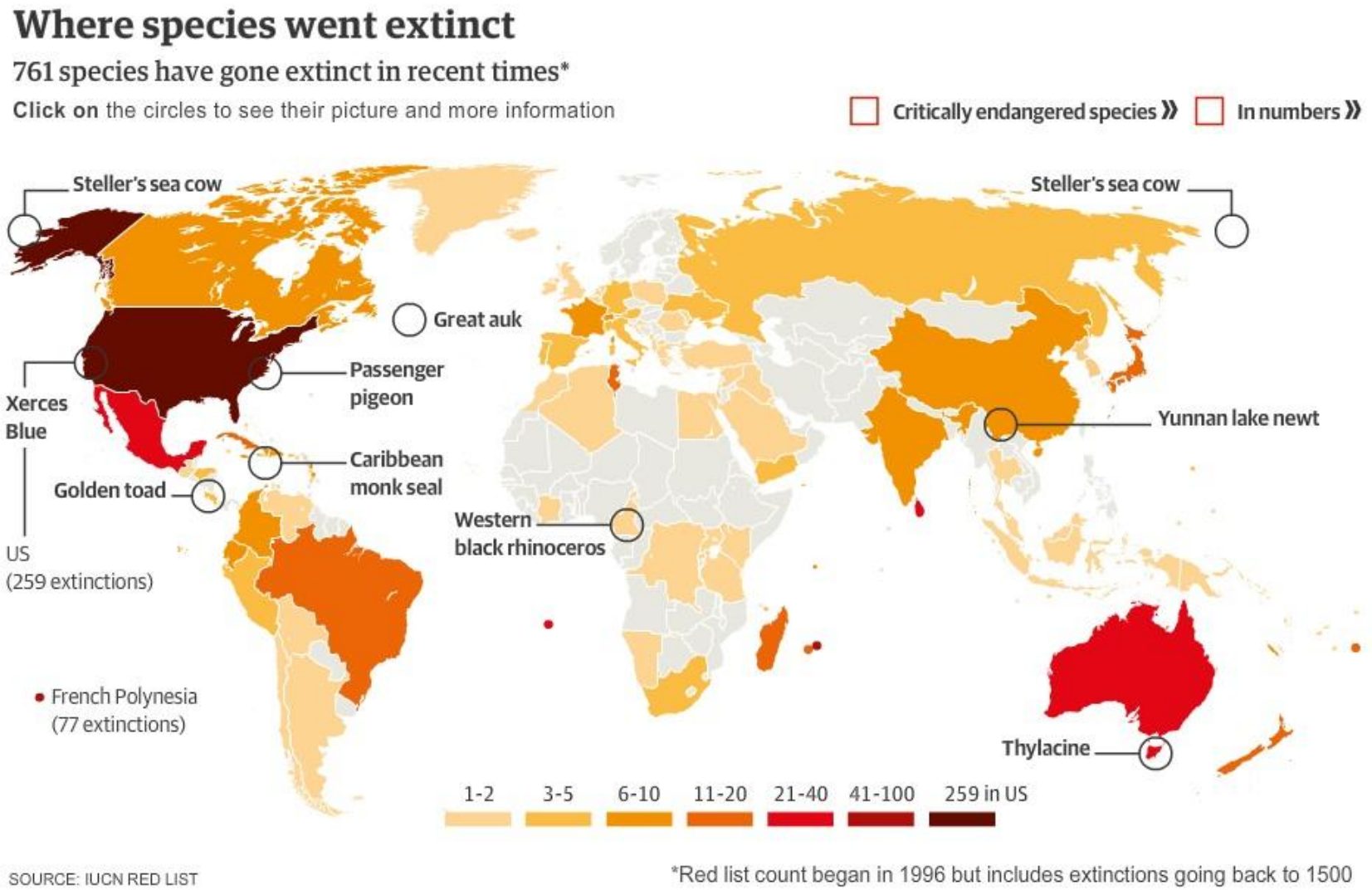
Quiz

What are the reasons why variability in productivity may decline with species richness?

a) Negative covariance
b) Overcompensation
c) Portfolio effect
d) Insurance effect

Biodiversity & Ecosystem Function

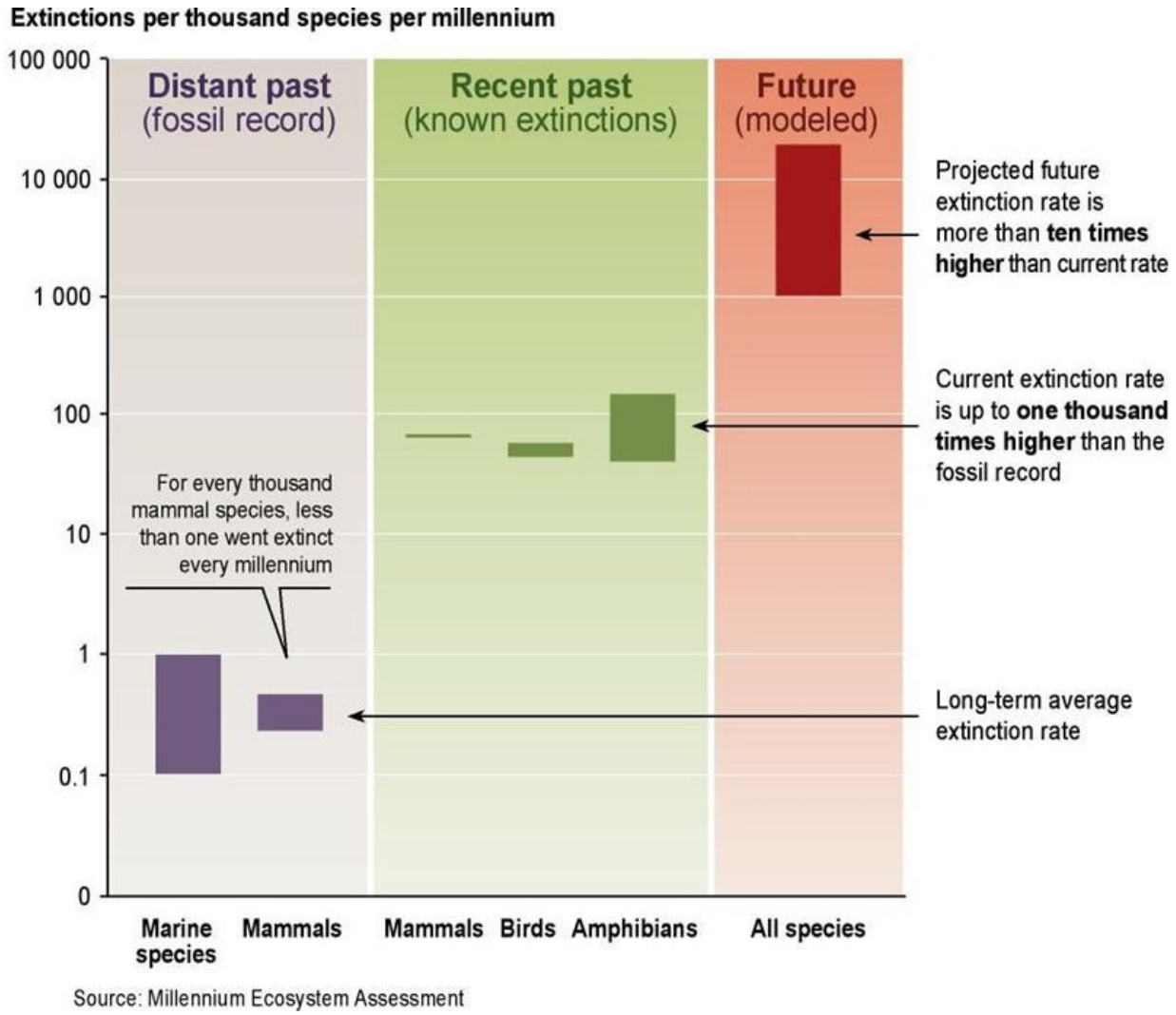
Distribution of species extinction since 1500



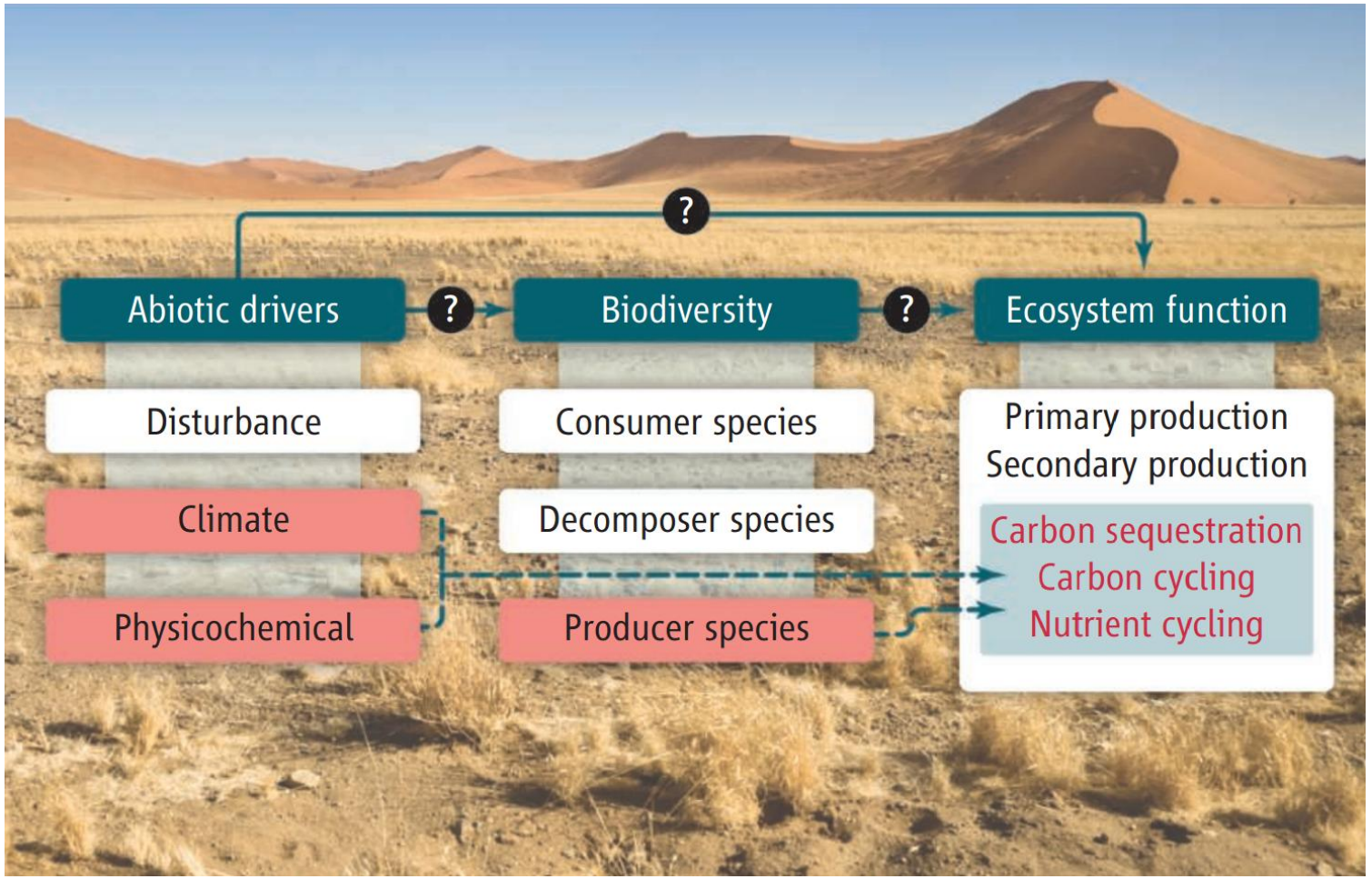
Rate of extinctions projected to increase

Millennium Ecosystem Assessment

- Historic rates estimated from fossil record
- Recent extinctions estimated from natural history literature
- Future extinction rates modeled using IUCN red list, species abundance distributions, and related techniques



What will be the consequences of this species loss for ecosystems?



Midgeley. 2012. Science 335:174

What is an ecosystem function?

- "Ecosystem functioning is a broad term that encompasses a variety of phenomena, including ecosystem properties, ecosystem goods, and ecosystem services"
  - Hooper et al. 2005. *Ecological Monographs* 75:3-35

- "An ecosystem fails when it ceases to provide the services or goods demanded of it. As with machines, the ecosystem does not have to collapse. For example, if a pond shifts from a desirable state as a net carbon sink to an undesirable state as a net carbon source (say, upon entering an anoxic state after eutrophication), the pond is still a functioning ecosystem, but it has failed in the sense that it no longer provides the original service desired of it.
  - Naeem, S. 1998. *Conservation Biology* 12:39-45

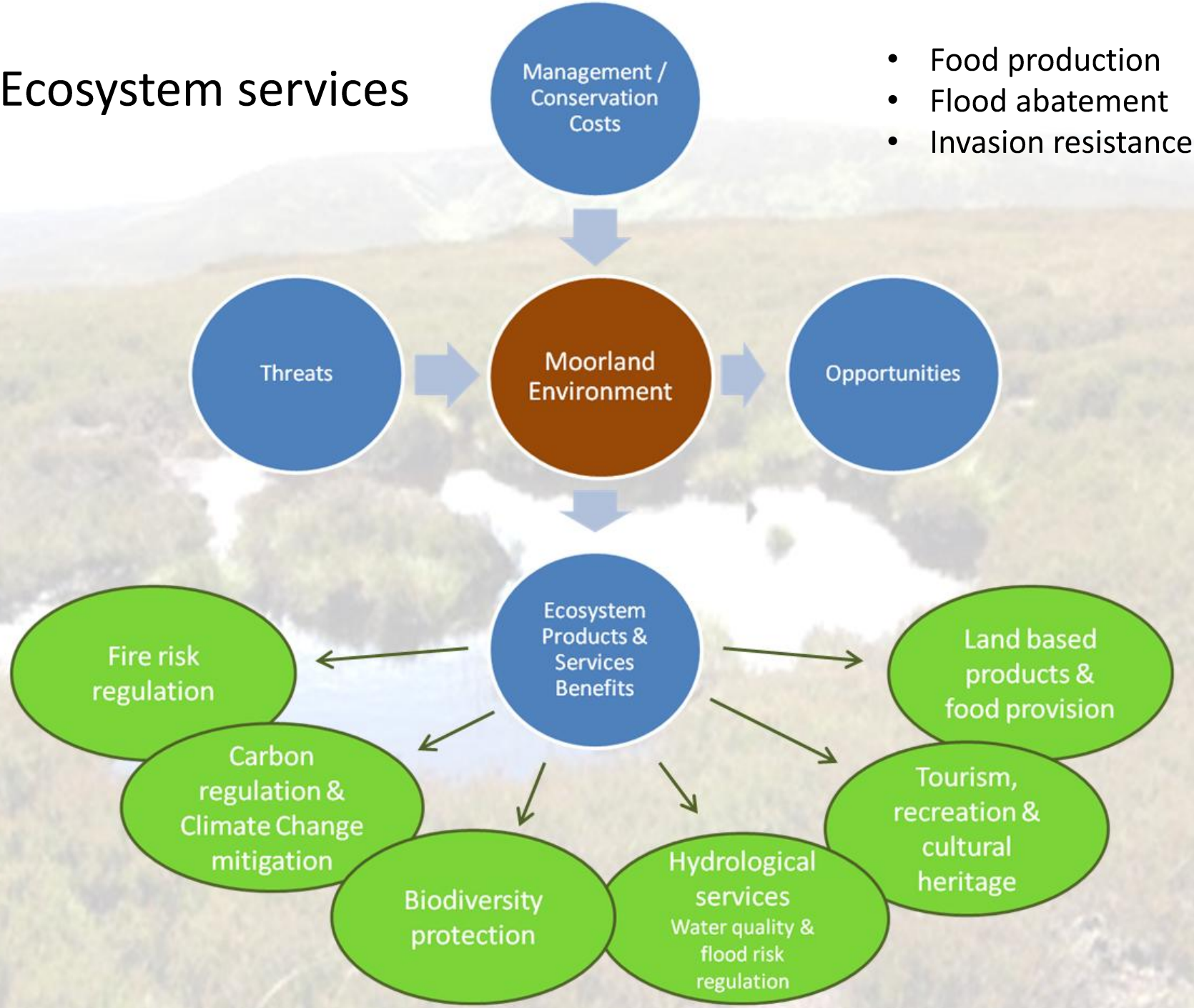
- "Ecosystem functioning reflects the collective life activities of plants, animals, and microbes, and the effects these activities—feeding, growing, moving, excreting waste, etc.– have on their environment. Note that "functioning" means "showing activity" and does not imply that organisms perform purposeful roles in ecosystem-level processes."
  - Naeem, S. et al. 1999. *Biodiversity and Ecosystem Functioning: Maintaining Natural Life Support Processes*. Ecological Society of America.

Ecosystem processes

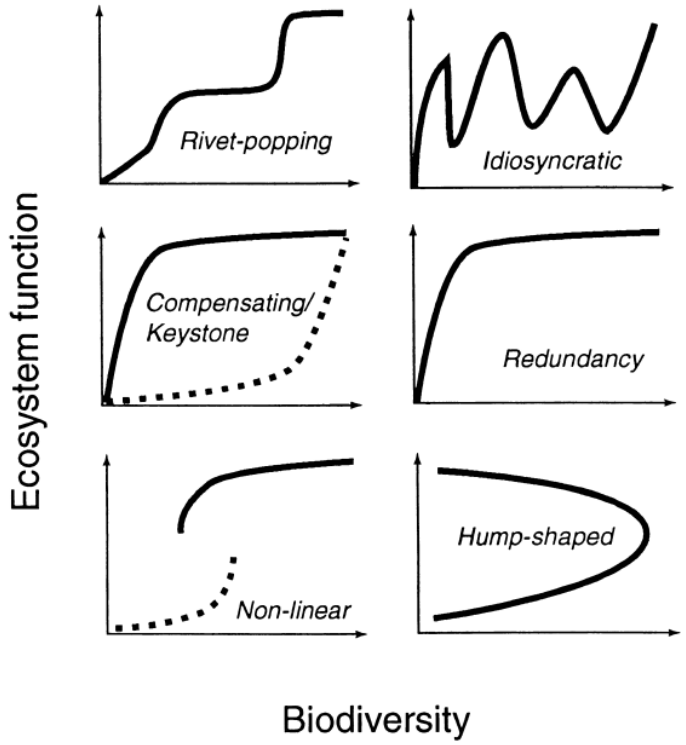
- Resource capture
- Energy transformation
- Material transformation
- Bioturbation
- Primary production
- Invasion resistance

Ecosystem services

- Food production
- Flood abatement
- Invasion resistance



Conjectural relationships between biodiversity and ecosystem process rates



Naeem, S. 1998. *Conservation Biology 12:39-45*.

Mechanisms underlying the biodiversity and ecosystem function relation

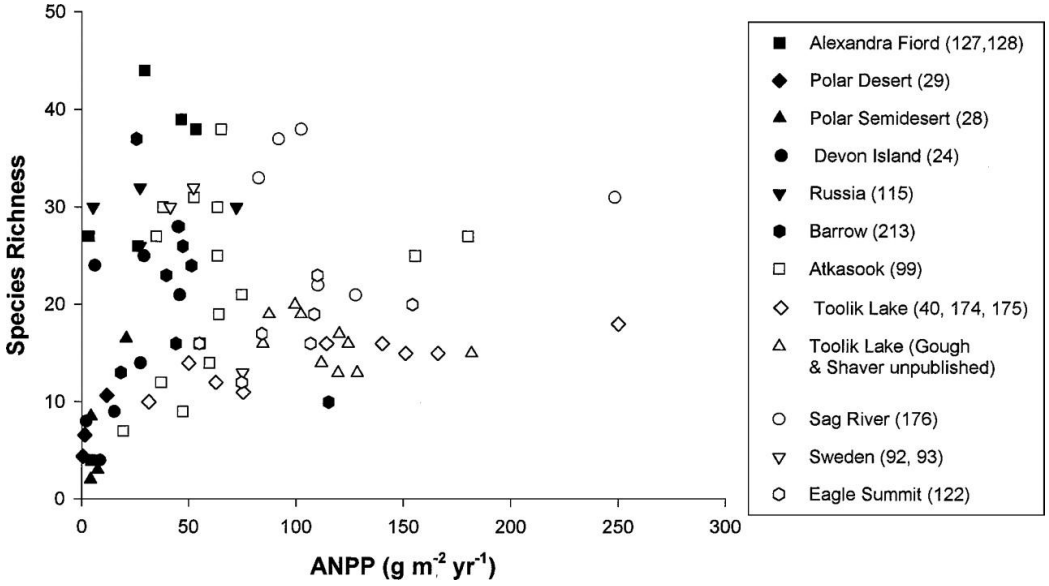
How do species' functional attributes aggregate in ecosystems?

- Functional differentiation
  - Niche complementarity
  - Facilitation
- Sampling effects
  - Statistical sampling: Increased probability that a community will contain highly functioning communities
  - Selection effects: Species with extreme trait values may contribute a dominant fraction of net ecosystem process
- Functional diversity
- Redundancy
- Resilience

Observational studies

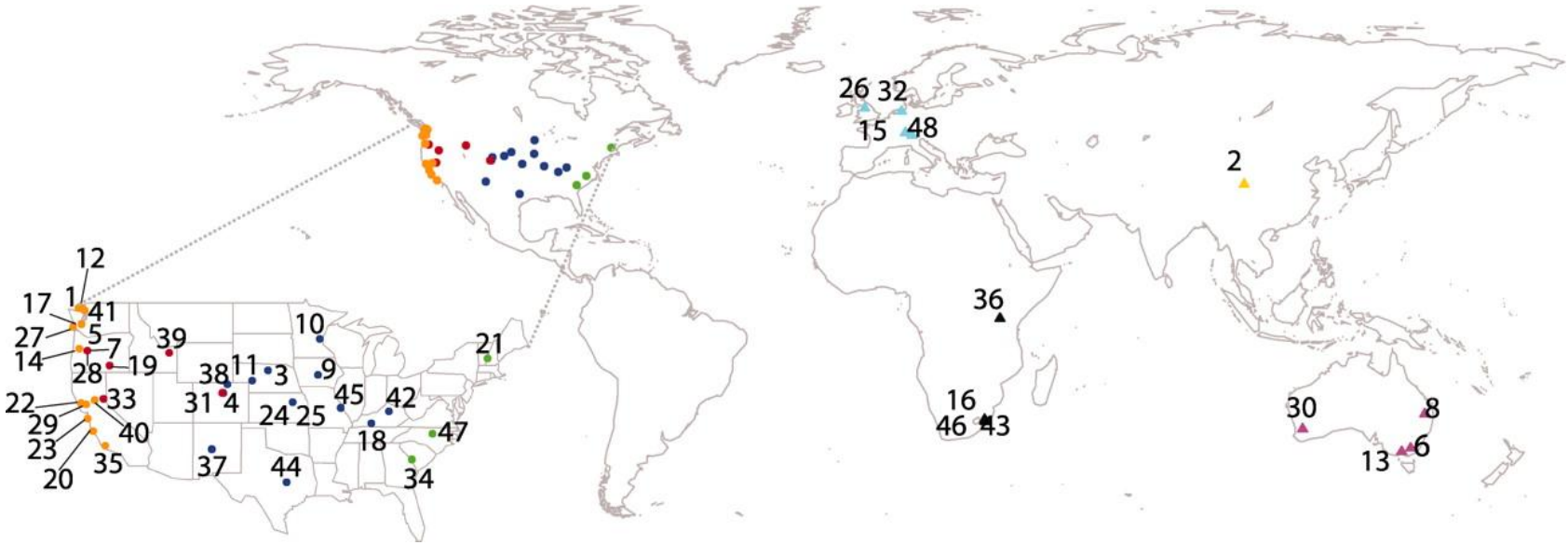
Are productivity and diversity related?

- Conjectured by Grime, Huston and others in the 1970s and empirically investigated through meta-analysis in the 1990s



Waide, R. et al. 1999. *Annual Review of Ecology, Evolution, and Systematics* 30:257-300

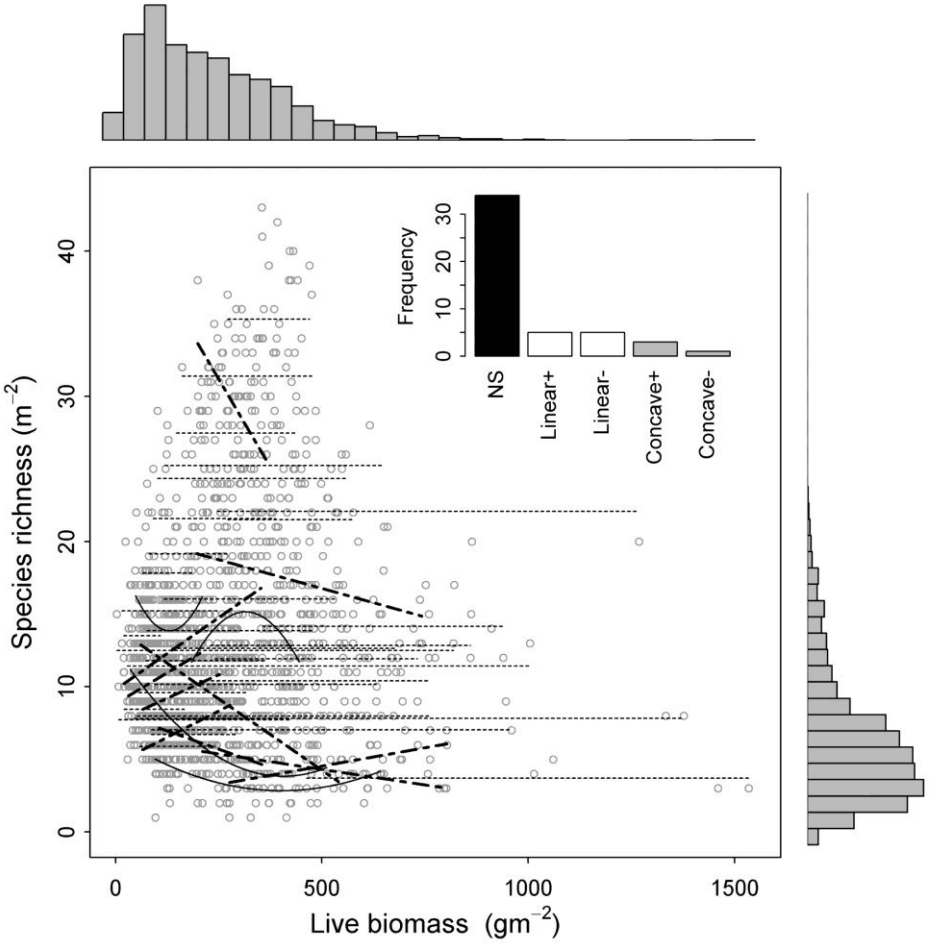
The Nutrient Network



Adler, P. et al. 2011. *Science* 333:1750-1753.


Nutrient Network site in Switzerland

The Nutrient Network



"We find no clear relationship between productivity and fine-scale (meters^{-2}) richness within sites, within regions, or across the globe."

Adler, P. et al. 2011. *Science* 333:1750-1753.

Experimental studies - In class exercise

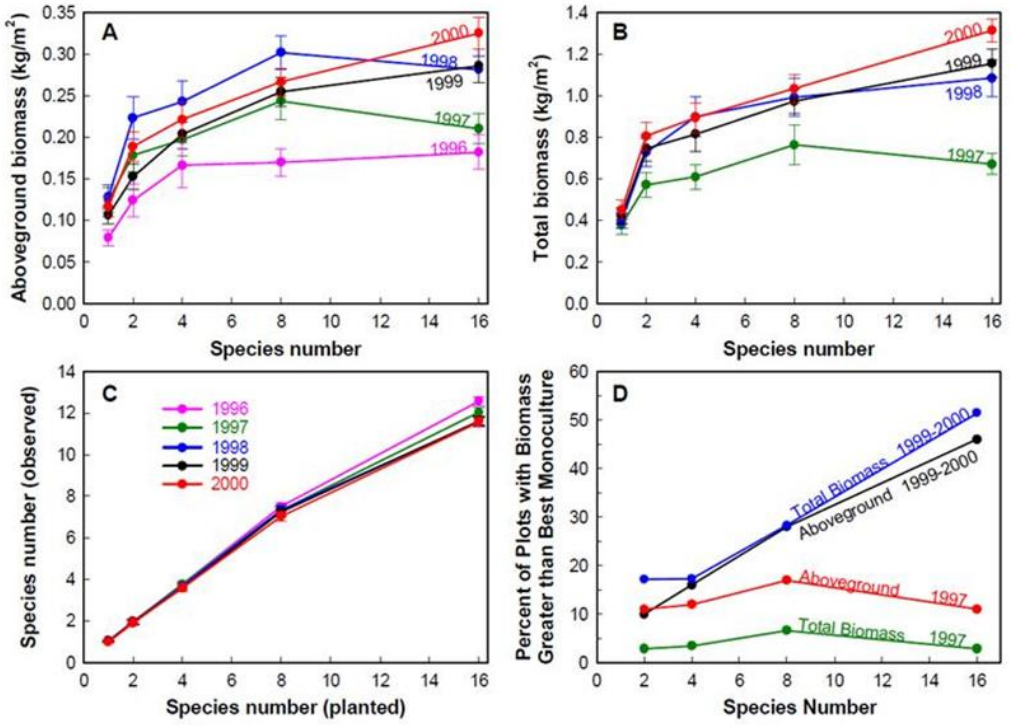
While providing important contributions to understanding how diversity and primary productivity are correlated, a problem with observational studies is that they are unable to disentangle cause and effect. In small groups, design an experimental study to determine if primary productivity changes with species diversity.

Cedar Creek Long Term Ecological Research Site

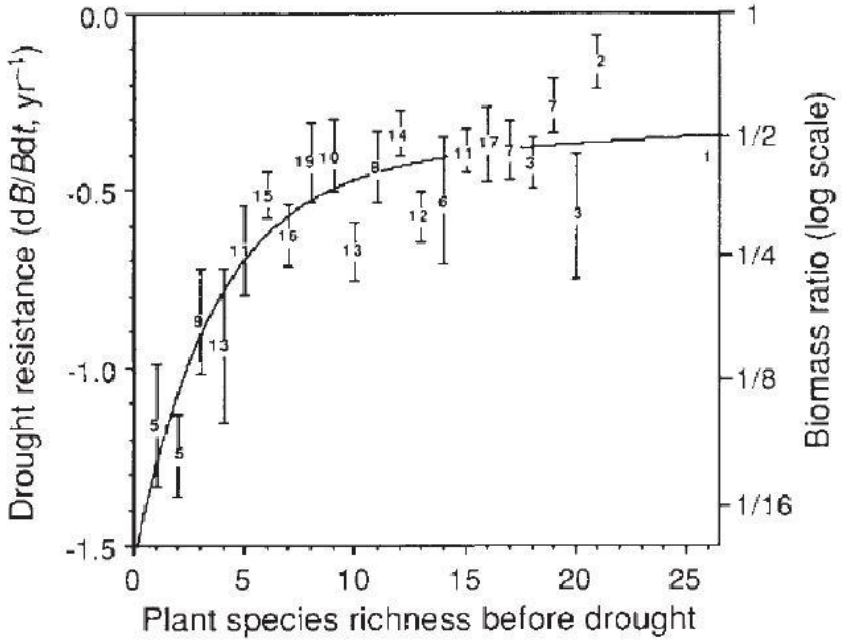
Long-term biodiversity plots

Cedar Creek Long Term Ecological Research Site

Productivity in long-term biodiversity plots

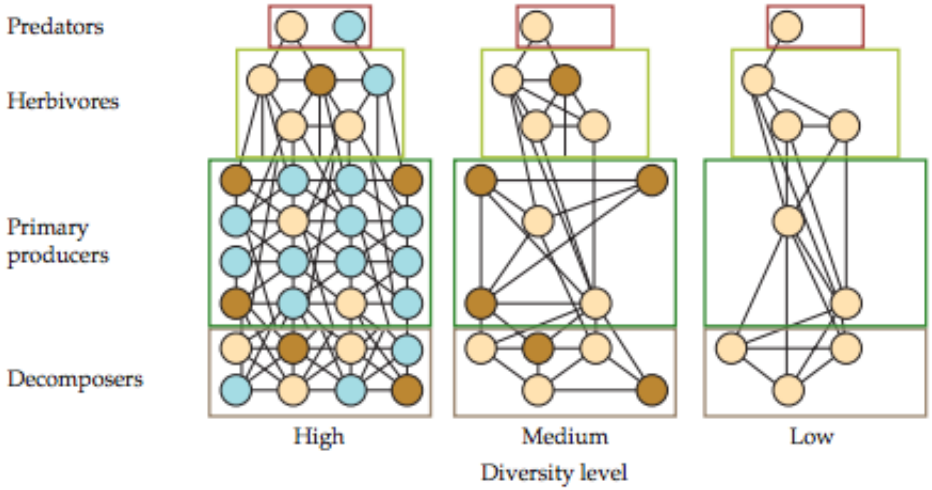


Cedar Creek Long Term Ecological Research Site



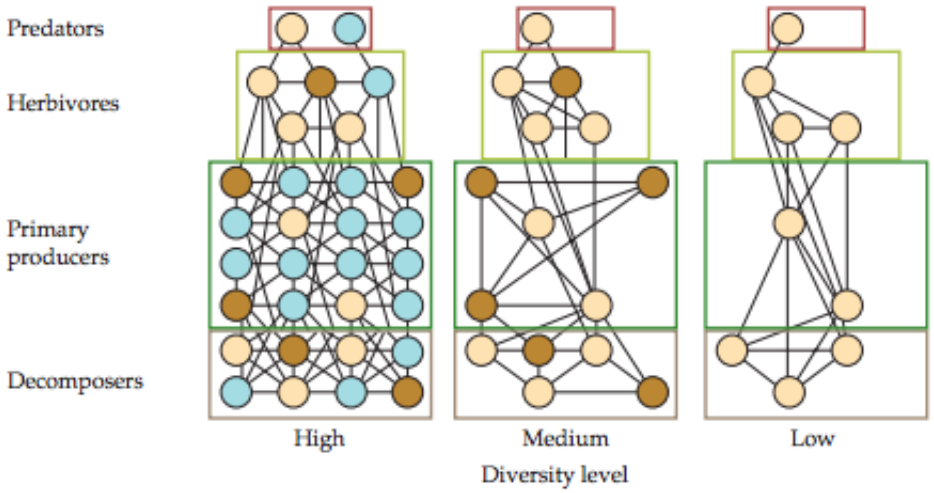
ECOTRON @ Silwood Park

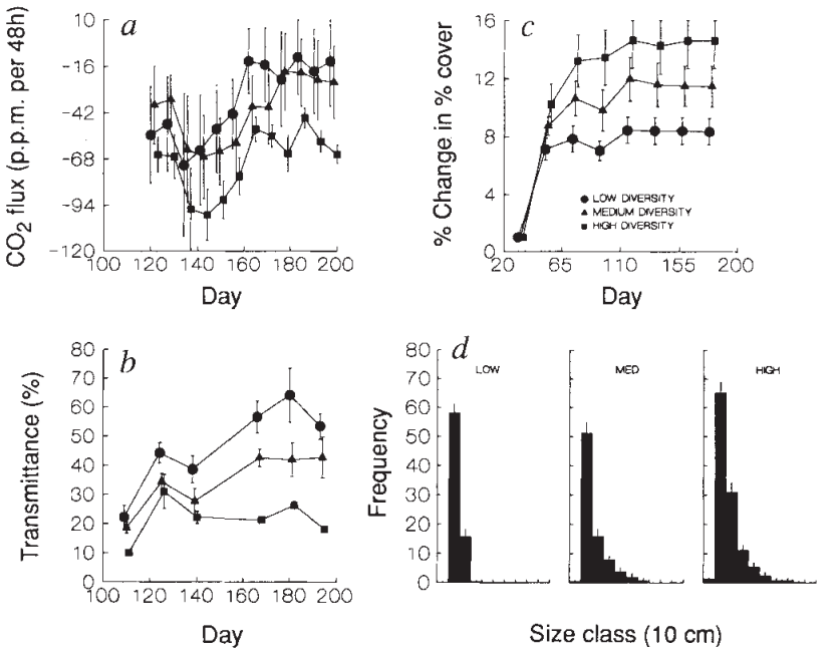
ECOTRON @ Silwood Park



Naeem, S. et al. 1994. *Nature* 368:734-737.

ECOTRON @ Silwood Park





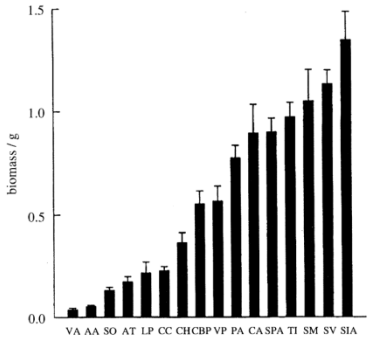
Increase in CO2 consumption (respiration rate)

Increase in primary productivity (e.g. photosynthesis)

Naeem, S. et al. 1994. *Nature* 368:734-737.

ECOTRON @ Silwood Park

← Least productive species – *Veronica arvensis*



Most productive species – *Sinapis arvensis* ↓

Ecosystem function	statistical analyses term	d.f.	f	*p*
1. community respiration	among[a]	2, 8	4.5	< **0.05**
	within	11, 88	0.2	NS
	interact	22, 88	2.7	< **0.001**
2. decomposition	among	2, 11	5.4	< **0.05**
short term, surface litter	within	1, 11	17.5	< 0.01
	interact	2, 11	2.9	NS
long term, below ground, wood	among	2, 11	0.6	NS
	within	3, 33	145.2	< 0.001
	interact	6, 33	0.8	NS
3. nutrient retention	among	2, 25	1.9	NS
available amonium	within	7, 175	74.7	< 0.001
	interact	14, 175	6.7	< **0.001**
available nitrate	among	2, 25	2.0	NS
	within	7, 175	1.5	NS
	interact	14, 175	1.8	< **0.05**
available total nitrogen	among	2, 25	2.6	NS
	within	7, 175	65.4	< 0.001
	interact	14, 175	6.2	< **0.001**
available phosphorus	among	2, 25	5.2	< **0.05**
	within	7, 175	129.6	< 0.001
	interact	14, 175	4.3	< **0.001**
available potassium	among	2, 25	9.9	< **0.01**
	within	7, 175	40.1	< 0.001
	interact	14, 175	3.9	< **0.001**
4. productivity[a]	among	2, 11	38.1	< **0.001**
	within	6, 66	402.5	< 0.001
	interact	12, 66	15.1	< **0.001**
5. water retention	among	2, 7	2.0	NS
	within	10, 70	8.1	< 0.001
	interact	20, 70	1.8	< **0.05**

Naeem, S. et al. 1995. *Philosophical Transactions of the Royal Society* 347:249-262.

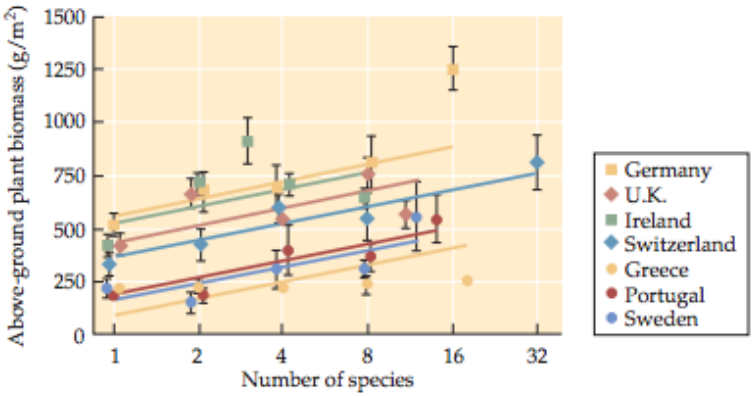
ECOTRON

Class discussion

- What have we learned from this study?
- What weaknesses does the study present?

BIODEPTH: Field site @ Silwood Park

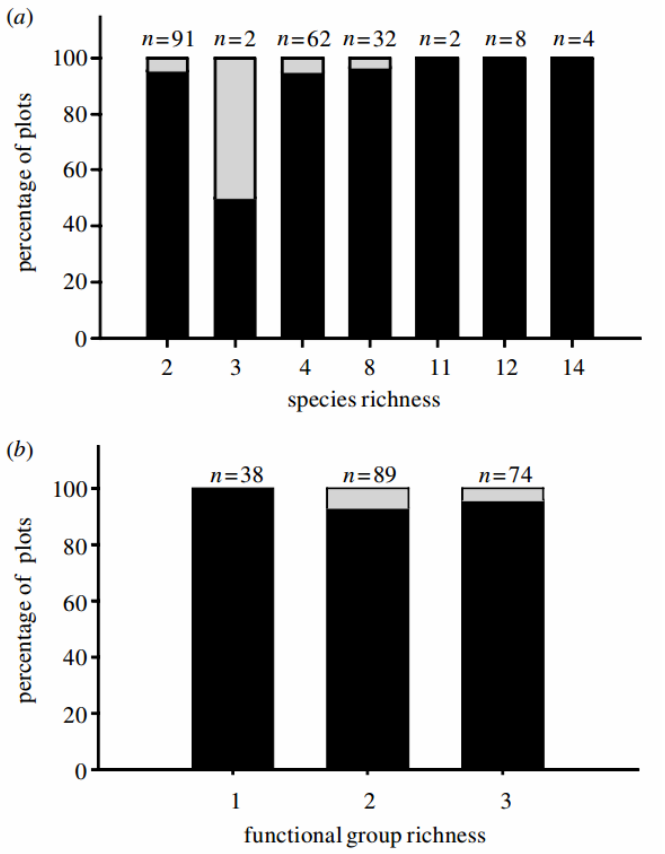
The BIODEPTH project showed that above ground primary productivity increased with species richness in random species assemblages across a large spatial extent

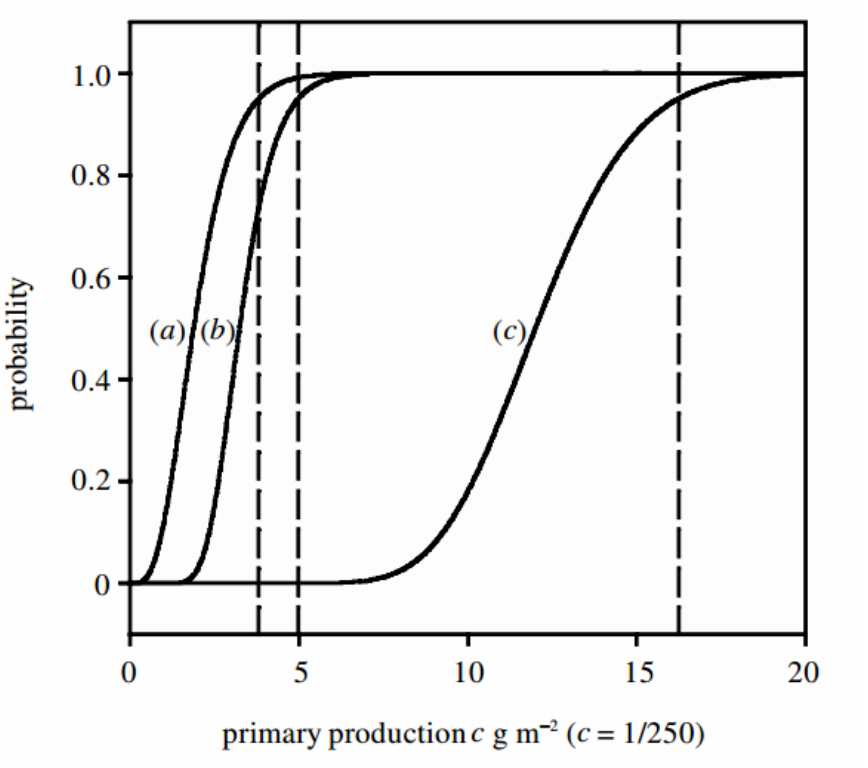


BIODEPTH: Testing for complementarity

A test for overyielding (complementary production) failed to detect any evidence for niche complementarity at either species or functional group level

Conclusion: the positive relationship between species diversity and primary productivity observed in the BIODEPTH experiment is probably due to sampling effects

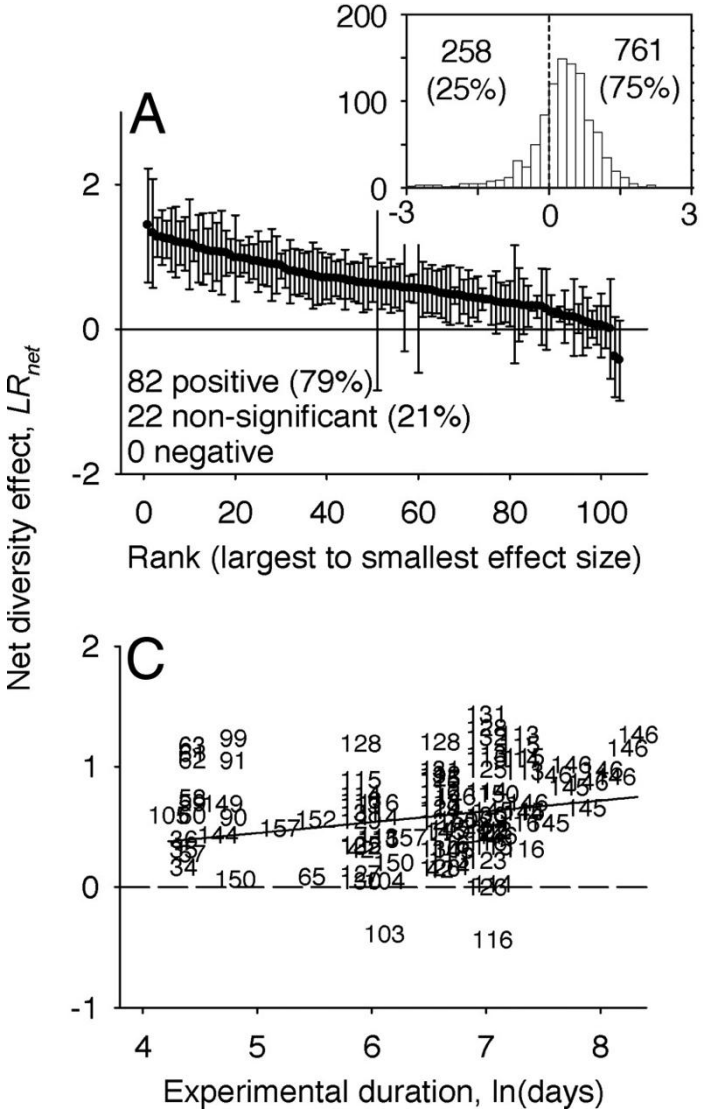




Drake, J.M. 2003. *PRSB* 270:1713-1719.

Meta-analysis

- A meta-analysis of 44 published experiments of plant species diversity and biomass production (Cardinale et al 2007 *PNAS*)
  - Polycultures produce more biomass than the mean of the same species in monocultures (82/104)
  - Productive species could produce more biomass than polycultures
  - No single species can produce more biomass than polycultures when a longer time span is considered.



Open questions

Summary

- “Ecosystem function” is a vague term that encompasses both ecosystem processes and evaluative societal judgments
- Net ecosystem process rates depend on the diversity of their constituent communities
- Mechanisms whereby species contribute to net rates are variable and difficult to disentangle but sampling effects appear to be common

Open Questions

- How do these fundamental properties affect the realized relationships in nature?
- How will non-random species loss affect functioning of natural and modified ecosystems?