Biodiversity and ecosystem functioning: Implications for the biosphere in a changing climate

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Importance of “vertical” diversity

Removal of sea otters

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Population explosion of sea urchins

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Overgrazing of kelp

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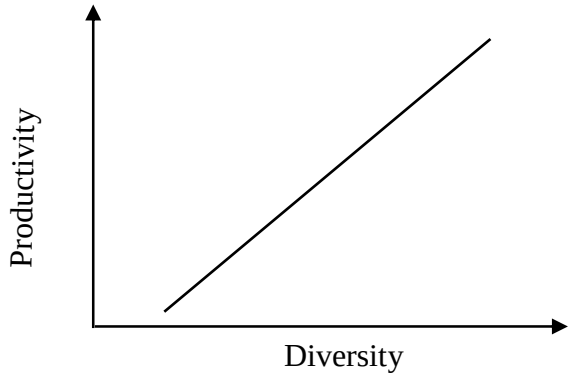
- Extinction of other species living in kelp
- Increased wave action, coastal erosion and storm damage
- Evolution of chemical defences in kelp

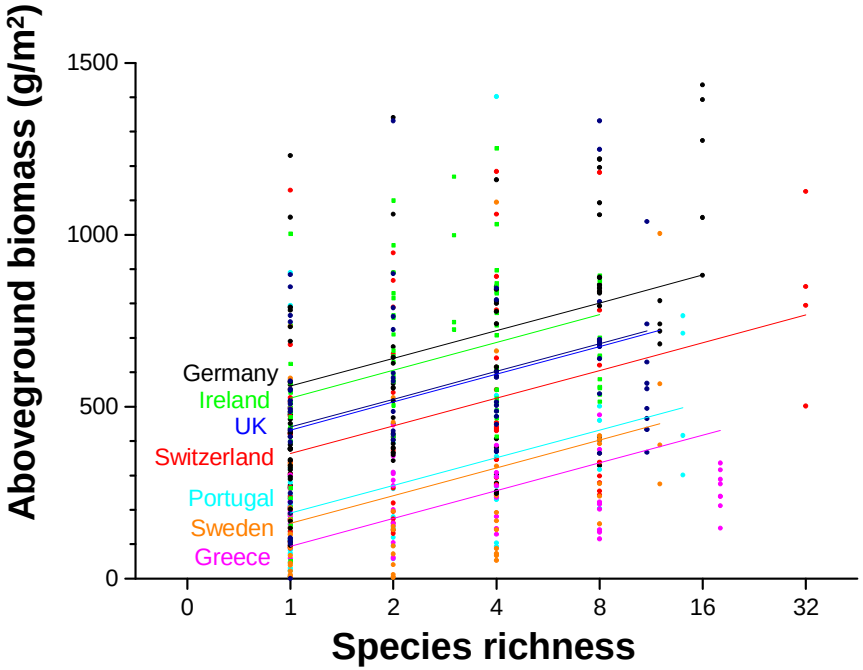
But what is the ecological significance of “horizontal” diversity?

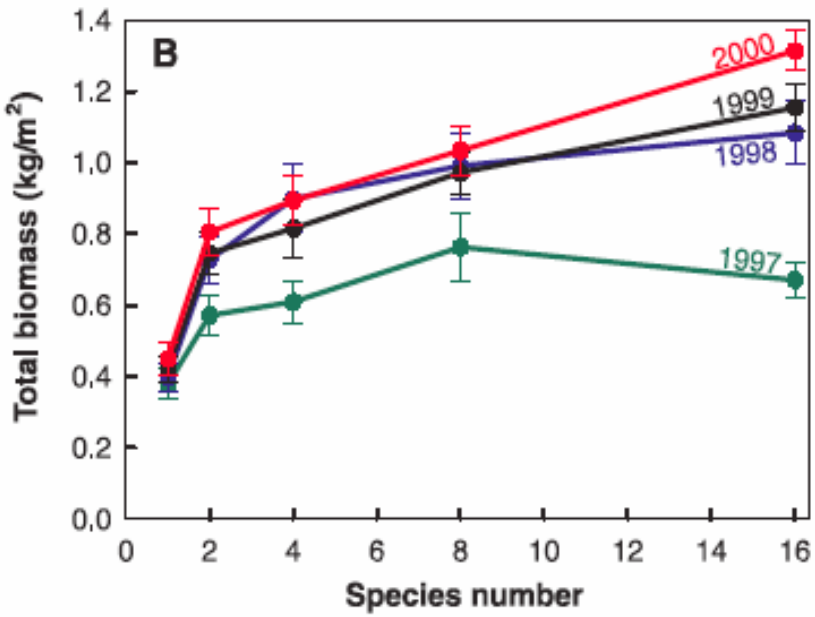
Neutral theory
Functional redundancy

Niche theory
Functional complementarity



Species diversity increases plant biomass production in grasslands





Hector et al., *Science* 286: 1123–1127 (1999)

Tilman et al., *Science* 294: 843–845 (2001)

Additive partitioning of biodiversity effects

$$\Delta Y = N.\overline{\Delta RY}.\overline{M} + N.\mathrm{cov}(\Delta RY, M)$$

Net effect — Complementarity effect — Selection effect

ΔY = deviation from expected yield of mixture

N = number of species

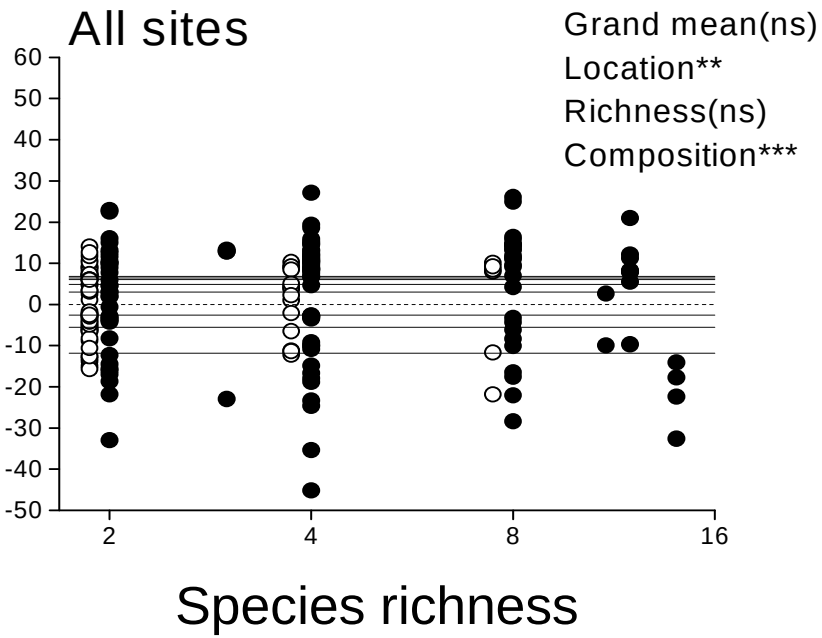
ΔRY_i = deviation from expected relative yield of species i

M_i = monoculture yield of species i

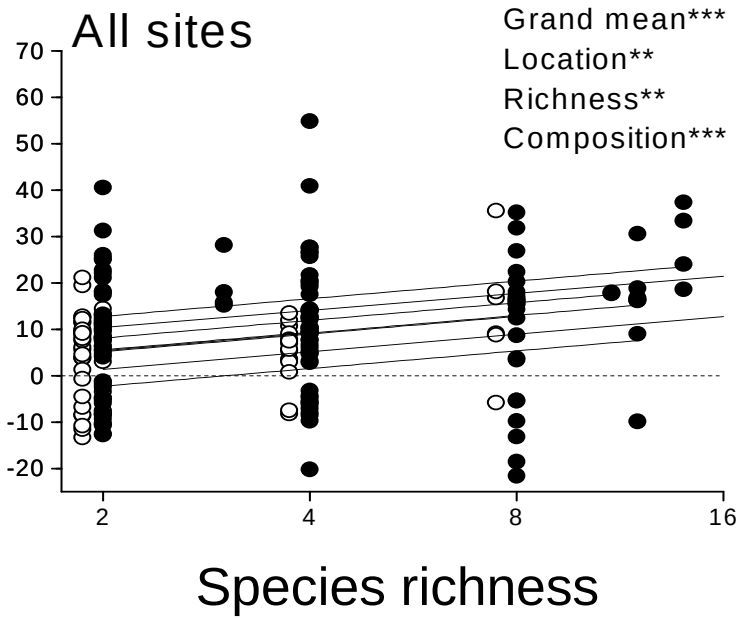
Loreau & Hector, *Nature* 412: 72–76 (2001)

Biodiversity effects on plant biomass production in a multisite experiment

Selection effect ($g^{1/2}/m$)



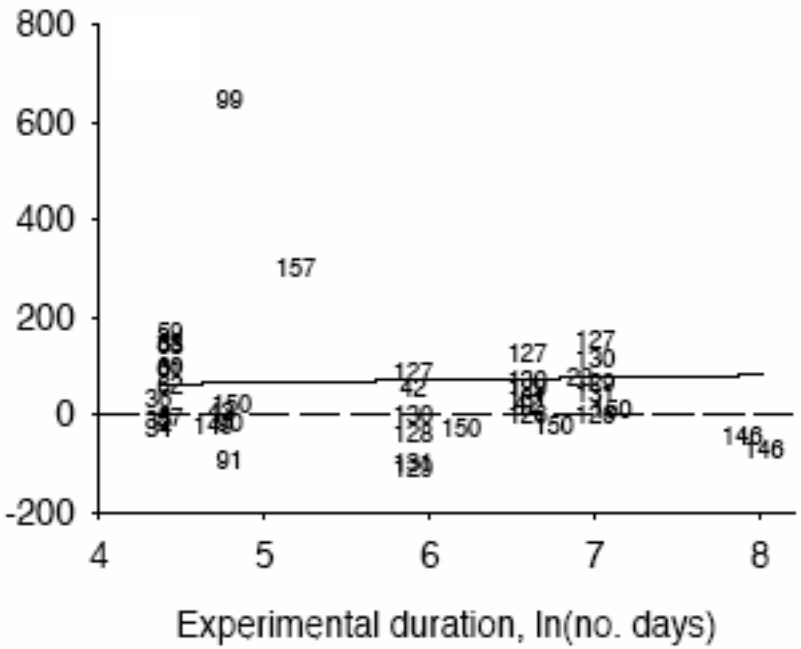
Complementarity effect ($g^{1/2}/m$)



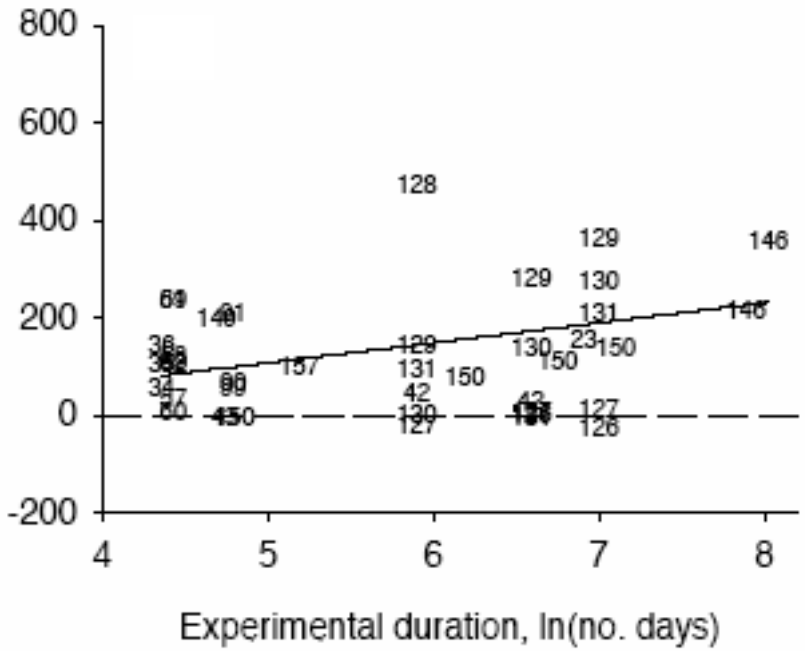
Loreau & Hector, *Nature* 412: 72–76 (2001)

Biodiversity effects on plant biomass production: A meta-analysis

Selection effect (g/m^2)

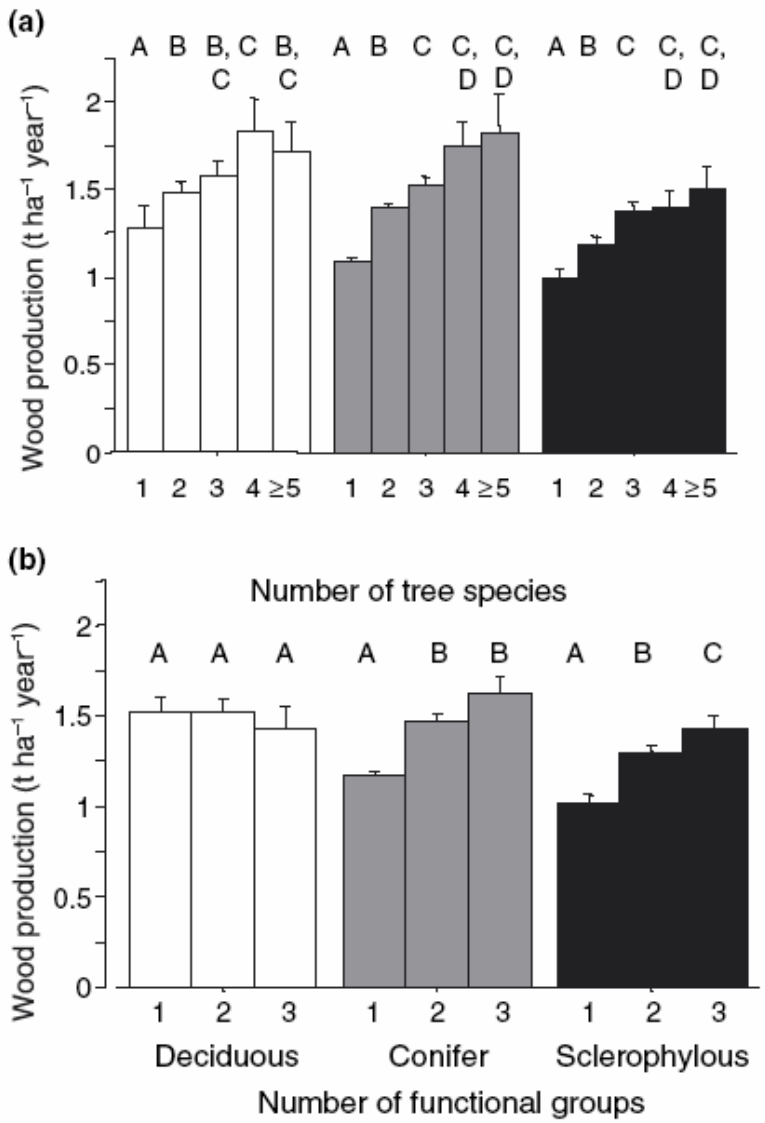


Complementarity effect (g/m^2)



Cardinale et al., submitted manuscript

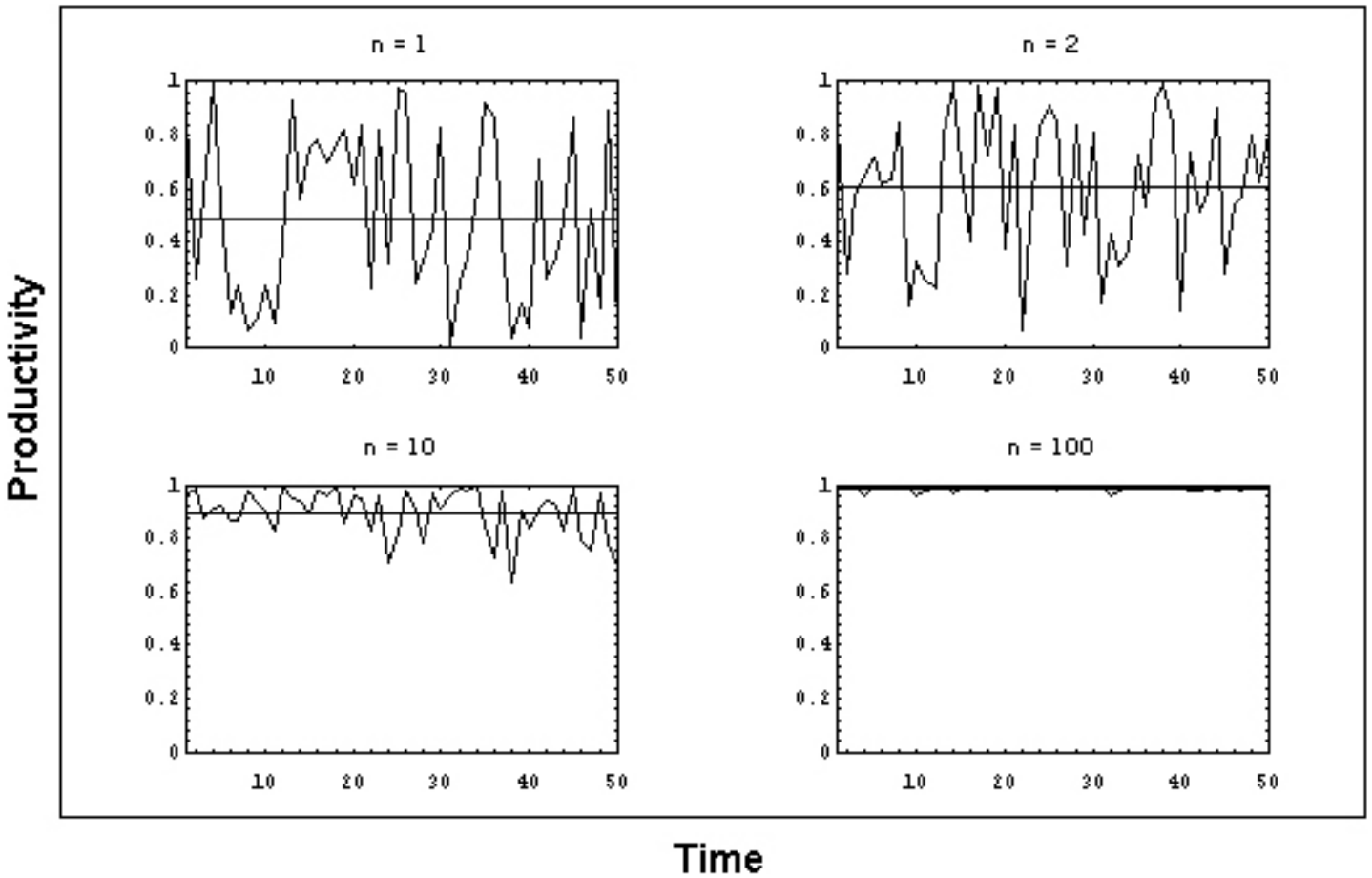
Biodiversity increases wood production in Mediterranean forests



⇒ Impact on carbon storage?

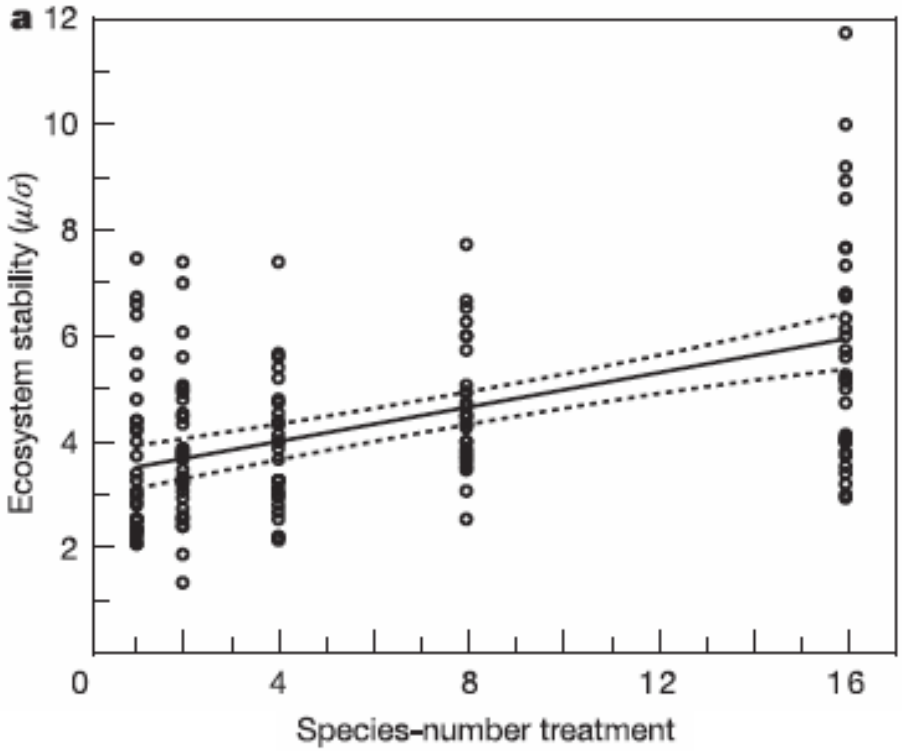
Vilà et al., *Ecol. Lett.* 10: 241–250 (2007)

Biodiversity as insurance against environmental changes



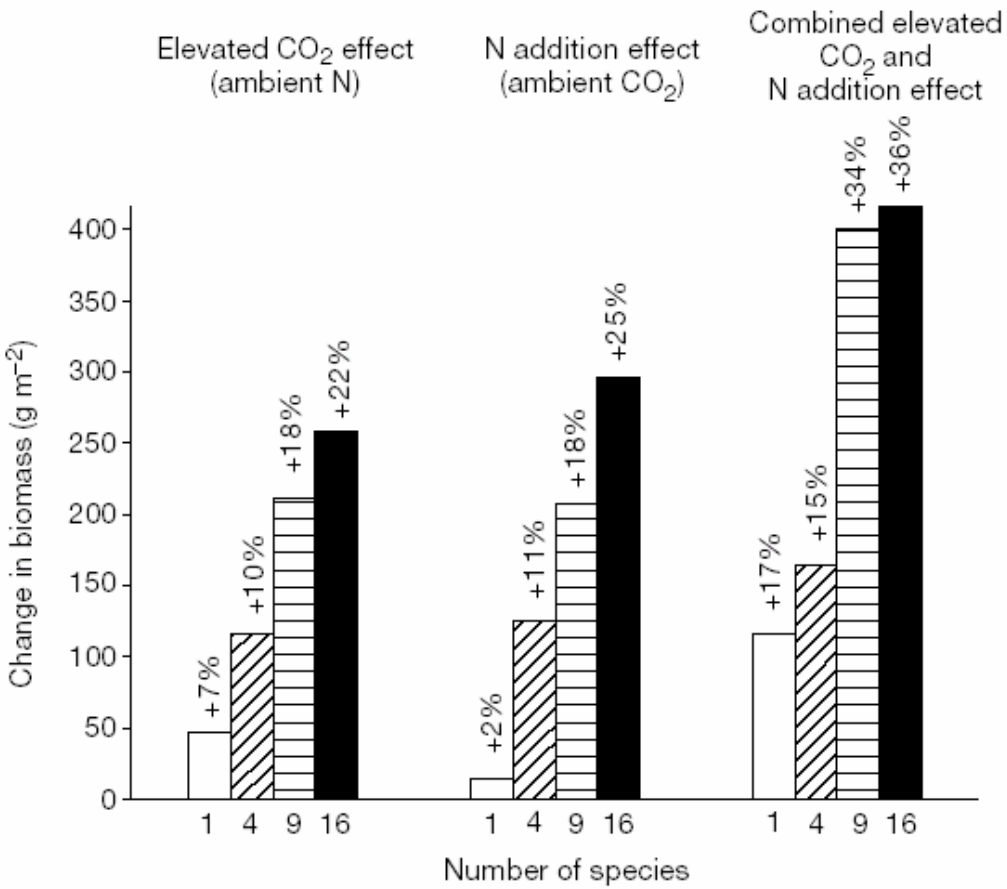
Yachi & Loreau, *PNAS* 96: 1463–1468 (1999)

Plant species diversity stabilises ecosystem processes in grasslands



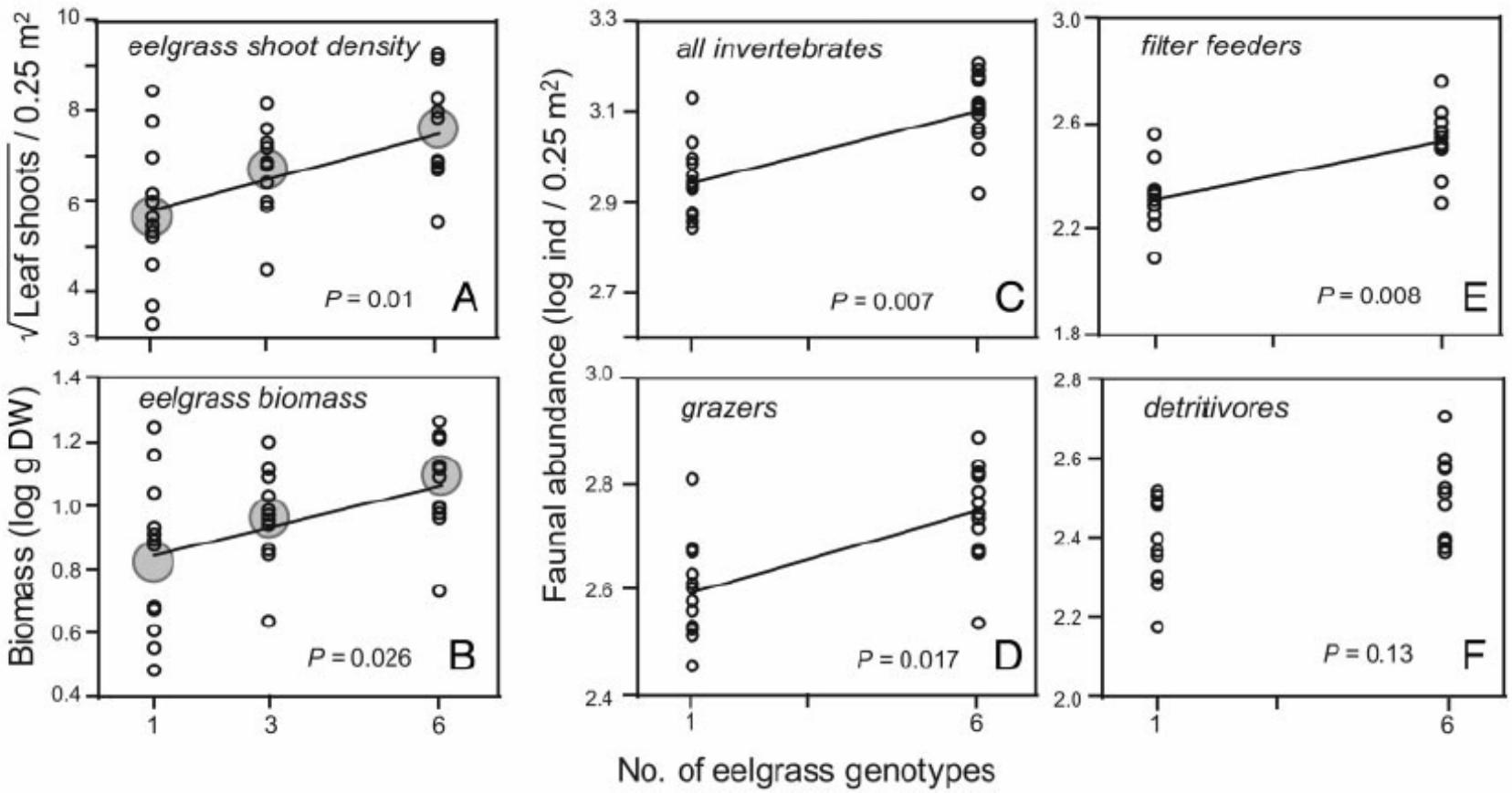
Tilman et al., *Nature* 441: 629–632 (2006)

Plant species diversity as a reservoir of adaptation to environmental changes



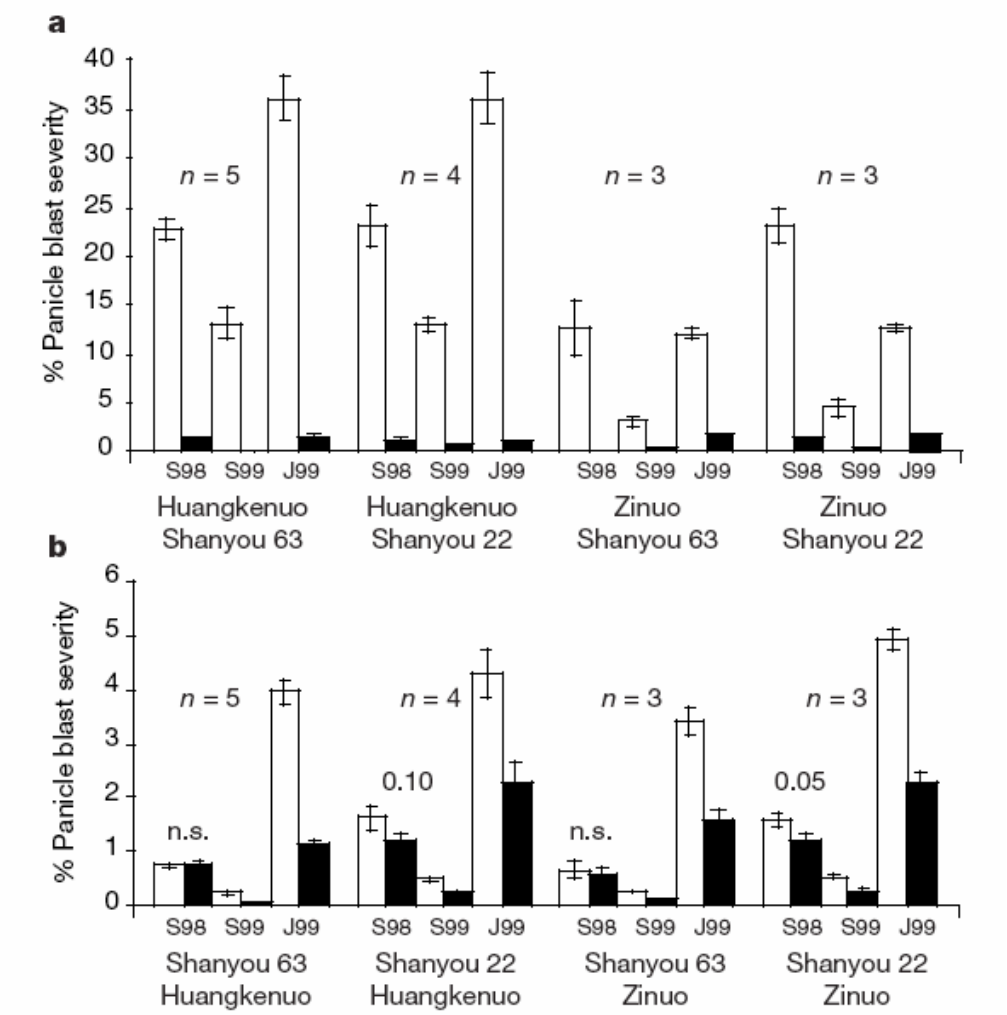
Reich et al., *Nature* 410: 809–812 (2001)

Plant genetic diversity buffers against extreme climatic events



Reusch et al., *PNAS* 102: 2826–2831 (2005)

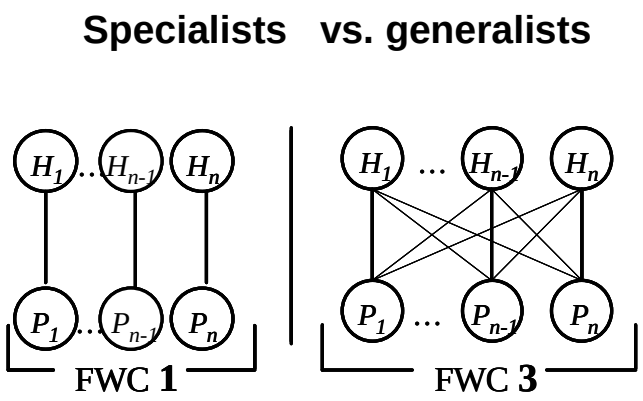
Genetic diversity increases rice resistance to blast disease

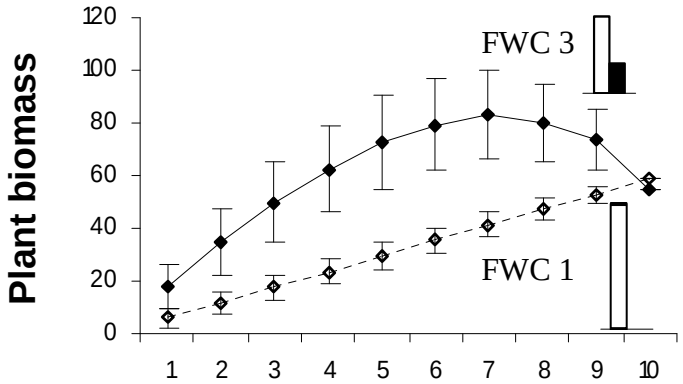


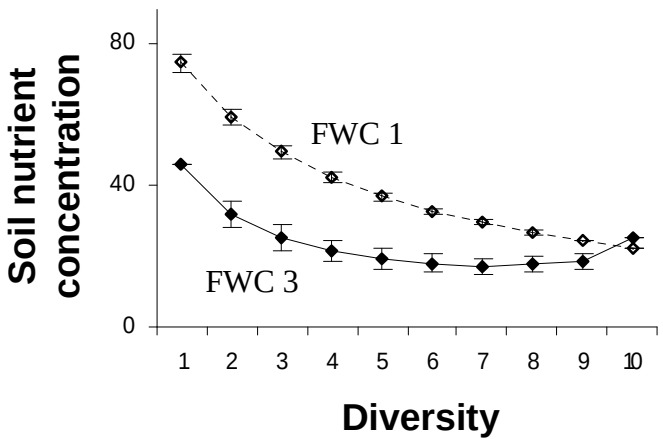
"Disease-susceptible rice varieties planted in mixtures had 89% greater yield and blast was 94% less severe than when they were grown in monoculture.
The experiment was so successful that fungicidal spray was no longer applied by the end of the two-year programme."

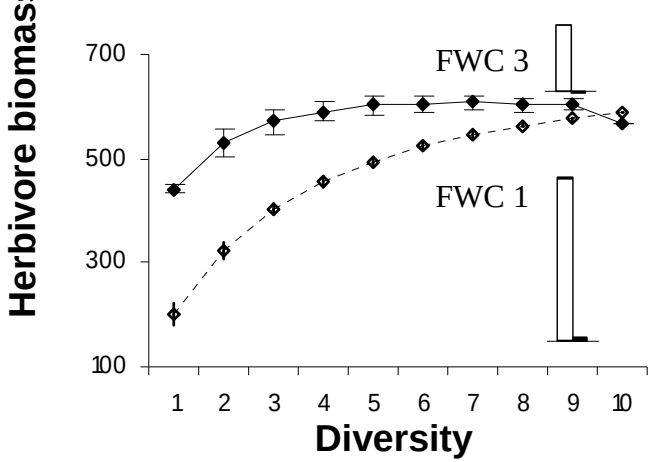
Zhu et al., *Nature* 406: 718–722 (2000)

Complex biodiversity–ecosystem functioning relationships in food webs









Thébault & Loreau, *PNAS* 100: 14949–14954 (2003)

Conclusions

- Biodiversity loss can have profound impacts on the functioning and stability of the natural systems upon which we rely directly and indirectly
- Species diversity enhances biomass production within a trophic level because of functional complementarity between species
- Species diversity stabilises ecosystem properties because of temporal complementarity between species
- Species and genetic diversity provide insurance against environmental changes, including changes in climate

Conclusions

- Trophic and non-trophic species interactions in complex interaction webs make biodiversity effects more complex and less predictable; they are potentially a major source of surprises and uncertainty in a changing climate