

# Biodiversity & Ecosystem Function

- Objectives:
  - Biodiversity and Ecosystem Function Paradigm (BEFP)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Paradigm
  - Does biodiversity correlate with ecosystem function?
    - Explosion of research in past ~10-15 years
      - Has not been a terribly friendly debate
        - » “...acrimonious tone includes questioning the ethics of scientific publishing houses that have published BEFP papers, questioning peer review, and questioning the integrity and motivation of the scientists promoting the BEFP” (Naeem 2002)
  - Widespread loss of biodiversity → concern over the impacts of this loss on ecological integrity and ecosystem function
    - How will biodiversity loss (in natural systems) impact ecosystem processes, goods, and services?
      - » “Earth is currently in the midst of the 6<sup>th</sup> major extinction event...”
      - » “...ecosystems collectively determine the biogeochemical processes that regulate the Earth system...”

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
    - Original community-focused paradigm (CTCE)
      - Central Thesis of Community Ecology (CTCE)
        - Excludes a strong role for biodiversity in determining ecosystem processes
      - Biodiversity is a function of abiotic (physical and chemical conditions) & biotic factors (interactions among species)
        - Abiotic factors set regional patterns in distribution & abundance
        - Biotic factors secondarily modify regional patterns
- $$S = f(\mathbf{d}, \mathbf{B}, \mathbf{e}, \mathbf{A}, \varepsilon)$$
- where  $S$  = biodiversity,  $\mathbf{d}$  = species density,  $\mathbf{B}$  = biotic interactions,  $\mathbf{e}$  and  $\mathbf{A}$  = abiotic conditions, and  $\varepsilon$  is a term that incorporates stochastic processes, chance events, and nonlinear processes

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - New ecosystem-focused paradigm (BEFP)
    - CTCE emphasized abiotic env. (& biotic interactions)
      - “*biodiversity appears to be largely a slave of the environment*”
    - But ecosystem processes (energy input, productivity, etc.) have long been recognized to modify how biotic interactions structure communities
    - In a BEFP world:

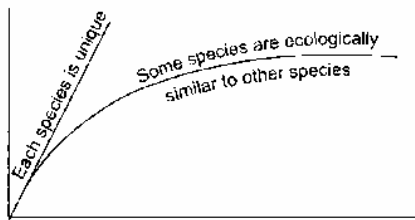
$$F = f(\mathbf{d}, \mathbf{B}, \mathbf{f}, \mathbf{P}, \mathbf{e}, \mathbf{A}, \varepsilon)$$

where  $F$  (an ecosystem function) is a function of biodiversity ( $\mathbf{d}, \mathbf{B}$ ), biogeochemical processes ( $\mathbf{f}, \mathbf{P}$ ), the abiotic environment ( $\mathbf{e}, \mathbf{A}$ ), and  $\varepsilon$  (stochastic processes, chance events, and nonlinear processes)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Does biodiversity correlate with ecosystem function?

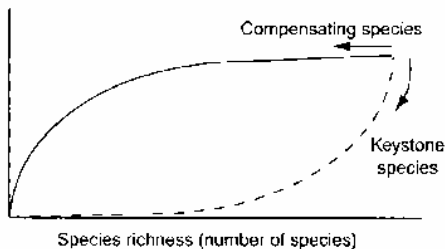
A. Effect of species number



B. Effect of species abundance



C. Effect of species type



- Often expressed as functional (not taxonomic) diversity

- » A functional type/group is a group of species that is similar with respect to their impacts on community or ecosystem processes
- » Trophic groups
- » C<sub>3</sub> vs. C<sub>4</sub> vs. leguminous forbs vs. non-leguminous forbs
- » Redundancy vs. singularity (biological insurance), dominance vs. rarity, keystone vs. compensating species, etc.

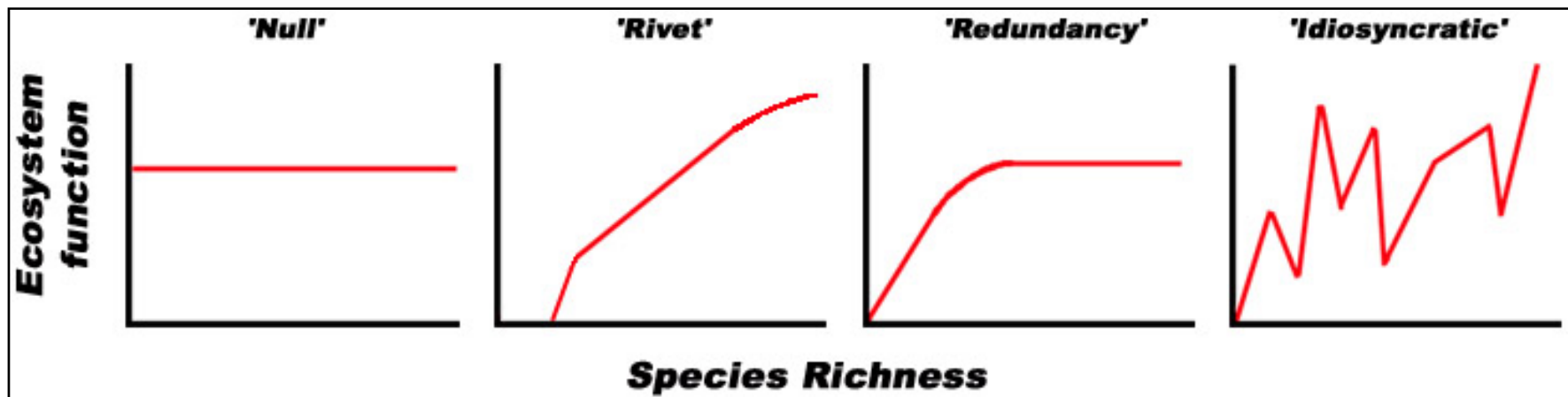
(Chapin et al. 2002)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Does biodiversity correlate with ecosystem function?
    - Ecosystem Function
      - Biogeochemical principles are at the core of BEFP
        - » Cycling of materials back & forth from organic to inorganic forms
        - » Organisms greatly accelerate biogeochemical cycles
      - Productivity (NPP)
        - » In annual and herbaceous perennials, peak aboveground biomass  $\approx$  current year's aboveground productivity
        - » ANPP vs. BNPP vs. TNPP
      - Variability, predictability, and reliability of function just as important, if not more so, than magnitude of function

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Does biodiversity correlate with ecosystem function?
    - Biota have strong effects on ecosystems
      - Alter interactive controls → regulate ecosystem processes
    - Does diversity have strong effects on ecosystems?
    - Several working hypotheses



# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - What is the mechanism(s) behind a biodiversity / ecosystem function correlation?
    - Complementarity (deterministic processes)
      - E.g., niche differentiation, facilitation, etc.
        - » Increases performance above that expected from monocultures
    - Sampling Effect (stochastic processes)
      - Systems that include many species have a higher probability of containing the one (or few) highly productive species

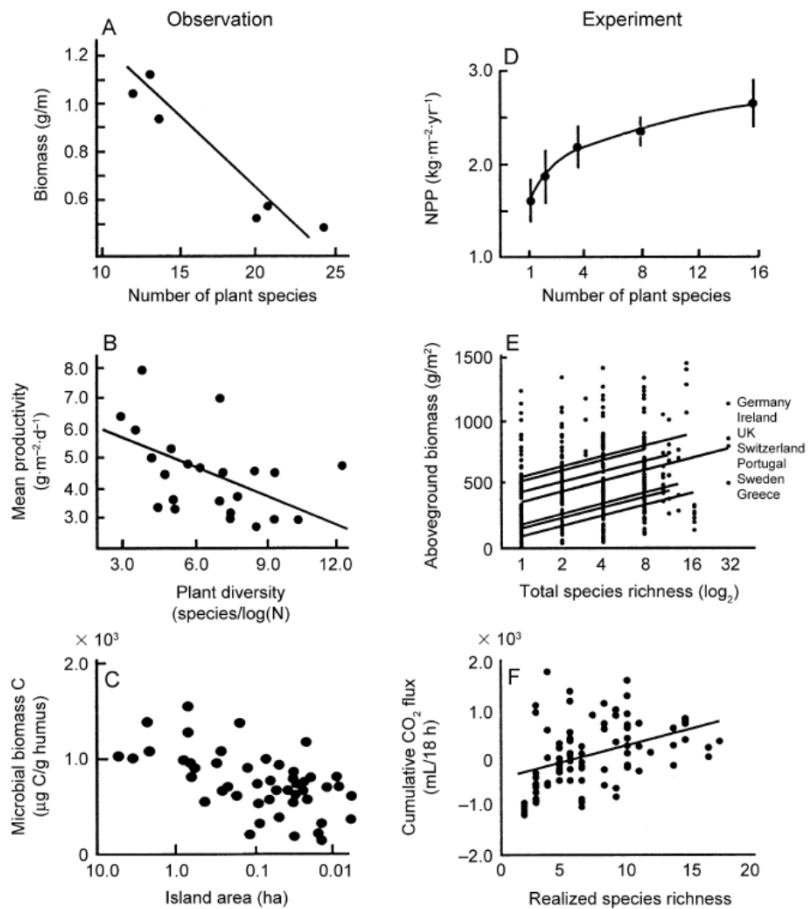


# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate

- Studies to date indicate that there is a correlation, but that it is opposite in sign for obs. vs exp. studies

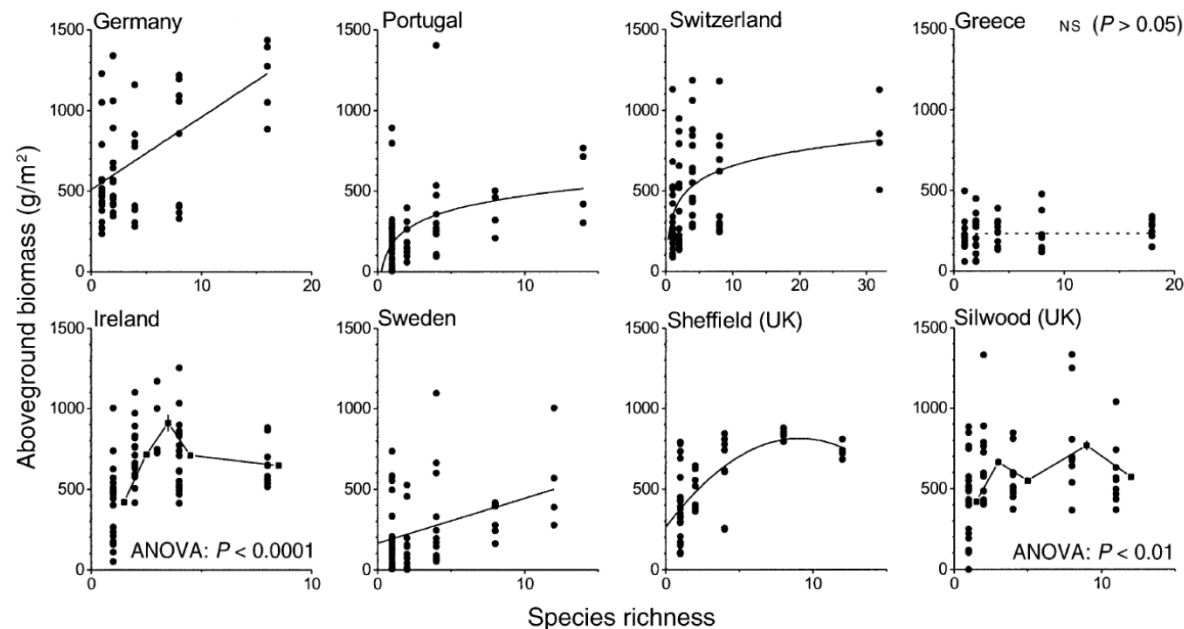
- Regional studies unable to separate diversity effects from covarying effects (climate, substrate, etc.)



(Naeem 2002)

# Biodiversity & Ecosystem Function

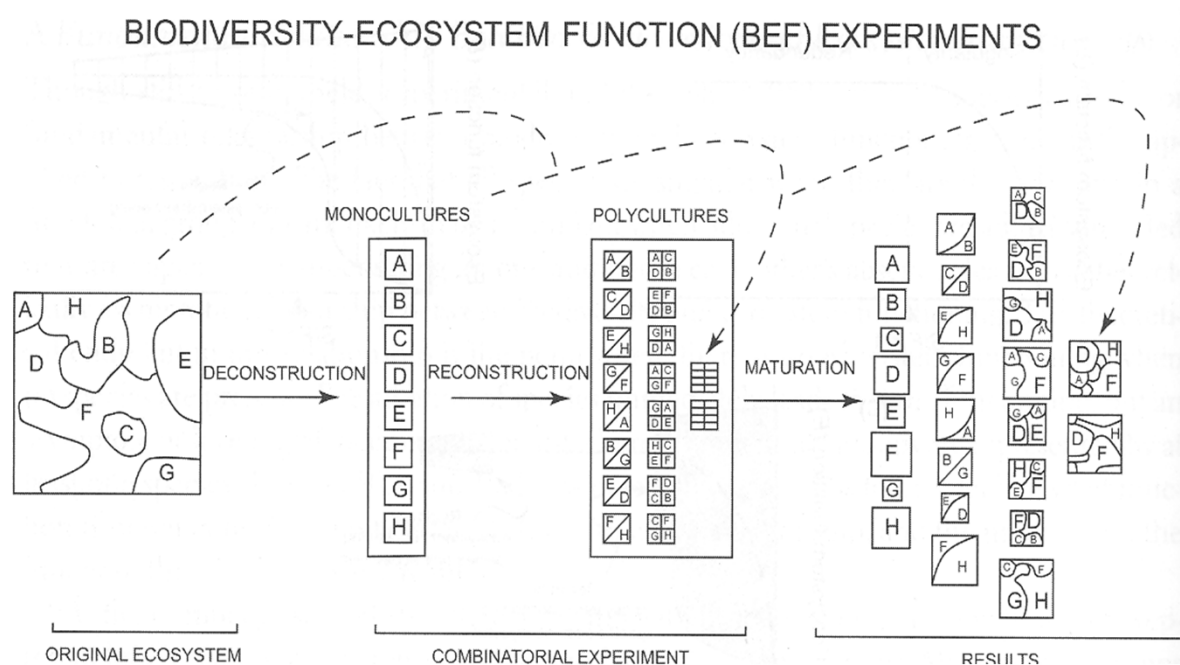
- Biodiversity & Ecosystem Function Debate
  - Exp. studies to date indicate that there is a correlation, but that it is not universal
    - Redundancy hypothesis has the most support
    - Sampling effect evident in all studies; Important?



(Hooper et al. 2005)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Most studies have been in highly controlled settings
    - Combinatorial experiments inherent in BEF studies
      - BEF aims to deconstruct and then construct ecological systems



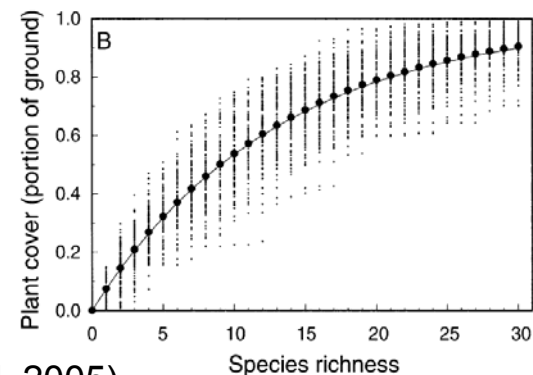
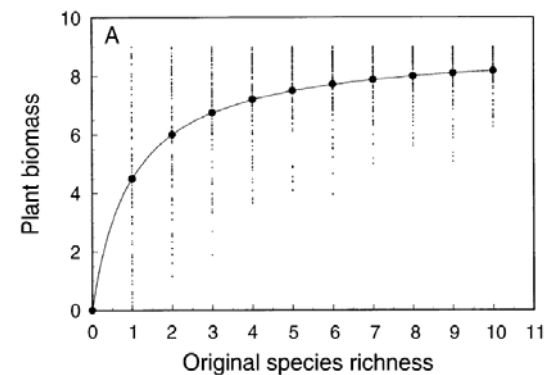
(Naeem 2006)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Addressed largely with the use of artificial microcosms
    - Small plots of grasses & forbs where species richness is manipulated
    - Two possible mechanisms
      - Sampling (Selection effect)
      - Biological effect



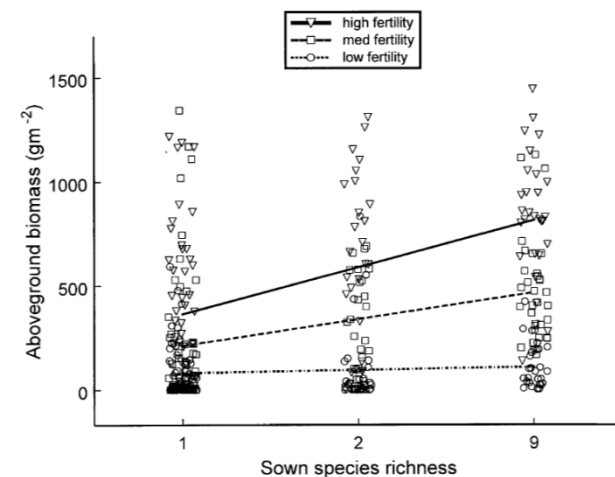
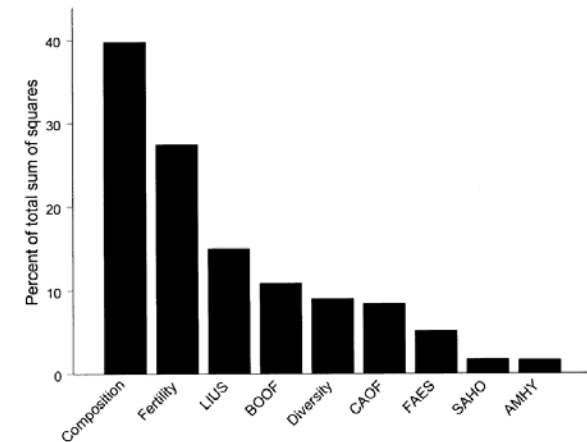
Cedar Creek LTER



(Hooper et al. 2005)

# Biodiversity & Ecosystem Function

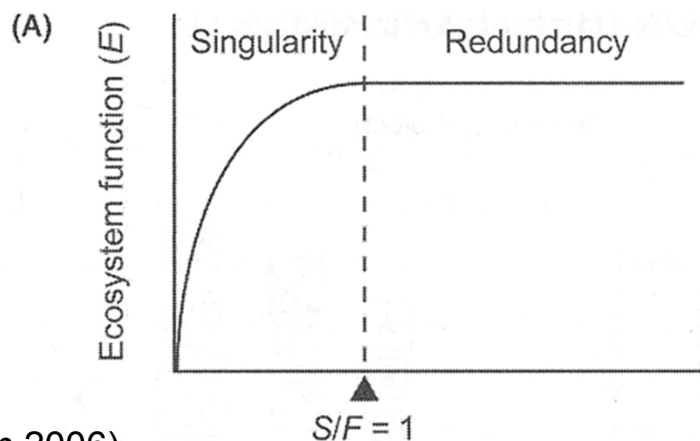
- Biodiversity & Ecosystem Function Debate
  - One key seems to be how species impact resource avail. (or vice versa)
    - Provides a biological mechanism
    - Resource availability controls both diversity & function in natural systems
    - Resource use efficiency & total resource supply important



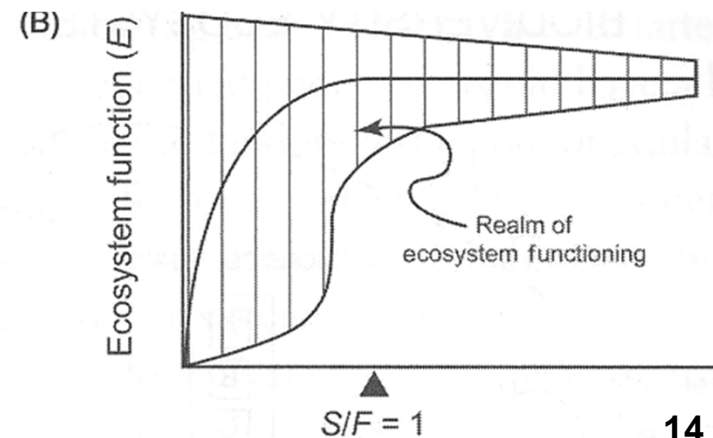
(Fridley 2002)

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Basic, fundamental relationship between biodiversity & ecosystem function (asymptotic relationship)
    - Species are singular when they are unique to a functional group
    - Species are redundant when there are  $\geq 2$  in a functional group
    - The fewer the species, the larger the possible range in function
      - Higher biodiversity acts as biological insurance with changing conditions



(Naeem 2006)



# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - What we know (or think we know)
    - Ecosystem function is facilitated by the presence of biota, much the way a chemical reaction is facilitated by an enzyme
    - Boundary conditions of ecosystem function set by abiotic factors, while biodiversity regulates function within these boundaries
    - Many species may be redundant for single functions
    - Functional diversity more important than taxonomic diversity
    - Ecosystem function asymptotes at relatively low biodiversity
    - Small amounts of biodiversity achieve the bulk of ecosystem function, but over longer terms and larger scales, greater diversity likely needed to ensure consistent function
    - Upper boundary is likely to be close to what the dominant species could achieve on its own

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - What we don't know (or think we don't know)
    - Experiments to date have been small scale, short term, mostly terrestrial, and very limited in trophic complexity
    - Sampling and complementarity mechanisms have not been directly tested or shown to be the cause of observed patterns
    - Continued debates over experimental design, statistical methods, and conflicts between results of large-scale correlative studies and small-scale experimental studies
    - Uncertainty how experimental results scale up to larger scales & if they can be generalized across ecosystem types & processes
    - How applicable are the results of highly controlled experimental mesocosms to the “real world”????



# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Lessons from “natural” ecosystems (Duffy 2009)
    - Criticisms regarding experimental BEF research have been overstated
    - *“Insights from BEF experiments are likely to underestimate, rather than overestimate, the importance of biodiversity to ecosystem functioning and the provision of ecosystem services in the real world”*

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Lessons from “natural” ecosystems (Duffy 2009)
    - Most BEF relationships result from statistical sampling effects, rather than from “true” effects of diversity
      - Who cares?
      - Could also occur from a combination of positive complementarity (i.e., resource partitioning or facilitation) and negative selection effects (i.e. dominance by a poor performer)
      - Over time, the BEF relationship and the importance of complementarity become stronger, and the number of species required to maximize function increases
      - As the number of ecosystem processes considered increases, redundancy among species decreases and the relationship between species richness and ecosystem functioning grows stronger

# Biodiversity & Ecosystem Function

- Biodiversity & Ecosystem Function Debate
  - Lessons from “natural” ecosystems (Duffy 2009)
    - BEF relationships usually reach an asymptote at very low species richness, and
    - Diversity may enhance ecosystem function in experiments, but the opposite pattern is found in nature
      - Theory predicts that the influence of diversity increases in heterogeneous environments or landscapes