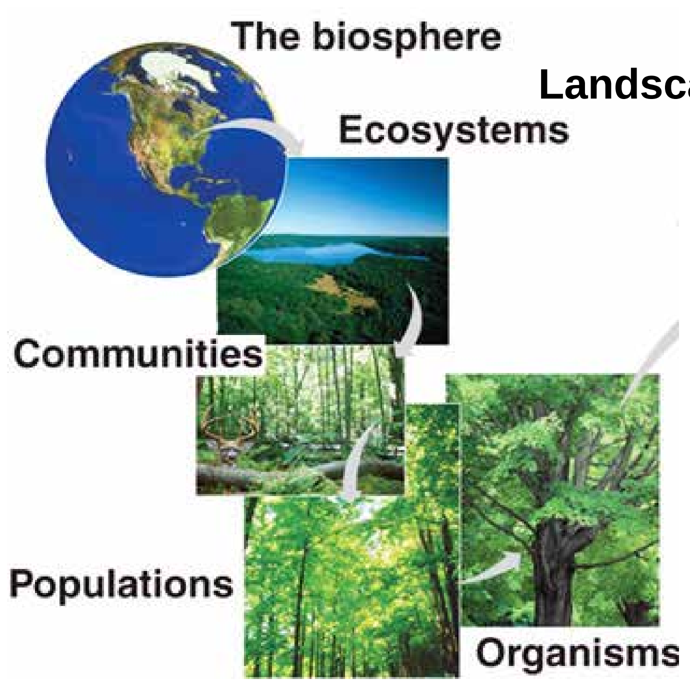
Ecosystem Ecology in a Restoration Context

- Objectives:
  - How can the foundations of and theory in ecosystem ecology ↔ restoration ecology ↔ ecological restoration
    1) Ecosystem Concept
    2) Biodiversity and Ecosystem Function (BEF) Paradigm

Ecosystem Ecology in a Restoration Context

- Ecological Hierarchy



Landscapes

(Individuals)

Ecosystem Ecology in a Restoration Context

- Importance of the ecosystem level for restoration ecology (from Intro. to Part II of Falk *et al*. 2006)
  - Provides a different view of the state & dynamics of ecological systems
    - Understanding ecosystem function requires knowledge of key ecological processes
    - Typically couched in terms of process rates → reflection of overall system performance
  - Increasing recognition that restoring ecological processes (i.e., function) is often critical to ecological restoration
    - Increasingly, restoring ecological processes is the primary objective of ecological restoration projects

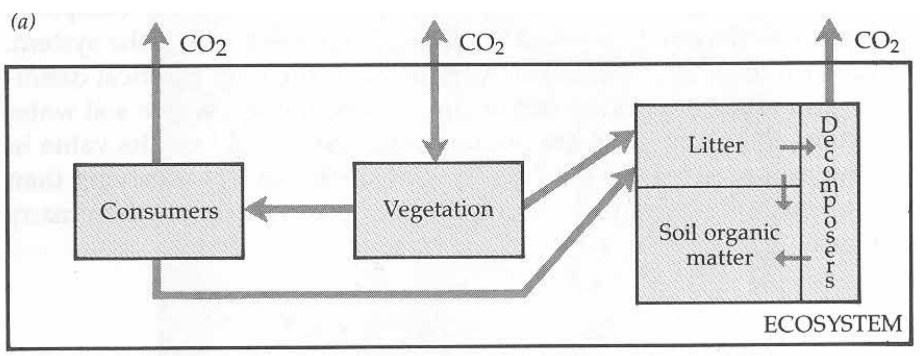
Ecosystem Ecology in a Restoration Context

- Ecosystem Ecology
  - Ecosystem: Bounded ecological system consisting of all of the organisms in a given area and the physical environment within which they interact
    - Biotic & abiotic components as a single interactive system
  - Eco. Ecology: Study of interactions among organisms & their physical environment as an integrated system
    - **Particular emphasis on the flow of energy and materials into, out of, and across ecosystems** (biogeochemistry)

Tropical Rainforest Ecosystem

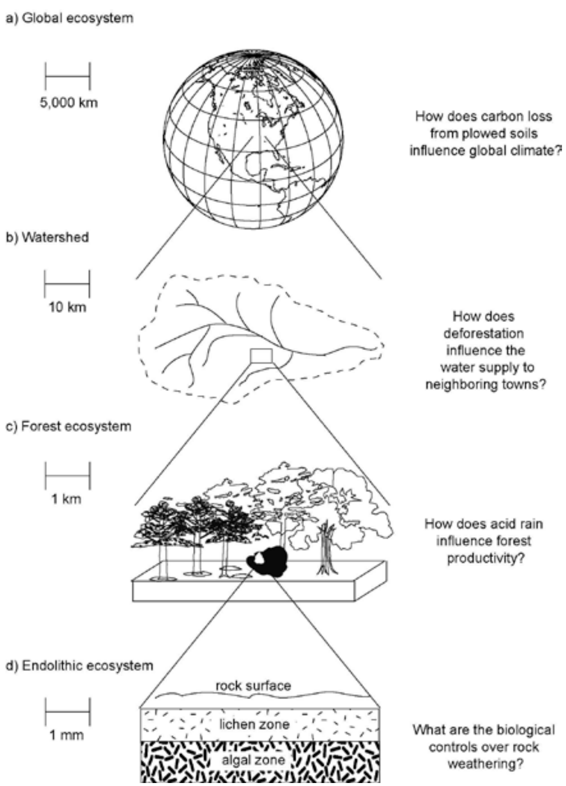
Ecosystem Ecology in a Restoration Context

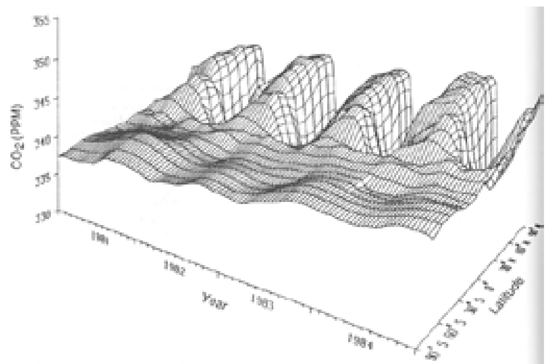
- Ecosystem characteristics
  - 3 basic components of all ecosystems:
    - autotrophs (photoautotrophs in most ecological systems)
    - heterotrophs (consumers and decomposers)
    - abiotic environment (water, atmosphere, substrate, etc.)
  - For most ecosystems, solar radiation supplies energy
    - C is the energy currency
  - Pools (quantities) and fluxes (flows) of energy and materials into, out of, and within an ecosystem
    - ~Biogeochemical cycles

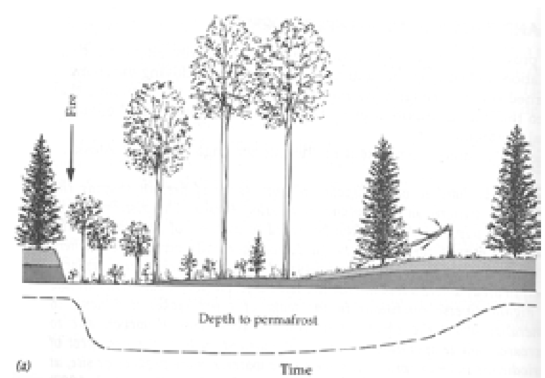


Ecosystem Ecology in a Restoration Context

- Ecosystem characteristics
  - Bounded spatially, but scale varies widely
  - Temporally dynamic

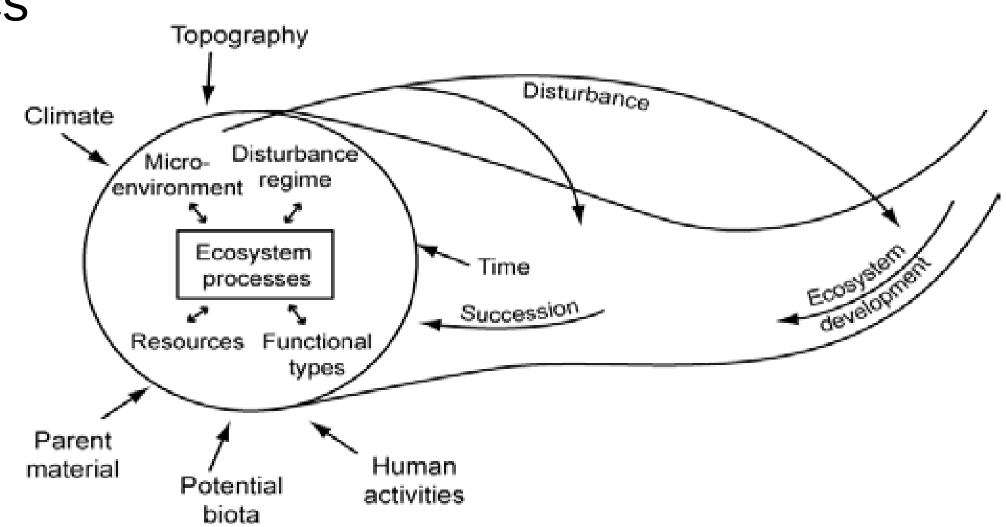






Ecosystem Ecology in a Restoration Context

- Ecosystem characteristics
  - 5 independent state variables
    - Set the bounds for the characteristics of a given ecosystem
    - These factors control but are not controlled by ecosystems
  - Human activities recently added as a 6th state variable
  - Also at least 4 “interactive controls”
    - Factors that both control & are controlled by ecosystem characteristics



Ecosystem Ecology in a Restoration Context

- Ecosystem Structure vs. Function
  - Ecosystem Structure
    - Species diversity (biodiversity)
    - Vertical and horizontal structure (habitat complexity)
    - Trophic webs
    - Abiotic environment (soils, parent material, atmosphere, H_2O)
  - Ecosystem Function/Processes
    - Biogeochemical processes
      - Productivity, decomposition, N mineralization, photosynthesis, respiration, hydrology, etc.
    - Energy and material flows (fluxes) and storage (pools)
    - Disturbance regimes play large role in ecosystem processes

Ecosystem Ecology in a Restoration Context

- Ecosystem perspective in a restoration context
  - Provides organizing framework within which all other aspects of restoration ecology fit
    - Forces ecological consideration of:
      - Spatial and temporal boundaries
      - Connections to adjacent ecosystems
      - Input, cycling & loss of materials and energy
      - Functional connections among organisms, & between biota and the physical environment
    - Sets limits on the biotic community & ecological processes
      - Restored site should be self-sustaining
    - “Build it and they will come” paradigm
      - Restoration of species does not necessarily lead to restoration of function

(Ehrenfeld & Toth 1997)

Ecosystem Ecology in a Restoration Context

- Ecosystem perspective in a restoration context
  - Provides conceptual tools to delineate targets and to monitor & evaluate restoration projects
    - Energy & material inputs/outputs
    - Trophic dynamics
    - Productivity (C cycling)
      - Pools (live & detrital) & fluxes of C
    - Hydrologic cycle
    - Intra-system cycling
      - Decomposition, nutrient cycling, turnover, transfers
    - Disturbance regimes
    - Stability
      - Resistance and resilience

(Ehrenfeld & Toth 1997)

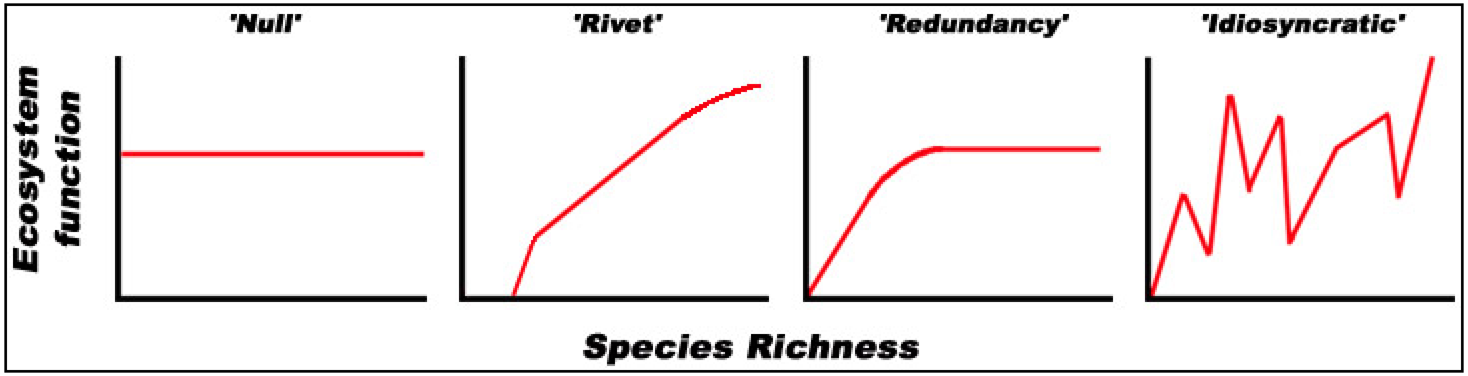
Ecosystem Ecology in a Restoration Context

- Ecosystem perspective in a restoration context
  - More likely to be useful for restoration of <u>function</u>
    - *How do ecological processes change over succession?*
    - *How can the concept of functional groups be used in restoration?*
    - *How do individual species affect ecosystem processes?*
    - *How sensitive are ecosystem processes to changes in biodiversity?*

(Ehrenfeld & Toth 1997)

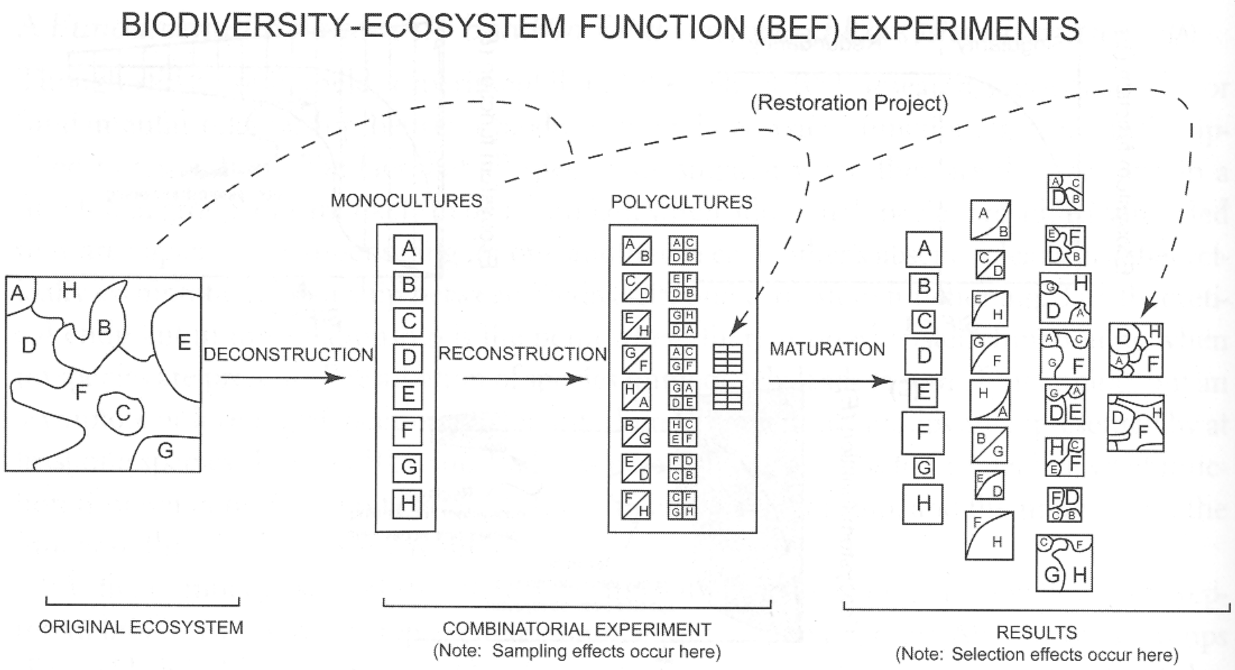
Ecosystem Ecology in a Restoration Context

- Biodiversity & Ecosystem Function (BEF)
  - Does biodiversity correlate with ecosystem function?
    - Explosion of research in past ~10-15 years
    - Species typically have strong effects on ecosystems
      - Alter interactive controls → regulate ecosystem processes
      - Taxonomic vs. functional “species”
    - Several working hypotheses



Ecosystem Ecology in a Restoration Context

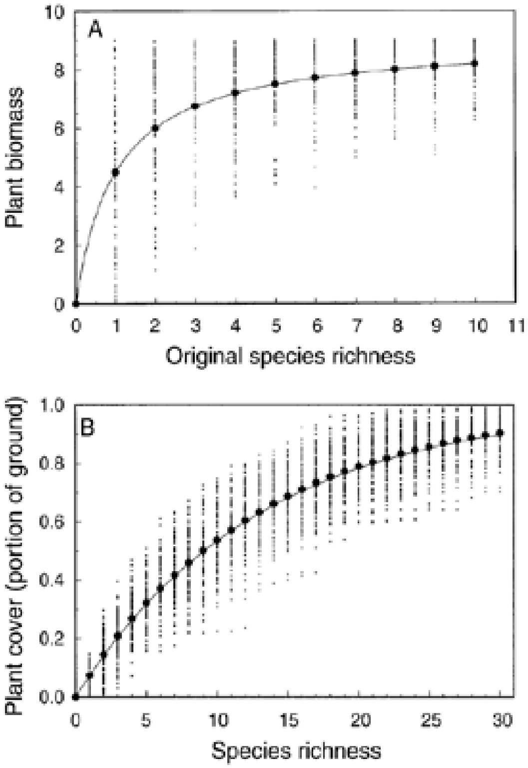
- BEF in a Restoration Context
  - Combinatorial experiments inherent in BEF studies
    - Very relevant to restoration ecology
      - BEF deconstructs and then constructs ecological systems
      - Restoration seeks to construct ecological systems



Ecosystem Ecology in a Restoration Context

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

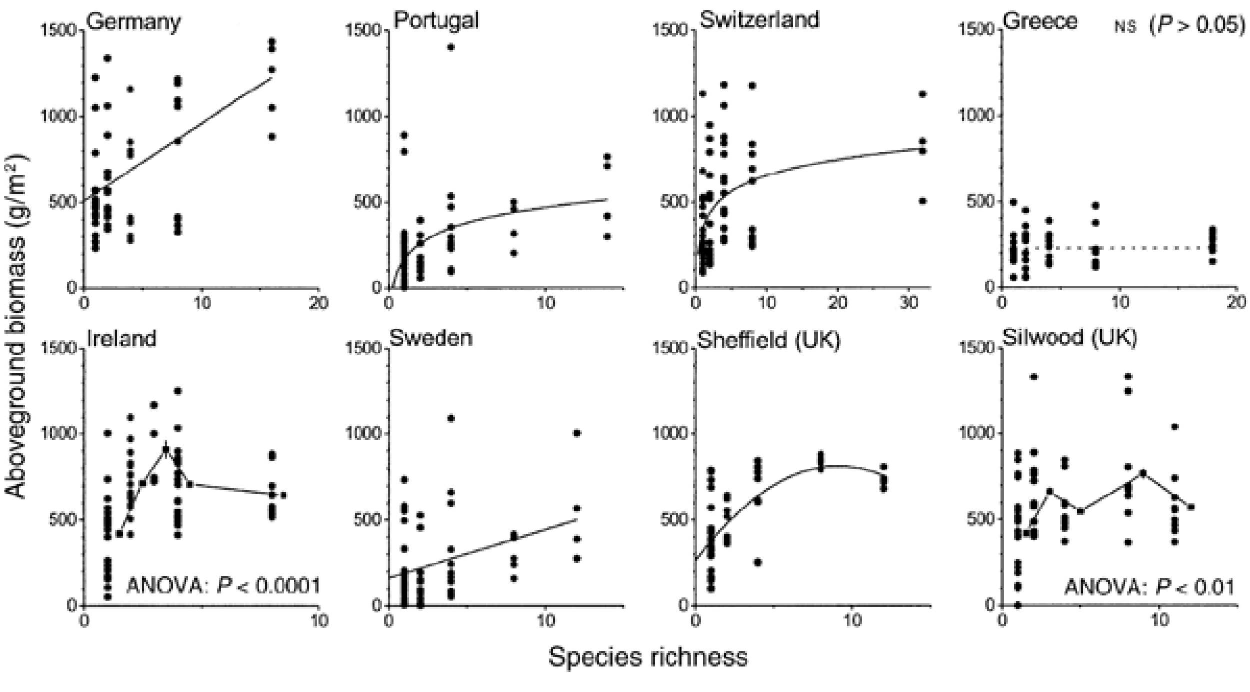
Cedar Creek LTER



(Hooper et al. 2005)

Ecosystem Ecology in a Restoration Context

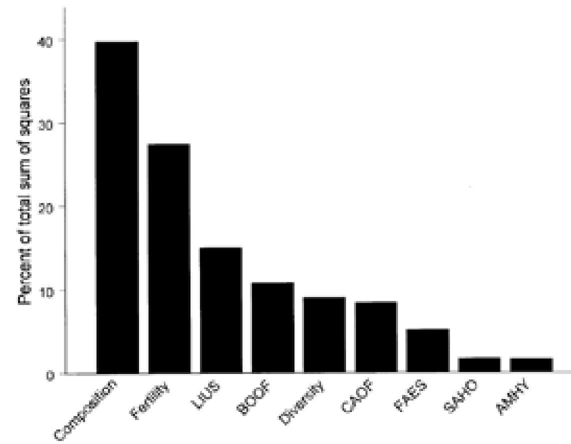
- Biodiversity & Ecosystem Functioning (BEF)
  - Studies to date indicate that there is a correlation, but that it varies somewhat from system to system
    - Redundancy hypothesis has the most support
    - Sampling/selection effect evident in all studies; Important?

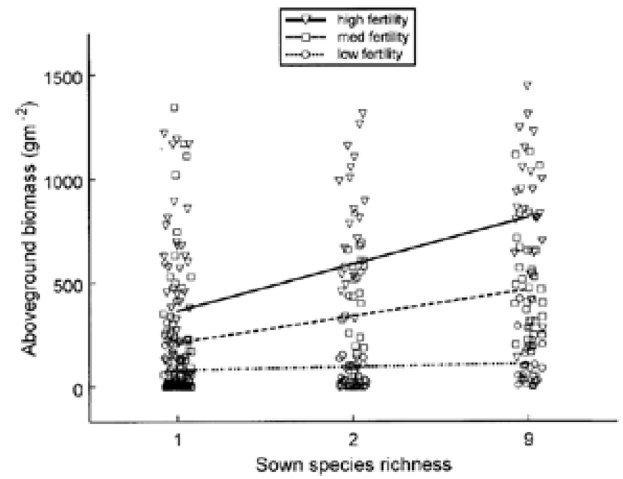


(Hooper et al. 2005)

Ecosystem Ecology in a Restoration Context

- Biodiversity & Ecosystem Functioning (BEF)
  - One key seems to lie in how species impact resources
    - Provides a biological mechanism
    - Resource availability controls both biodiversity & function in natural systems

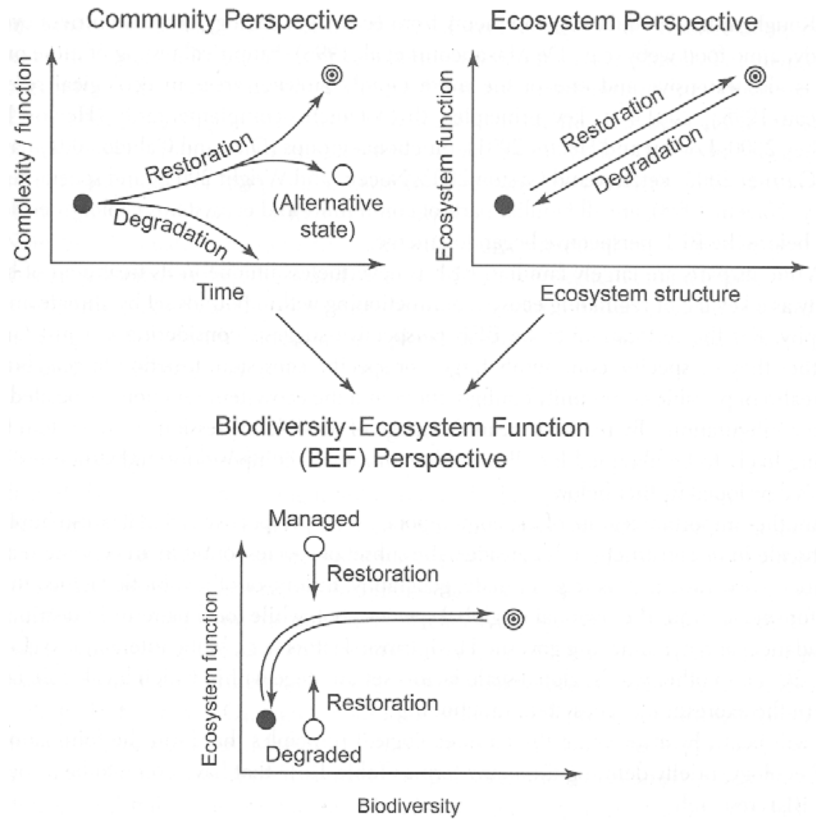




(Fridley 2002)

Ecosystem Ecology in a Restoration Context

- Biodiversity & Ecosystem Functioning (BEF)
  – Naeem (2006) glosses over all this and assumes a redundancy relationship is the norm

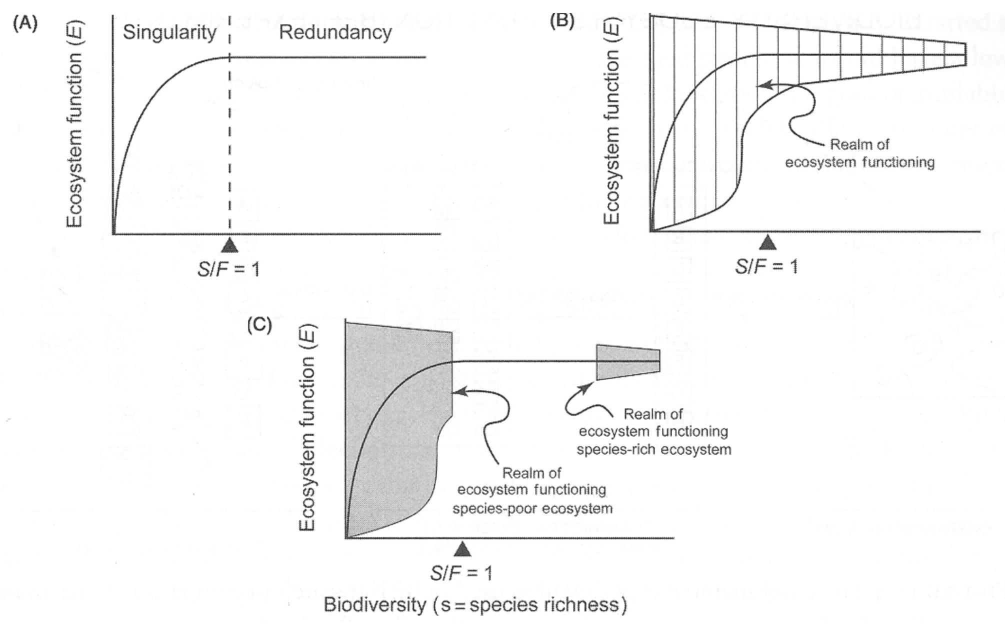


Ecosystem Ecology in a Restoration Context

- Biodiversity & Ecosystem Functioning (BEF)
  - Based on community & ecosystem ecology principles
    - Bounds set by climate, geography, regional species pool
    - Biotic interactions determine local patterns
      - Niche complementarity, functional groups, dominance, species redundancy, etc.
    - Biodiversity defined commonly on a functional group basis
    - Biogeochemical principles are at the core of BEF
      - Species cycle materials from organic to inorganic forms
        - » Ecosystem processes quantified by measuring flux
        - » Important tools to gauge ecosystem response to change
    - Variability, predictability, and reliability of function just as important, if not more so, than magnitude of function

Ecosystem Ecology in a Restoration Context

- Biodiversity & Ecosystem Functioning (BEF)
  - Basic, fundamental relationship between biodiversity & ecosystem function (asymptotic relationship)
    1) Species are singular when they are unique to a functional group
    2) Species are redundant when there are ≥2 in a functional group
    3) The fewer the species, the larger the possible range in function



Ecosystem Ecology in a Restoration Context

- BEF in a Restoration Context
  - Most of an ecosystem's functioning may be achieved with 1 or a few species in each functional group
    - Upper boundary likely to be close to what the dominant species could do in isolation
    - Ecosystem functioning asymptotes at relatively low levels of biodiversity
    - However, the more species per functional group, the more stable (resistant and resilient) the ecosystem
  - The fewer the species, the larger the range of possible function
    - Probability of selecting single most vs. single least productive species in a monoculture is equal
    - For polycultures, probability of including the most productive species is high, even if randomly selected

Ecosystem Ecology in a Restoration Context

- BEF in a Restoration Context
  - Are mesocosm experiments at all applicable to the real world (Duffy 2009)?
    - Complex ecosystems & large spatial and temporal scales are the norm in nature
    - BEF focuses more on general patterns, rather than species-level, applied conservation or restoration problems
    - From few studies that address these issues in the “real world”:
      - Imp. of biodiversity to function ↑ as more trophic levels considered
      - Imp. of biodiversity to function ↑ with time
      - Imp. of biodiversity to function ↑ with environmental heterogeneity

Week 9 Readings/Lecture Slide Highlights

1. Restoring ecosystem function/ecological processes is increasingly a primary goal of ecological restoration. This focus necessitates an understanding of patterns and mechanisms associated with ecosystem function/processes, and an ecosystem ecology context facilitates this understanding.

Week 9 Readings/Lecture Slide Highlights

2. All ecosystems have 3 basic components (autotrophs, heterotrophs, and the abiotic environment). For almost all ecosystems, energy is supplied initially in the form of solar radiation, and photoautotrophic organisms convert the chemical energy in light to stored energy in the form of carbon-based compounds. As such, carbon is the energy currency of ecosystems.

Week 9 Readings/Lecture Slide Highlights

3. Species, particularly dominant species, have a large influence on ecosystem processes. Research over the past two decades has highlighted that increased biodiversity, particularly functional biodiversity, typically enhances ecosystem function. Increased ecosystem function with increasing biodiversity can be the result of a biological effect, or a sampling/selection effect.

Week 9 Readings/Lecture Slide Highlights

4. Most of an ecosystem’s functioning may be achieved with one or a few species in each functional group, and the upper boundary of function is typically close to what the dominant species could do in isolation. While ecosystem function seems to asymptote at relatively low levels of biodiversity, the more species per functional group, the more stable (resistant and resilient) and predictable the ecosystem.

Week 9 Readings/Lecture Slide Highlights

5. From the perspective of ecosystem function, functional diversity is the most relevant component of biodiversity. Species are singular when they are unique to a functional group, and redundant when there are ≥2 in a functional group. The more species in an ecological community, the more redundancy and the narrower the range of potential function.