Community Diversity

Topics

- **What is biodiversity and why is it important?**
- **What are the major drivers of species richness?**
  - **Habitat heterogeneity**
  - **Disturbance**
  - **Species energy theory**
  - **Metobolic energy theory**
  - **Dynamic equilibrium hypothesis (interactions among disturbance and energy)**
  - **Resource ratio theory**
- **How does biodiversity influence ecosystem function?**
  - **Biodiversity and ecosystem function hypothesis**
- **Integration of biodiversity theory**
- **How might the drivers of species richness and hence levels of species richness differ among biomes?**

Community Diversity Defined

Biodiversity

Merriam-Webster - the existence of many different kinds of plants and animals in an environment.

Wikipedia - the degree of variation of life forms within a given species, ecosystem, biome, or an entire planet.

U.S. Congress Office of Technology Assessment - the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance."

Community Diversity Defined

Species richness -

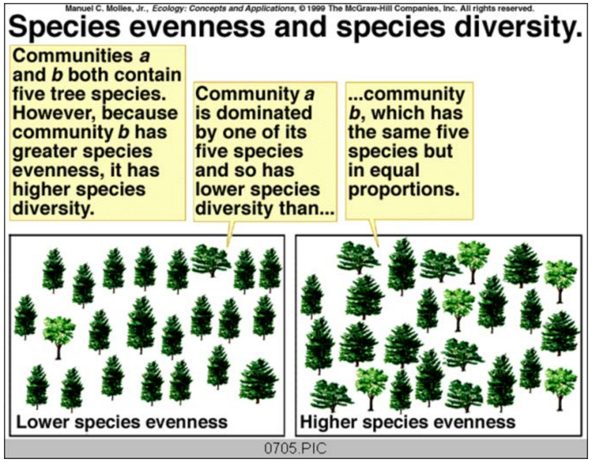
Species evenness -

Species diversity -

Community Diversity Defined

Species richness - number of species present in the community (without regard for their abundance).

Species evenness - relative abundance of the species that are present.



Species diversity - Considers both the number of species (richness) in the community and their relative abundance (evenness or equability).

Shannon-Wiener Diversity Index

$$H' = -\sum_{i=1}^{s} p_i \log_e p_i$$

Where:

H' = the value of the Shannon-Wiener diversity index

p_i = the proportion of the ith species

$\log_e$ = the natural logarithm

s = the number of species in the community

Community Diversity Defined

Community

- Richness
- Shannon's index
- Abundance

Guild – group of species that make their living in a similar way

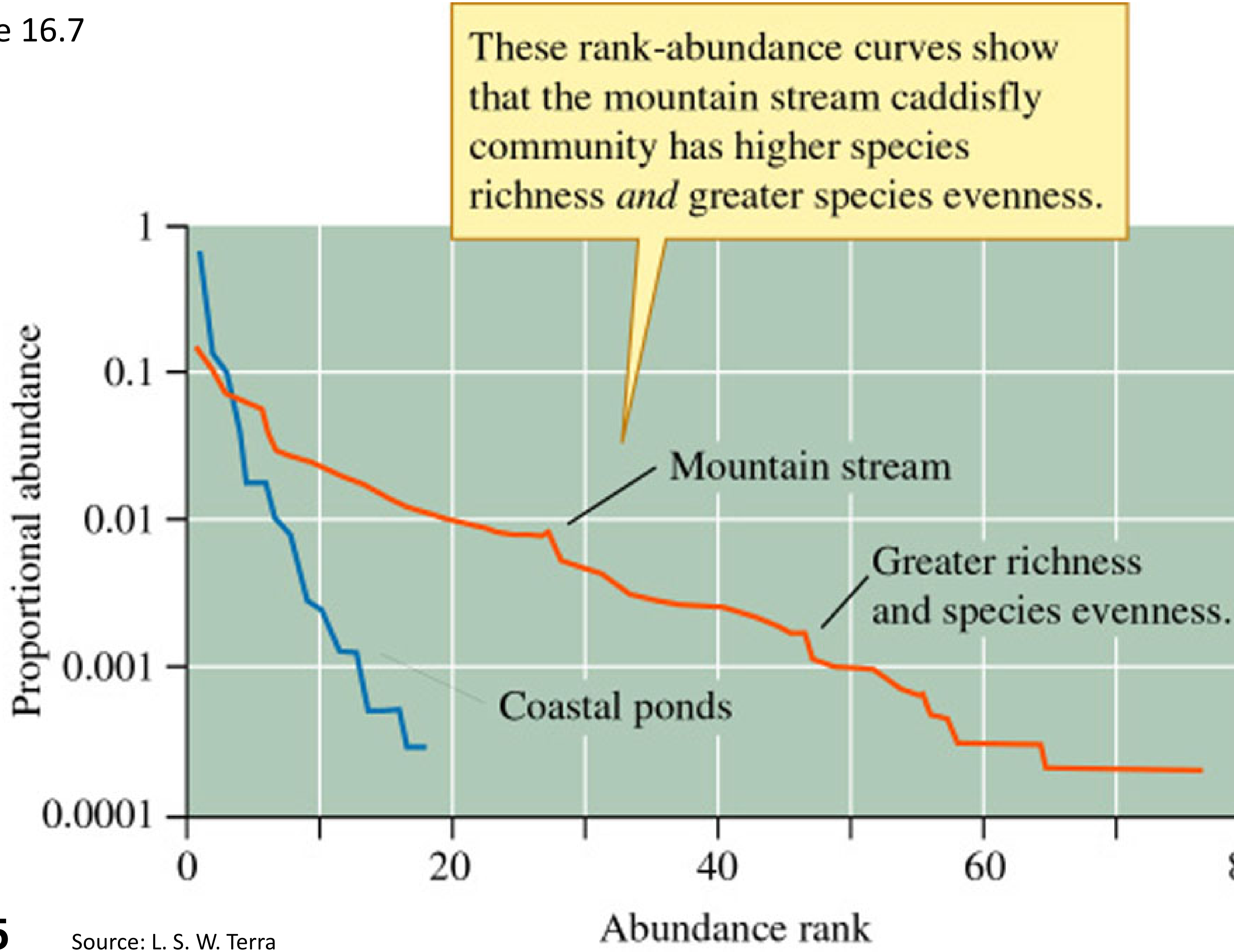
- Richness
- Shannon's index
- Abundance

Individual species

- Abundance

Rank-abundance curves for caddisflies

Figure 16.7

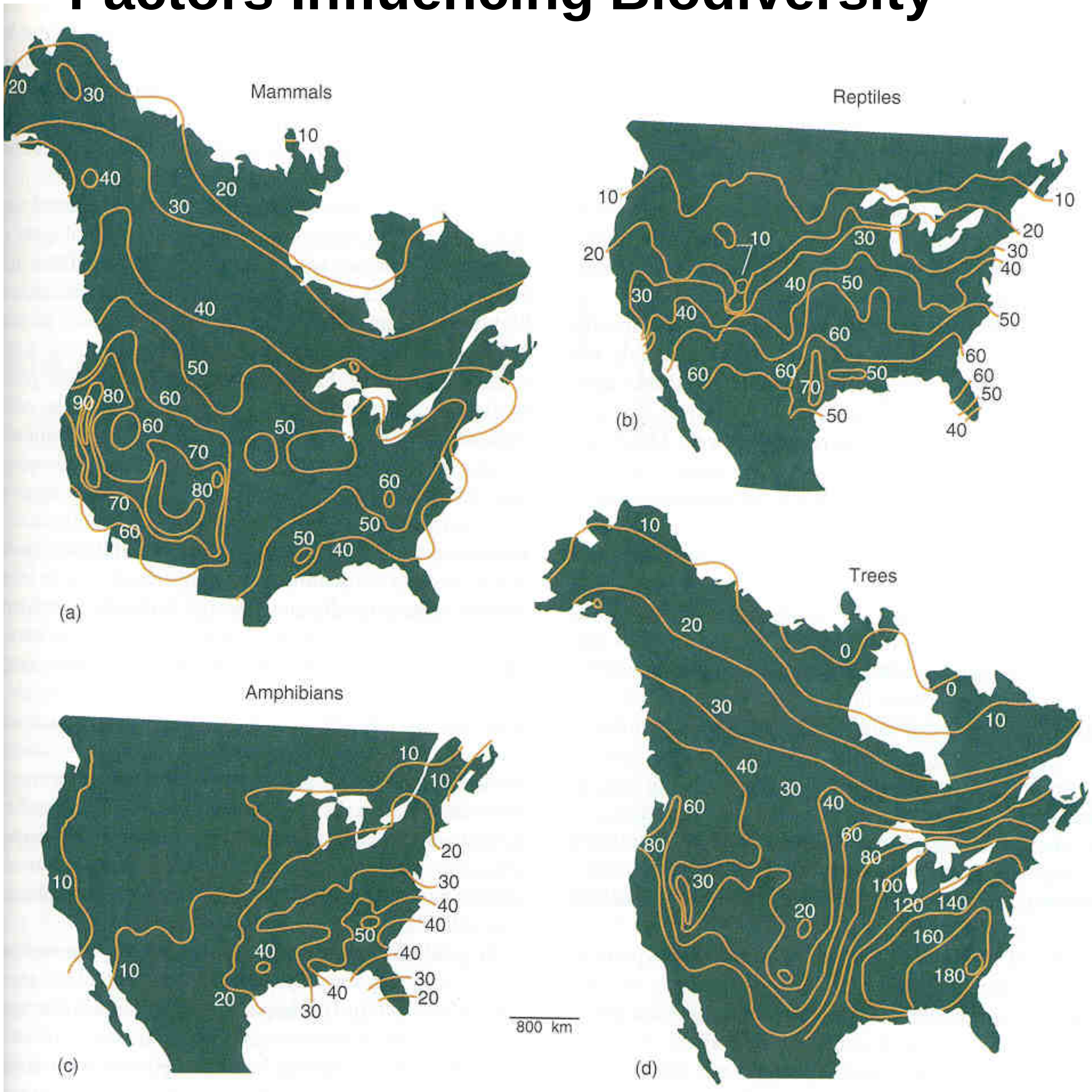


Source: L. S. W. Terra

Community Diversity Defined

Why do we care about biodiversity?

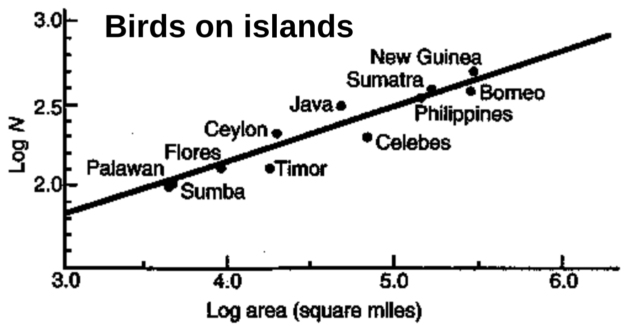
Factors Influencing Biodiversity

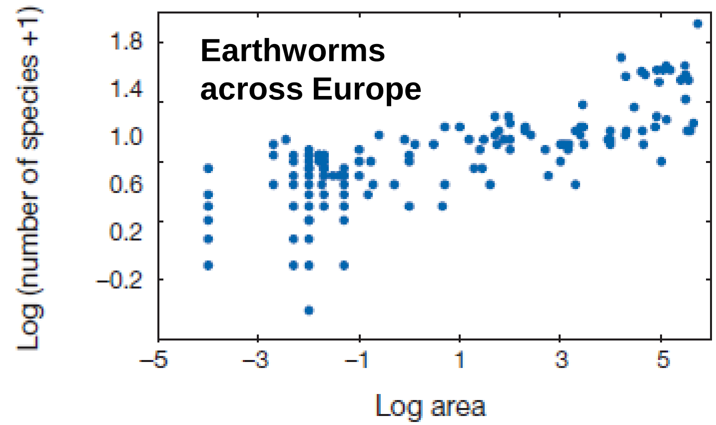


Factors Influencing Biodiversity

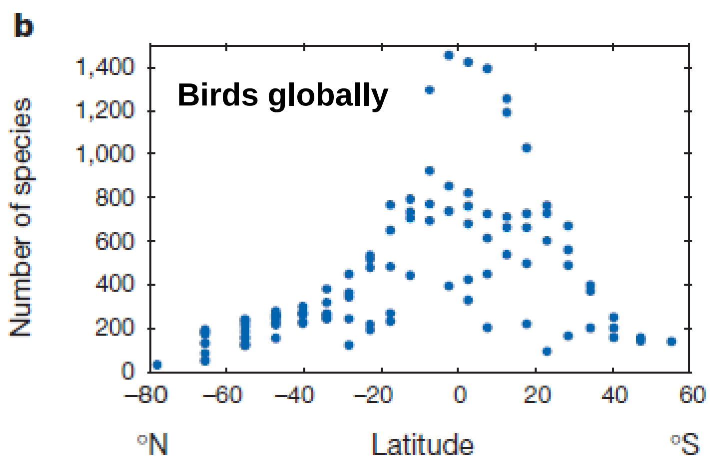
Proximate Factors

- **Area**



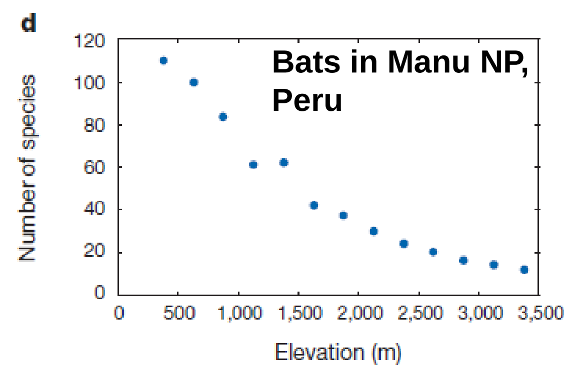


- **Latitude**



Gaston 2000

- **Elevation**



Factors Influencing Biodiversity

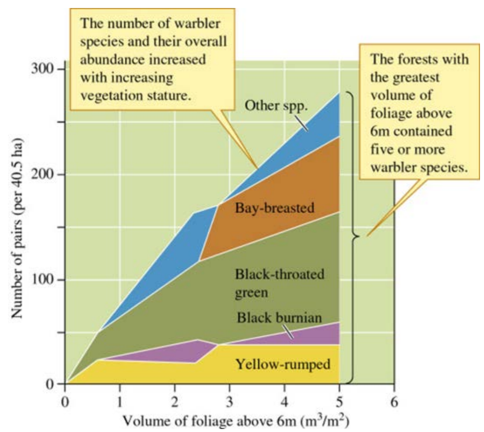
Ultimate Factors

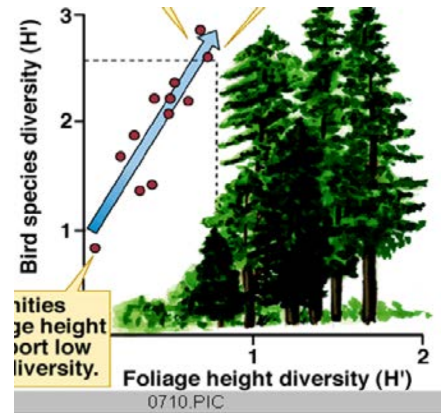
- **Habitat heterogeneity**
- **Disturbance**
- **Species energy theory**
- **Metobolic energy theory**
- **Dynamic equilibrium hypothesis (interactions among disturbance and energy)**
- **Resource ratio theory**

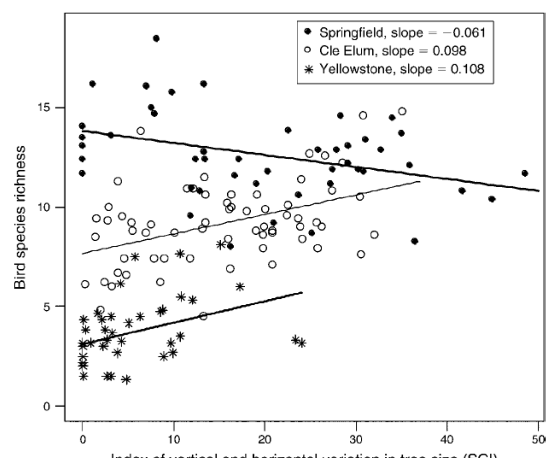
Factors Influencing Biodiversity

Habitat Heterogeneity

Species richness increases with vertical and horizontal habitat heterogeneity because habitat comprises niche axes for species and more niches can fit into areas with heterogeneous habitats.





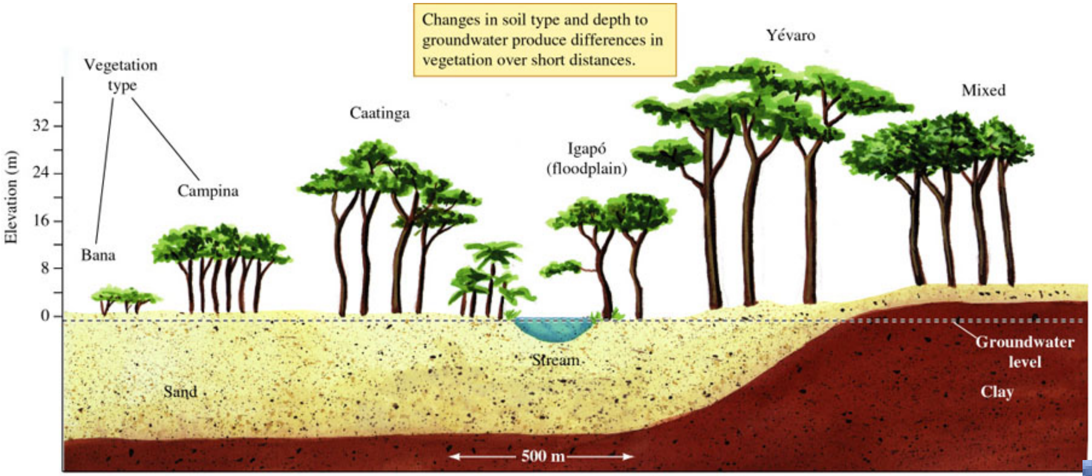


Verschuyl et al. 2008

Factors Influencing Biodiversity

Habitat Heterogeneity

Geomorphic variation also contributes to habitat heterogeneity



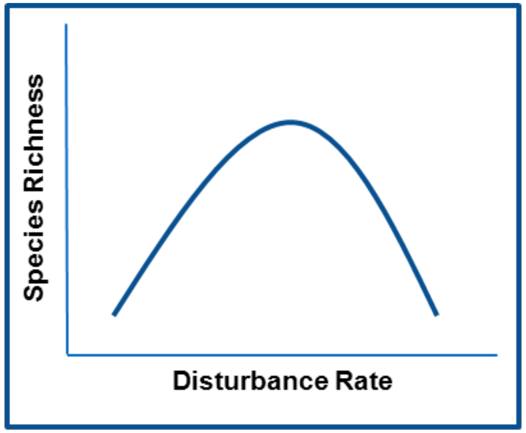
Factors Influencing Biodiversity

Disturbance

Species richness is maximized at intermediate rates of disturbance because habitat is provided for both early and late seral specialists.

r-selected species –

K-selected species -



Intermediate Disturbance Hypothesis
(Connell 1978)

Factors Influencing Biodiversity

Disturbance

Species richness is maximized at intermediate rates of disturbance because habitat is provided for both early and late seral specialists.

r-selected species – In unstable or unpredictable environments, r-selection predominates as the ability to reproduce quickly is crucial. There is little advantage in adaptations that permit successful competition with other organisms, because the environment is likely to change again. Traits that are thought to be characteristic of r-selection include: high fecundity, small body size, early maturity onset, short generation time, and the ability to disperse offspring widely.

K-selected species - In stable or predictable environments, K-selection predominates as the ability to compete successfully for limited resources is crucial and populations of K-selected organisms typically are very constant and close to the maximum that the environment can bear (unlike r-selected populations, where population sizes can change much more rapidly). Traits that are thought to be characteristic of K-selection include large body size, long life expectancy, and the production of fewer offspring, which often require extensive parental care until they mature.

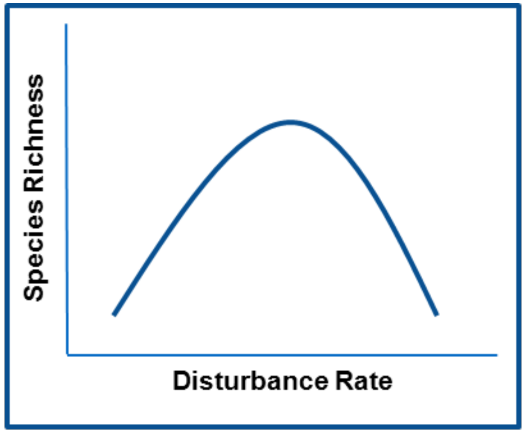
Factors Influencing Biodiversity

Disturbance

Species richness is maximized at intermediate rates of disturbance because habitat is provided for both early and late seral specialists.

r-selected species –

K-selected species -

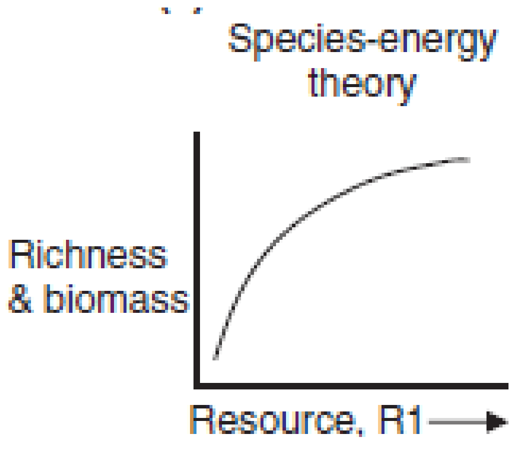


Intermediate Disturbance Hypothesis
(Connell 1978)

Factors Influencing Biodiversity

Species Energy Theory

Abundant food resources or warmer thermal conditions allow higher survival and reproduction of individuals within a population, and larger population sizes reduce the chance of species extinctions (Wright 1983).



Factors Influencing Biodiversity

Species Energy Theory

Wright, D. H. 1983. Species–energy theory, an extension of species-area theory. Oikos 41: 496–506.

A more general biogeographic theory of island species number is produced by replacing area with a more direct measure of available energy in the models of Mac-Arthur and Wilson and Preston. This theory, species-energy theory, extends beyond species-area theory in that it applies to islands that differ in their per-unit-area productivity due to differences in physical environment, such as climate

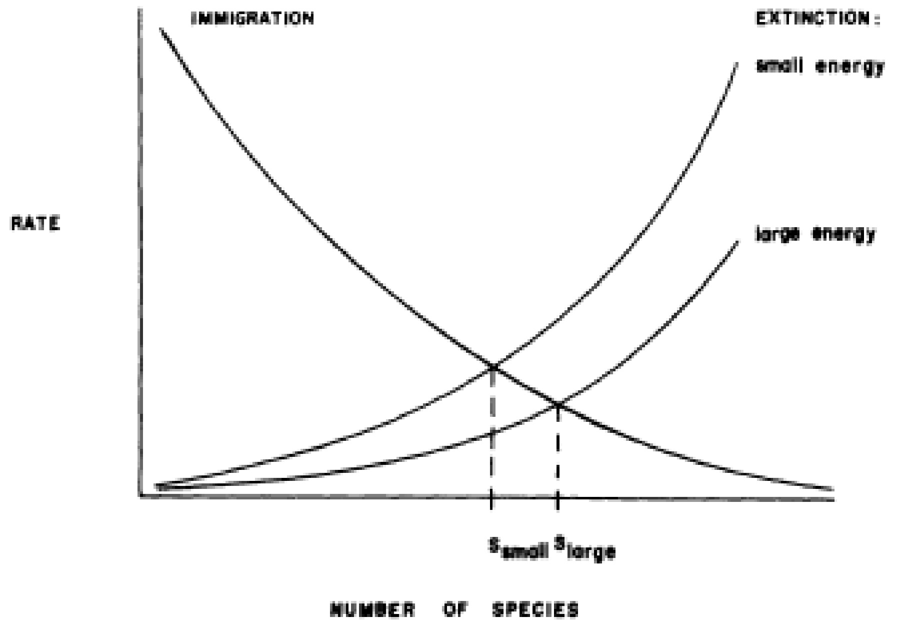


Fig. 1. Immigration and extinction rates versus number of species present on an island. Islands with larger total amounts of available energy have lower extinction rates, resulting in a higher equilibrium number of species ($S_{large} > S_{small}$).

Factors Influencing Biodiversity

Species Energy Theory

Angiosperm Species

AET – based on climate (temp, PPT, ET)

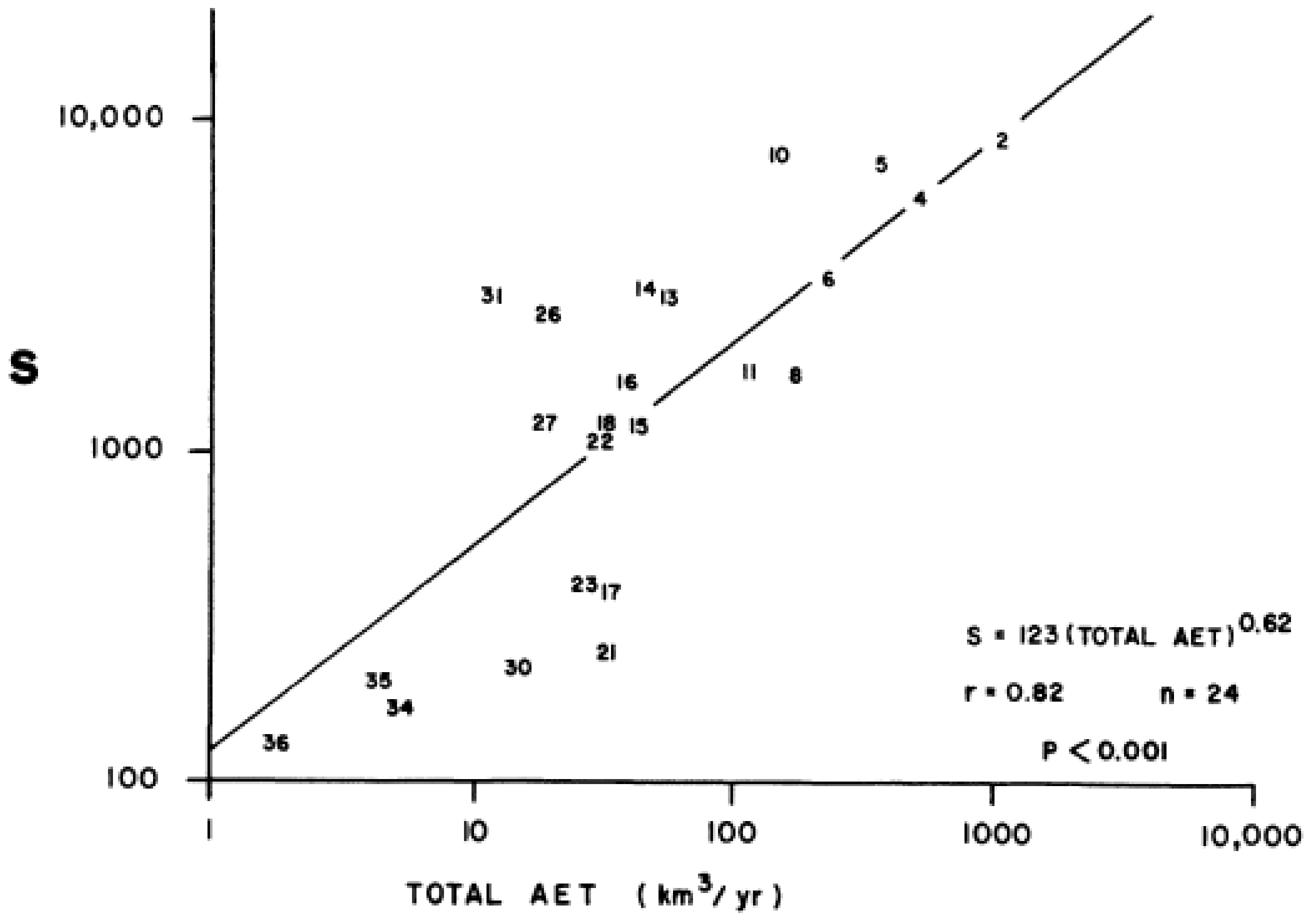


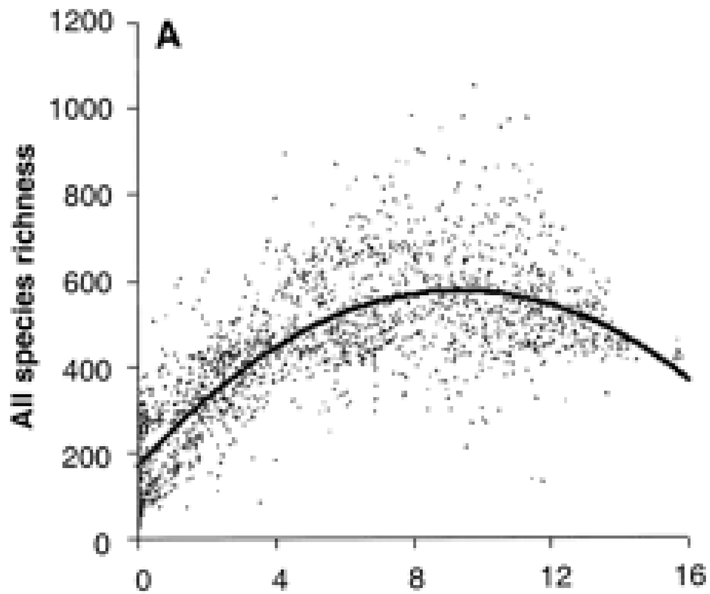
Fig. 3. Number of angiosperm species (S) on 24 islands worldwide, plotted against the total actual evapotranspiration (Total AET) from the island annually. Numbers in the plot refer to islands listed in Tab. 1.

Wright 1983

Factors Influencing Biodiversity

Species Energy Theory

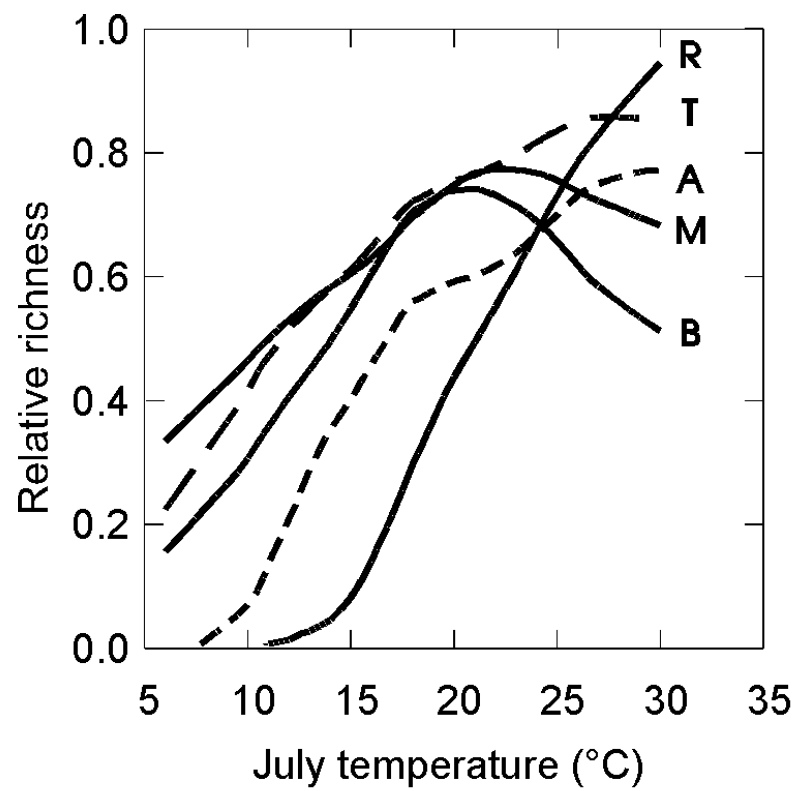
African Vertebrate Richness



Net primary productivity

Balmford et al. 2001

North American Groups



Currie 2002

Factors Influencing Biodiversity

Species Energy Theory

Biodiversity is often strongly correlated with energy.

Energy

Heat – e.g., temperature, potential evapotranspiration

Ecological productivity – e.g., NPP

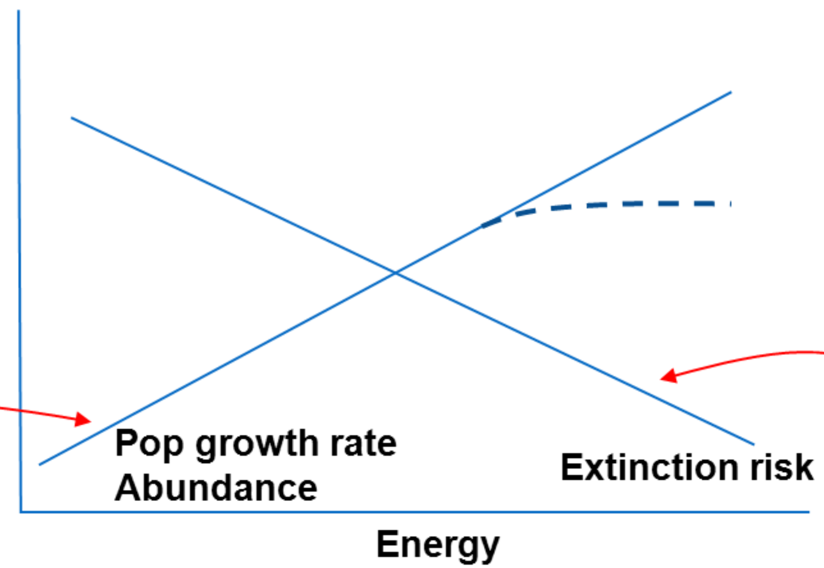
Why?

Abundant food resources or warmer thermal conditions allow higher survival and reproduction of individuals within a population, and larger population sizes reduce the chance of species extinctions (Wright 1983).

“Measures of energy (heat, primary productivity)…[and water balance]…explain spatial variation in richness better than other… variables in 82 of 85 cases”, Hawkins et al. 2003.

Factors Influencing Biodiversity

Ecosystem Energy

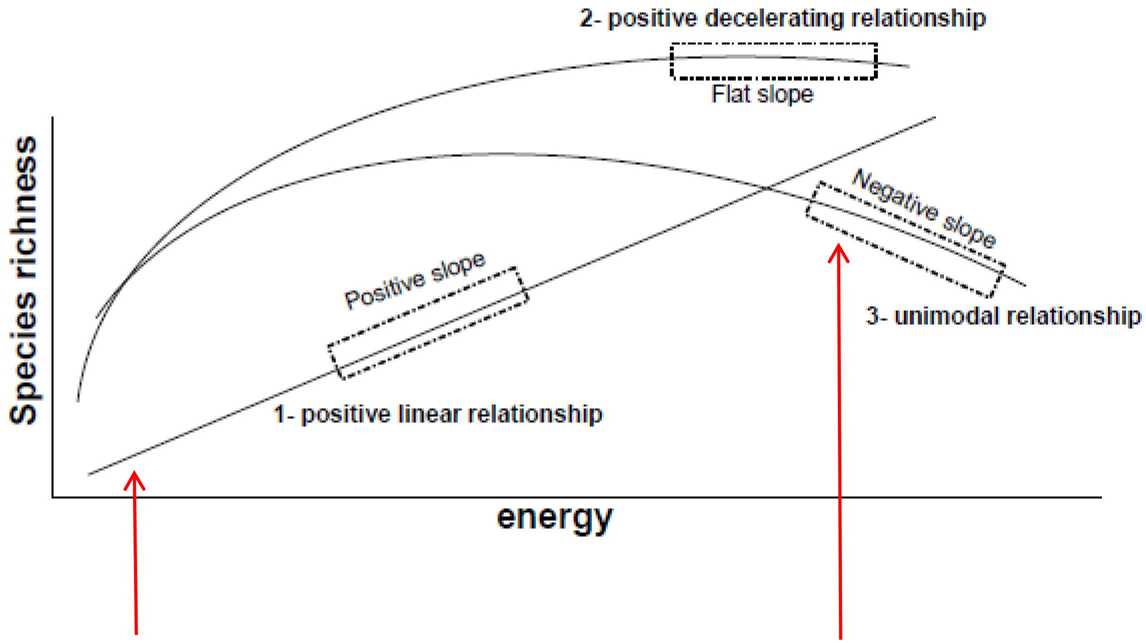


The enhanced survival and reproduction may result from greater food resources or increased heat, which may allow individuals to divert resources from thermoregulation to activities such as reproduction.

Larger populations are less likely to go extinct.

Factors Influencing Biodiversity

Species Energy Theory



More Individuals Hypothesis

Abundant food resources or warmer thermal conditions allow higher survival and reproduction of individuals within a population, and larger population sizes reduce the chance of species extinctions

Competitive Exclusion Hypothesis

One or a few canopy tree species dominate the community and competitively exclude other plant species and plant diversity, structural complexity and foods for consumers.

Species Richness for Landbirds across North America

USGS Breeding Bird Survey data
BBS native diurnal landbirds

Richness = aGPP – aGPP^2 - %SCV + PET

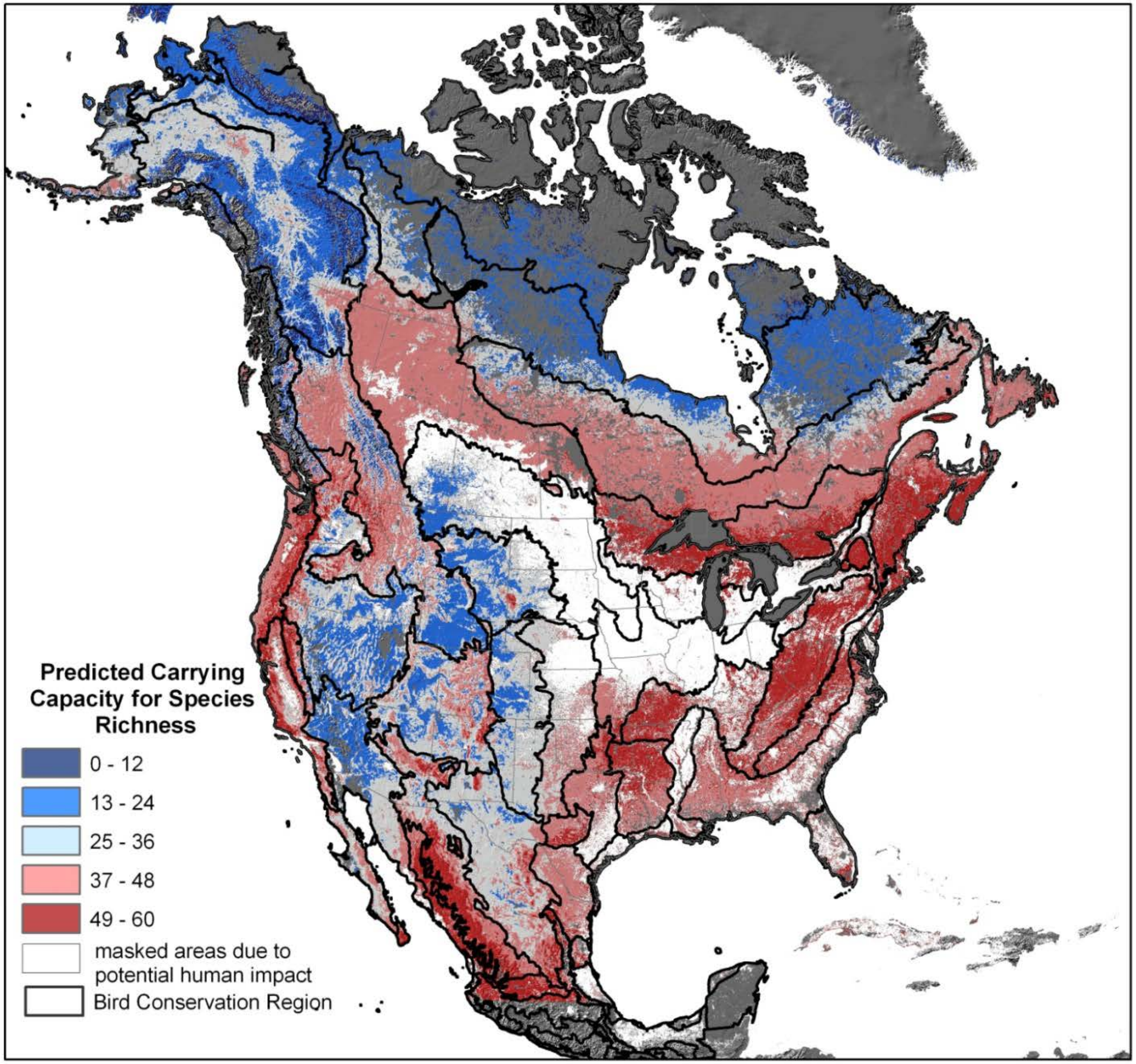
%SCV: Interannual variation in GPP

Adj. R2 = 0.70

Hansen et al. 2011. Global Ecology and Biogeography

Hypothesis	Typical Predictors
Kinetic energy	Temperature (mean annual)
	Temperature (mean June)
	Potential evapotranspiration
Water	Precipitation (mean annual)
	Precipitation (mean June)
	Evapotranspiration (annual sum)
Potential Energy	NDVI (mean annual or mean June)
	Gross Primary Productivity (mean annual)
	Gross Primary Productivity (June)
	Seasonality (June GPP/annual GPP)
	Interannual variation in GPP
Habitat complexity	Elevation range
	Cover type variation
	Percent tree

Carrying Capacity for Species Richness for Landbirds across North America



Hansen et al. 2011.

Factors Influencing Biodiversity

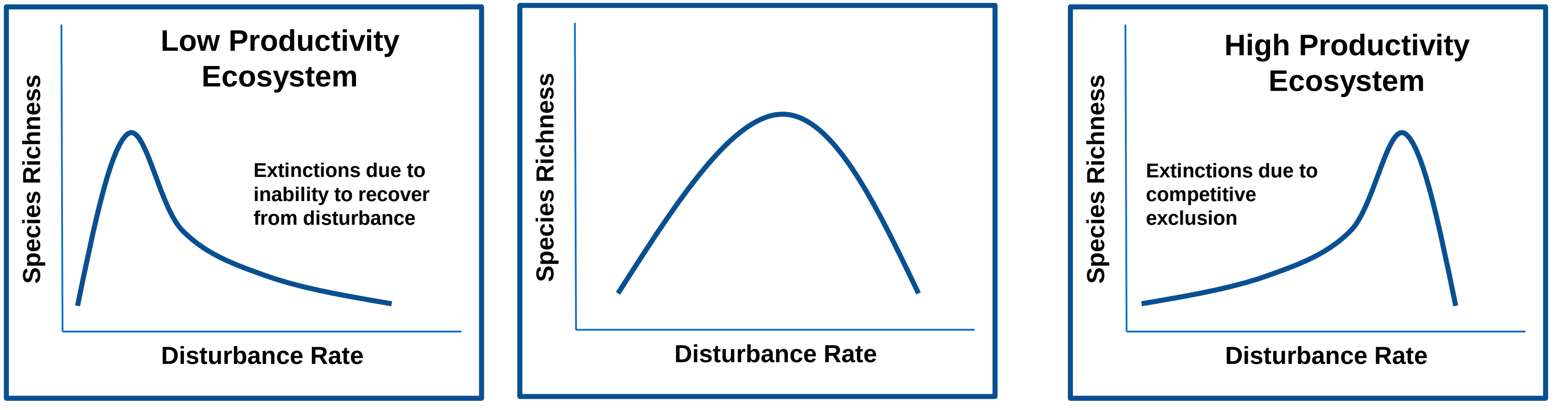
Species Energy Theory

Unresolved Issues:

- **the form and magnitude of species energy relationship are known to differ among groups of organisms and between scales of observation; yet, we currently have no mechanism to explain how or why PDR might qualitatively shift at different scales or levels of biological organization.**
- **studies have tended to use a plethora of different variables to represent diversity and productivity (climate, NPP, GPP, biomass…). Many studies have argued that these variables are not interchangeable, nor do they even show the same qualitative relationship to species diversity.**
- **Most studies are correlational and thus do not demonstrate causality. Large-scale experiments are difficult to impossible.**

Factors Influencing Biodiversity

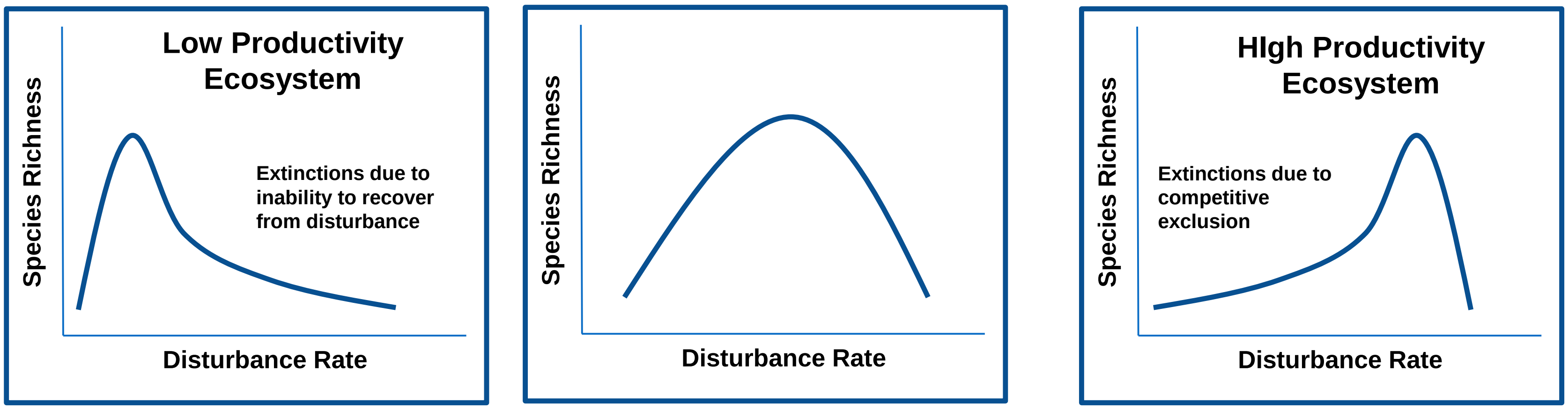
Interactions Among Factors



Dynamic Equilibrium Hypothesis

Factors Influencing Biodiversity

Interactions Among Factors



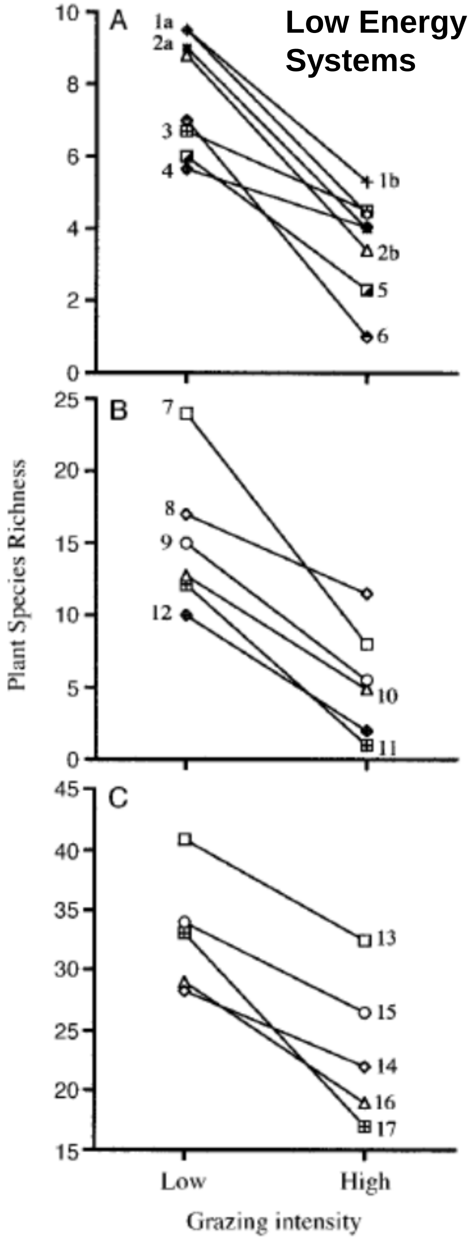
Increased disturbance reduces species richness.

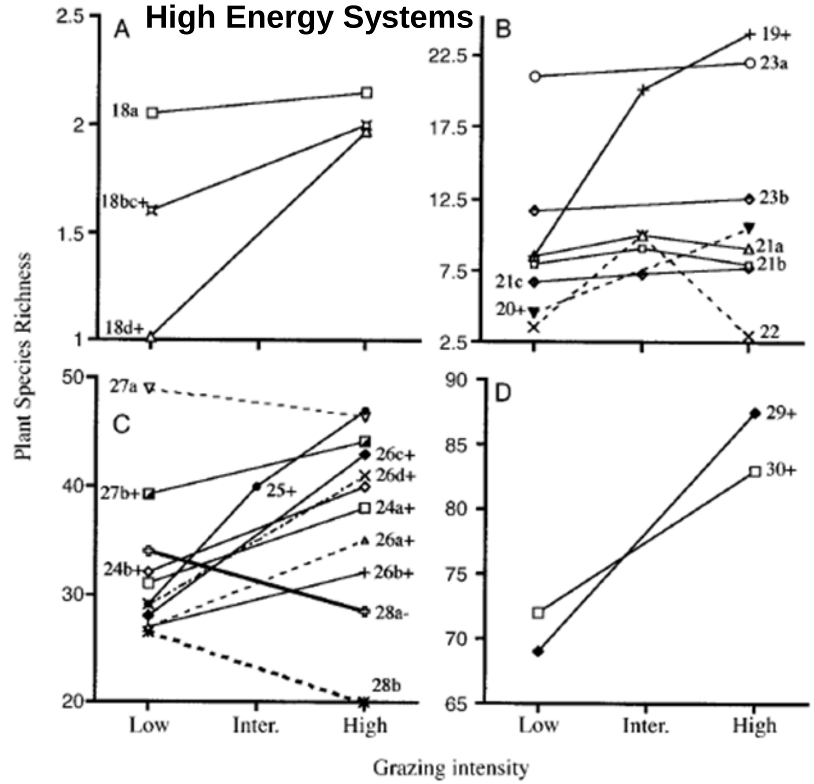
Increased disturbance increases species richness.

Dynamic Equilibrium Hypothesis

Factors Influencing Biodiversity

Proulx and Mazumder (1998) - Meta analysis of 30 studies of plant species richness in lake, stream, grassland, and forest grazing systems.





All 19 comparisons from non-enriched or nutrient-poor ecosystems exhibited significantly lower species richness under high grazing than under low grazing.

14 of 25 comparisons from enriched or nutrient-rich ecosystems showed significantly higher species richness under high grazing than under low grazing.