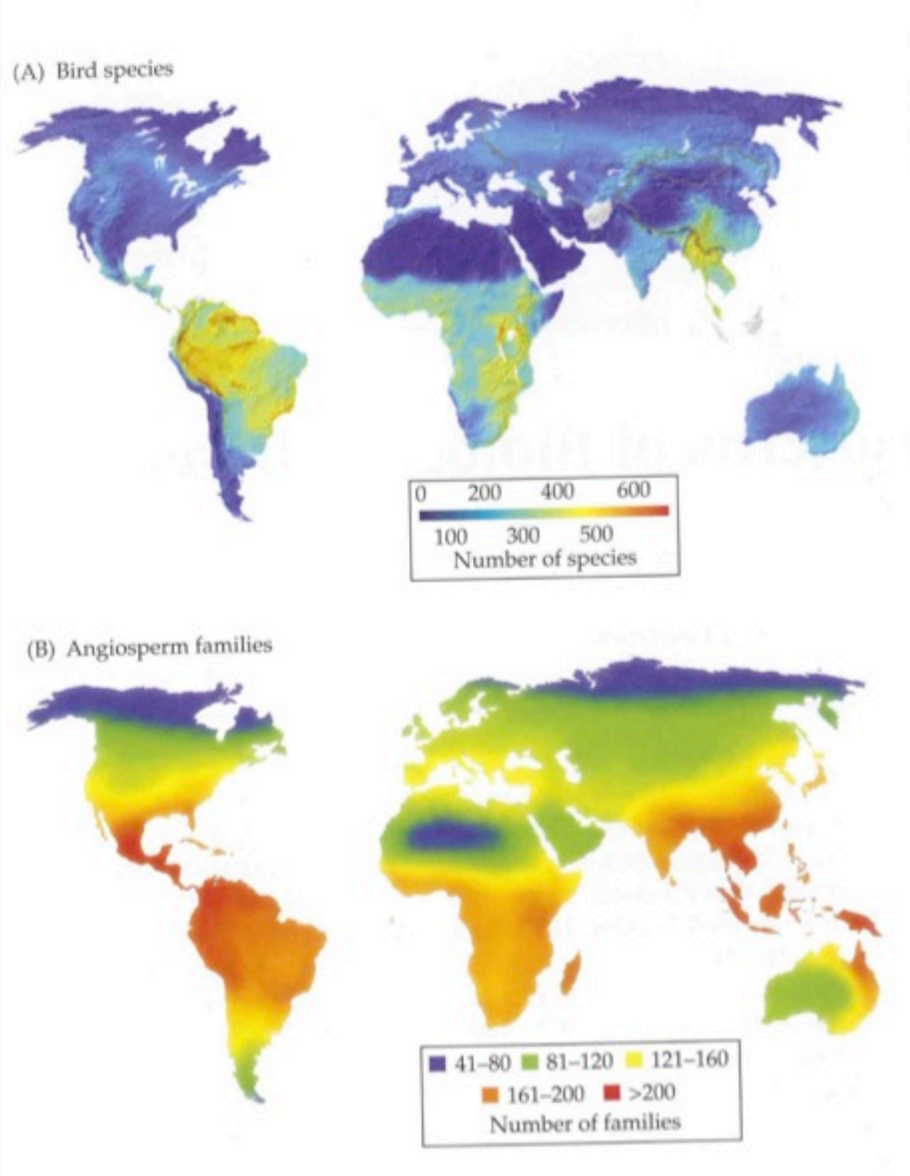
Patterns of Biological Diversity

1. What is biodiversity?
2. Measuring and estimating biodiversity
3. Biodiversity patterns across spatial scales
4. What explains the most prevalent biodiversity pattern, the Latitudinal Diversity Gradient?

Recommended Reading: Chapter 2
Mittelbach 2012 Community Ecology

'Biodiversity, the variety of life, is distributed heterogeneously across Earth' – Gaston 2000



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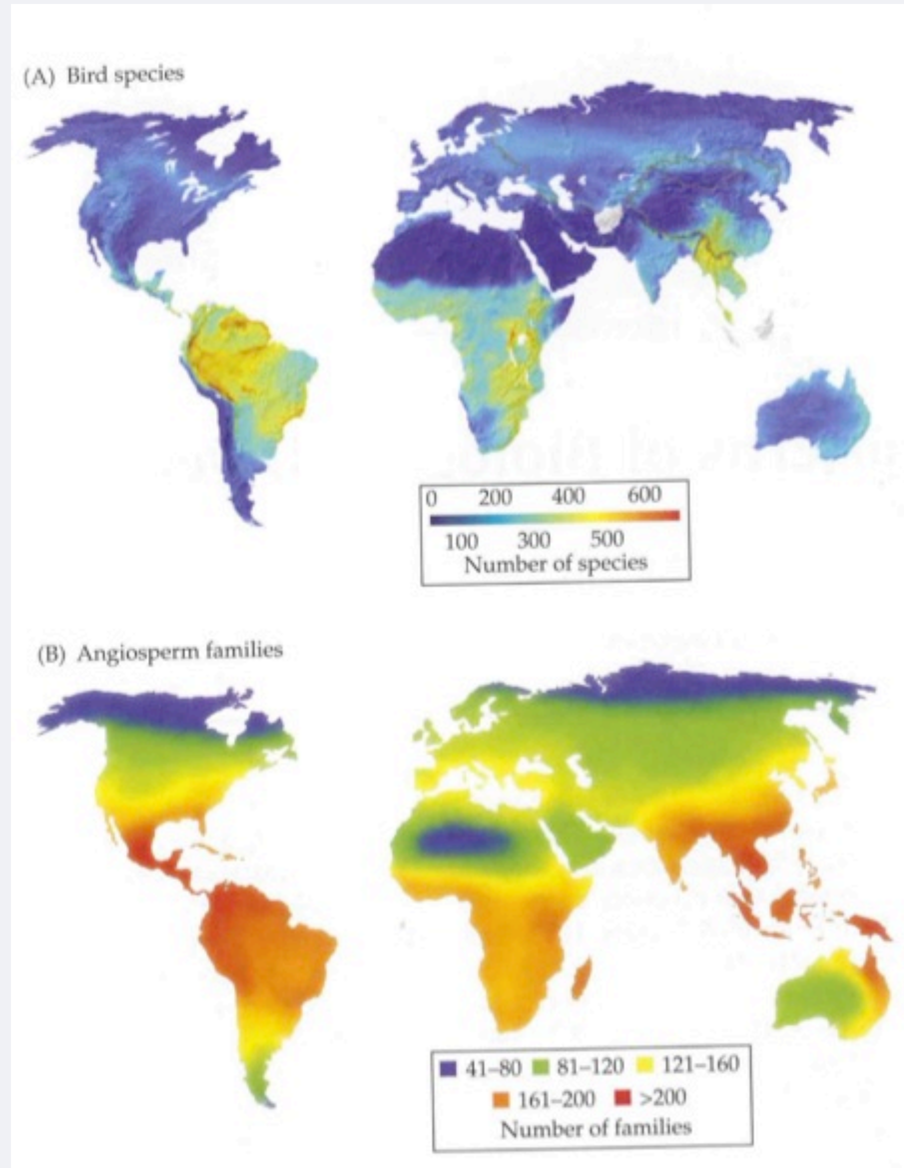

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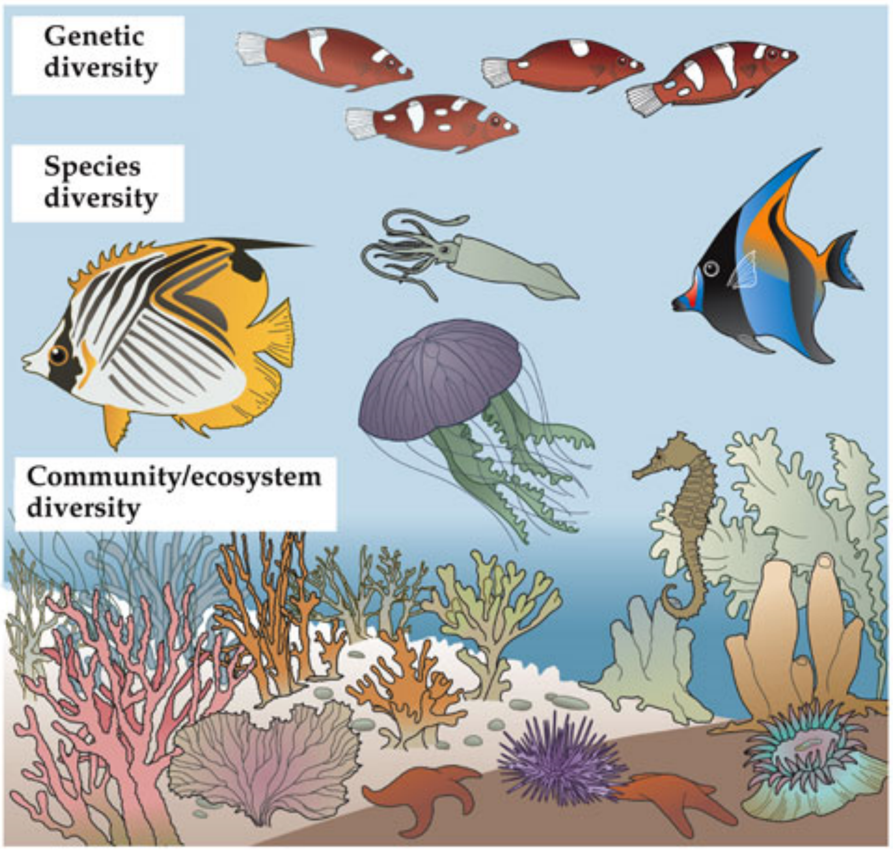
What is biodiversity?

"The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"

Convention on Biological Diversity

Three compositional levels of biodiversity



ESSENTIALS OF CONSERVATION BIOLOGY, 5e, Figure 2.1

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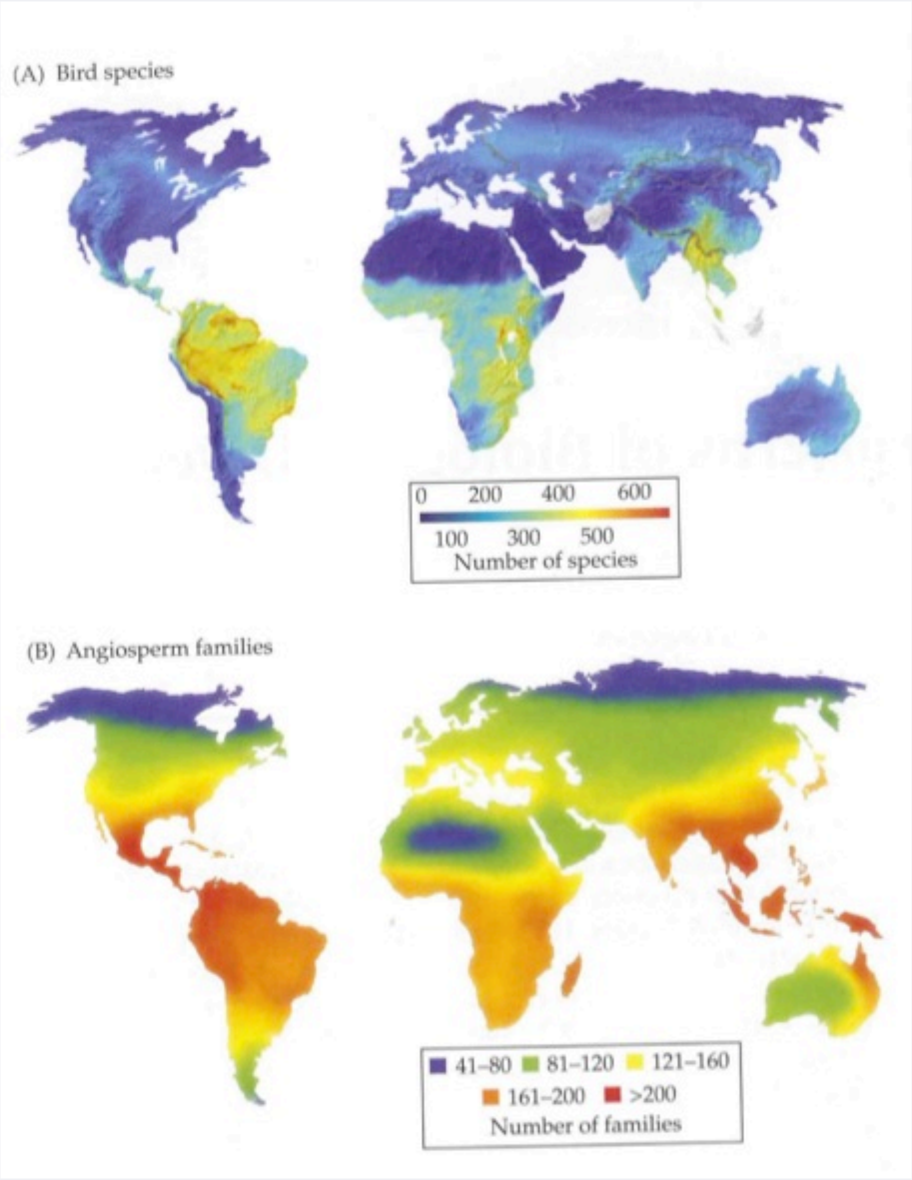
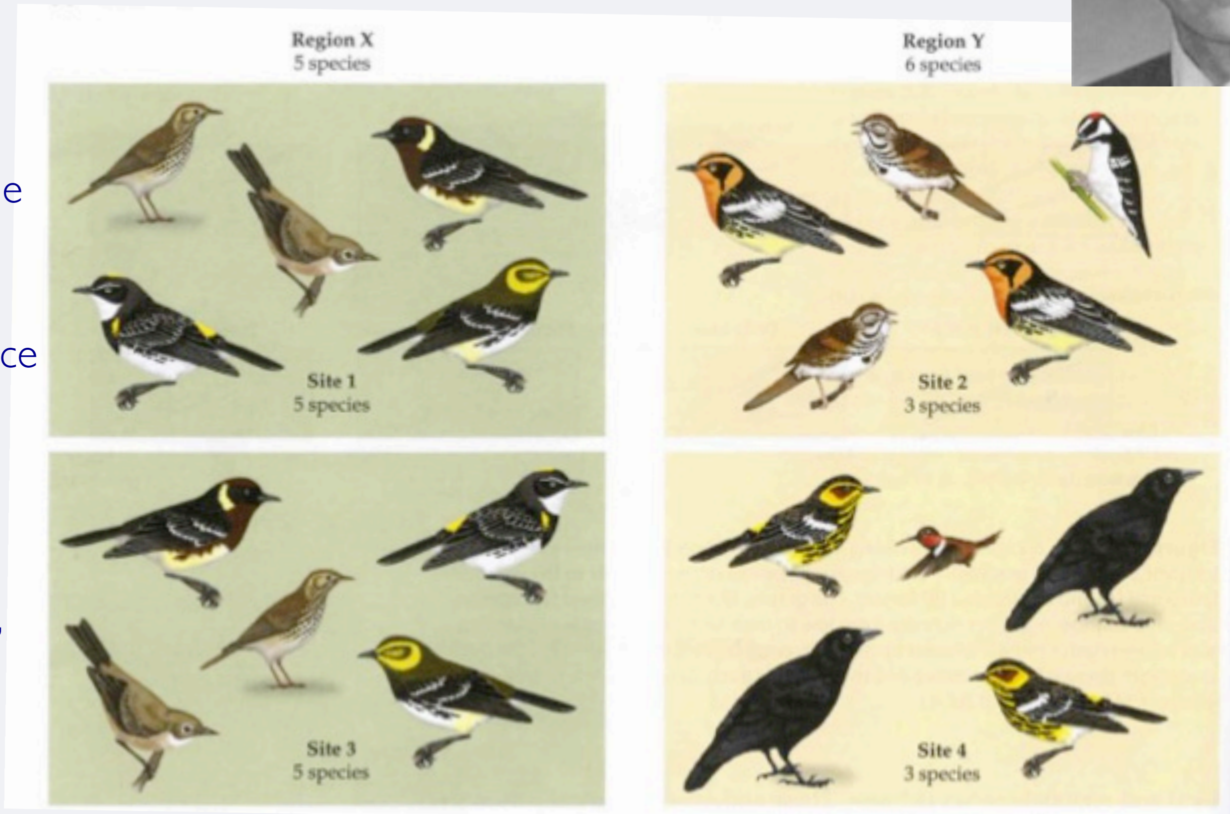


Species diversity across spatial scales

- Alpha, beta, and gamma diversity at 4 sites in 2 regions.
- **Alpha diversity** = # of species found at a local scale (i.e. w/i a given site or habitat).
- **Beta diversity** =the difference in species composition, or turnover, between sites within a given region
- **Gamma diversity** = total species richness in a region, assessed across all sites.



What is a region? – large, containing many habitats and communities,

- an area from which species, over time, have a good probability of colonizing a local community of interest. These species are the <u>regional species pool</u>
- in global diversity studies, **biogeographic regions,** representing distinct evolutionary histories, used to delineate regional diversity

Species Diversity

The number and relative abundances of species in a given community.

SPECIES RICHNESS

The number of species

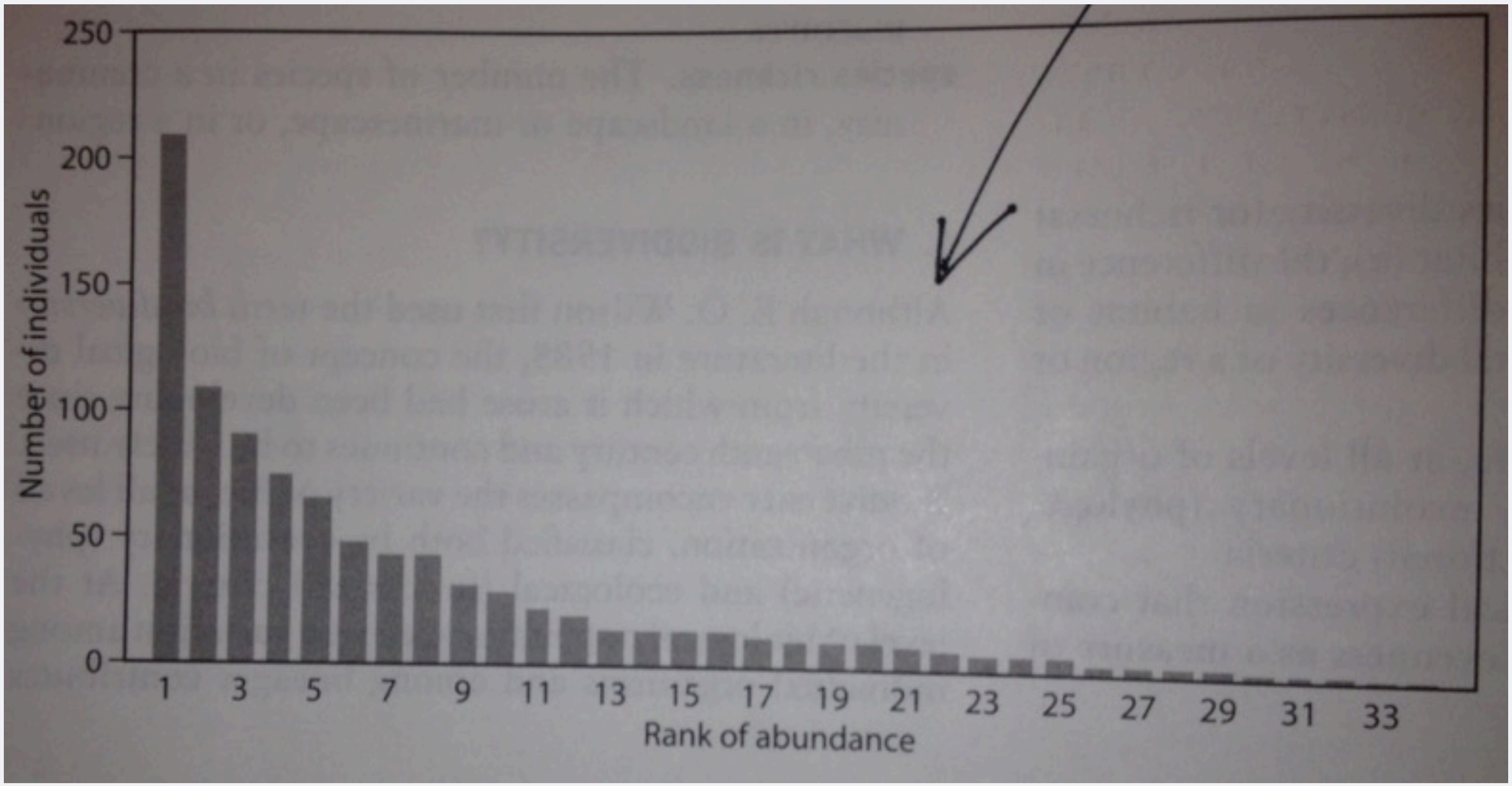
SPECIES EVENNESS

The equitability of abundance across species

Different color = different species

The distribution of species abundance

Rank Abundance Curve: each species represented by a vertical bar proportional to its abundance



Example of a community with low **evenness.**

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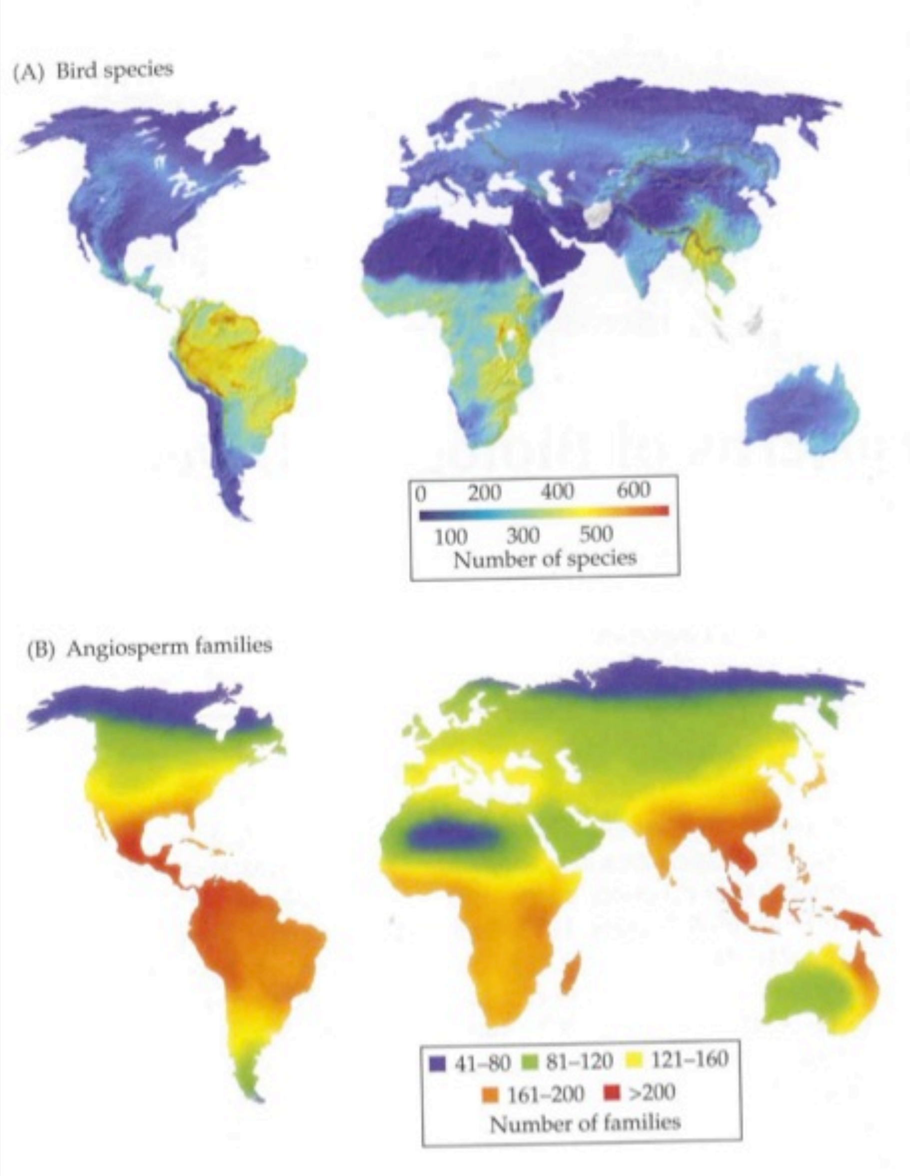
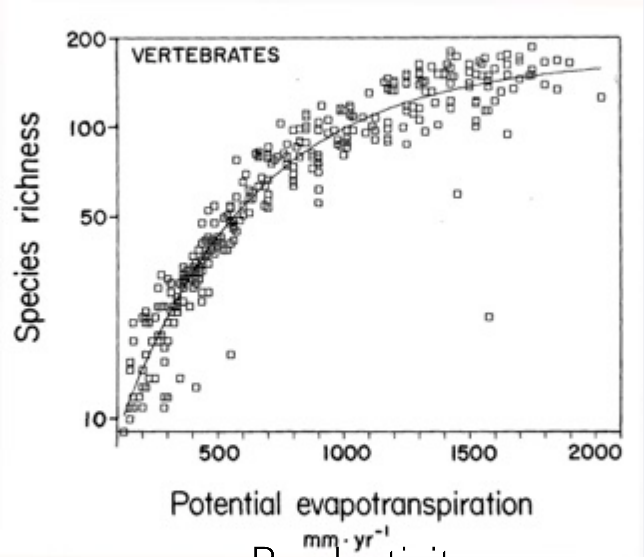


Productivity and species richness

Productivity – diversity relationships: typically positive at regional scales

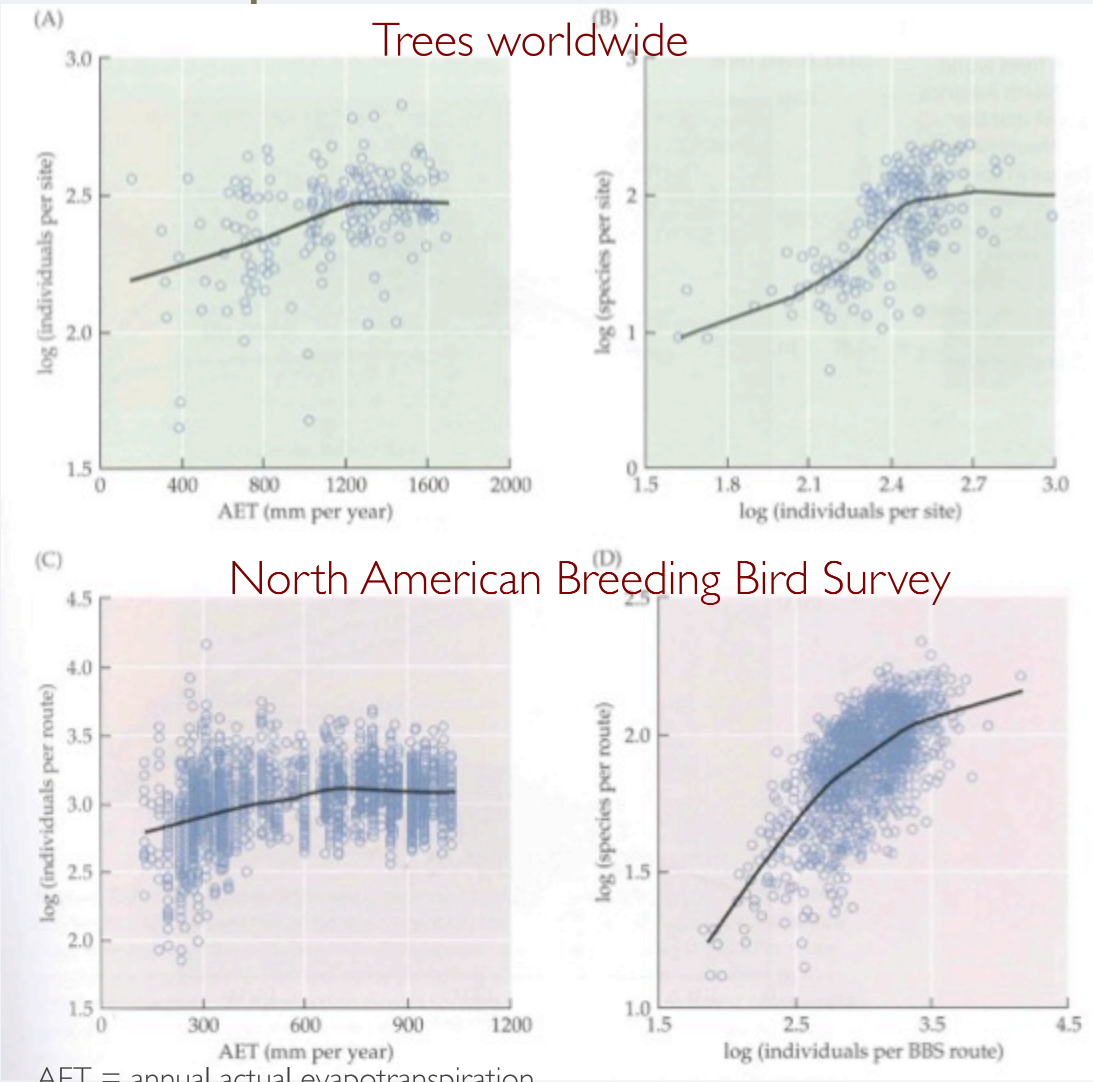


≈ Productivity

Why? Premise:

1) more productive environments (i.e. those w. more energy) should support more individuals (A, C)

2) areas that support more individuals will contain more species (B, D)



AET = annual actual evapotranspiration, a measure of productivity

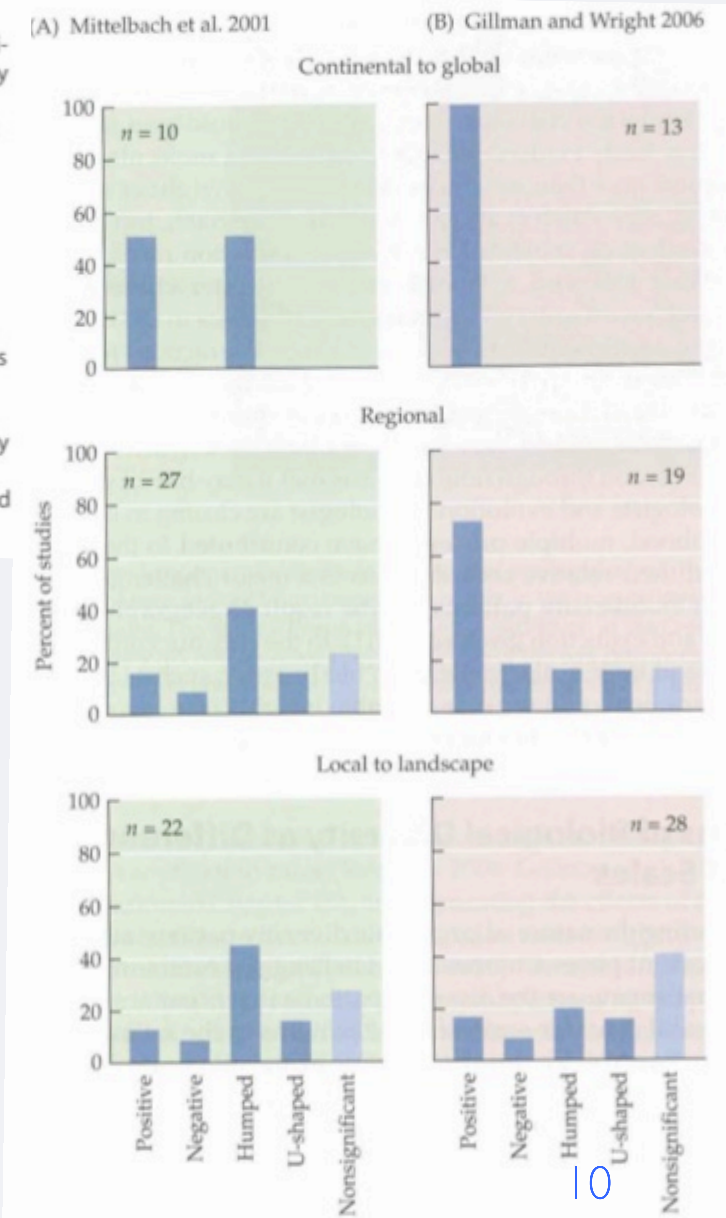
Productivity and species richness

Productivity – diversity relationships:
typically positive at regional scales

BUT

At smaller spatial scales, rel'ship much more varied: positive, negative, hump-shaped, U-shaped

Figure 2.12 Types of productivity–diversity relationships in plant communities at different spatial scales. Statistically significant productivity–diversity relationships were classified into four types: positive, negative, hump-shaped, and U-shaped. (A) Mittelbach et al.'s (2001) initial analysis of the literature showed that hump-shaped relationships were most common at smaller spatial scales, whereas positive and hump-shaped relationships predominated at the largest spatial scale. (B) Gillman and Wright's (2006) subsequent literature review concluded that positive, hump-shaped, and U-shaped relationships were equally represented at small spatial scales, and that positive relationships predominated at large spatial scales.



Why would diversity decline at high productivity?
Remains unresolved. Possibly:
-shift from nutrient limitation to light limitation at high productivity, resulting in a decline in plant species richness in very productive environments (Tilman and Pacala 1993)
-high productivity magnifies the impact of competition, leading to a loss of species richness in very productive environments (Abrams 2001)

Note: Shift in pattern across spatial scales!

Species-area relationship (SAR)

SAR: larger areas contain more species

Why?

1) larger areas usually encompass more habitat types
2) larger areas can support larger populations, which have a lower extinction probability. Thus, even in areas of homogeneous habitat, larger areas expected to have more species

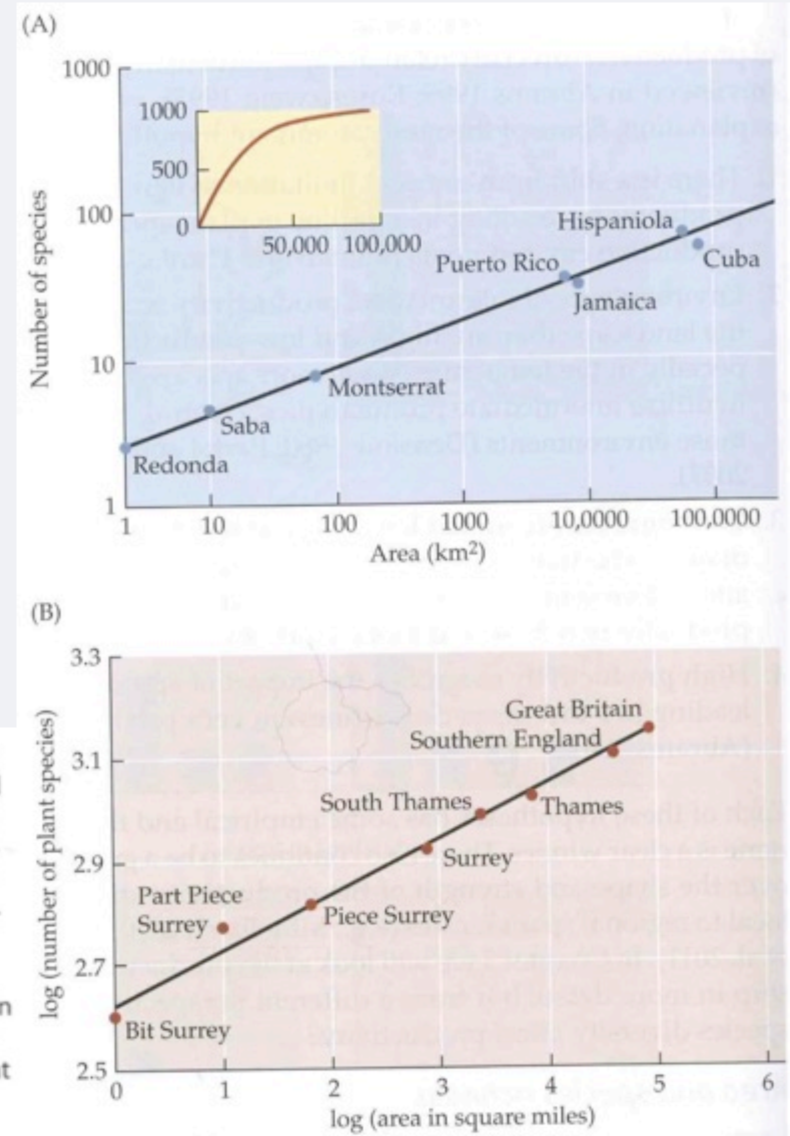


Figure 2.13 Two species–area curves. Note that the axes are logarithmic and that the relationships are well fitted by a straight line based on Equation 2.1 ($S = cA^z$, where c and z are fitted values; the arithmetic relationship is depicted in the inset in panel A). (A) MacArthur and Wilson plotted the number of reptile and amphibian species present against the size of several islands in the Greater and Lesser Antilles. (B) One of the first species–area curves was constructed by H. C. Watson in 1859 for plant species in Great Britain. He constructed the curve based on different-sized regions within Great Britain and the island as a whole. (A after MacArthur and Wilson 1967, data from Darlington 1957; B after Rosenzweig 1995.)

Species-area relationship (SAR)

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McArthur and Wilson's (1967) model of island biogeography illustrates this effect:

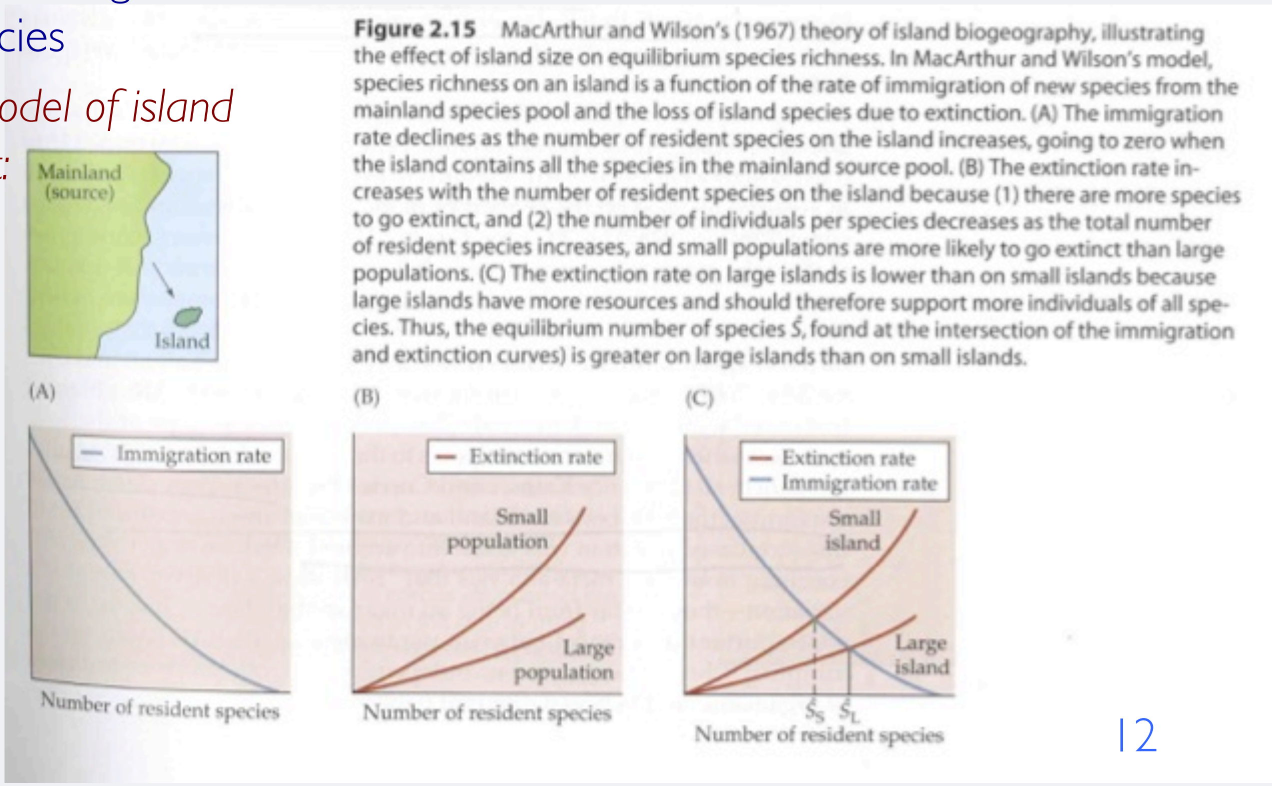


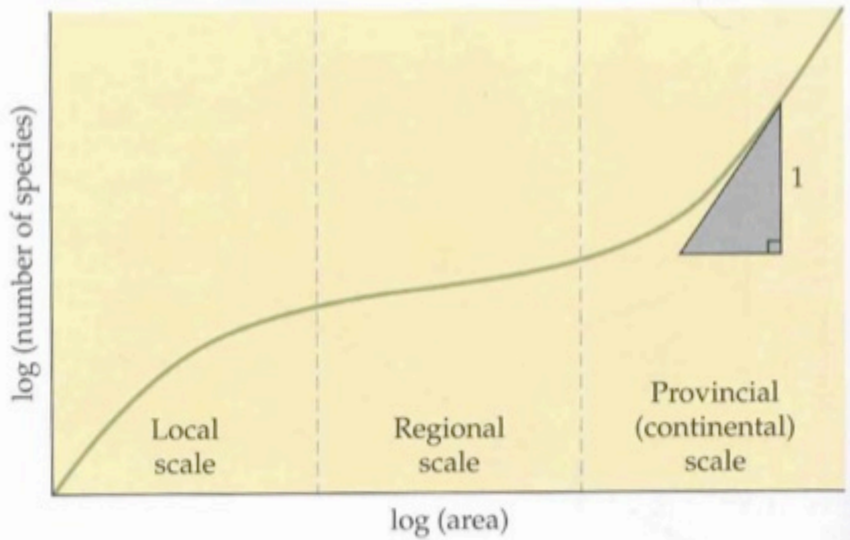
Figure 2.15 MacArthur and Wilson's (1967) theory of island biogeography, illustrating the effect of island size on equilibrium species richness. In MacArthur and Wilson's model, species richness on an island is a function of the rate of immigration of new species from the mainland species pool and the loss of island species due to extinction. (A) The immigration rate declines as the number of resident species on the island increases, going to zero when the island contains all the species in the mainland source pool. (B) The extinction rate increases with the number of resident species on the island because (1) there are more species to go extinct, and (2) the number of individuals per species decreases as the total number of resident species increases, and small populations are more likely to go extinct than large populations. (C) The extinction rate on large islands is lower than on small islands because large islands have more resources and should therefore support more individuals of all species. Thus, the equilibrium number of species $\hat{S}$, found at the intersection of the immigration and extinction curves) is greater on large islands than on small islands.

Species-area relationship (SAR)

SAR: larger areas contain more species

z, the rate at which new species are encountered as area increases, **varies with spatial scale**

Figure 2.16 The triphasic species–area relationship (Rosenzweig 1995; Hubbell 2001). The SAR curve is steepest at the provincial scale (i.e., when diversities are compared between biogeographical regions) and is shallower at regional scales (i.e., within provinces). Allen and White (2003) and McGill (2011) showed that the slope of the SAR will approach a value of 1 when the spatial scale of study is larger than most species' ranges.



At regional scale, variation in z related to climate: greater z-values with increased temperature and precipitation; z increases when moving from poles to equator

Local-regional diversity relationships

Possibilities:

1) **Linear** (Type I): if local community richness (alpha) determined largely by the input of species from the regional pool (gamma);

2) **Saturating** (Type 2): if local communities have 'limited membership' (Elton 1950) and species interactions such as competition and predation restrict which species are able to coexist

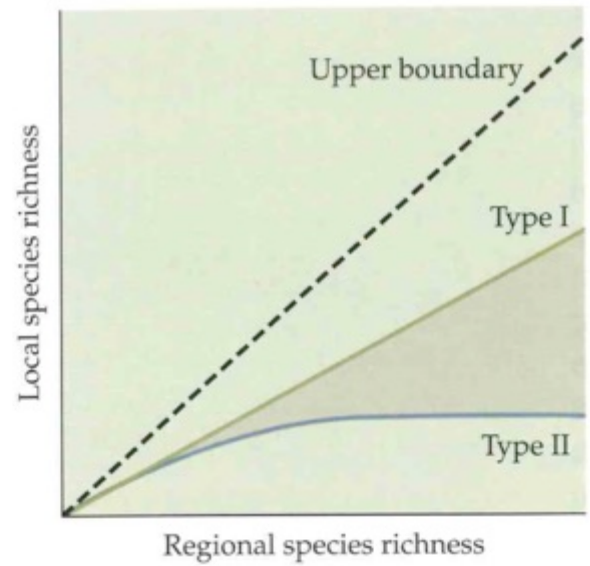


Figure 2.18 Theoretical curves for the relationship between local and regional species richness. In the type I curve, local species richness increases linearly (proportionally) with regional species richness. In the type II curve, the relationship is nonlinear and saturating because of biotic interactions and niche-filling in the local community. Real communities are likely to fall somewhere in the continuum between these two extremes (shaded area). The "boundary" represents the upper limit of the relationship, as local species richness can not exceed regional species richness. (After Cornell and Lawton 1992.)

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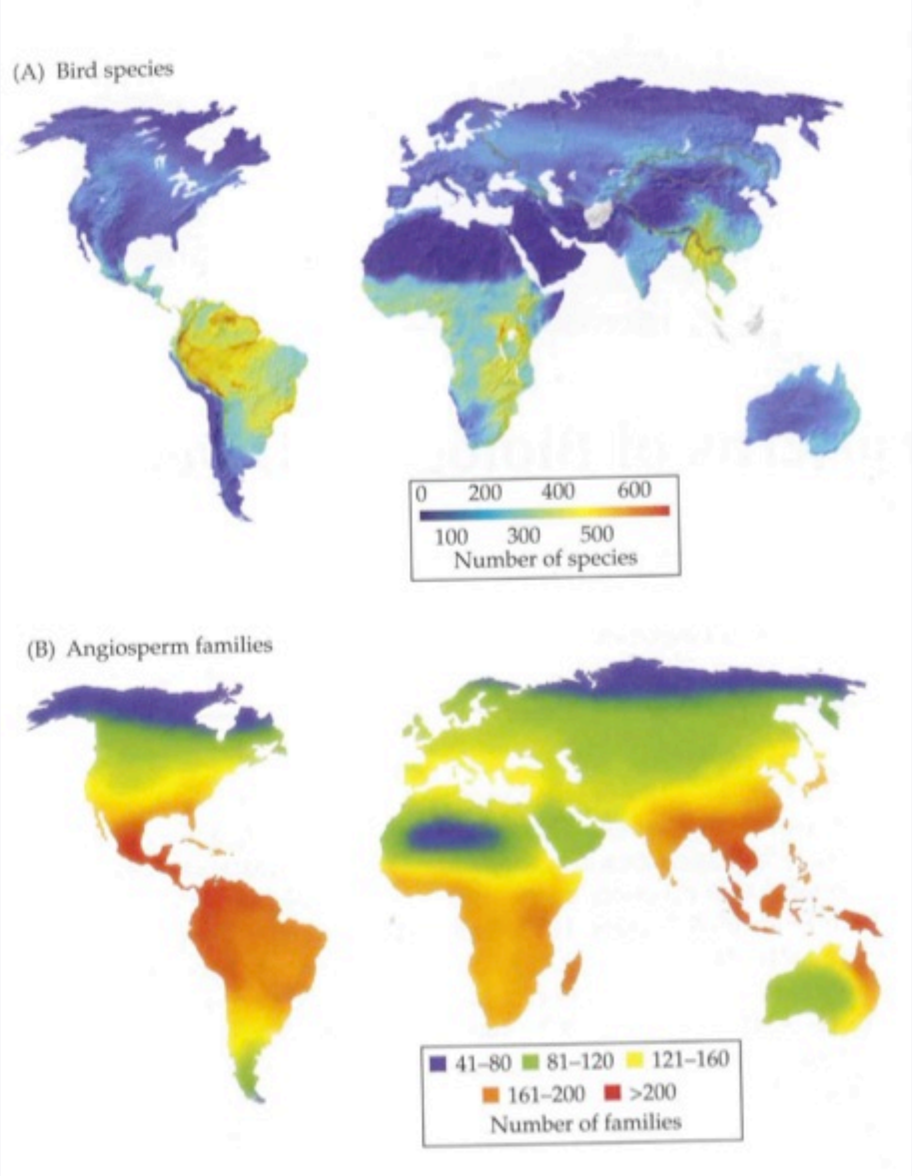
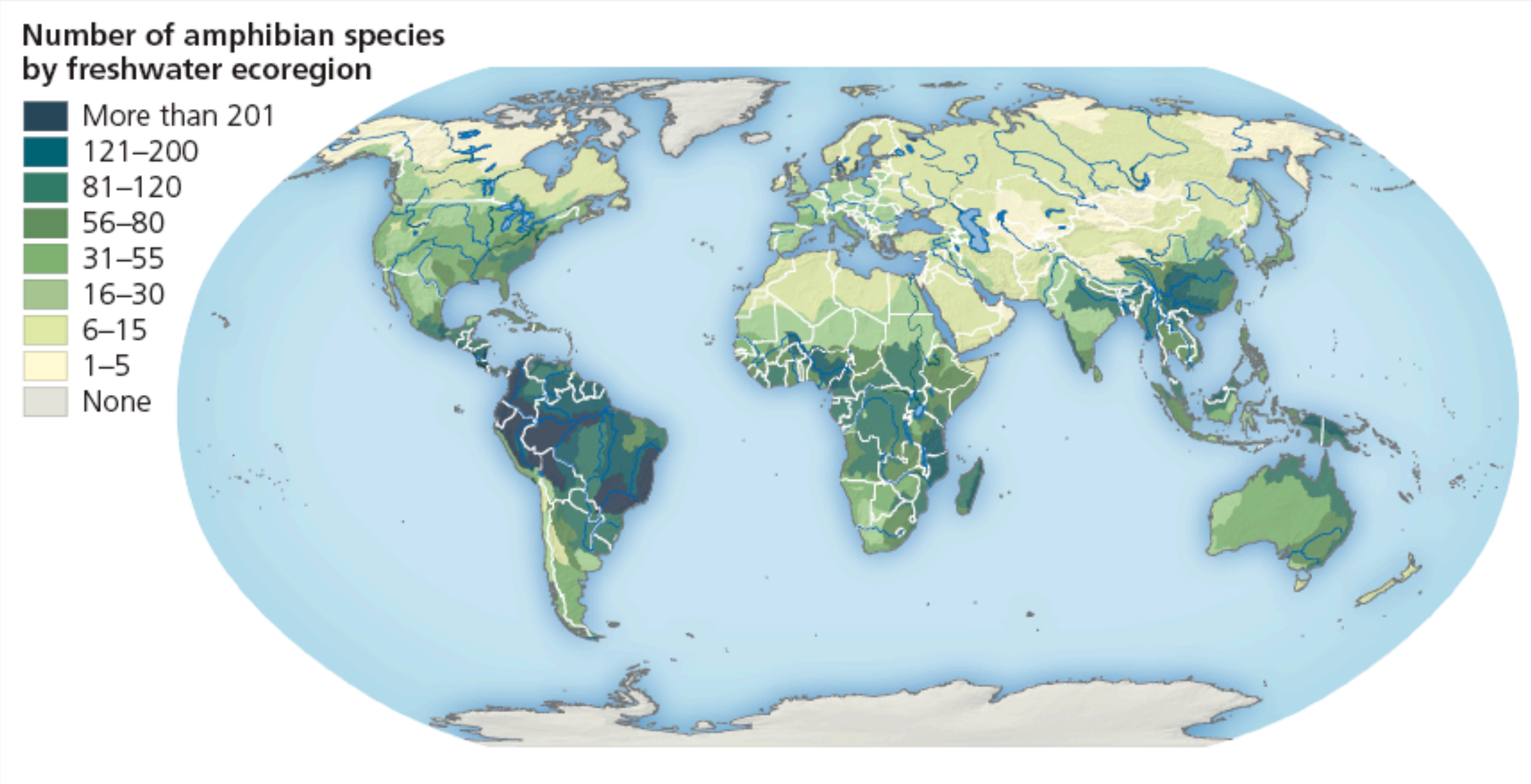


Latitudinal Diversity Gradient (LDG)



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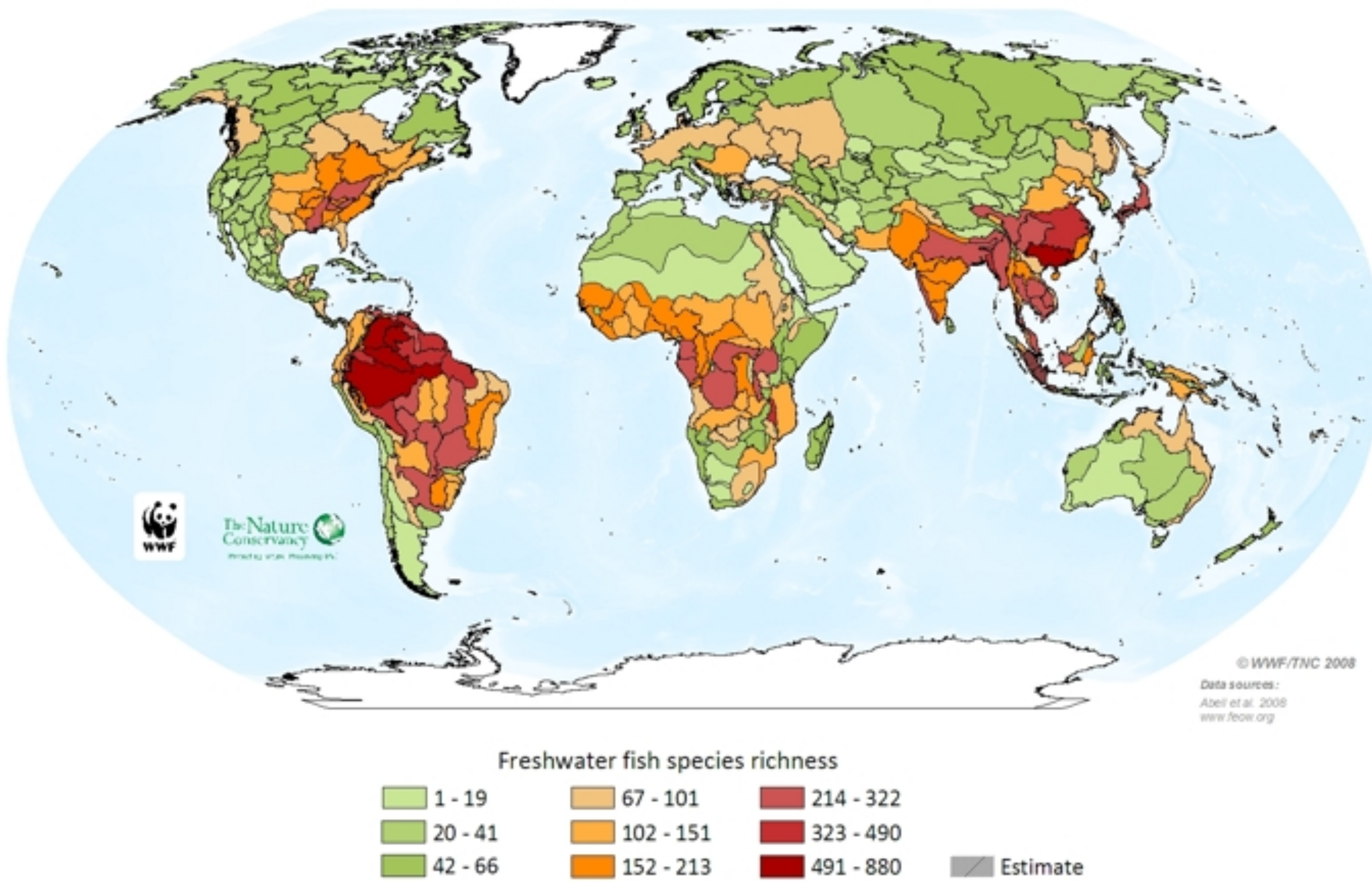

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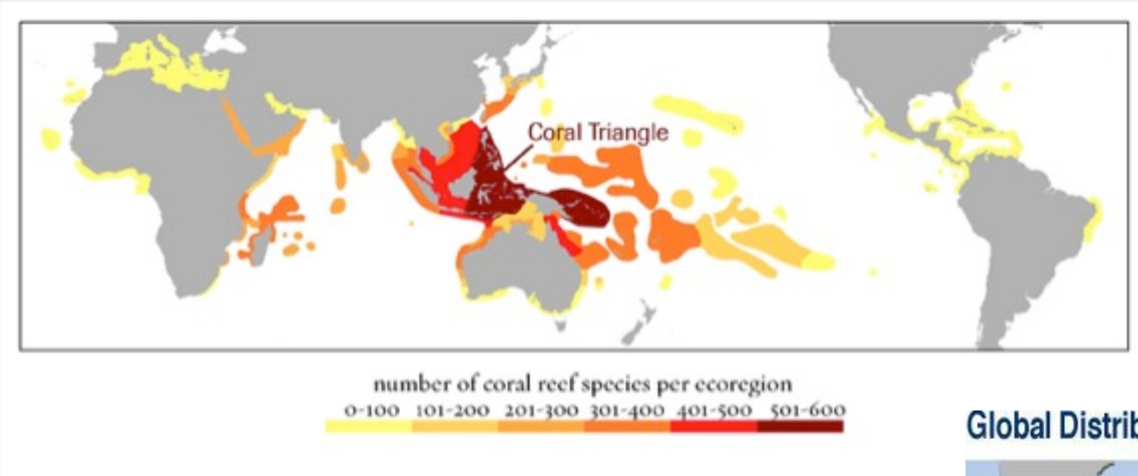
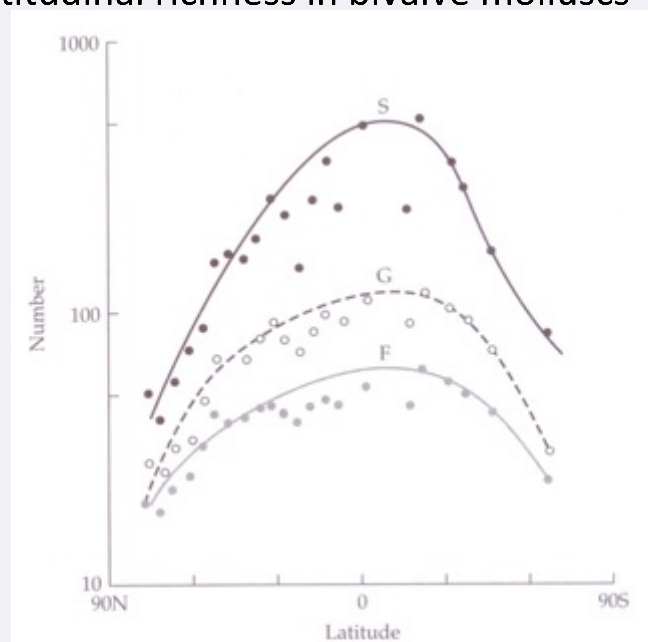
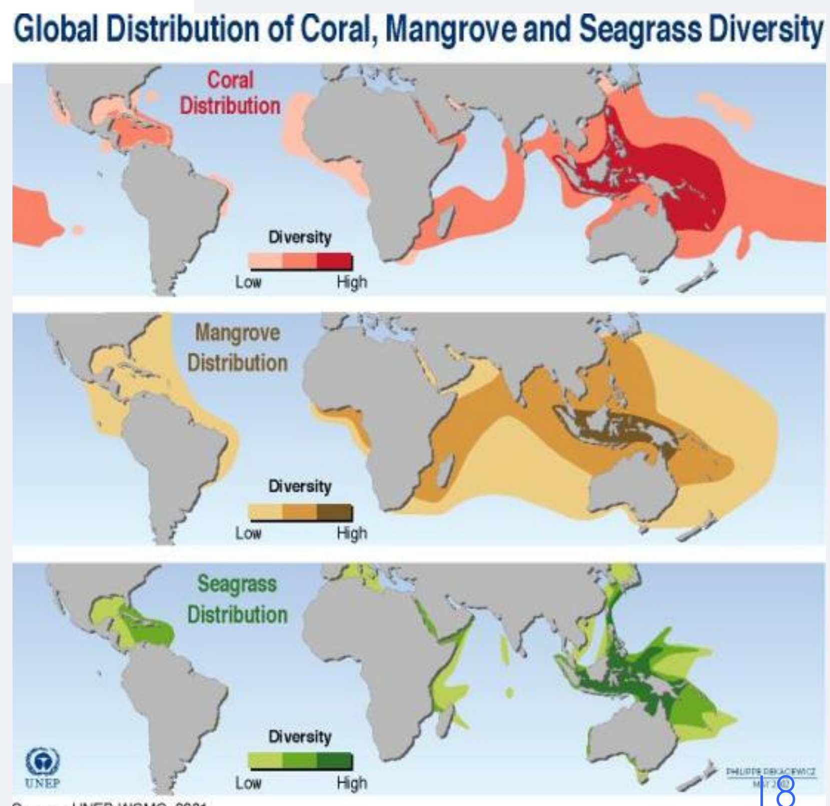


Latitudinal richness in bivalve molluscs





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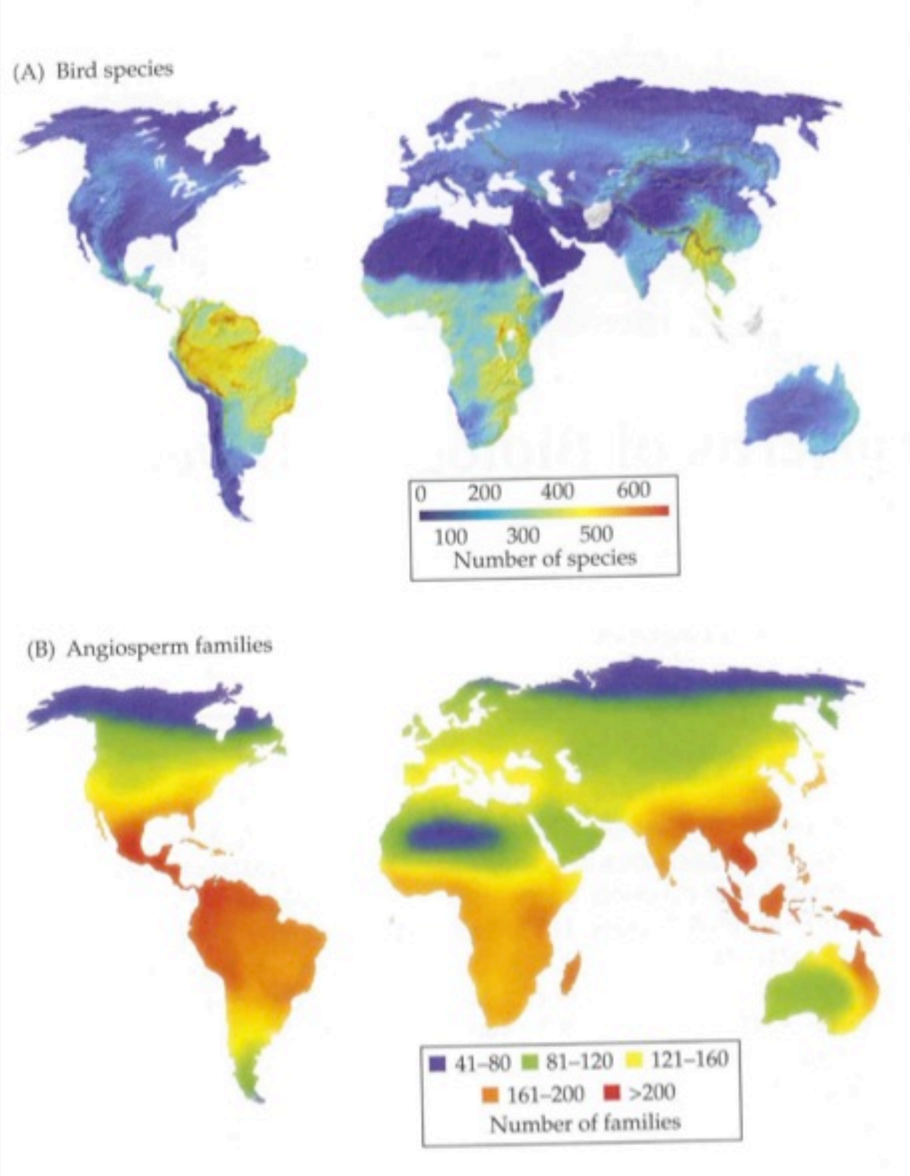
It is 'the major, unexplained pattern in natural history… one that mocks our ignorance'
-Robert Ricklefs, quoted in Lewin 1989



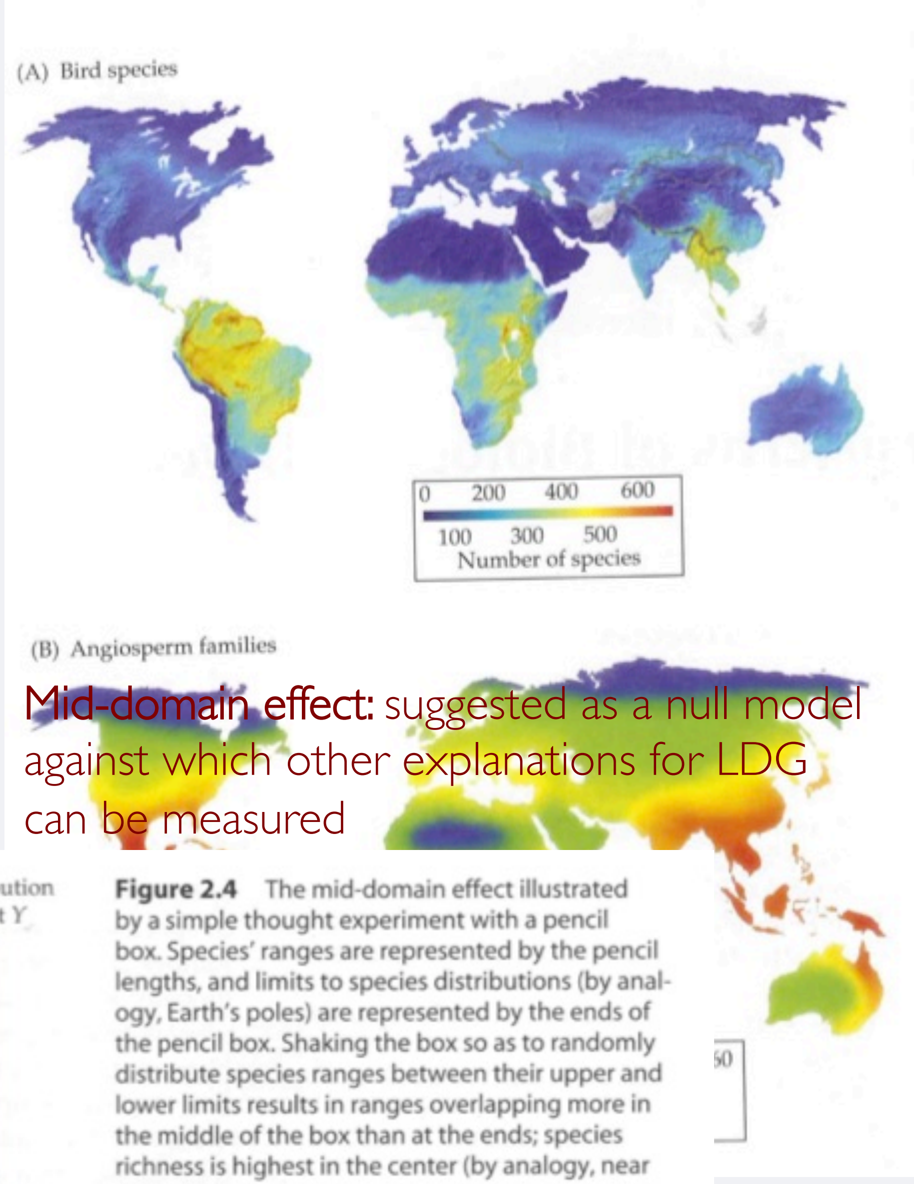
Latitudinal Diversity Gradient (LDG)

Hypotheses:

1. <u>Null-model explanations</u> based on geometric constraints on species ranges distributed around the globe

Null model: attempts to specify how a pattern in nature should look in the absence of a particular mechanism; a pattern-generating model based on randomization of ecological data. The randomization produces a pattern that would be expected in the absence of a particular mechanism

LDG may simply reflect outcome of placing species ranges on a bounded domain (the globe) (Colwell and Hurtt 1994).



Mid-domain effect: suggested as a null model against which other explanations for LDG can be measured

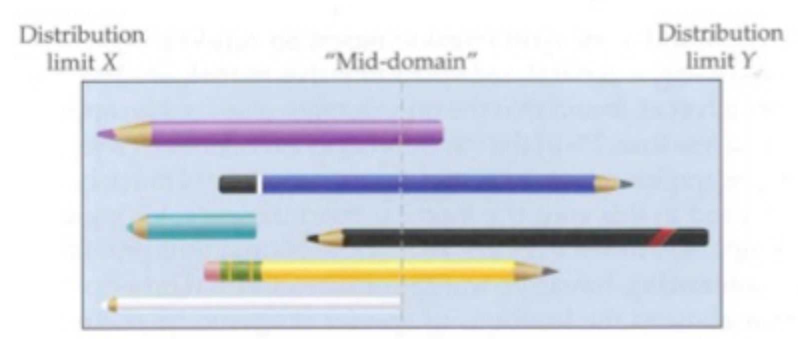


Figure 2.4 The mid-domain effect illustrated by a simple thought experiment with a pencil box. Species' ranges are represented by the pencil lengths, and limits to species distributions (by analogy, Earth's poles) are represented by the ends of the pencil box. Shaking the box so as to randomly distribute species ranges between their upper and lower limits results in ranges overlapping more in the middle of the box than at the ends; species richness is highest in the center (by analogy, near the equator).

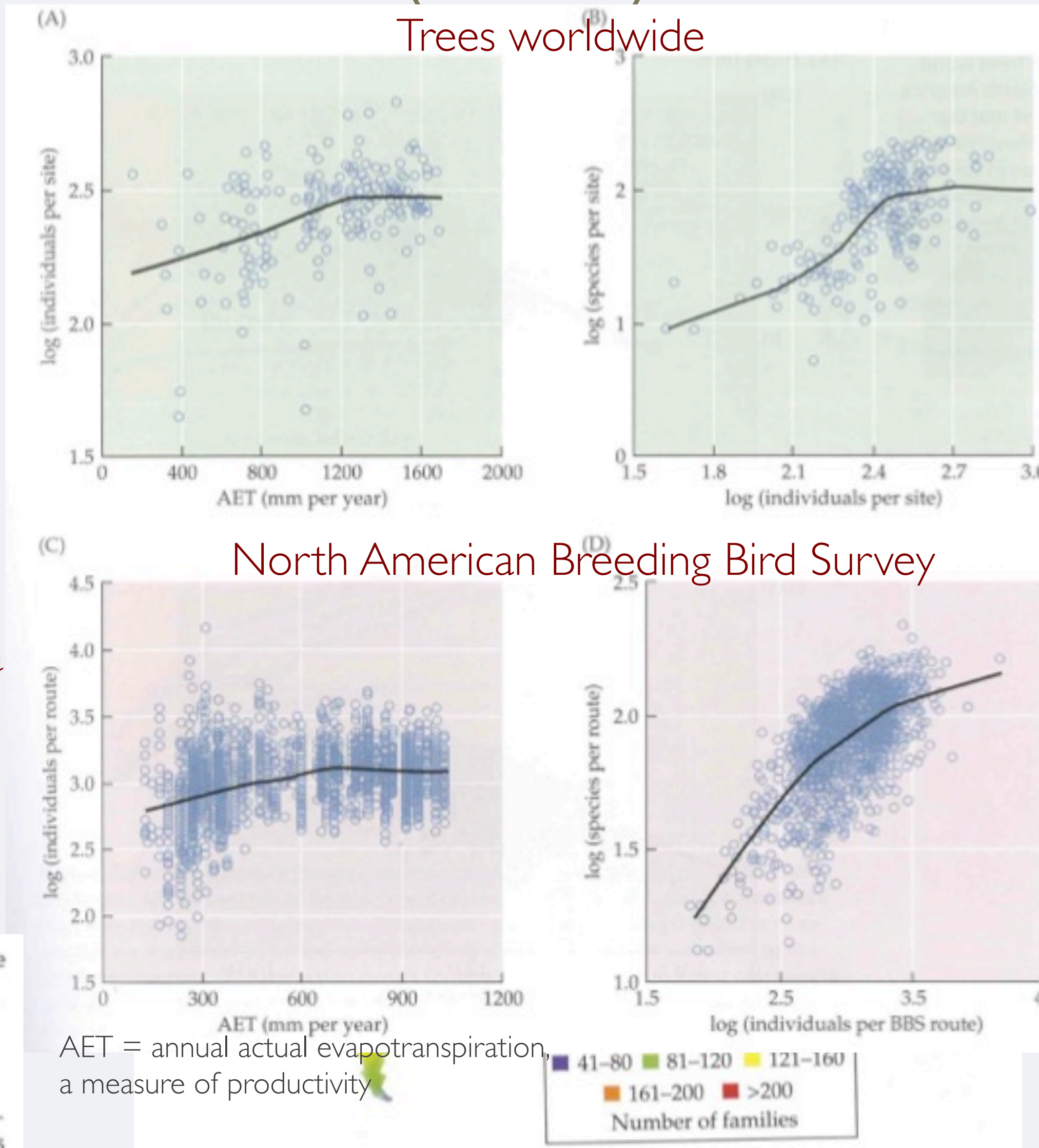
Latitudinal Diversity Gradient (LDG)

Hypotheses:

1. Null-model explanations based on geometric constraints on species ranges distributed around the globe
2. Ecological hypotheses focused on an area's carrying capacity for species

Species-energy hypothesis:

tropics tend to be highly productive
more productivity supports more individuals/area
more individuals contain more species



AET = annual actual evapotranspiration, a measure of productivity

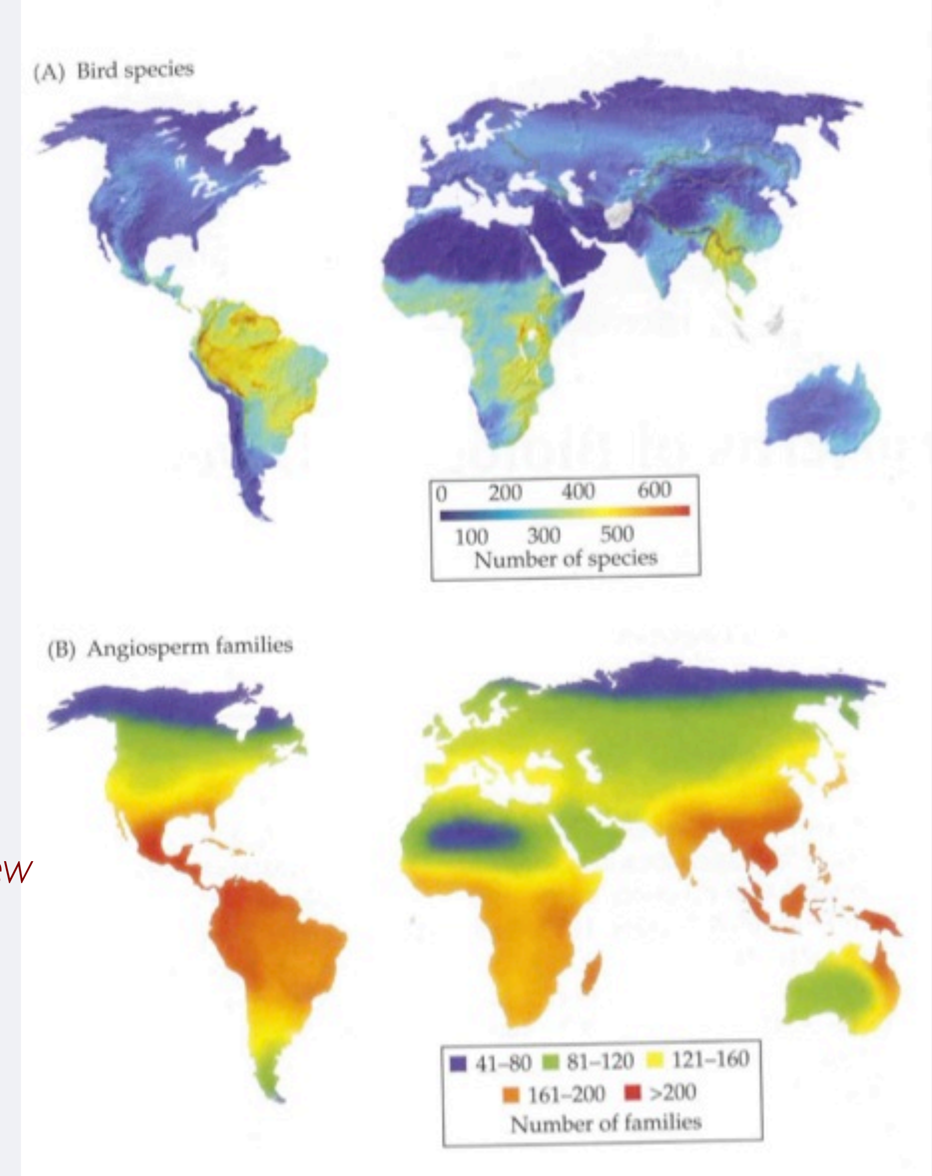
Figure 2.5 Components of the species–energy hypothesis (also known as the "more individuals hypothesis") as applied to the latitudinal diversity gradient. The premise reasons that (1) more productive environments, such as the humid tropics, can support more individuals; and (2) areas that support more individuals will contain more species. (A, B) Data for trees worldwide; Gentry's counts of individuals in 0.1-ha plots. (C, D) Data for North American birds from the North American Breeding Bird Survey (BBS routes). Areas of higher productivity (as measured by annual actual evapotranspiration, AET) contain more individuals (panels A and C), and areas with more individuals have more species (panels B and D). Thus, these data support the two assumptions of the species–energy hypothesis. (After Currie et al. 2004.)

Latitudinal Diversity Gradient (LDG)

Hypotheses:

1. Null-model explanations based on geometric constraints on species ranges distributed around the globe
2. Ecological hypotheses focused on an area's carrying capacity for species
3. Historical hypotheses: the **time-and-area hypothesis**
4. Evolutionary hypotheses: do rates of diversification (speciation minus extinction) differ across latitude?

   Tropics as a 'cradle' for the generation of new taxa or a 'museum' for the preservation of existing diversity



Latitudinal Diversity Gradient (LDG)

Hypotheses:

1. Null-model explanations based on geometric constraints on species ranges distributed around the globe
2. Ecological hypotheses focused on an area's carrying capacity for species
3. Historical explanations based on geologic history and the time available for diversification
4. Evolutionary hypotheses that focus on rates of diversification (speciation minus extinction)