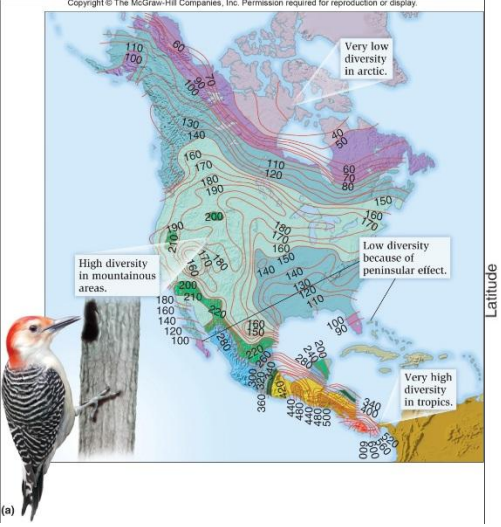
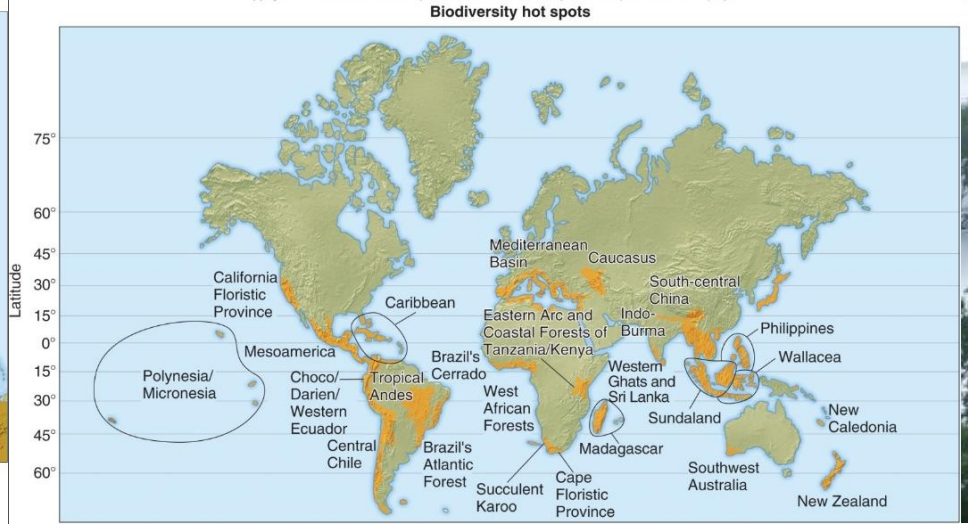
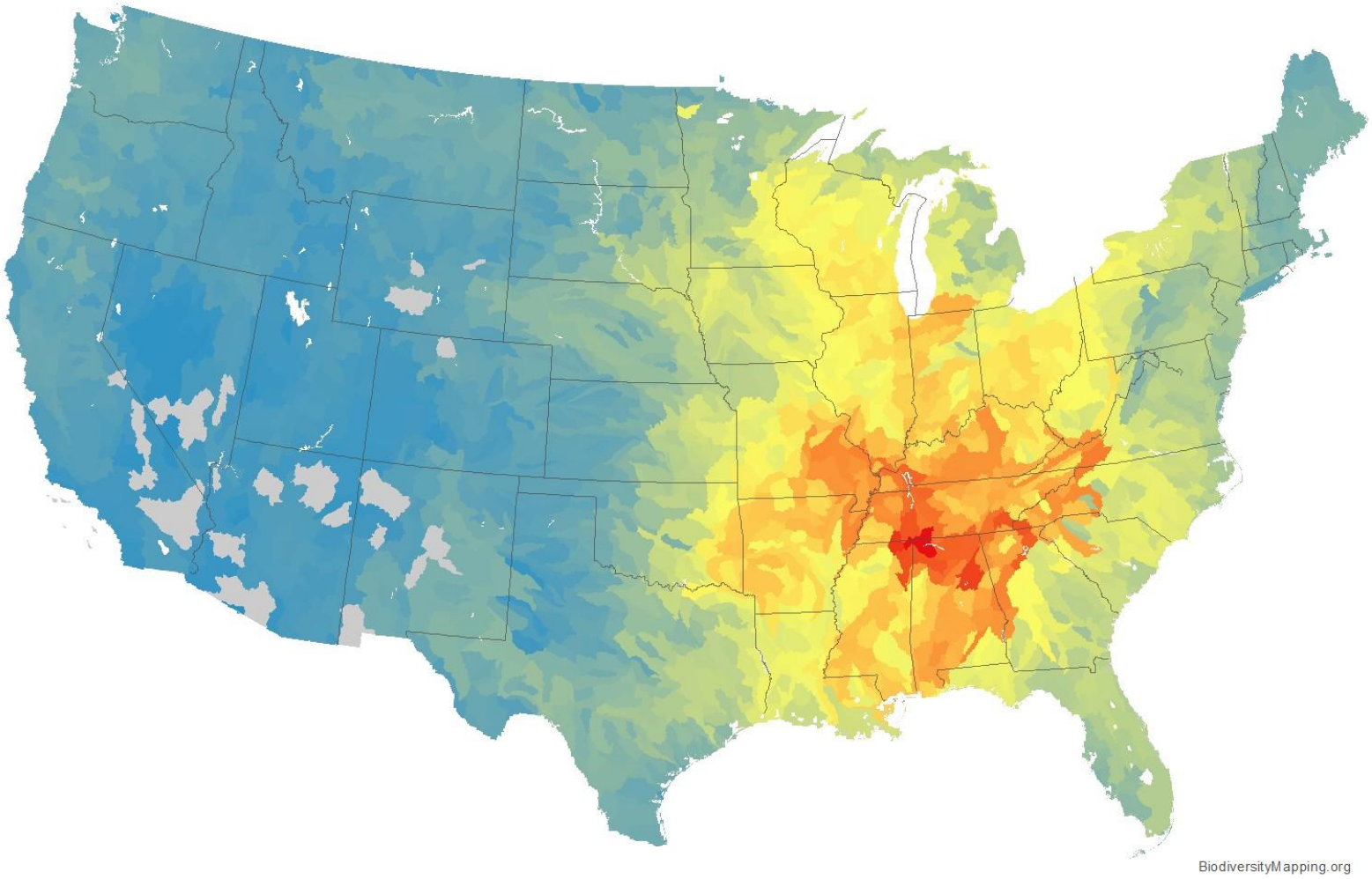


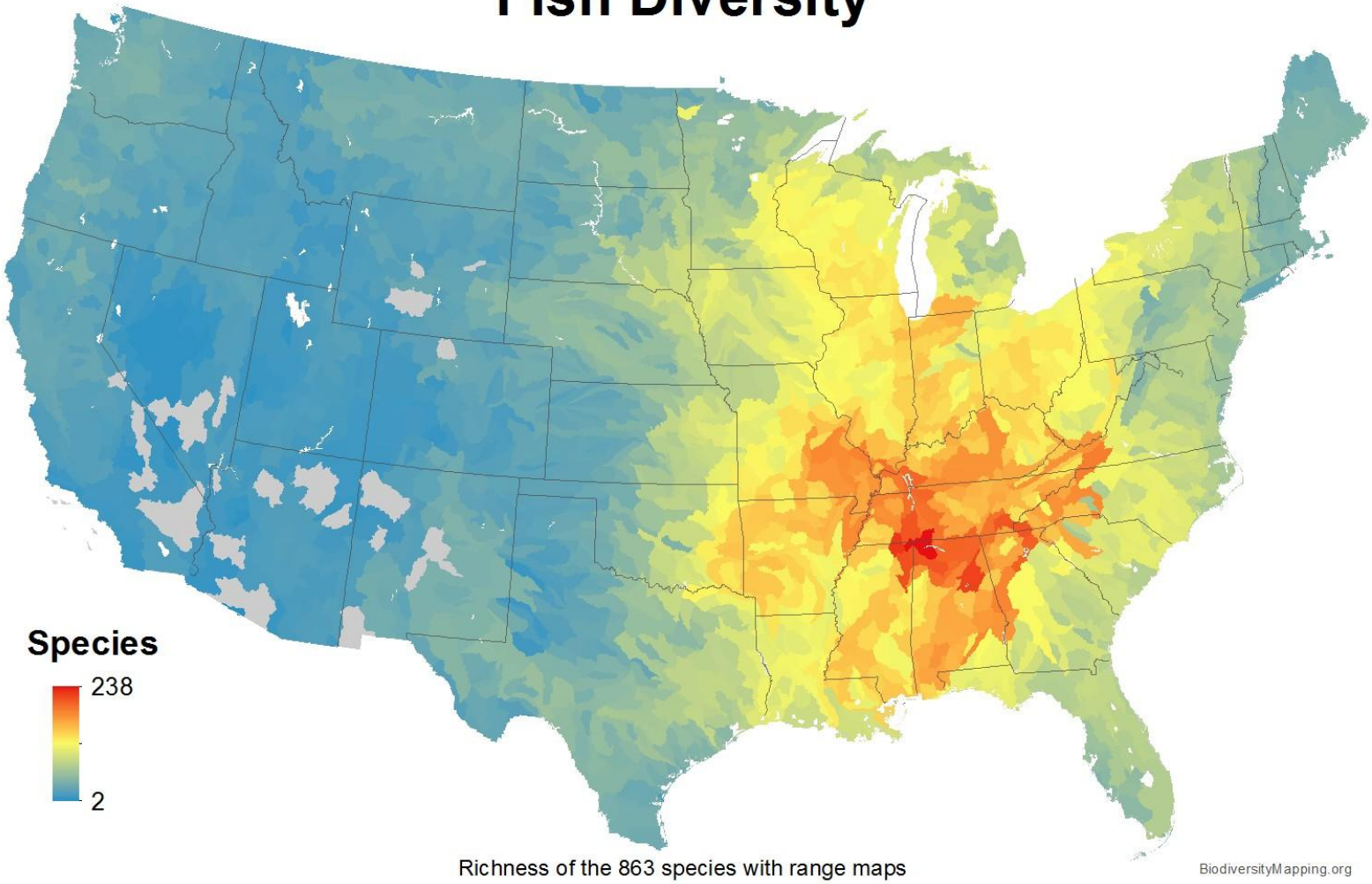




Community ecology: Species richness patterns


BiodiversityMapping.org

Fish Diversity



Richness of the 863 species with range maps

BiodiversityMapping.org

The ten principles of ecology

1. Evolution organizes ecological systems into hierarchies.
2. The sun is the ultimate source of energy for most ecosystems.
3. Organisms are chemical machines that run on energy.
4. Chemical nutrients cycle repeatedly while energy flows through an ecosystem.
5. dN/dt = B-X+I
6. dS/dt = D-X+I
7. Organisms interact – do things to each other - in ways that influence their abundance.
8. Ecosystems are organized into webs of interactions.
9. Human populations have an outsized role in competing with, preying upon, and helping other organisms.
10. Ecosystems provide essential services to human populations.

Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) Species-energy relationships

3) Species-time relationships

4) Species-area relationships

5) Implications for conservation

Topics for today

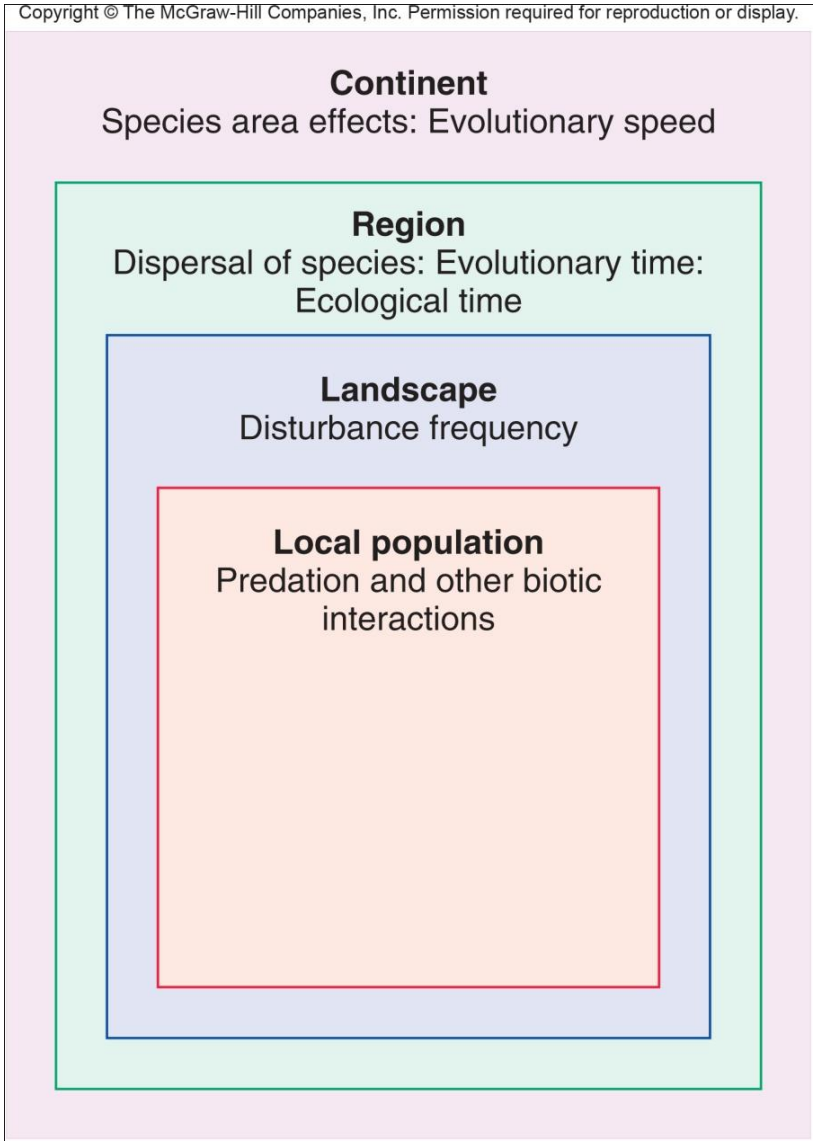
Everything we discuss today can be viewed as an attempt to answer our fundamental ecological question: *How and why species abundance and diversity vary in time and space*

What controls richness at different scales?

Figure 18.11. Processes affecting species richness at different spatial scales.

We need to think about speciation and extinction in the context of geographical richness gradients.

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(Each level includes all lower ones and nests within all higher ones.)

Both evolution and competition control species richness at small scales

Speciation is adding species. Competition (and other negative species interactions) can lead to extinctions.

Observed species richness in one location (e.g., a continent) is the net result of speciation and extinction



Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) Species-energy relationships

3) Species-time relationships

4) Species-area relationships

5) Implications for conservation

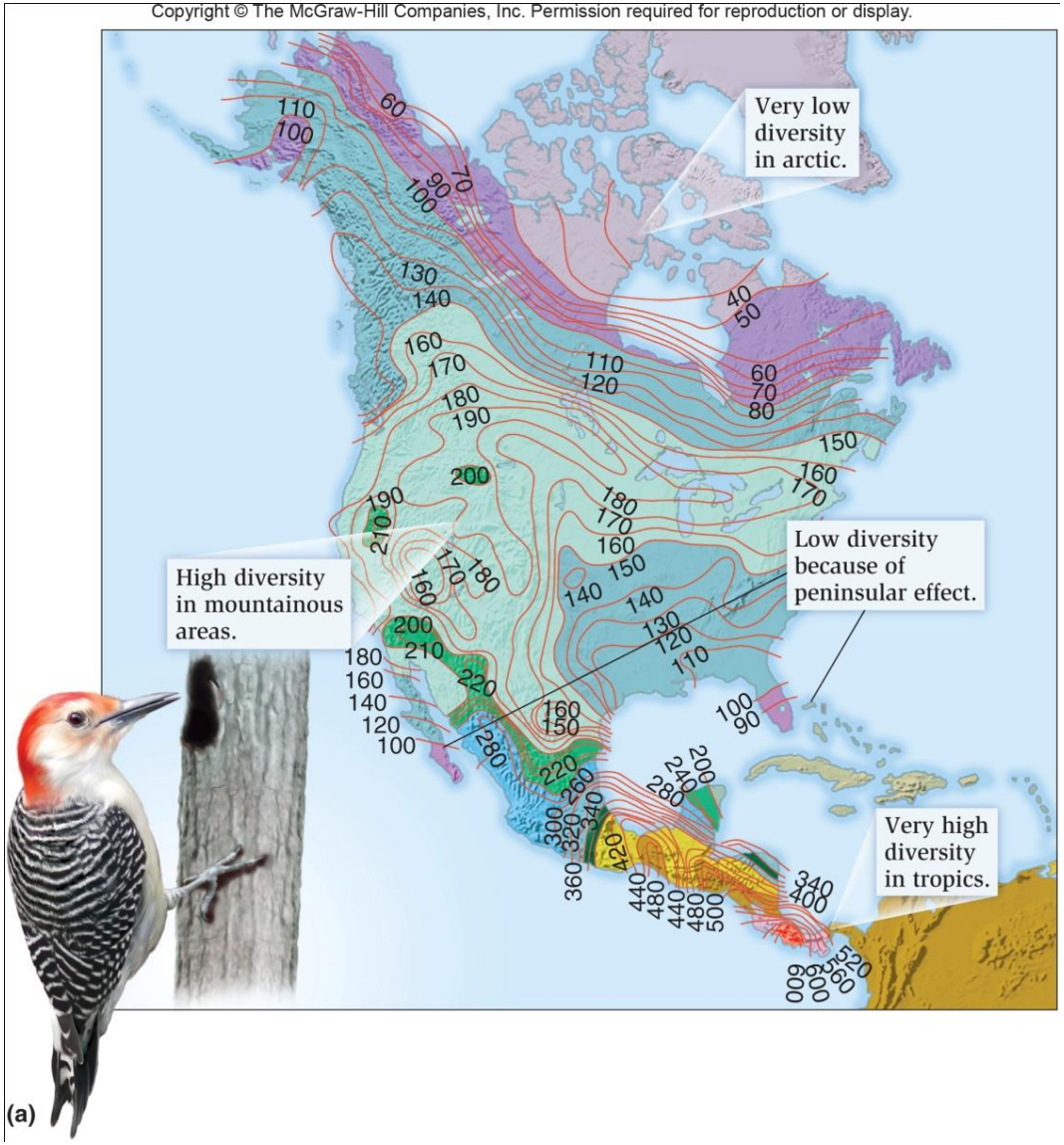
Latitudinal richness gradient

- The number of species of most taxa generally increases from polar to temperate to tropical areas
- known as the latitudinal species richness gradient.

Latitudinal richness gradient

Figure 18.1 Species richness in North American vertebrates follows a polar-equatorial gradient. Contour lines show equal numbers of bird species.

(a) Birds. (Redrawn from Cook, 1969)



Latitudinal richness gradient

Figure 18.1 Species richness in North American vertebrates follows a polar-equatorial gradient. Contour lines show equal numbers of mammal species.

(b) Mammals. (Redrawn from Simpson, 1964) Note the pronounced latitudinal gradient heading south toward the Tropics and the high mammal diversity in California and northern Mexico, regions of considerable topographic relief and habitat diversity.



Latitudinal richness gradient

Three of the most important hypotheses underlying this latitudinal gradient:

Species richness increases with increased

1) **productivity / energy**,
2) **time**, and
3) **area**.

Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) **Species-energy relationships**

3) Species-time relationships

4) Species-area relationships

5) Implications for conservation

Species-energy relationship

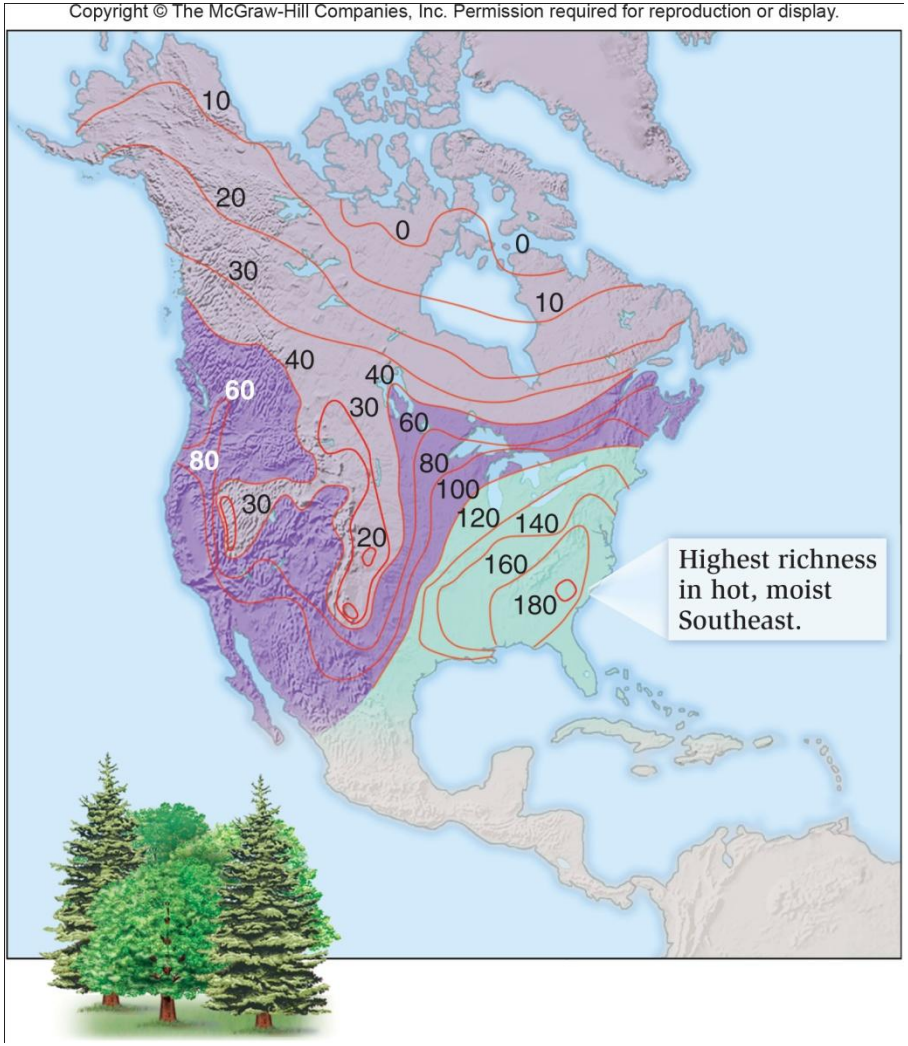
The species-energy hypothesis proposes available energy determines species-richness.

- Increased solar energy, together with an abundance of water, results in high productivity of plants.
- An increase in plant productivity (e.g., the total weight of plant material produced annually) leads to an increase in the number of herbivores.
- This in turn leads to an increase in the number of predator, parasite, and scavenger species.

Species-energy relationship

Figure 18.7 Tree species richness in the United States and Canada is influenced by climate and rainfall.

The highest richness is associated with areas with the highest evapotranspiration rates, in the southeastern United States.



Species-energy relationship

Terrestrial evapotranspiration: rate of water movement into the atmosphere through the processes of evaporation from the soil and transpiration of plants

(affected by both precipitation and solar energy).

- Evapotranspiration rates and tree richness, are highest in the southeast United States.
- Tree richness is low in the desert southwest because rainfall and water availability are low, even though temperatures are high.

Species-energy relationship

There are exceptions to the species-energy hypothesis:

- Some tropical areas (southeast Pacific near coastal Colombia and Ecuador) have low productivity, but high species richness.
- The sub-Antarctic Ocean has a high productivity but low species richness.
- Estuarine areas, where rivers empty into the sea are very productive yet are low in species.

Species-energy relationship

While patterns of tree richness in North America support the species-energy hypothesis, **the pattern does not hold** for broad comparison between continents.

- Example: the number of tree species in temperate forests is 729 in eastern Asia, 253 in North America and 124 in Europe.
- Also, why would we expect increased productivity should promote increased species richness instead of high population densities of just a few species?

Robert Latham and Robert Ricklefs

Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) Species-energy relationships

3) **Species-time relationships**

4) Species-area relationships

5) Implications for conservation

Species-time relationship

- The species-time hypothesis suggests that communities diversify (gain species) with time
- Temperate regions are less species-rich than tropical regions because they are younger (recently recovered from glaciations and severe climate disruption).

Species-time relationship

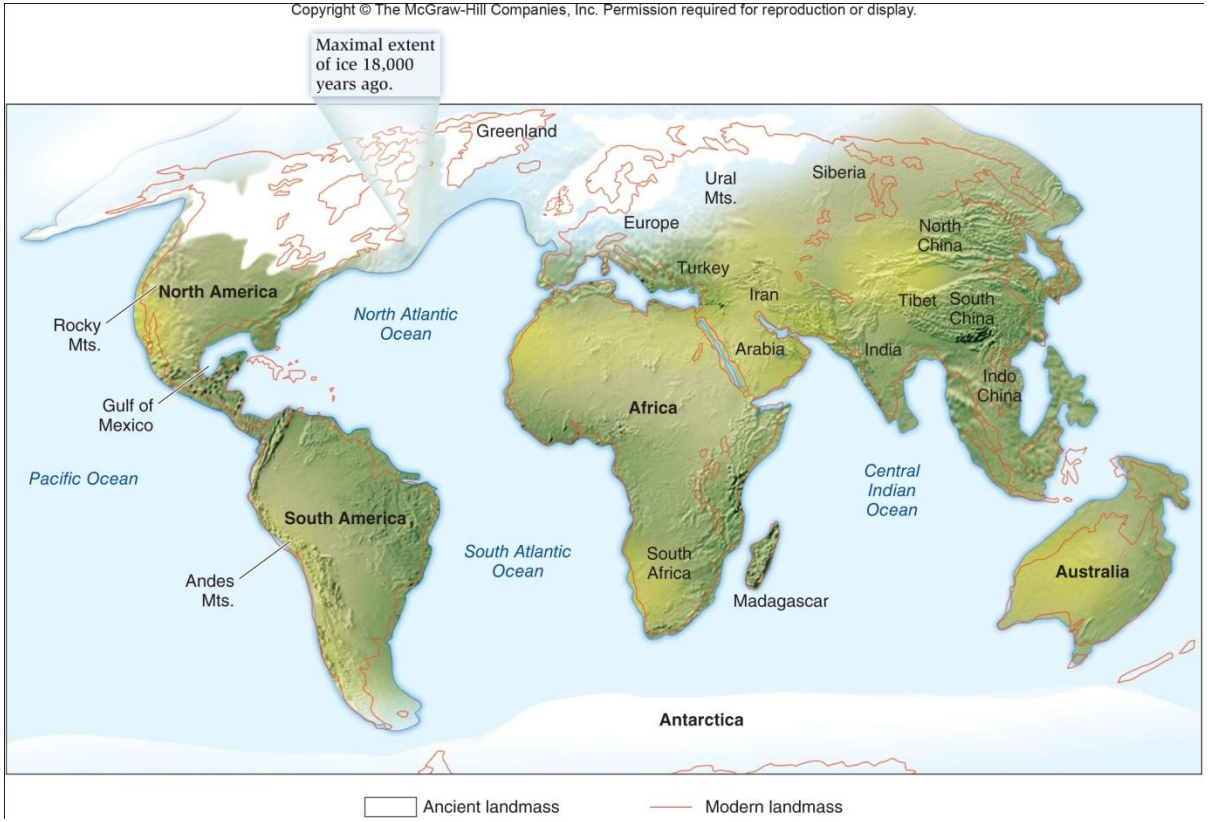


Figure 18.3 The maximum extent of ice sheets during the last ice age 18,000 years ago.

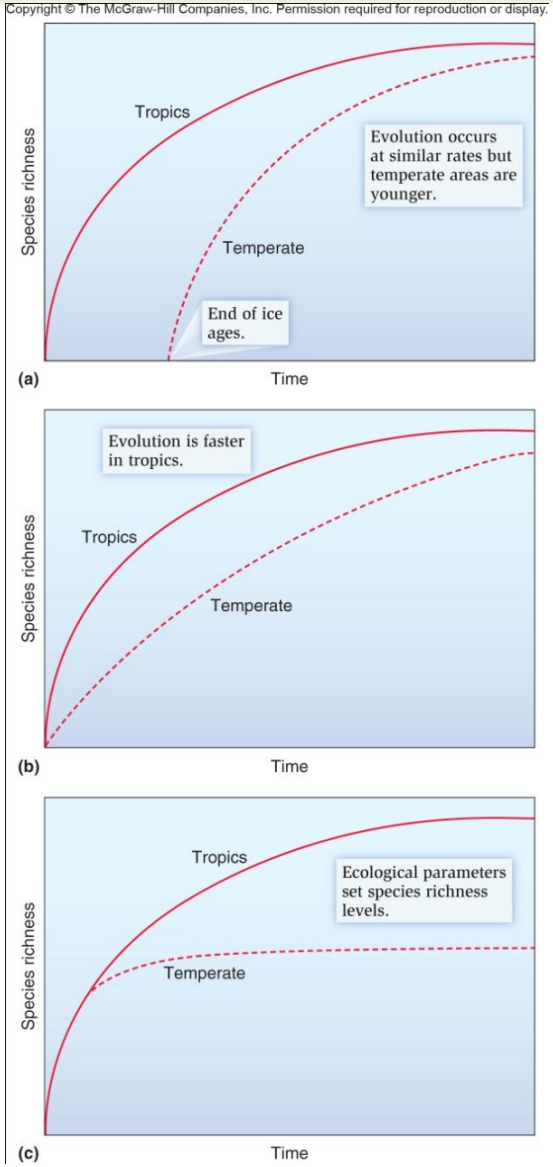
Temperate species in North America and northern Europe were displaced during this time.

Species-time relationship

Figure 18.2 The accumulation of species in tropical and temperate areas has been attributed to…

(a) A longer time for speciation in the tropical areas following climate change in temperate areas, for example, the end of the ice ages, **(b)** higher speciation and/or extinction rates in the tropical areas, **(c)** different ecological factors in each realm. (After Mittelbach, et al., 2007)

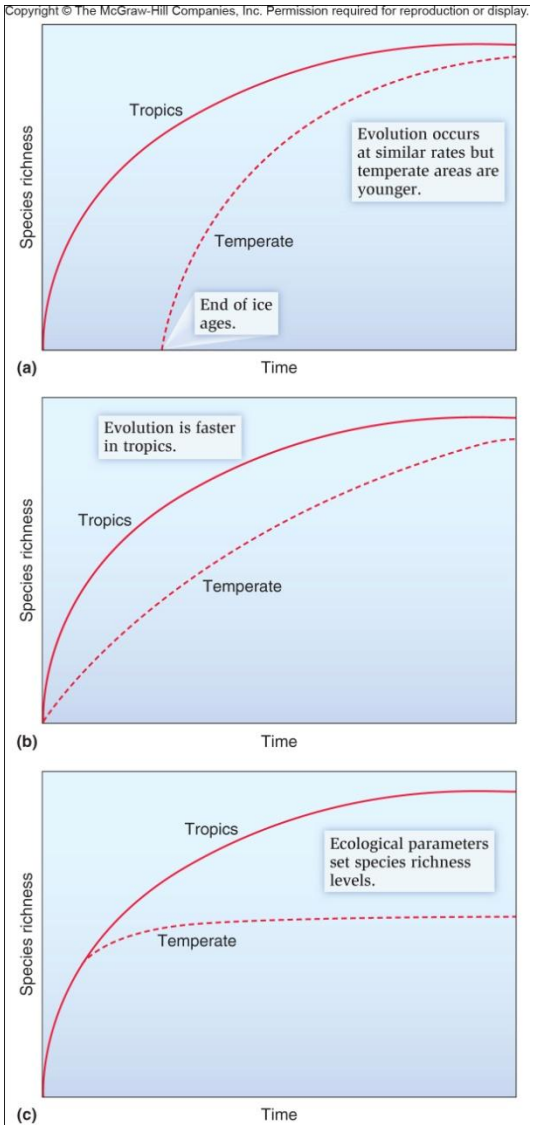
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*The **evolutionary speed hypothesis** proposes that evolution is faster in the Tropics due to high ambient temperatures, short generation times, and increased mutation rates, and this has produced more species.*

Species-time relationship

Evidence for a slightly different hypothesis: An analysis of 2,300 mammal and 6,700 bird species suggests evolution is faster in temperate regions, but extinction is also much faster (Botero et al. 2013)

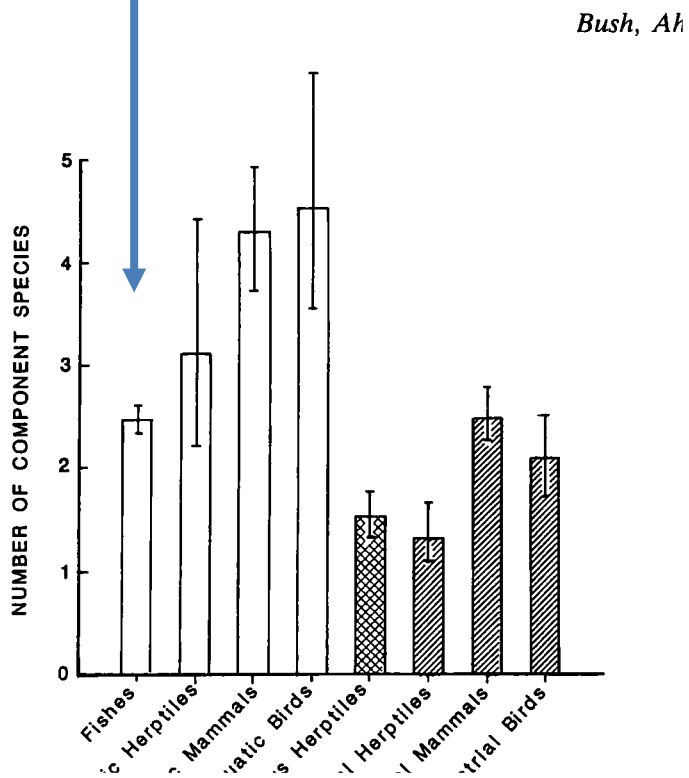


Species-time relationship

There are drawbacks to the utility of the species-time hypothesis.

1. Other datasets do not support the species-time hypothesis.
   - Albert Bush et al. (1990) examined the helminth parasite richness of vertebrates.
   - According to the species-time hypothesis, the oldest vertebrate lineages, the fish, should have more species than the youngest lineages, birds and mammals, with lizards and snakes in between.
   - Data showed that habitat mattered more. Aquatic vertebrates, regardless of taxon had more helminth species than terrestrial ones.

Oldest host lineage, but has fewest parasite species (aquatic)



Bush et al. 1990

Species-time relationship

2. Even if the species-time hypothesis helps explain variations in the species richness of terrestrial organisms, it has **limited applicability to marine organisms**.

- Terrestrial species might not redistribute themselves quickly following a glaciation, especially if there is a barrier to overcome.
- However, there seems to be no barriers to marine organisms shifting their distribution patterns during glaciations.
- The polar-equatorial gradient of species richness still exists in marine habitats.

Species-time relationship

3. Comparisons of speciation rates between tropical and temperate areas have yielded conflicting results.

- Example: Shane Wright compared the rate of molecular evolution in 45 congeneric or conspecific rainforest plant species.

  One member occurred in the tropics and one in temperate realms.

  Tropical plant species had more than twice the rate of molecular evolution than their closely related temperate congeners.

Species-time relationship

Jason Weir and Dolph Schluter compared the speciation and extinction rates of 309 sister pairs of New World birds and mammals.

- The highest speciation **and** extinction rates occurred at high latitudes and declined towards the tropics.

Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) Species-energy relationships

3) Species-time relationships

4) **Species-area relationships**

5) Implications for conservation

Species-area relationship

The species-area hypothesis proposes that large areas contain more species than small areas because they can support larger populations and a greater range of habitats.

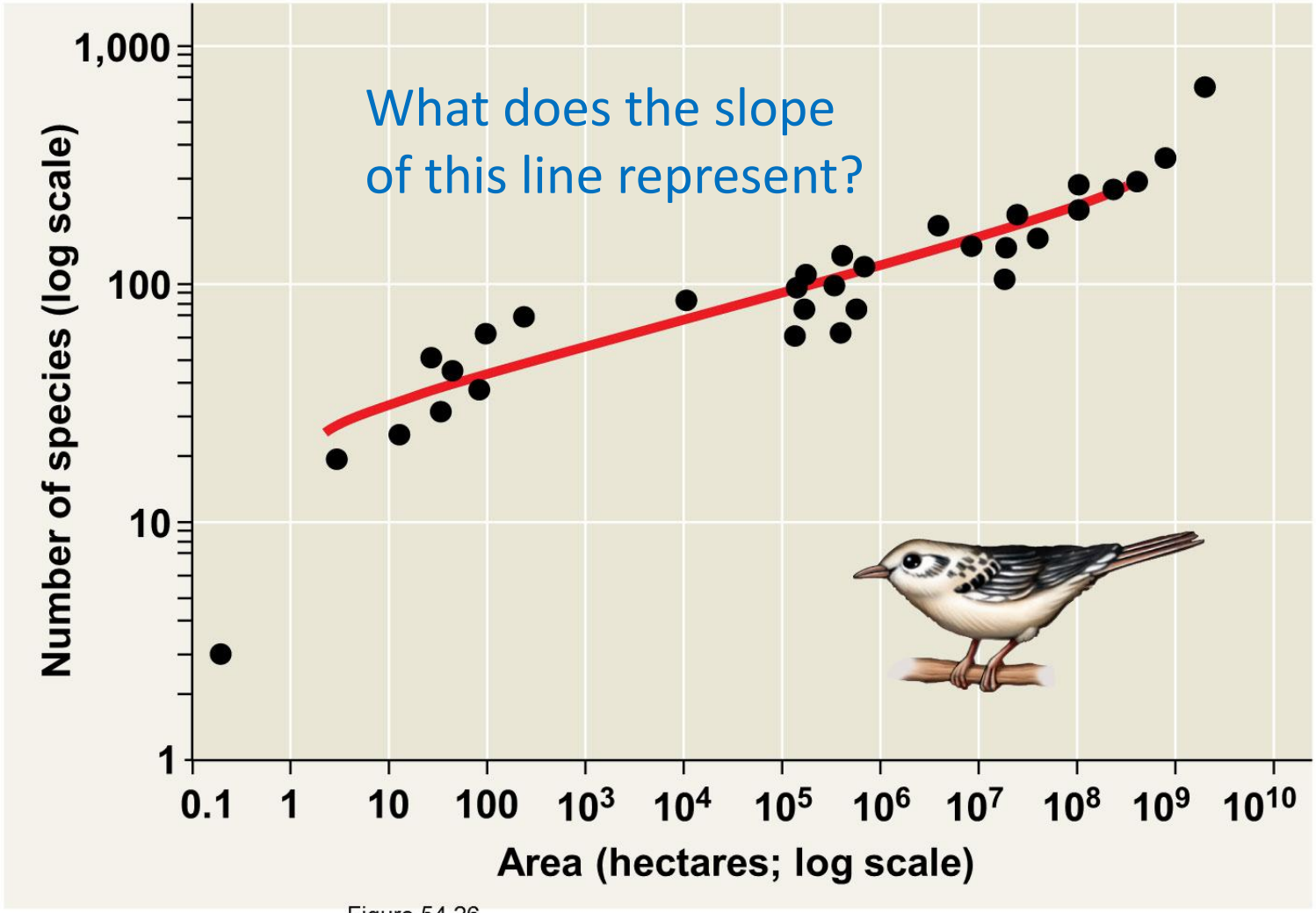
- Larger populations are more resistant to extinctions.
- Greater ranges of habitats promote increased speciation rates.

Species-area relationship

- Species area relationships
  - In general, there should be more species the larger the area that's sampled
  - **$S = cA^z$**
    - S = species richness, *c* and *z* are constants determined from data.
    - A = area sampled
    - z = rate of increase in species with area

Species-area relationship

The **species-area curve** quantifies the idea that, all other factors being equal, a larger geographic area has more species



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Figure 54.26

Species-area relationship

Evidence to support the species-area hypothesis.

- Donald Strong (1974) showed that insect species richness on tree species in Britain was correlated with the ranges of tree species (area covered in Britain).
- Other crop (sugarcane) species planted across the world show that the species richness of pests is better correlated with the area over which it was planted rather than the time since it was planted.

Species-area relationship

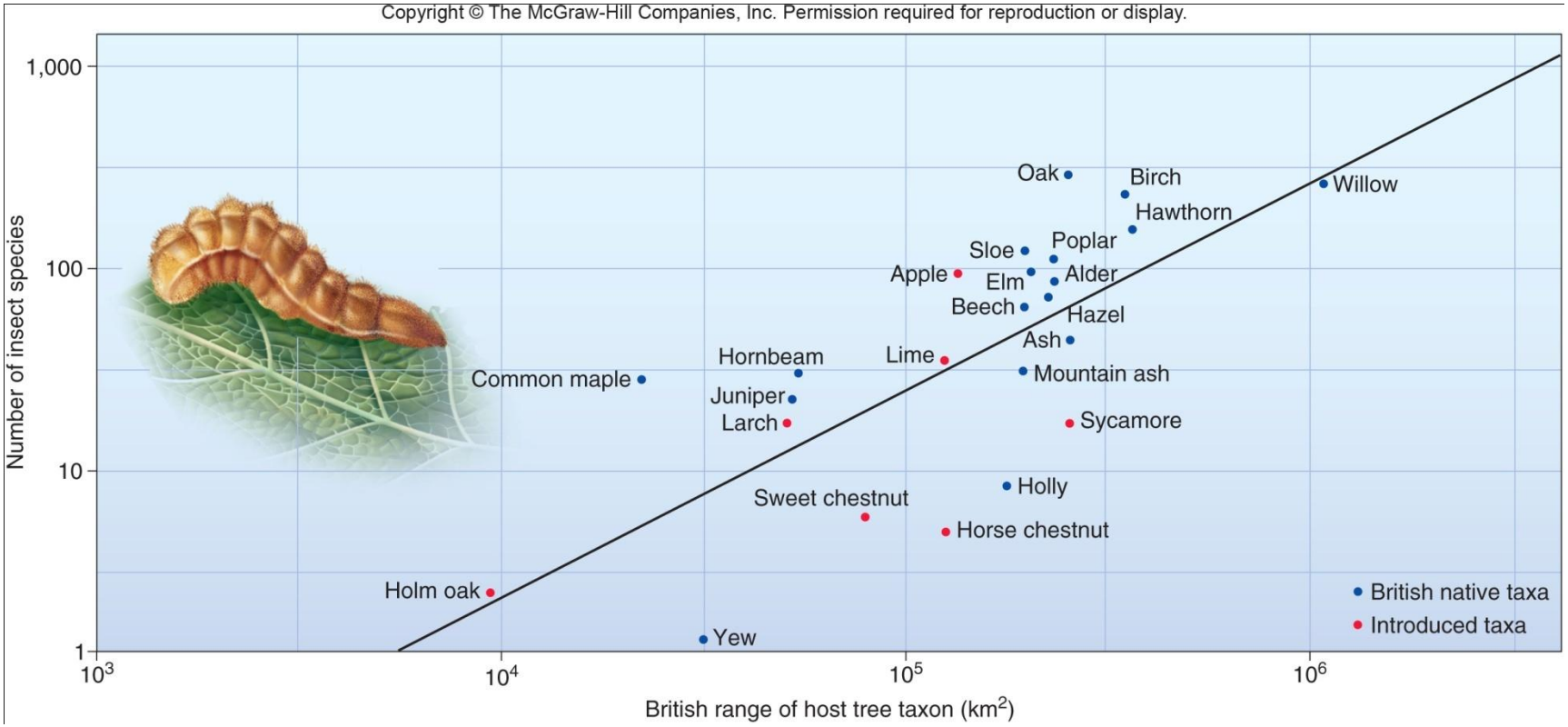


Figure 18.5 Relationship between insect species richness on British trees and area.

A positive correlation is found between insect species richness and the host tree's present range (in km^2). Note the log scales. Range represents an area in Britain known to contain trees of each species. Red dots represent introduced species.

Species-area relationship

-A symmetry of climate exists between polar regions and temperate areas in the Northern and Southern Hemispheres.

-Symmetrically similar climates are only adjacent in the Tropics, which create one large area.

-This has been proposed as a reason why the tropics have greater species-richness than temperate or polar areas.

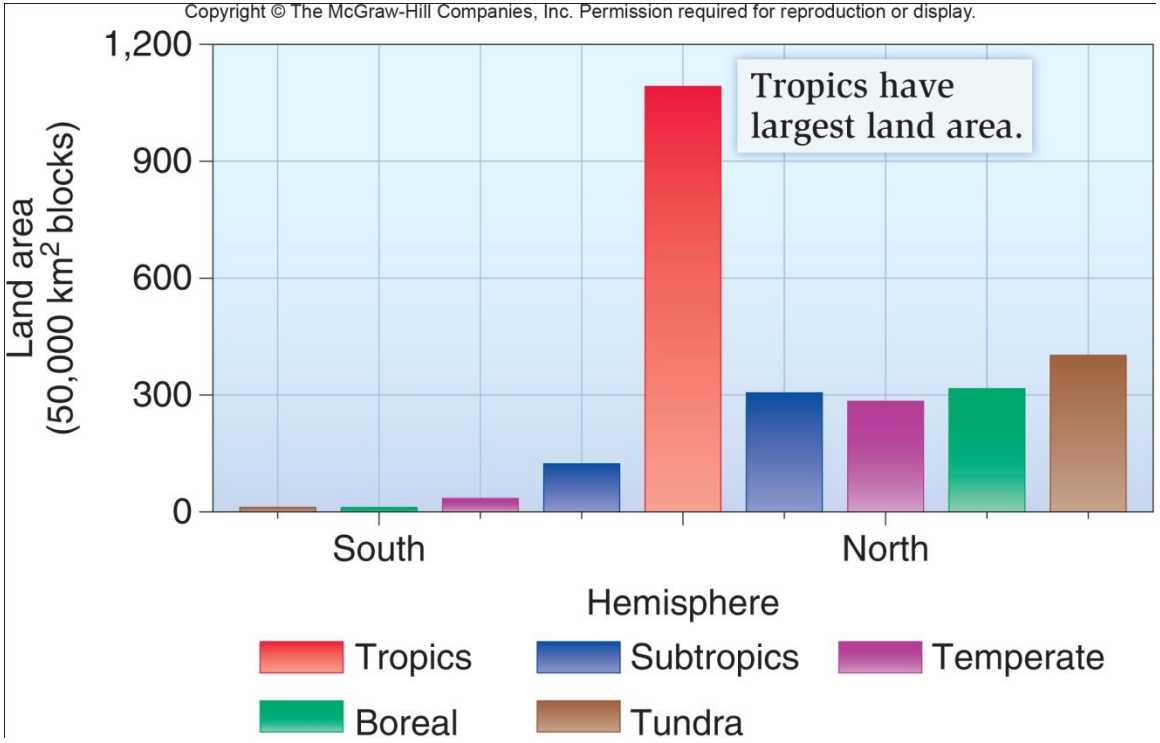


Figure 18.6 Land areas in five broad zones of the Earth.

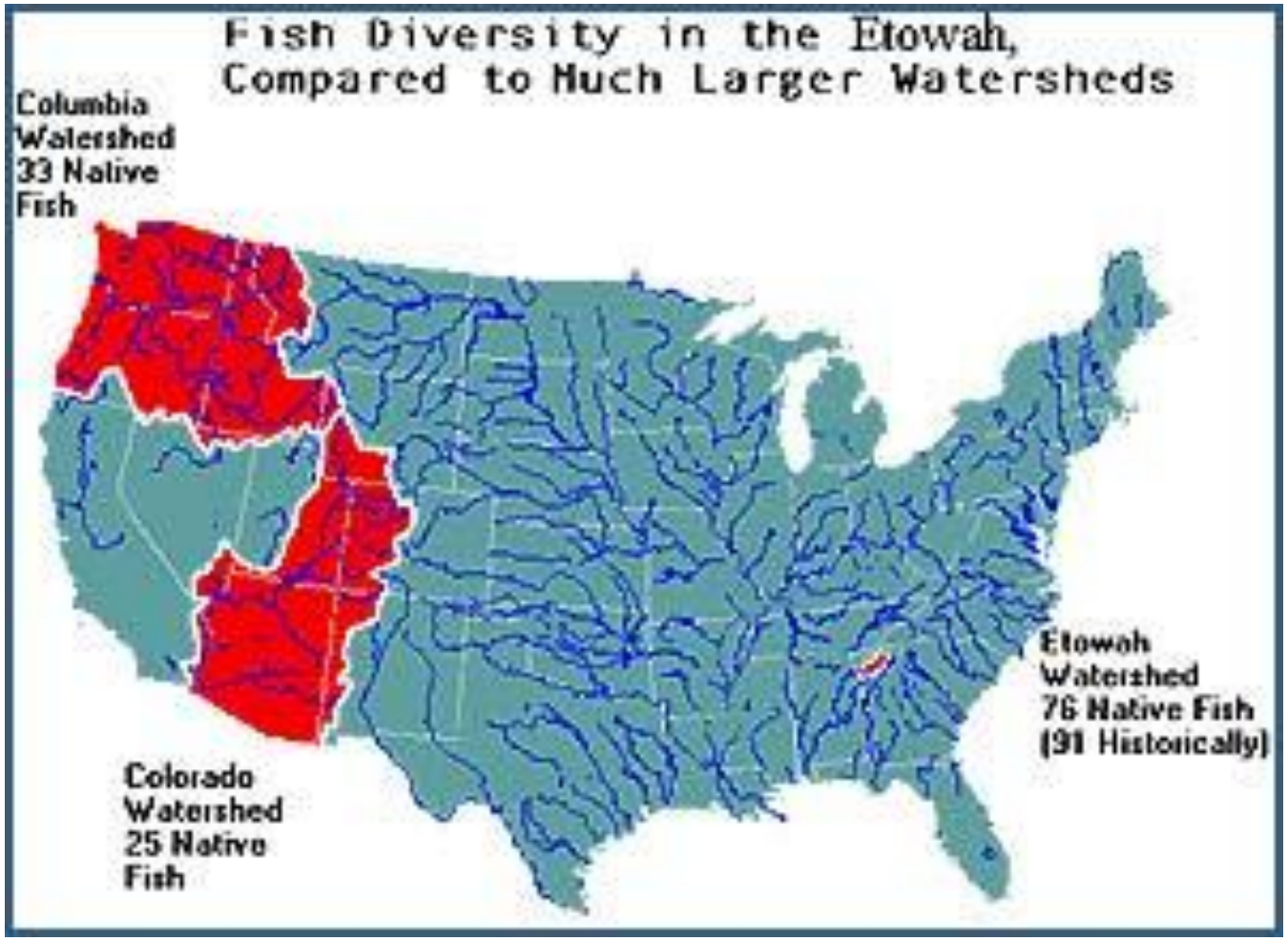
The Tropics are half an order of magnitude bigger than other zones. (Redrawn from Rosenzweig, 1992)

Species-area relationship

BUT, the species-area hypothesis seems unable to explain why, if increased richness is linked to increased area, more species are not found in certain regions, such as:

- The vast contiguous landmass of Asia.
- Or, while tundra may be a large land biome, it has very low species richness.
- Or, why the open ocean has the greatest volume of any habitat even though it has fewer species than tropical surface waters, which have a relatively small volume.

Fish species diversity: N. America example



Age is really important factor that drives fish diversity

BUT Global Freshwater Species Patterns still follow latitudinal pattern

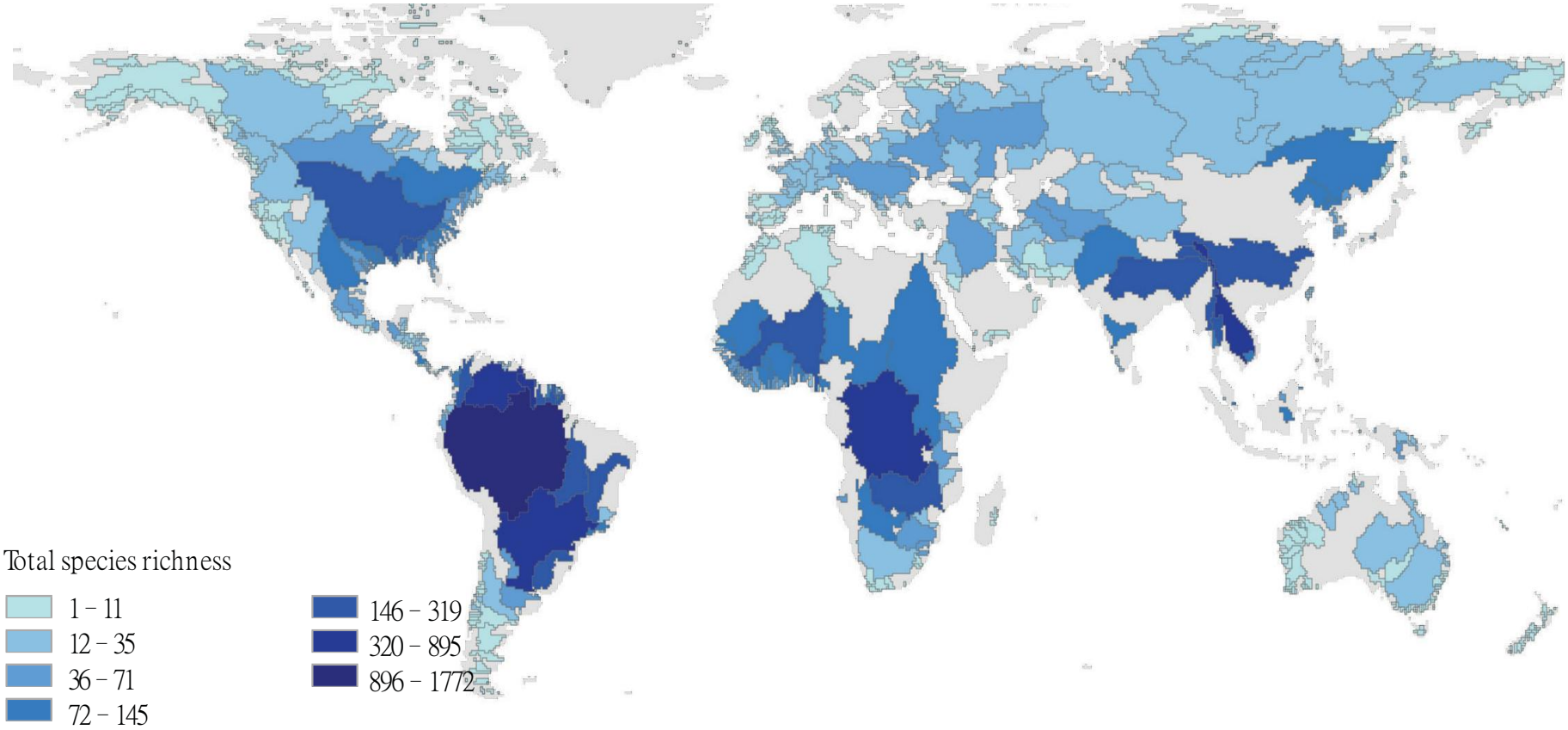


Figure 1: Global freshwater fish species richness patterns at the drainage basin grain.

Oberdorff et al. 2011

Topics for today

1) Latitudinal (polar-equatorial) richness gradient

2) Species-energy relationships

3) Species-time relationships

4) Species-area relationships

5) **Implications for conservation**

Conservation at large scales

Conservation biologists have focused on saving species by the use of four different strategies:

1. Megadiversity countries
2. Biodiversity hotspots
3. Crisis ecoregions
4. “Last of the wild”

Conservation at large scales

Megadiversity countries approach

Just 17 countries are home to nearly 80% of all known species. So, conservation efforts should be focused on these countries.

- A drawback here is that some megadiversity countries contain similar species.

Mittermeier et al. 1997

Conservation at large scales

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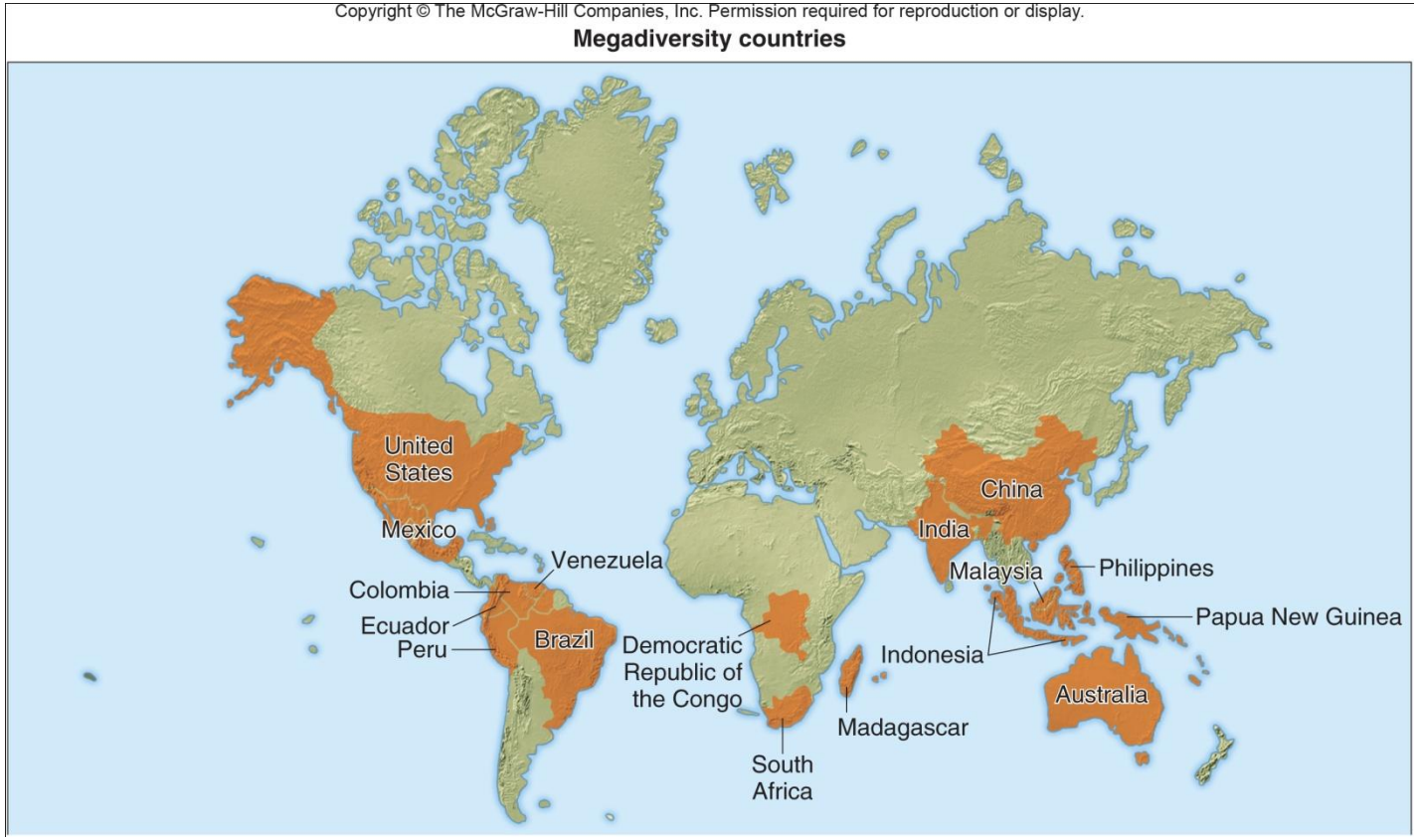


Figure 18.16 Maps of four global biodiversity conservation priority approaches

(a) Megadiversity countries. (After Mittermeier et al. 1997)

Conservation at large scales

Biodiversity hotspots approach

-Biodiveristy hotspots focus on the number of species that are endemic, found only in a particular place or region.

-must contain at least 1,500 species of endemic vascular plants and have lost at least 70% of its original habitat.

-identified 34 hotspots that together occupy 2.3% of the Earth's surface but contain 150,000 endemic plant species, or 50% of the world's total.

-Using this strategy, tropical forests would receive most of the attention.

Conservation at large scales

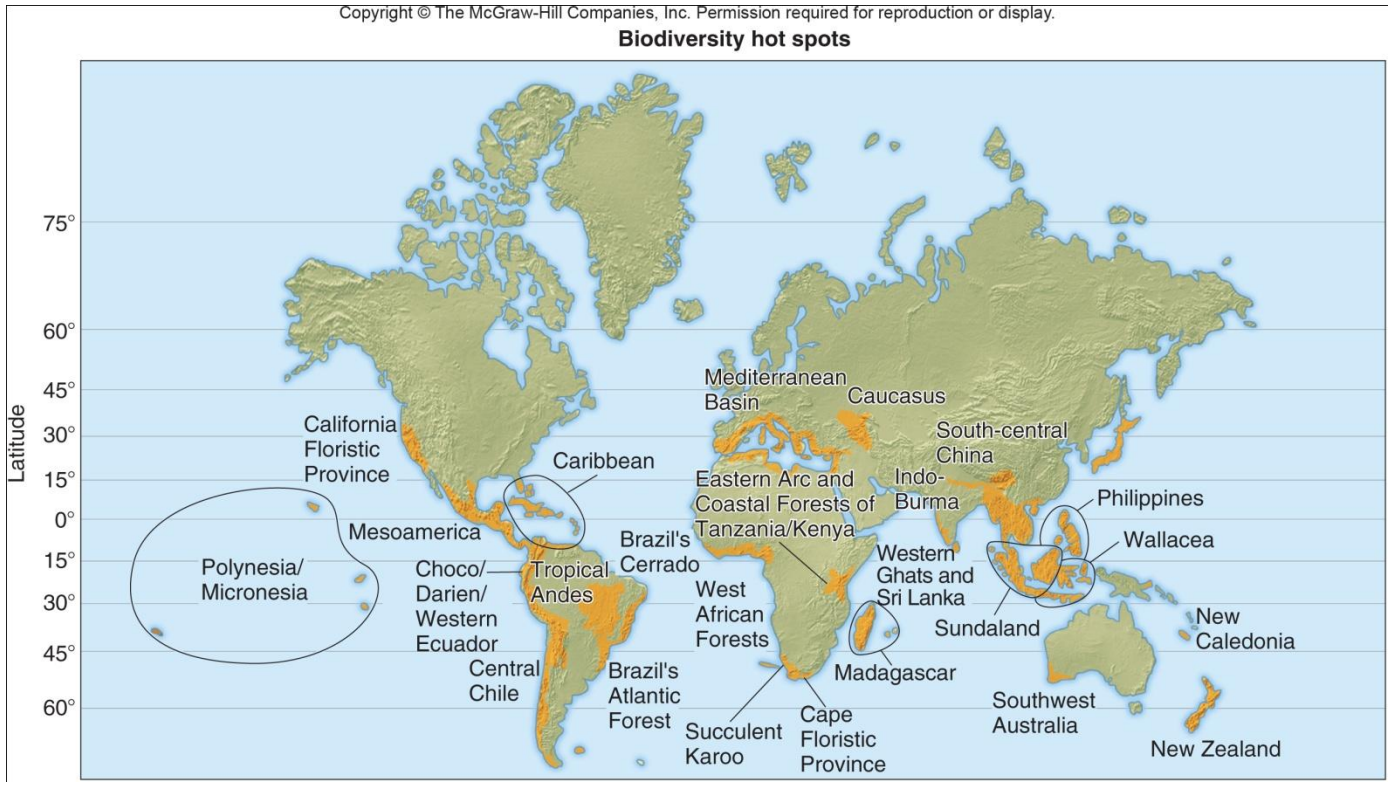


Figure 18.16 Maps of four global biodiversity conservation priority approaches

(b) Biodiversity hotspots. (After Mittermeier et al. 2004)

Conservation at large scales

Crisis ecoregions

-This strategy identifies biomes at greatest risk of habitat loss

-Habitat loss has been most extensive in temperate grasslands and tropical and temperate deciduous forests.

-Less than 10% of these agriculturally rich areas have been protected and they are termed crisis ecoregions.

Conservation at large scales

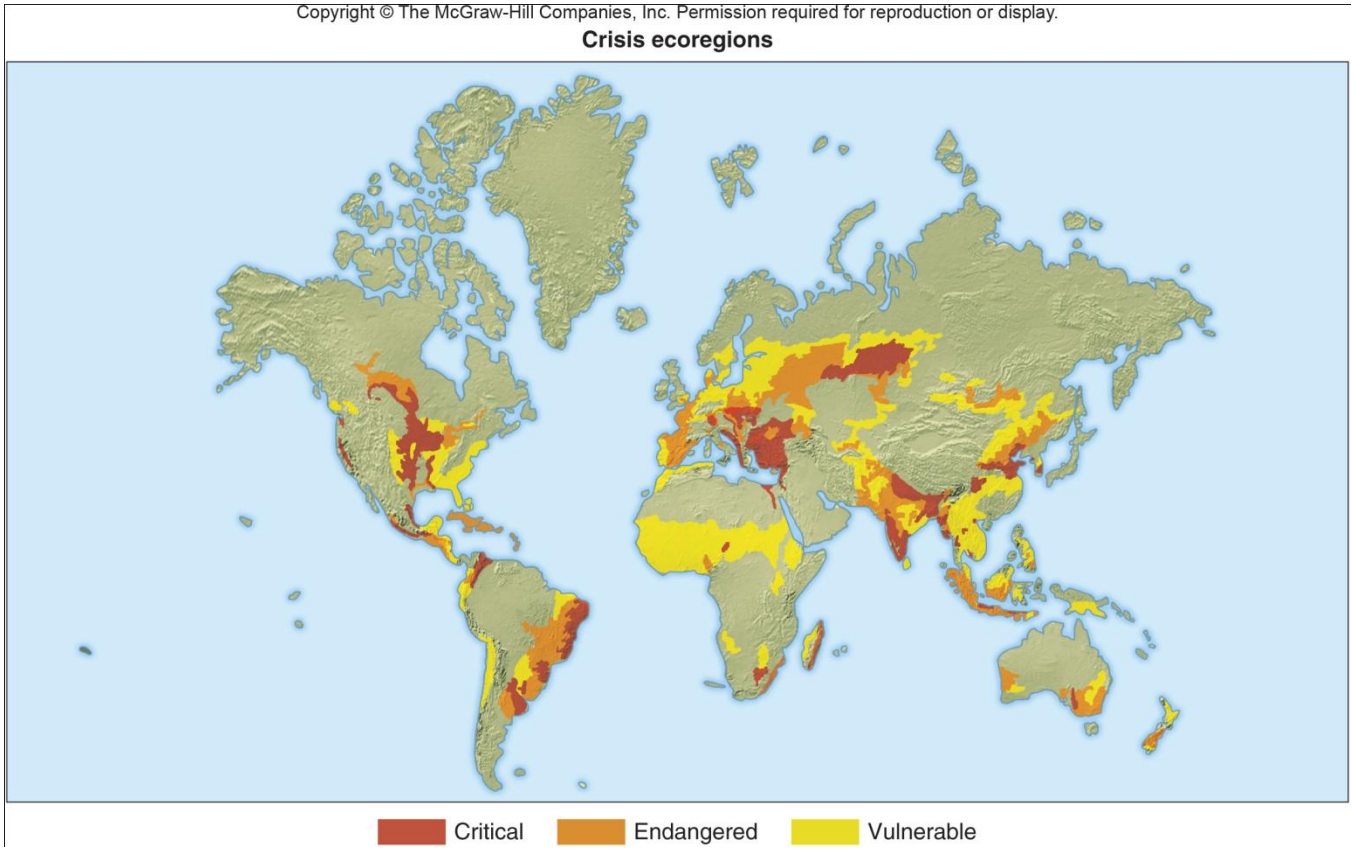


Figure 18.16 Maps of four global biodiversity conservation priority approaches

(c) Crisis ecoregions. (After Hoekstra et al. 2005)

Conservation at large scales

“Last of the wild”

-Areas of the Earth that fall within the lowest 10% of human affected areas are called “Last of the wild.”

-Such pristine areas offer a great opportunity for conservationists because of their relatively intact communities.

-Includes tundra and boreal forests of Russia and Canada, as well as some desert biomes and tropical forests.

Conservation at large scales

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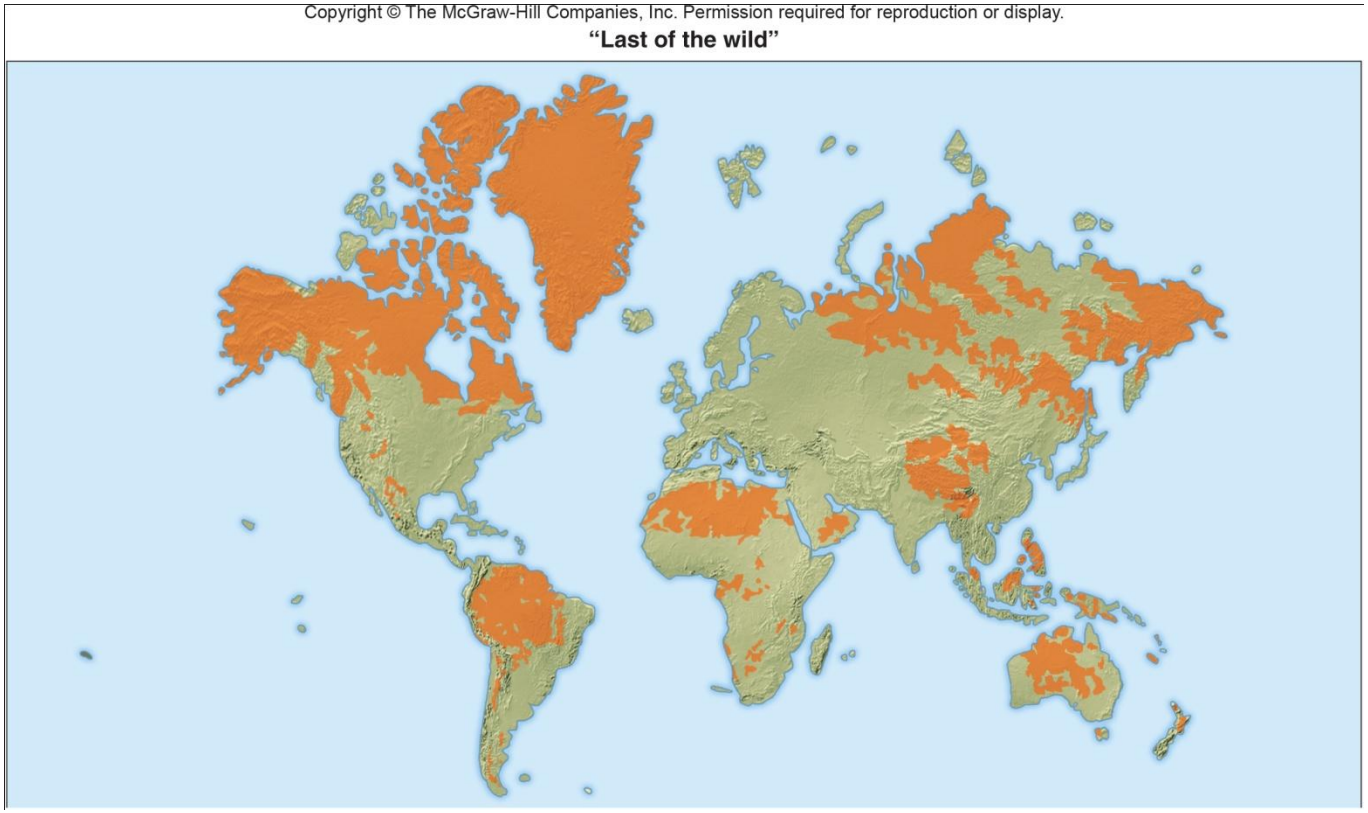


Figure 18.16 Maps of four global biodiversity conservation priority approaches

(d) "Last of the wild." (After Sanderson et al. 2002)

Apply your understanding

1. If you had to choose one large-scale conservation strategy for tallgrass prairie ecosystems, what would it be and why?
2. Compare and contrast the 3 large-scale species diversity patterns we discussed today.