BIOL 3340 Ecology Study Guide for Exam 2: Lecture 15: Species Richness Patterns

Source: the lecture slides (text, figures and slide notes). No textbook.
Each heading is one Study Lab objective. [L13 s08] = Lecture 13, slide 8.
(teal italics) = plain meaning of the word before it. ⚠ Do not mix up = a look-alike pair to keep apart. **Amber dotted words** = names printed on the figure beside them.

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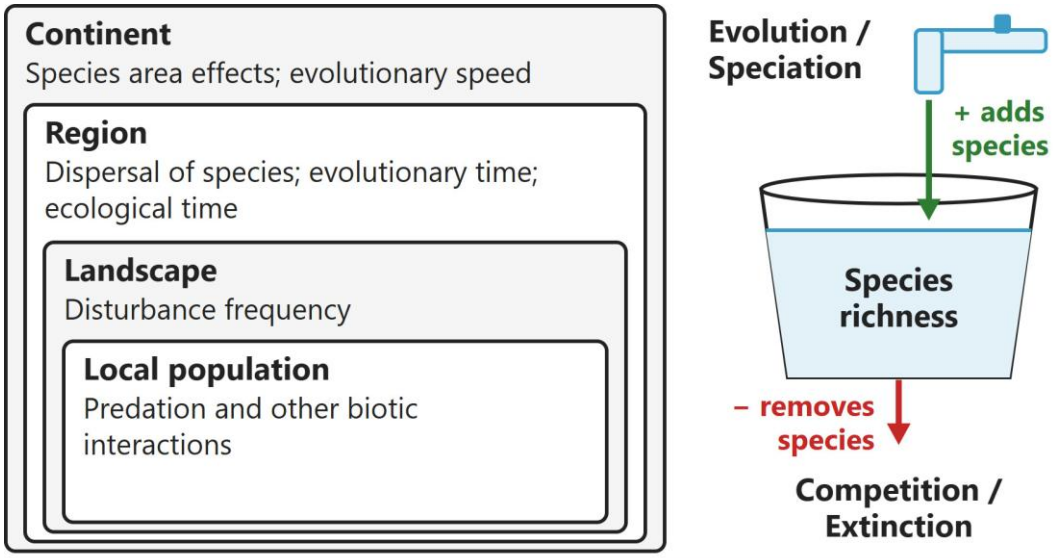
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Click a line to jump to it. The PDF side panel (bookmarks) has the same parts.

L15.1 What controls richness: scale, speciation vs extinction, the latitudinal gradient

⚠ **Do not mix up: Observed richness is NOT speciation alone: it is the net result of speciation and extinction.** [L15 s08]

Fundamental question: how and why species abundance and diversity vary in time and space. [L15 s06]
Know the energy, time and area relationships, with evidence for and against each. [L15 s05]
Different processes control richness at different **spatial scales** *(sizes of area studied)*. [L15 s07]



Nested scales with their controls, and the bucket of species gained and lost [L15 s07]
On the figure: Speciation · Competition · extinctions · Evolution · species richness

Each scale includes all lower ones and nests within all higher ones. [L15 s07]
Think about **speciation** and extinction in the context of geographical richness gradients. [L15 s07]
Speciation *(new species forming)* is adding species. [L15 s08]
Competition and other negative species interactions can lead to **extinctions**. [L15 s08]
Observed species richness in one location (a continent) is the net result of speciation and extinction. [L15 s08]

Richness as a bucket: **evolution** and speciation pour species in; competition and extinction drain them out. [L15 s08]

Both evolution and competition control species richness at small scales. [L15 s08]

Latitudinal species richness gradient: species of most **taxa** *(groups of organisms)* **increase** from polar to temperate to tropical. [L15 s10]

Also called the **polar-equatorial gradient** *(poles to equator)*. [L15 s11]

North American birds: lines of equal bird species numbers rise from the **arctic** to the **tropics**. [L15 s11]

Birds: very low diversity in the arctic, very high diversity in the tropics. [L15 s11]

Birds: high diversity in **mountainous** areas; low diversity on the Florida peninsula (**peninsular effect**). [L15 s11]

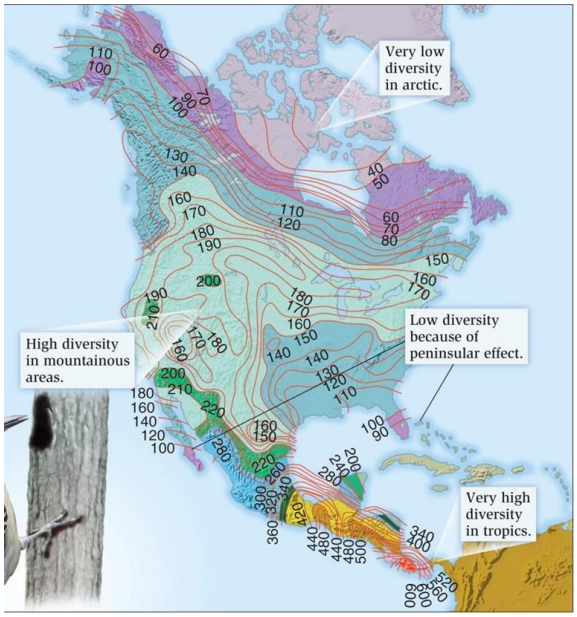
North American mammals: a pronounced gradient, with more mammal species heading south toward the Tropics. [L15 s12]

Mammals: high diversity in California and northern Mexico, regions of **topographic relief** *(mountains and valleys)* and habitat diversity. [L15 s12]

United States fish: species richness is highest in the Southeast and lowest across the West. [L15 s02, L15 s03]

Three main hypotheses for the gradient: richness **increases** with more **productivity/energy**, **time**, and **area**. [L15 s13]

Review question: compare and contrast the three large-scale richness hypotheses (energy, time, area). [L15 s49]



North American bird species richness: lowest in the arctic, highest in the tropics [L15 s11]

On the figure: **arctic** · **tropics** · **mountainous** · **peninsular effect**

Shared point: all three try to explain why richness rises from poles to tropics. [L15 s13, L15 s49]

What controls richness at each scale

Scale	Process affecting species richness
Local population	Predation and other biotic interactions
Landscape	Disturbance frequency
Region	Dispersal of species; evolutionary time; ecological time
Continent	Species area effects; evolutionary speed

Table source: [L15 s07]

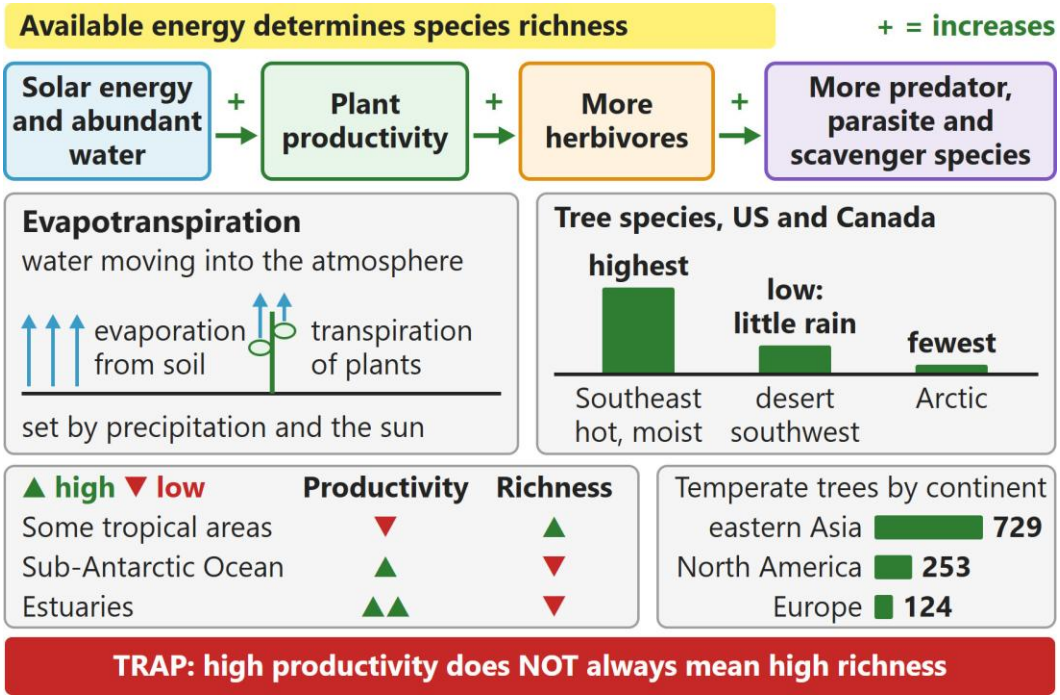
Comparing the three richness hypotheses

Hypothesis	Idea	One support	One problem
Species-energy	More sun and water, more plant productivity, more species	North American trees richest where evapotranspiration is highest (Southeast)	Sub-Antarctic Ocean and estuaries are productive but species poor; fails between continents
Species-time	Older regions gained more species; temperate areas are young after glaciations	Ice sheets displaced temperate species **18,000 years** ago	Gradient still exists in the sea; habitat mattered more than host age for parasites
Species-area	Larger areas: larger populations, more habitats, more species	Insects on British trees rise with tree range; Tropics have the largest land area	Asia, tundra and open ocean are large but not the richest

Table source: [L15 s49, L15 s13, L15 s15, L15 s17, L15 s18, L15 s19, L15 s21, L15 s22, L15 s25, L15 s26, L15 s30, L15 s34, L15 s35, L15 s36]

L15.2 Species-energy hypothesis and its exceptions

⚠ **Do not mix up: High productivity does NOT always mean high richness: sub-Antarctic Ocean and estuaries are species poor.** [L15 s18]



Energy to plant productivity to herbivores to predators, with exceptions and tree counts [L15 s15]

On the figure: productivity · herbivores · evapotranspiration · sub-Antarctic Ocean · Estuaries · Arctic

Species-energy hypothesis: available energy determines species richness. [L15 s15]

1. More solar energy plus abundant water gives high **productivity of plants**. [L15 s15]
2. Higher **plant productivity** *(total weight of plant material made per year)* **increases** the number of **herbivores**. [L15 s15]
3. More herbivores **increase** the number of predator, parasite and scavenger species. [L15 s15]

Trees in the United States and Canada: tree richness is influenced by climate and rainfall. [L15 s16]

Highest tree richness is in the **hot, moist Southeast**, where **evapotranspiration** rates are highest. [L15 s16, L15 s17]

Tree species counts drop toward the far north, with the fewest in the **Arctic**. [L15 s16]

Terrestrial evapotranspiration: rate water moves into the atmosphere by soil evaporation and plant **transpiration** *(water loss from leaves)*. [L15 s17]

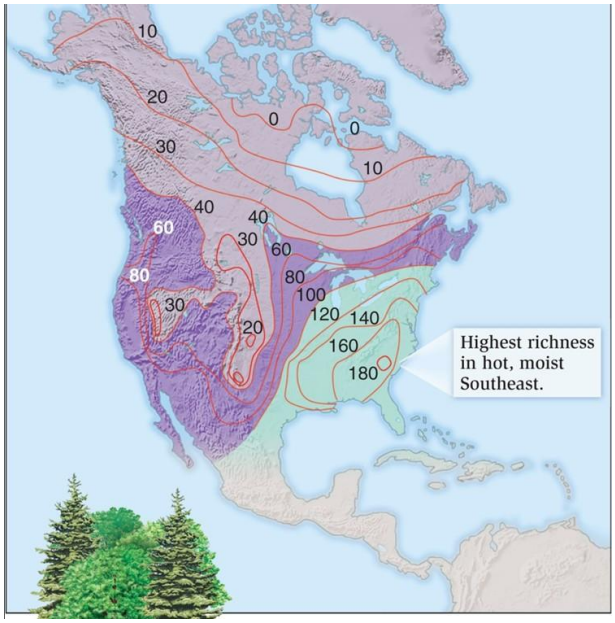
Evapotranspiration is affected by both precipitation and solar energy. [L15 s17]

Desert southwest: tree richness is low because rainfall and water are low, though temperatures are high. [L15 s17]

North American tree richness supports species-energy, but the pattern does not hold between continents. [L15 s19]

Temperate forest trees: **729 species** in eastern Asia, **253** in North America, **124** in Europe. [L15 s19]

Open problem: why would more productivity give more species, not high densities of a few species? [L15 s19]



Tree species richness in the United States and Canada: highest in the Southeast [L15 s16]

On the figure: hot, moist · Southeast

Exceptions to the species-energy hypothesis

Place	Productivity	Species richness
Some tropical areas (southeast Pacific near coastal Colombia and Ecuador)	Low	High
Sub-Antarctic Ocean	High	Low
Estuarine areas (where rivers empty into the sea)	Very high	Low

Table source: [L15 s18]

L15.3 Species-time hypothesis and the evidence against it

⚠ **Do not mix up: Birds and mammals do NOT speciate fastest in tropics: speciation AND extinction peak at high latitudes.** [L15 s24, L15 s28]

Species-time hypothesis: communities **diversify** *(gain species)* with time. [L15 s21]

Temperate regions are less species rich than tropical regions because they are **younger**. [L15 s21]

Younger: recently recovered from glaciations and severe climate disruption. [L15 s21]

Last ice age: ice sheets reached their maximum extent **18,000 years** ago. [L15 s22]

Temperate species in North America and northern Europe were displaced during this time. [L15 s22]

In all three explanations, tropical richness stays above temperate richness over time. [L15 s23, L15 s24]

Evolutionary speed hypothesis: evolution is faster in the **Tropics**, and this produced more species. [L15 s23]

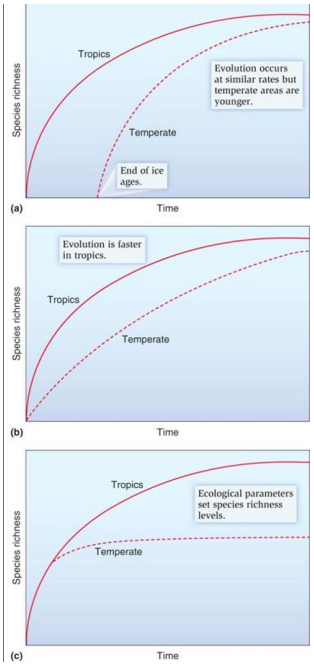
Its reasons: high ambient temperatures, short generation times and **increased** mutation rates. [L15 s23]

2,300 mammal and 6,700 bird species: evolution faster in temperate regions, but extinction also much faster. [L15 s24]

Drawback **1**: other datasets do not support the species-time hypothesis. [L15 s25]

Helminth *(parasitic worm)* **richness of vertebrates**: species-time predicts the oldest hosts (fish) carry the most species. [L15 s25]

Predicted order: fish most, lizards and snakes in between, birds and mammals (youngest) fewest. [L15 s25]



Three ways tropical richness stays above temperate richness over time [L15 s24]

On the figure: Tropics · Temperate · younger

Result: habitat mattered more; **aquatic** vertebrates of any taxon had more helminth species than terrestrial ones. [L15 s25]

Fish, the **oldest host lineage**, had the **fewest parasite species** among aquatic hosts. [L15 s25]

Drawback **2**: species-time has limited applicability to **marine organisms**. [L15 s26]

Land species might not redistribute quickly after a glaciation, especially past a barrier. [L15 s26]

Marine organisms seem to have no barriers to shifting their distributions during glaciations. [L15 s26]

Yet the polar-equatorial richness gradient still exists in marine habitats. [L15 s26]

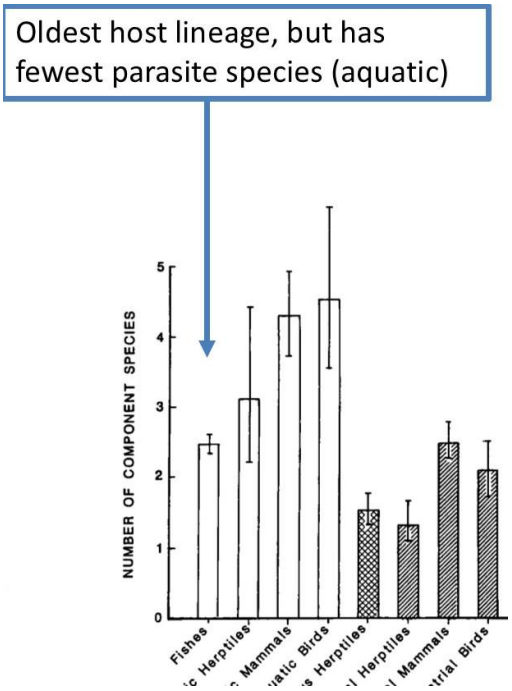
Drawback **3**: tropical versus temperate speciation rate comparisons have yielded conflicting results. [L15 s27]

45 rainforest plant species pairs: one tropical, one temperate, **congeneric** *(same genus)* or **conspecific** *(same species)*. [L15 s27]

Tropical plants had more than twice the rate of molecular evolution of temperate relatives. [L15 s27]

309 sister pairs *(closest related species pairs)* **of New World birds and mammals**: speciation and extinction rates compared. [L15 s28]

Highest speciation AND extinction rates were at high latitudes, declining toward the tropics. [L15 s28]



Helminth species per host group: oldest host lineage has fewest parasite species [L15 s25]

On the figure: oldest host lineage · fewest parasite species · aquatic

Three ways the tropics gained more species

Explanation	Idea
Longer time in the tropics	Evolution at similar rates, but temperate areas are younger and start at the end of the ice ages
Faster evolution in the tropics	Higher speciation and/or extinction rates; the tropics curve rises faster
Different ecological factors	Ecological factors in each realm set richness levels; the temperate curve levels off lower

Table source: [L15 s23]

L15.4 Species-area hypothesis (S = cA^z) and freshwater fish

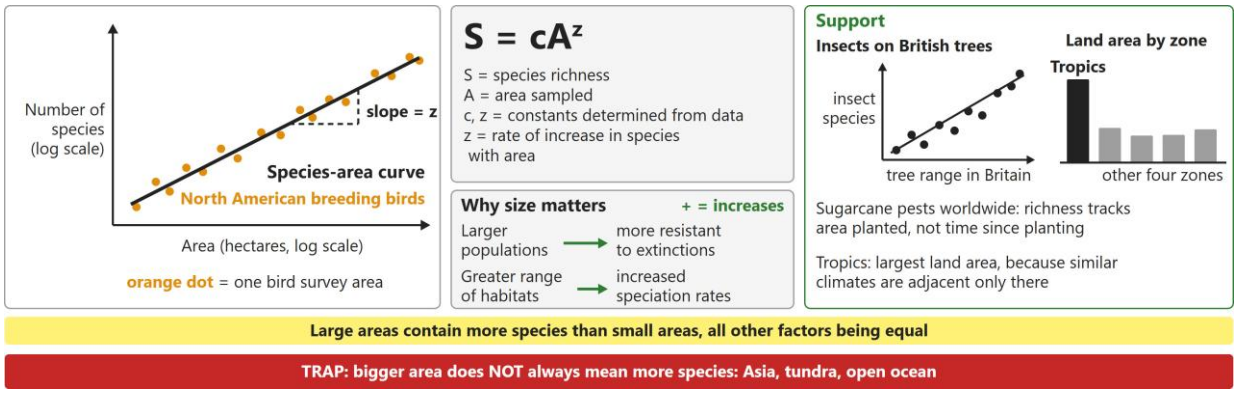
⚠ **Do not mix up: Bigger area does NOT always mean more species: Asia, tundra and open ocean are exceptions.** [L15 s36]

Species-area hypothesis: large areas contain more species than small areas. [L15 s30]

Why: large areas support larger populations and a greater range of habitats. [L15 s30]

Larger populations are more resistant to extinctions. [L15 s30]

Greater ranges of habitats promote **increased** speciation rates. [L15 s30]



Species-area curve, the S = cA^z terms, and the support from trees and land zones [L15 s34]

On the figure: Species-area curve · North American breeding birds · Larger populations · Insects on British trees · Sugarcane pests · Tropics

S = cA^z: species richness equals a constant c times area raised to the power z. [L15 s31]

Species-area curve: all other factors equal, a larger geographic area has more species. [L15 s32]

North American breeding birds: the number of species rises steadily as area **increases**. [L15 s32]

Slope of the species-area line = z, the rate species **increase** with area. [L15 s31, L15 s32]

Insects on British trees: insect richness on each tree species rises with its range in Britain. [L15 s33, L15 s34]

Range here = area in Britain known to contain trees of that species. [L15 s34]

Sugarcane pests worldwide: pest richness correlates better with area planted than with time since planting. [L15 s33]

Earth's land zones: the **Tropics** are half an order of magnitude bigger than other zones. [L15 s35]

Of tropics, subtropics, temperate, boreal and tundra, the Tropics have the largest land area. [L15 s35]

Climate symmetry: polar and temperate climates mirror each other in Northern and Southern Hemispheres. [L15 s35]

Symmetrically similar climates are adjacent **only** in the Tropics, creating one large area. [L15 s35]

Proposed reason the tropics are richer than temperate or polar areas: one large area. [L15 s35]

Problem: the vast contiguous landmass of Asia does not have more species. [L15 s36]

Problem: tundra is a large land biome but has very low species richness. [L15 s36]

Problem: open ocean has the greatest volume but fewer species than small-volume tropical surface waters. [L15 s36]

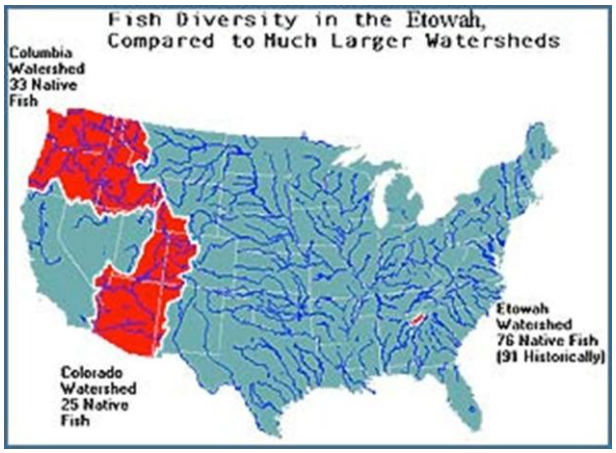
North American fish watersheds: the small **Etowah** watershed has **76 native fish** (91 historically). [L15 s37]

The much larger **Columbia** (33 native fish) and **Colorado** (25) watersheds have far fewer. [L15 s37]

Age: age is a really important factor that drives fish diversity. [L15 s37]

Global freshwater fish: richness per drainage basin still follows the latitudinal pattern. [L15 s38]

Richest basins lie in tropical South America, central Africa and southern Asia; high latitudes have few. [L15 s38]



Small Etowah watershed has far more native fish than the larger Columbia and Colorado [L15 s37]

On the figure: **Etowah** · **Columbia** · **Colorado** · **native fish**

Terms of S = cA^z

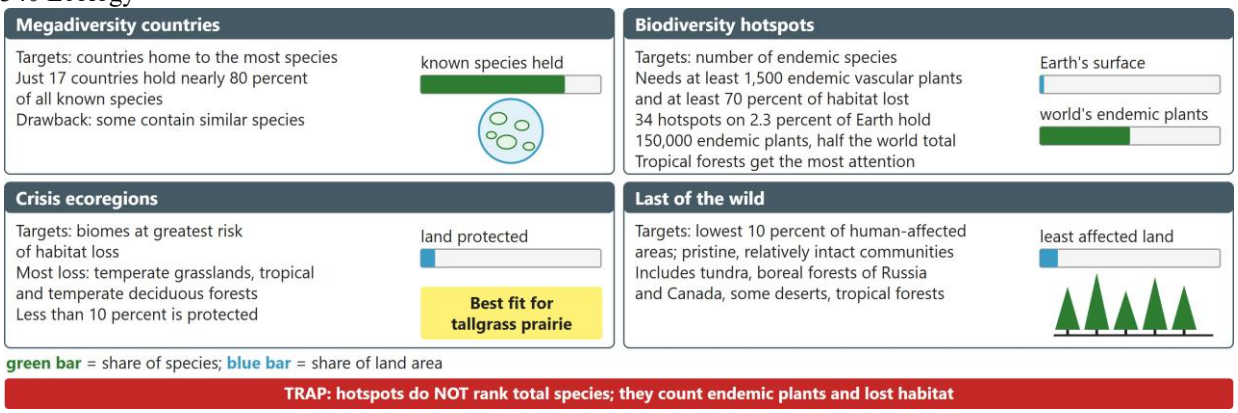
Letter	Meaning
S	Species richness
A	Area sampled
c	Constant determined from data
z	Constant determined from data: rate of **increase** in species with area

Table source: [L15 s31]

L15.5 Four large-scale conservation strategies

⚠ **Do not mix up: Hotspots do NOT rank total species: they count endemic species and need 70 percent habitat lost.** [L15 s43]

Conservation biologists save species with four large-scale strategies. [L15 s40]



Four large scale conservation strategies with what each targets [L15 s45]

On the figure: Megadiversity countries · Biodiversity hotspots · Crisis ecoregions · Last of the wild · endemic · tallgrass prairie

Megadiversity countries: just **17** countries are home to nearly **80** percent of all known species. [L15 s41]

So conservation efforts should be focused on these countries. [L15 s41]

Drawback: some megadiversity countries contain similar species. [L15 s41]

Biodiversity hotspots: focus on the number of **endemic** *(found only in one place or region)* species. [L15 s43]

A hotspot must contain at least **1,500 species** of endemic **vascular plants**. [L15 s43]

A hotspot must also have lost at least **70** percent of its original habitat. [L15 s43]

34 hotspots occupy **2.3** percent of Earth's surface but contain **150,000** endemic plant species. [L15 s43]

Those **150,000** endemic plant species are **50** percent of the world's total. [L15 s43]

Using the hotspot strategy, tropical forests would receive most of the attention. [L15 s43]

Crisis ecoregions: biomes at greatest risk of habitat loss. [L15 s45]

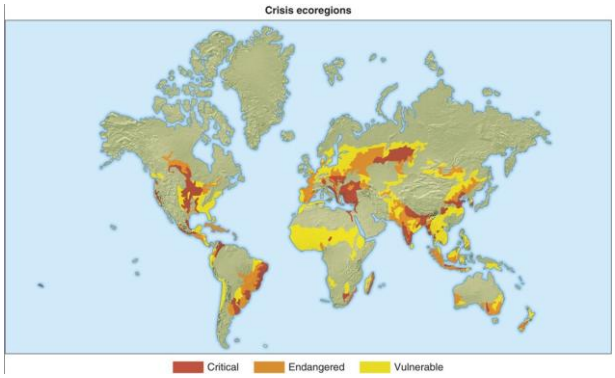
Habitat loss is most extensive in temperate grasslands and tropical and temperate deciduous forests. [L15 s45]

Less than **10** percent of these agriculturally rich areas are protected, so they are crisis ecoregions. [L15 s45]

Crisis ecoregions are ranked **critical**, **endangered** or **vulnerable**; central North America includes critical areas. [L15 s46]

Last of the wild: areas in the lowest **10** percent of human-affected areas. [L15 s47]

Such **pristine** *(untouched)* areas offer a great opportunity because of their relatively intact communities. [L15 s47]



World map of crisis ecoregions ranked critical, endangered or vulnerable [L15 s46]

On the figure: Crisis ecoregions · critical · endangered · vulnerable

Includes tundra and boreal forests of Russia and Canada, plus some deserts and tropical forests. [L15 s47]

Review question, tallgrass prairie: choose the **crisis ecoregions** strategy. [L15 s49, L15 s45]

Why: habitat loss is most extensive in temperate grasslands, and less than **10** percent is protected. [L15 s45, L15 s49]

Hotspots fit poorly: that strategy sends most attention to tropical forests. [L15 s43, L15 s49]

Last of the wild fits poorly: it targets pristine areas, but grasslands lost much habitat. [L15 s45, L15 s47, L15 s49]

Four large-scale conservation strategies

Strategy	What it targets	Key numbers	Note
Megadiversity countries	Countries home to the most species	**17** countries hold nearly **80** percent of known species	Drawback: some contain similar species
Biodiversity hotspots	Number of endemic species	At least **1,500** endemic vascular plants; at least **70** percent habitat lost; **34** hotspots	Tropical forests get most attention
Crisis ecoregions	Biomes at greatest risk of habitat loss	Less than **10** percent protected	Temperate grasslands, tropical and temperate deciduous forests
Last of the wild	Least human-affected areas	Lowest **10** percent of human-affected areas	Tundra, boreal forests of Russia and Canada, some deserts, tropical forests

Table source: [L15 s40, L15 s41, L15 s43, L15 s45, L15 s47]