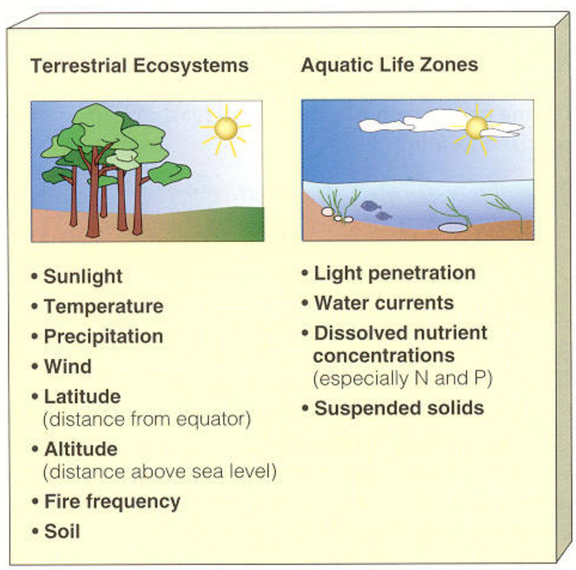
What factors correlated with high diversity?

- Energy
- Precipitation
- Temperature
- Area
- Habitat heterogeneity (e.g., foliage height and birds)
- Stable environment
- Moderate (intermediate) disturbance level

  (shifting mosaic, no climax)

46

Distribution and Abundance



Other Miller 2003

Figure 4-12 Key physical and chemical or abiotic factors affecting terrestrial ecosystems (left) and aquatic life zones (right).

Distribution and Abundance

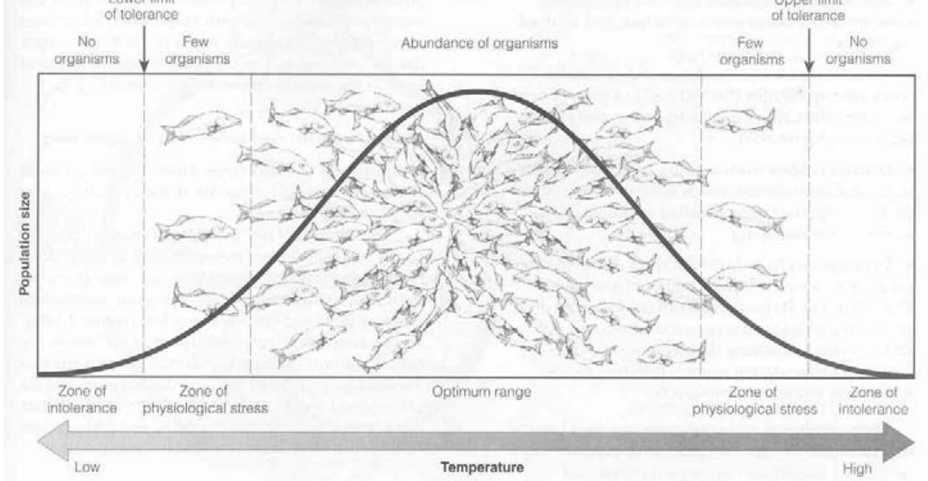


Figure 2-16 *Range of tolerance* for a population of organisms to an abiotic environmental factor—in this case, temperature.

Miller, 2003

Range of tolerance of abiotic factor(s)

48

Terrestrial Biomes

(Forest, Desert, Grassland, Tundra, etc.)
Biotic (~Vegetative) Communities

Climate
1. Temperature
2. Precipitation
(3. Soil type)

- Latitude
- Altitude

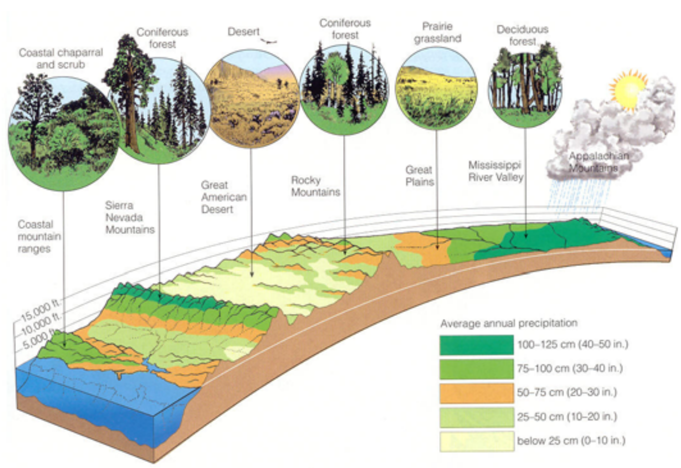


Figure 4-9 Major biomes found along the 39th parallel across the United States. The differences reflect changes in climate, mainly differences in average annual precipitation and temperature (not shown).

Miller 2003 3-5

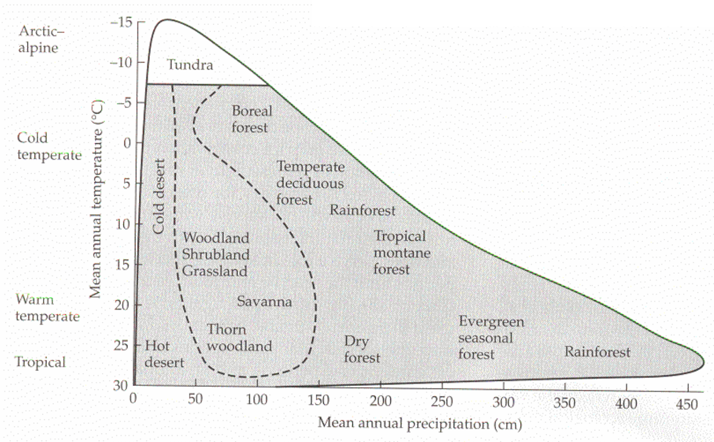


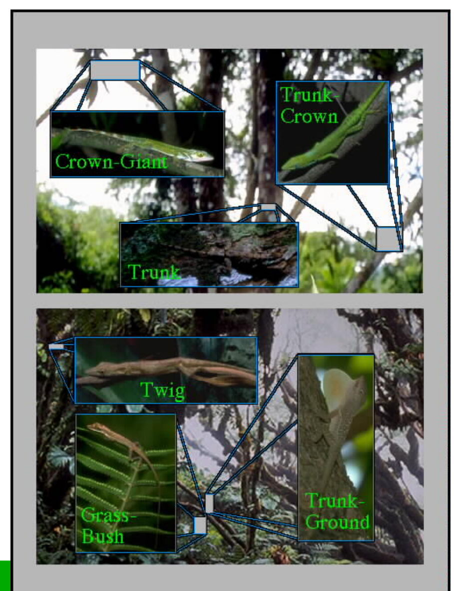
Figure 2.4 Biomes and climate. Distributions of the major biomes are plotted on axes of mean annual precipitation. Within the region bounded by the dashed line, factors such as seasonality of drought, fire, and grazing strongly affect which type of vegetation is present (Modified from Whittaker 1970.)

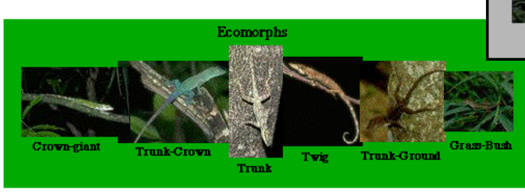
Groom et al. 2006

50

1. Competition

Anolis





Ecomorphs on Caribbean Islands

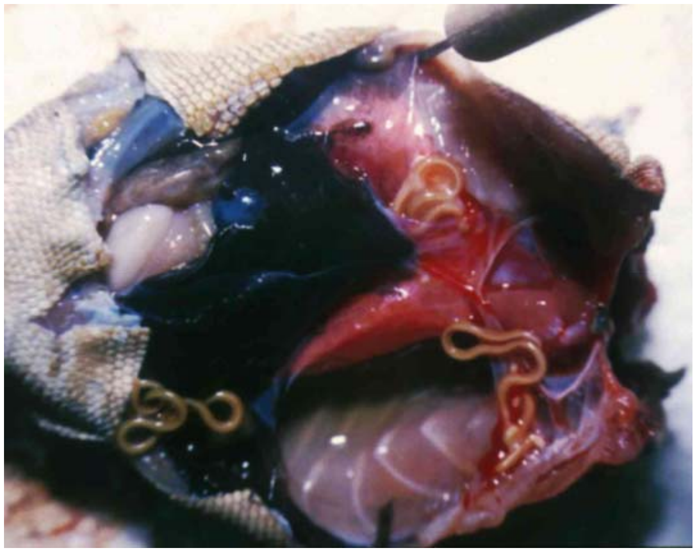
Pisaster (predatory sea star)
Paine
15 vs. 8 spp.
(mussels)

52

2. Predation

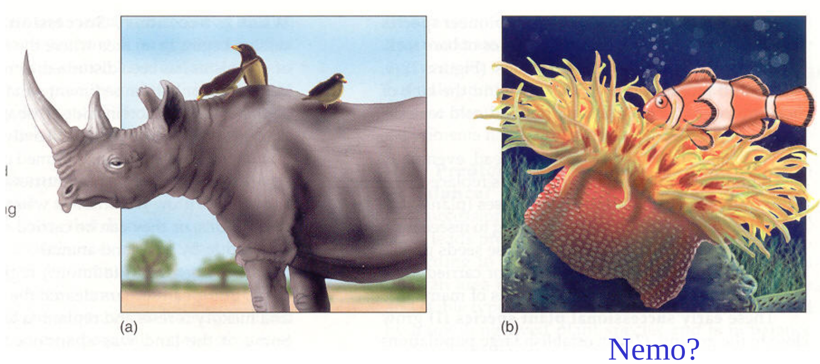
53

3. Parasitism



54

4. Mutualism



Nemo?

See 4-2 in Miller 2003

55

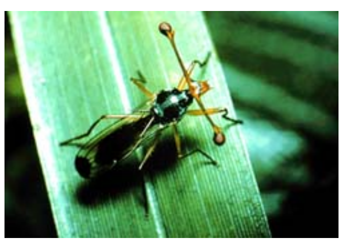
5. Commensalism

Florida

Ecuador

Bromeliads

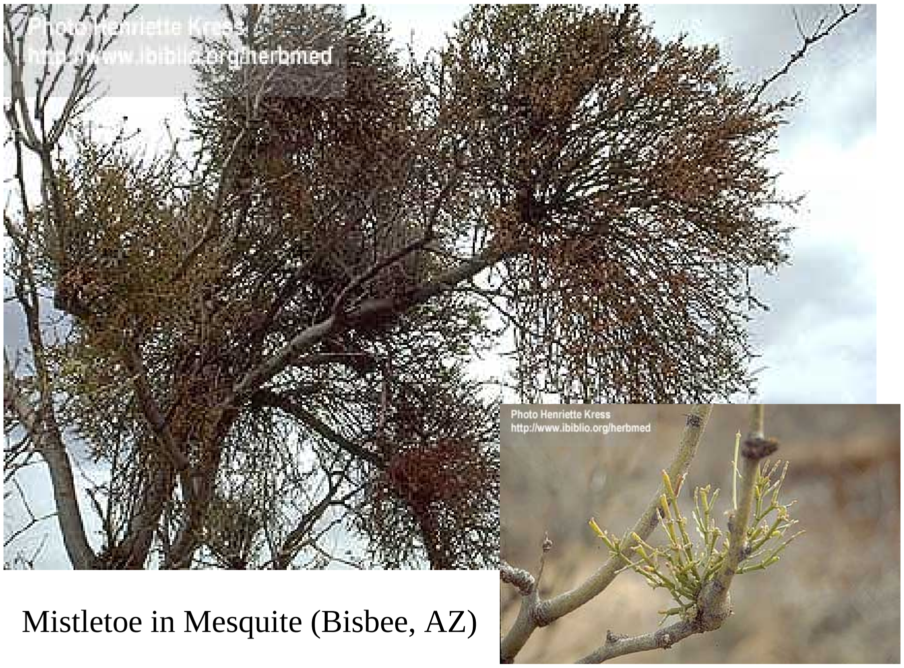
56



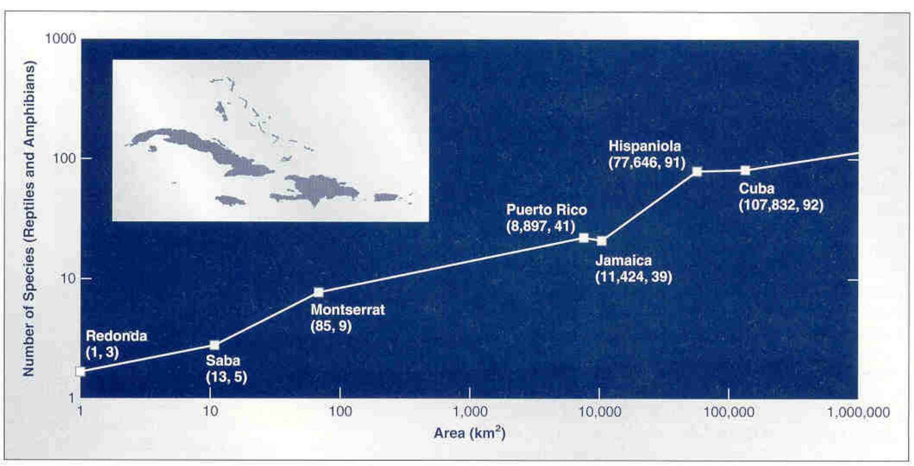
Stalk-Eyed Flies

Sexual Selection

57



Mistletoe in Mesquite (Bisbee, AZ)



Van Dyke 2003

Figure 4.4
A general species-area relationship among some Caribbean islands. Note that species richness on islands increases with increasing area.
Based on data from Darlington (1957:483).

Species-Area Relationship

59

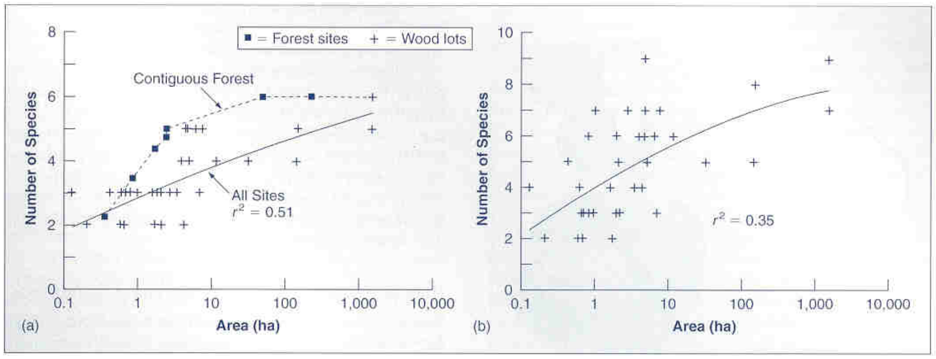


Figure 4.5

An illustration of the relationship between area and species richness of (a) granivores and (b) all small mammal species in woodlots (crosses) and contiguous forest sites (squares). Species richness increases with woodlot area. In (a), note that granivore species richness increases with area more rapidly in contiguous forest than in woodlots. This pattern suggests that species richness not only declines with habitat loss, but also with habitat fragmentation.

Van Dyke 2003

After Nupp and Swihart (2000).

Woodlots vs. contiguous forest

60

Species-Area Relationship

3 step loss of biodiversity (Rosenzweig)

1. Endemics
2. Sink populations
3. Stochasticity

$S = cA^Z$

S = species richness
c = taxon-specific constant
A = area
Z = extinction coefficient for taxon

Therefore end up with lower steady state species richness and loss of biodiversity

Endemism and Islands (Tuatura, Silversword)
Island Biogeography

3 step loss of biodiversity (Rosenzweig)

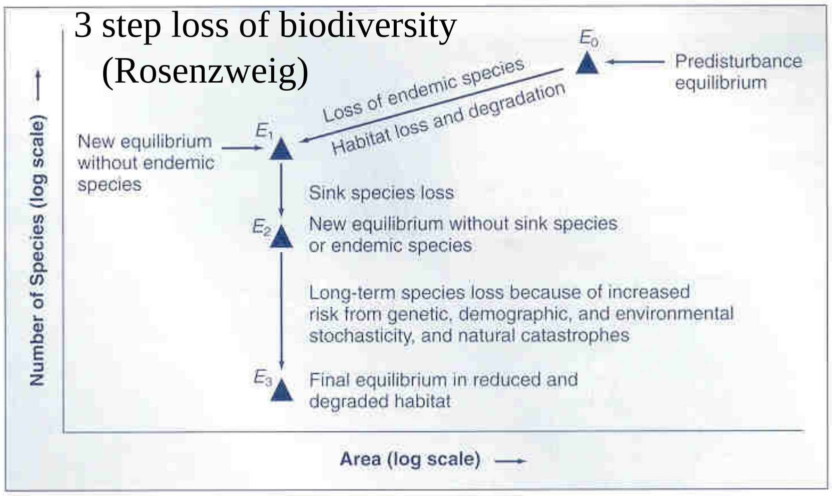


Figure 4.6
When the size of a natural area is decreased, the first species lost are endemics. Next, sink species (those that are not reproducing fast enough to replace themselves) go extinct locally. Finally, failure to replace accidental losses fast enough brings the province to a still lower steady state of biodiversity.

After Rosenzweig (1999).

2

Van Dyke 2003

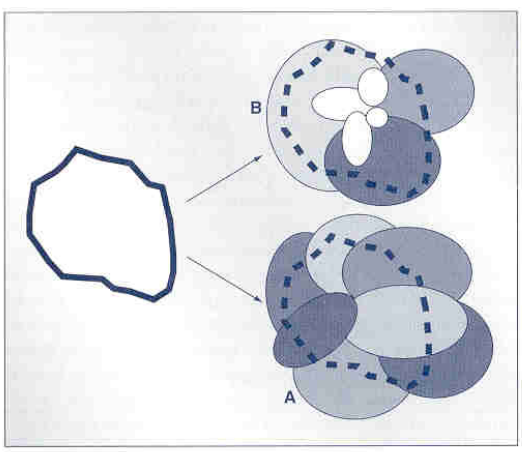


Figure 4.7
The "cookie cutter" model of the effects of habitat loss on endemic species. If the cookie cutter strikes at subarea A, seven species lose habitat but none is exterminated. In contrast, if the cookie cutter strikes subarea B, an area containing species with more restricted ranges, seven species lose habitat, and four species are exterminated. Thus, random habitat loss produces a disproportionately high rate of extinction in endemic species.

After Pimm (1998).

Van Dyke 2003

Endemics
Habitat Size
Habitat Loss

63

Species Focus ---> Biodiversity and Process Focus (ESA)

What being lost vs. why…

64

Species = ?

Biological Species Concept (Mayr)
"a group of interbreeding populations that are reproductively isolated from other such groups"

2-morphological/typological species concept (plants)
3-evolutionary species concept
4-genetic species concept
5-paleontological species concept
6-cladistic species concept

65

Biological Species Concept

1. Testable and operational
2. Definition compatible with established legal concepts
3. Focus on level of biodiversity that agrees with tradition of conservation

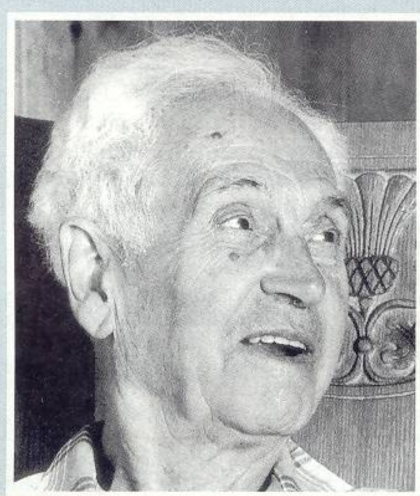
Conserve Species as

TYPES

or as

EVOLUTONARY UNITS

66



Ernst Mayr is one of the greatest influences on evolutionary biology since Darwin. Mayr was one of the architects of the evolutionary synthesis of the 1930s and 1940s, which unified biology by integrating Darwin's theory of natural selection with new discoveries in genetics, paleontology, and taxonomy. Mayr based his views on evolution mainly on relationships among bird species that he studied on Pacific islands. Now 89 years old, Mayr, Professor Emeritus at Harvard, is still going strong and generating exciting new ideas. His latest book, One Long Argument *(Harvard University Press, 1991), analyzes Darwin's theories. I interviewed Professor Mayr at his summer cottage in New Hampshire.*

Campbell 1993

Ernst Mayr (1904-2005)
Published papers for > 80 years

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Figure 22.3
Ernst Mayr in New Guinea, 1927. During his expedition, the naturalist (on the right, photographed with his guide) was struck by the almost exact match in how he and the native Papuans divided the birds of the Arafak Mountains into separate species. It was one of many experiences that led to Mayr's biological species concept, which emphasizes interbreeding within species and reproductive isolation between species.

You've also written that we humans have extraordinary responsibility because of our uniqueness as a species. Yes, humans are basically responsible for all the bad things that at the present time happen to our planet, and we are the only ones who can see all these things and do something about them. If we would stop the human population explosion, we would have already won two-thirds of the battle. That we live here just as exploiters of this planet is an ethic that does not appeal to me. Having become the dominant species on our planet, we have the responsibility to preserve the well-being of this planet. I feel that it should be a part of our ethical system that we should preserve and maintain and protect this planet that gave origin to us.

Ernst Mayr interviewed in Campbell 1993

Galapagos Finches

(b)

Brassica oleracea

Figure 17–8 A number of common vegetables are members of the same species, *Brassica oleracea,* including cauliflower, broccoli, cabbage, brussels sprouts, and kale. Artificial selection is responsible for the variation shown within this species.
(Raymond Tschoepe)

(c)

Solomon et al. 1993

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Aspidoscelis (*Cnemidophorus*)
Species vs. Parthenospecies…

70

1. Indicator Species
   - -migratory birds
   - -amphibians

2. Keystone Species
   - -top predators
   - -key pollinators

Rana pipiens
Northern Leopard Frog

3. Umbrella Species

Native Species
vs.
Nonnative, exotic, alien

71

Measuring Biodiversity
- alpha - beta - gamma

Alpha
species within a community

community
- all populations occupying a given area at a given time
- often broken into taxonomic groups or functional roles

1) Species Richness (# of species)
2) Species Evenness (how many of each type?)

Shannon Diversity Index (richness and evenness)

$H' = -\sum_i p_i \ln(p_i)$, ($i$ = 1, 2, 3 ... S)

p_i = proportion of total community abundance represented by ith species

72

Table 4.3 Abundance (individuals/10 ha) and diversity (Shannon index, $H' = -\Sigma(p_i \ln p_i)$) of avian species from two tallgrass prairie sites at DeSoto National Wildlife Refuge, Iowa. Note that site A, with fewer species (8) and two highly abundant species (common yellowthroat and field sparrow), has a lower value of diversity than site B, which has more species (11) that are more equally abundant. Van Dyke 2003

SPECIES	SITE A	SITE B
Common yellowthroat	8.24	1.21
Field sparrow	2.94	2.84
Dickcissel	1.18	2.23
Red-winged blackbird	0.29	0.81
Brown-headed cowbird	2.06	1.82
American goldfinch	1.47	1.02
Ringneck pheasant	0.59	1.63
Mourning dove	1.18	0.61
Eastern kingbird	—	1.60
Grasshopper sparrow	—	4.48
Northern bobwhite	—	2.64
Shannon diversity (H')	1.64	2.25

Shannon Index in Tallgrass Prairie

(indiv spp abundance relative to total abundance)

What if removed three species from B?

73

1.64					2.25			
a	prop	ln	propxln		b	prop	ln	propxln
8.24	0.459053	-0.77859	-0.35741		1.21	0.057922	-2.84865	-0.165
2.94	0.163788	-1.80918	-0.29632		2.84	0.13595	-1.99547	-0.27128
1.18	0.065738	-2.72208	-0.17894		2.23	0.10675	-2.23727	-0.23883
0.29	0.016156	-4.12546	-0.06665		0.81	0.038775	-3.24999	-0.12602
2.06	0.114763	-2.16488	-0.24845		1.82	0.087123	-2.44043	-0.21262
1.47	0.081894	-2.50233	-0.20493		1.02	0.048827	-3.01947	-0.14743
0.59	0.032869	-3.41522	-0.11226		1.63	0.078028	-2.55069	-0.19902
1.18	0.065738	-2.72208	-0.17894		0.61	0.029201	-3.53357	-0.10318
					1.6	0.076592	-2.56927	-0.19678
					4.48	0.214457	-1.53965	-0.33019
					2.64	0.126376	-2.06849	-0.26141
17.95	1		**-1.64391**		20.89	1		**-2.25177**
drop top 3					drop bottom 3			
b	prop	ln	propxln		b	prop	ln	propxln
					1.21	0.099425	-2.30835	-0.22951
					2.84	0.233361	-1.45517	-0.33958
					2.23	0.183237	-1.69697	-0.31095
0.81	0.055441	-2.89243	-0.16036		0.81	0.066557	-2.70969	-0.18035
1.82	0.124572	-2.08287	-0.25947		1.82	0.149548	-1.90014	-0.28416
1.02	0.069815	-2.6619	-0.18584		1.02	0.083813	-2.47917	-0.20779
1.63	0.111567	-2.19313	-0.24468		1.63	0.133936	-2.01039	-0.26926
0.61	0.041752	-3.176	-0.13261		0.61	0.050123	-2.99327	-0.15003
1.6	0.109514	-2.2117	-0.24221					
4.48	0.306639	-1.18208	-0.36247					
2.64	0.180698	-1.71093	-0.30916					
14.61	1		**-1.8968**		12.17	1		**-1.97163**

74

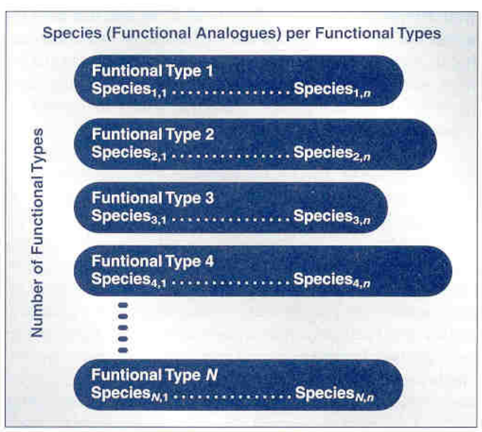

Figure 4.3
Total species diversity can be measured as the product of the number of functional types and the number of species per functional type. Two populations may have the same species diversity and still differ. For example, one may have many functional types and few functional analogues, and the other may have many analogues but few functional types. The relative number of functionally analogous species within each functional type is indicated by the width of the oval. Van Dyke 2003

Process and Pattern

1 Functional Types
2 Functional Analogs

Increase either to increase biodiversity

Which to preserve?

Niche:
Ecological role of a species in a community

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Measuring Biodiversity
- alpha - beta - gamma

Beta
area or regional diversity (beta richness)
diversity of species among communities across landscape

gradient
- slope, moisture, temperature, precipitation, disturbance, etc.

Whittaker's Measure = (S/alpha) - 1

where S = # spp in all sites, alpha = avg. # spp/site

a) if no community structure across gradient = 0
-broad ecological tolerances, niche breadth

b) 100/10 - 1 = 9 high beta diversity

Beta Diversity

1) quantitative measure of diversity of communities that experience changing environmental gradients

2) are species sensitive, or not, to changing environments?
are there associations of species that are interdependent (plants, pollinators, parasites, parasitoids)?

3) how are species gained or lost across a TIME gradient?

Succession, community composition, effects of disturbance

Alpha and Beta Diversity Hotspots

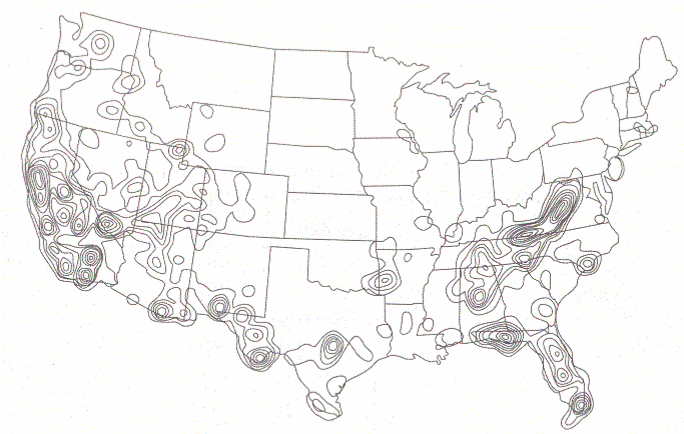

Figure A Hot spots of rarity and species richness in the lower 48 United States. Read as a topographic map with concentric circles showing higher values of the rarity-weighted species richness index (RWRI). Hotspots are found in CA, the Death Valley region of Nevada, the Appalachian Mountains, and the Florida panhandle and Everglades. Many other regions of higher diversity are found in other parts of the U.S., and the Hawaiian islands (not shown) have the greatest concentration of range-restricted species by far. To achieve a high RWRI both α- and β-diversity must be high. (Modified from Stein et al. 2000.)

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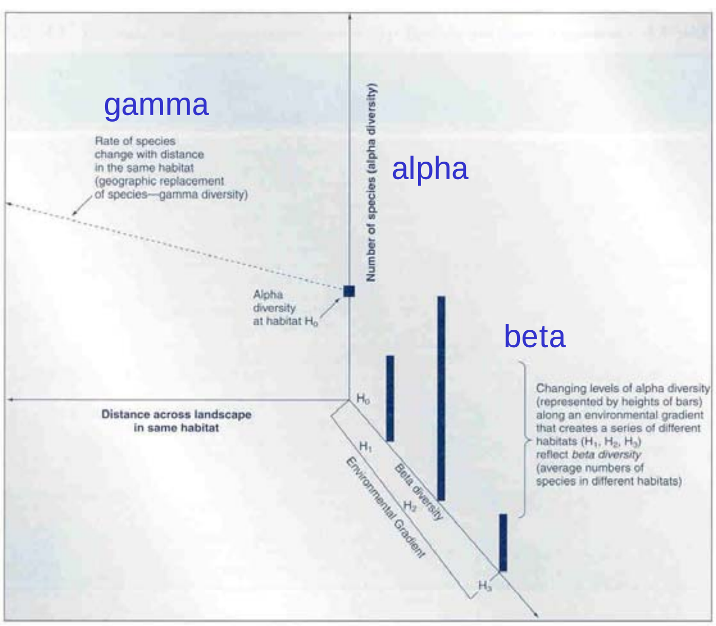
Groom et al. 2006



Van Dyke 2003

Figure 4.2
The number of species on a given site in one kind of habitat is a measure of alpha diversity (species richness). The average number of species per site along an environmental gradient (number of species per habitat) is a measure of beta diversity. The rate of species change over landscape scale distances in the same habitat is a measure of gamma diversity (geographic replacement of species).

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Measuring Biodiversity
- alpha - beta - gamma

Gamma

rate of change of species composition with distance
(geography, rate of gain and loss of species)

alpha rarity with increased number of species
(fewer of each type)

beta rarity with habitat specialists

gamma rarity if restricted to particular geographic areas

80

Measuring Biodiversity
- alpha - beta - gamma

Missing?

Species role in ecosystem?
Rarity
Phylogenetic Representation
Ecological Redundancy

Edges vs. Interior (e.g., fragmentation)
(spp richness increases, but are broad generalists, not interior habitat specialists)

All species are not equivalent (normative valuation?)

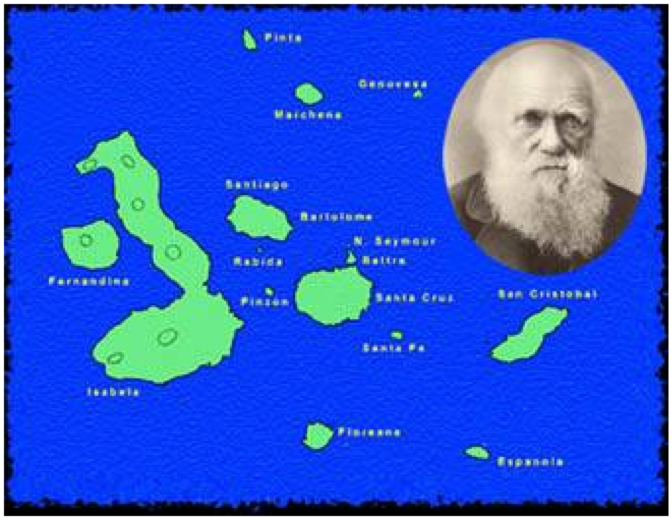
81

Endemism...

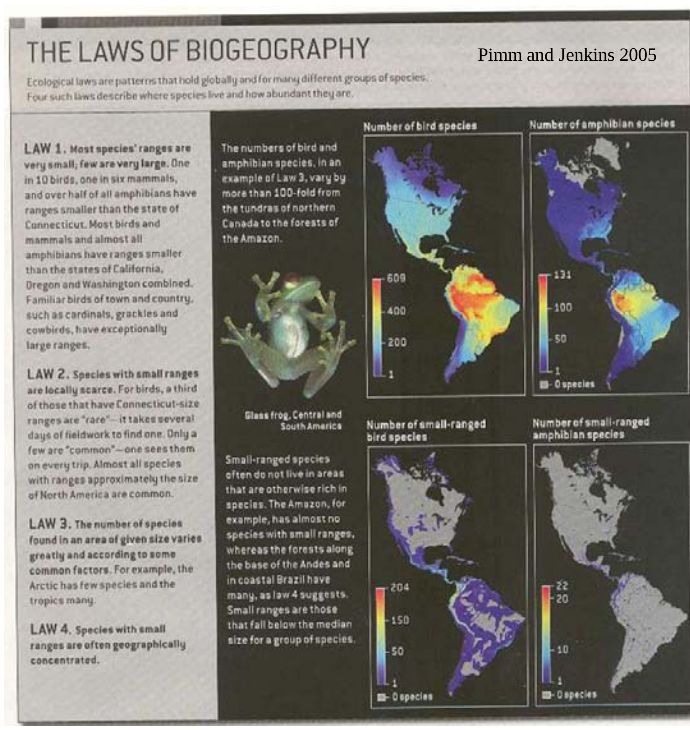
82

http://www.rit.edu/~rhrsbi/GalapagosPages/DarwinFinch.html

83



84



THE LAWS OF BIOGEOGRAPHY

Pimm and Jenkins 2005

Ecological laws are patterns that hold globally and for many different groups of species. Four such laws describe where species live and how abundant they are.

LAW 1. Most species' ranges are very small; few are very large. One in 10 birds, one in six mammals, and over half of all amphibians have ranges smaller than the state of Connecticut. Most birds and mammals and almost all amphibians have ranges smaller than the states of California, Oregon and Washington combined. Familiar birds of town and country, such as cardinals, grackles and cowbirds, have exceptionally large ranges.

LAW 2. Species with small ranges are locally scarce. For birds, a third of those that have Connecticut-size ranges are "rare"—it takes several days of fieldwork to find one. Only a few are "common"—one sees them on every trip. Almost all species with ranges approximately the size of North America are common.

LAW 3. The number of species found in an area of given size varies greatly and according to some common factors. For example, the Arctic has few species and the tropics many.

LAW 4. Species with small ranges are often geographically concentrated.

The numbers of bird and amphibian species, in an example of Law 3, vary by more than 100-fold from the tundras of northern Canada to the forests of the Amazon.

Glass frog, Central and South America

Small-ranged species often do not live in areas that are otherwise rich in species. The Amazon, for example, has almost no species with small ranges, whereas the forests along the base of the Andes and in coastal Brazil have many, as law 4 suggests. Small ranges are those that fall below the median size for a group of species.

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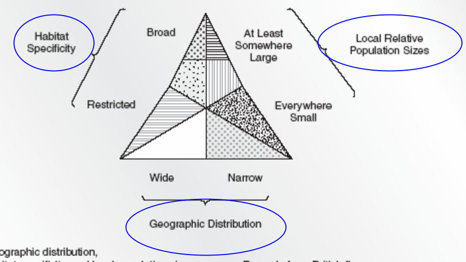

Symbol	Geographic distribution, habitat specificity, and local population size	Example from British flora
	Wide, broad, at least somewhere large	*Deschompsia cespitosa*, tufted hair-grass
	Wide, broad, everywhere small	*Hypochoeris maculata*, spotted gosmore
	Wide, restricted, at least somewhere large	*Ammophila arenaria*, marram grass
	Wide, restricted, everywhere small	*Draba muralis*, wall whitlow grass
	Narrow, broad, at least somewhere large	*Primula scotica*, Scottish bird's-eye primrose
	Narrow, restricted, at least somewhere large	*Agrostis setacea*, bristle-leaved bent
	Narrow, broad, everywhere small	(no example)
	Narrow, restricted, everywhere small	*Lloydia serotina*, alpine lily

Figure 4.9
Eight categories of species abundance in British plants based on geographic range, habitat use, and relative population size. Note that only one category (broad habitat specificity, wide geographic distribution, and large local population) can truly be considered "common." Species in the other seven categories are rare in one or more dimensions.

Adapted from Rabinowitz, Cairns, and Dillon (1986).

VanDyke 2003

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Cyprinodon macularius

Desert Pupfish

Photograph Courtesy of John Rinne

Desert pupfish declined due to the introduction and spread of exotic predatory and competitive fishes, water impoundment and diversion, water pollution, groundwater pumping, stream channelization, and habitat modification.

Healthy population of almost 10,000 fish inhabits this oasis. This last refuge of a unique fish is being actively managed.

Cyprinodon macularius

Desert Pupfish

Family Cyprinodontidae

Photograph Courtesy of John Rinne

-1-1/4 inches long
max. age of three years

-females are gray and drab
males are bluish, turning bright blue during spring breeding season.

-feed on insect larvae and other organic matter from pond bottom.

-prefer shallow pond depths, about 12 to 18 inches deep.

Quitobaquito pupfish (Endangered since 1986)

This tiny fish was once part of a widespread population, the range of which included the Colorado, Gila, San Pedro, Salt and Santa Cruz rivers and their tributaries in Arizona and California. The ancestors of the Quitobaquito and Sonoyta river pupfish are believed to have been cut off from their relatives in the Colorado River drainage about one million years ago.

The warm, slightly brackish water at Quitobaquito is ideal habitat for pupfish. Pupfish can tolerate salinity levels ranging from normal tap water to water three times saltier than the ocean. Therefore, they are well suited to desert environments where high evaporation rates create water with high salinity levels.

Although the water temperature at the spring is a constant 74°F, the water temperature in the pond fluctuates greatly during the year, from about 40°F or cooler in January to almost 100°F in August, especially in shallow areas… very tolerant of rapid temperature change and low oxygen content due to summer heat.

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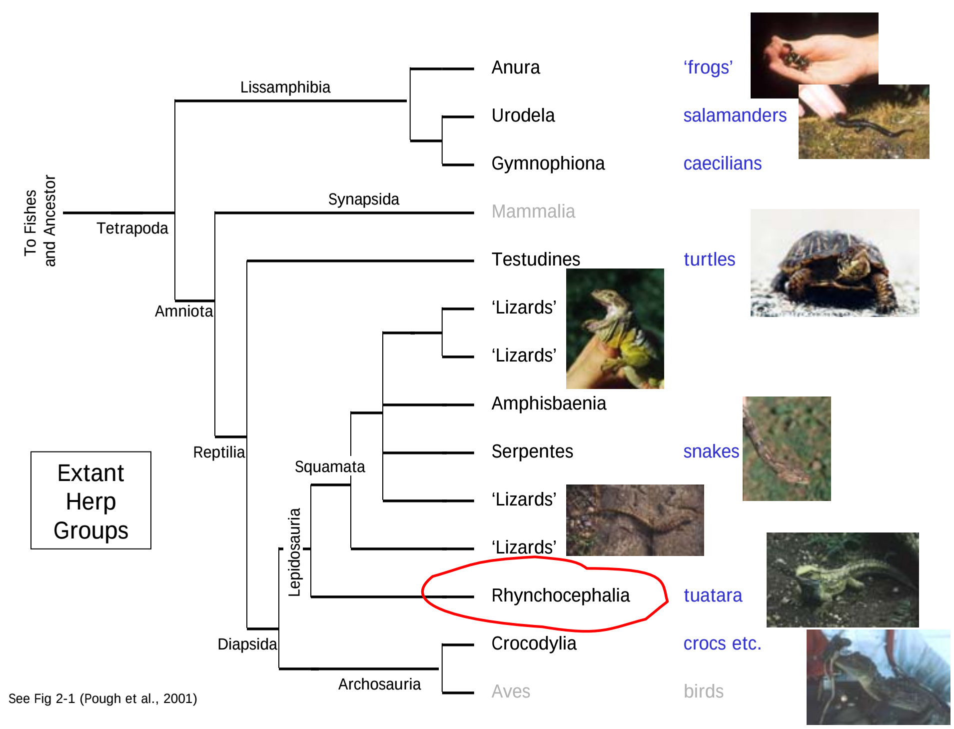
Pricing Biodiversity

$R_I = (D_i + U_i)(\text{delta}P_i/C_i)$

D = distinctiveness
U = utility
delta P = enhanced probability of survival
C = cost of strategy

Direct limited funds…
Ecological Contribution?



Rhynchocephalia

- evolved before dinosaurs

- world-wide distribution in Mesozoic

- most extinct at end Cretaceous (65mya)

Sphenodontidae

- 1 extant genus (*Sphenodon*)
- 2 extant species

- restricted to small islands of New Zealand

- long lived

Pricing Biodiversity

$R_I = (D_i + U_i)(\text{delta}P_i/C_i)$

D = distinctiveness
U = utility
delta P = enhanced probability of survival
C = cost of strategy

Direct limited funds...
Ecological Contribution?

Discussion:

Biodiversity vs. Wilderness

“no essential contradiction between social interests and biodiversity conservation”

p.109, VanDyke (Sarkar, 1999)

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END

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