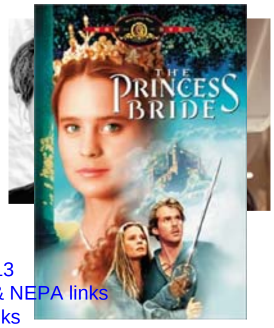
Lecture 07, 11 Sept 2007
Biodiversity

Conservation Biology
ECOL 406R/506R
University of Arizona
Fall 2007

Kevin Bonine
Cathy Hulshof



Upcoming Readings
today: Text Ch. 4, and pp. 207-213
Thurs 13 Sept: Text Ch. 2; ESA & NEPA links
Tues 18 Sept: SDCP and ESA links

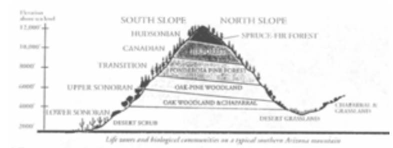
Thanks to Guy McPherson
Q2 due 13 Sept if you choose
Readings for Debate

1

Conservation Biology Lab 406L/506L

Next Lab SATURDAY 15 September
0700h S or W side BSE (4th and Highland)
Hat, water, sunscreen, close-toed shoes
Lunch, snacks, weather gear, ($?)

Readings on Course Website – print:
Handouts 1 and 2,
last 3 pages of:
"Miscellaneous Mt. Lemmon-related information "



2

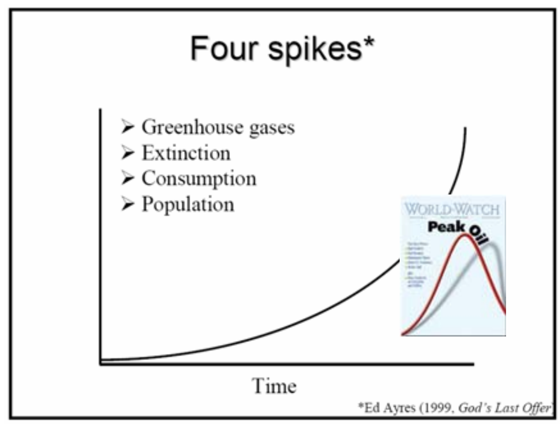
Debate 20 Sept 2007: Should the flat-tailed horned lizard (*Phrynosoma mcallii*) be ESA listed?

Slight Schedule Change:

Three groups – one will debate, another will evaluate, third will observe, then we rotate.

406	506
Debate 1 (20 Sept.)	Debate 1 (20 Sept.)
Group A debate	506 A assist
Group B evaluate	506 B assist
Group C observe	506 C observe
Debate 2 (23 Oct.)	Debate 2 (23 Oct.)
Group A observe	506 A observe
Group B debate	506 B assist
Group C evaluate	506 C assist
Debate 3 (15 Nov.)	Debate 3 (15 Nov.)
Group A evaluate	506 A assist
Group B observe	506 B observe
Group C debate	506 C assist

3



A U.S. Geological Survey report released in November 2006 indicated that the Beaufort Sea polar bear population has experienced a significant drop in cub survival. The study also determined that adult males weighed less and had smaller skulls than those captured and measured two decades ago.

In recent years, winter sea ice has fallen by at least 600,000 square miles, double the size of Texas.

Ursus maritimus

Conservationists hope — and Alaska business interests fear — that designating polar bears as threatened due to global warming will carry a huge economic cost, forcing federal agencies around the country to consider the affect on polar bears before granting permits that would increase greenhouse gas emissions.

Arizona Daily Star, 10 April 2007

Published: 09.08.2007
New forecast: Two-thirds of polar bears could die off
THE ASSOCIATED PRESS
WASHINGTON — Two-thirds of the world's polar bears will be killed off by 2050 — and the entire population gone from Alaska — because of thinning sea ice from global warming in the Arctic, government scientists forecast Friday.
Only in northern Canada and northwestern Greenland are polar bears expected to survive through the end of the century, said the U.S. Geological Survey, which is the scientific arm of the Interior Department.
USGS projects that polar bears during the next half-century will lose 42 percent of the Arctic range they need to live in during summer in the Polar Basin when they hunt and breed. A polar bear's life usually lasts about 30 years.

7

Biodiversity (Biological Diversity)

"structural and functional variety of life forms at genetic, population, community, and ecosystem levels"

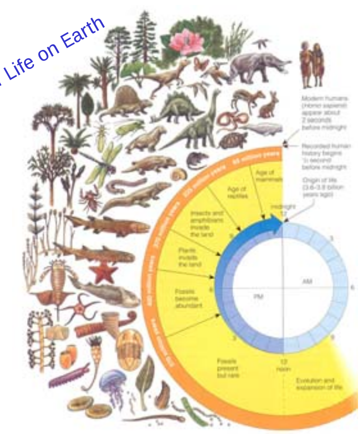
8

Nothing in biology makes sense except in the light of evolution.

THEODOSIUS DOBZHANSKY

9

Evolution of Life on Earth



Miller 2003

Figure 5-3 Greatly simplified overview of the biological evolution of life on the earth, which was preceded by

10

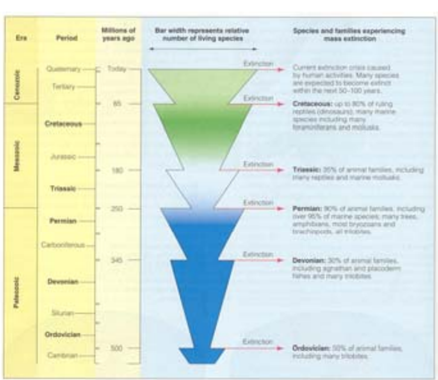


Figure 5-9 Fossils and radioactive dating indicate that five major mass extinctions (indicated by arrows) have taken place over the past 500 million years. Mass extinctions leave large numbers of organism roles (niches) unoccupied and create new ones. As a result, each mass extinction has been followed by periods of recovery (represented by the wedge shapes) called adaptive radiations. During these periods, which last over 10 million years or more, new species evolve to fill new or vacated ecological roles (niches). Many experts believe that we are now in the midst of a sixth mass extinction, caused primarily by human activities.

Miller 2003

Major Extinction Events

1

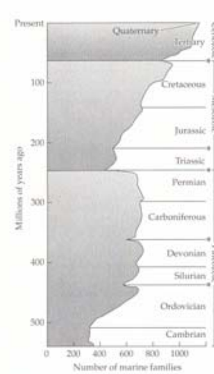


Figure 2.5 Diversity of marine families from the Cambrian to the present. The asterisks mark the five major mass extinction events.

Groom et al. 2006

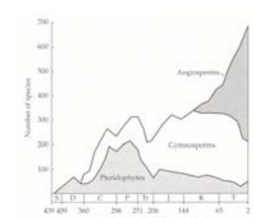


Figure 2.6 Terrestrial plant species richness. Ferns, gymnosperms, and angiosperms have, in turn, dominated the world's flora. (Modified from Signor 1990.)

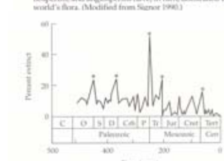
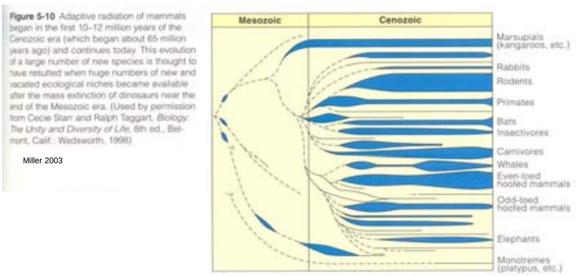


Figure 2.7 Extinctions of families through geologic time. The five historical mass extinction events are marked with an asterisk.

Adaptive Radiation



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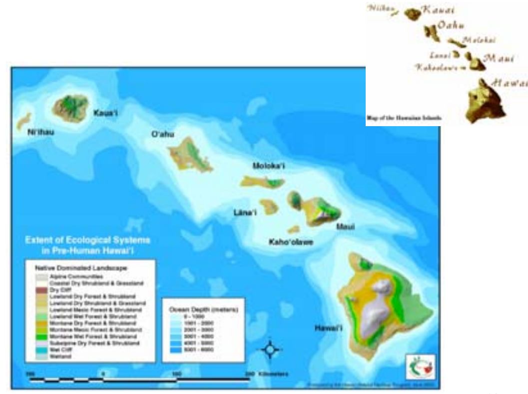

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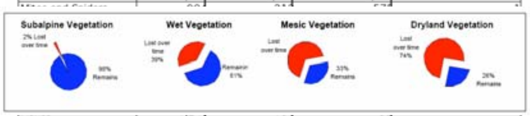
Estimates of Numbers and Status of Species in Hawai'i

Taxon	Total*	Endemic	Non-Indigenous	Threatened or Endangered
Cyanobacteria (b/g alg	201	11	0	
Algae	1,118	104	5	
Other Protists	1,229	1	0	
Fungi and Lichens	3,149	972	8	
Flowering Plants	2,142	896	1,139	262
Other Plants	639	226	37	13
Cnidarians	457	102	28	
Insects	8,155	5,246	2,782	1
Amphibians	7	0	7	
Reptiles	29	0	26	
Birds	309	63	55	31
Mammals	44	2	19	1
Other vertebrates	77	0	0	
TOTAL	**25,714**	**9,987**	**5,171**	**31**



328 as of Sept 2007

http://hawaiiconservation.org/conservationresources.asp (2003)

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http://ecos.fws.gov/tess_public/Boxscore.do
10 September 2007

Group	United States Endangered	Threatened	Total Listings
Mammals	69	12	81
Birds	75	14	89
Reptiles	13	24	37
Amphibians	13	10	23
Fishes	74	65	139
Clams	62	8	70
Snails	64	11	75
Insects	47	10	57
Arachnids	12	0	12
Crustaceans	19	3	22
Corals	0	2	2
Animal Subtotal	**448**	**159**	**607**
Flowering Plants	570	143	713
Conifers and Cycads	2	1	3
Ferns and Allies	24	2	26
Lichens	2	0	2
Plant Subtotal	**598**	**146**	**744**
Grand Total	**1046**	**305**	**1351**

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Hawaiian Endangered Species
Unfortunately, Hawai'i has the highest number of listed threatened and endangered species in the nation. There are 394 threatened and endangered species in the State of Hawai'i, of which 294 are plants, 57 invertebrates, and 43 vertebrates.

http://www.fws.gov/pacificislands/wesa/endspindex.html#Hawaiian

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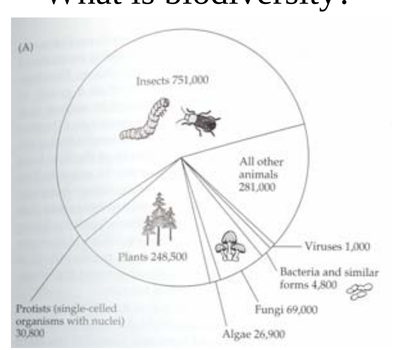
What is biodiversity?



Primack 2006, Fig 3.6

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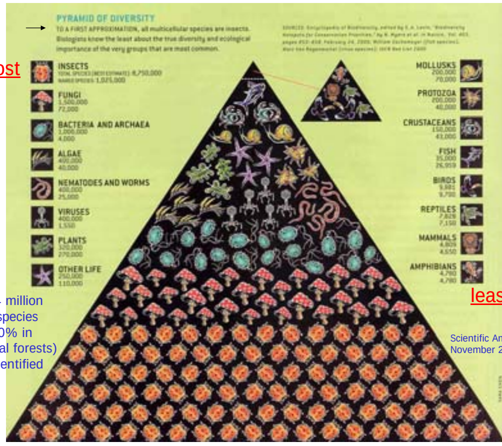


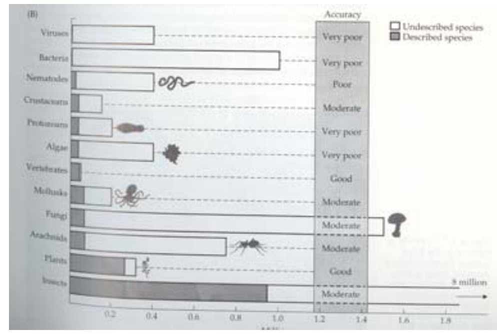
most

least

~12-14 million
total species
(50-90% in
tropical forests)
~1.7 identified

Scientific American
November 2001

How many species on earth?



Primack 2006, Fig 3.6

Research Focus?

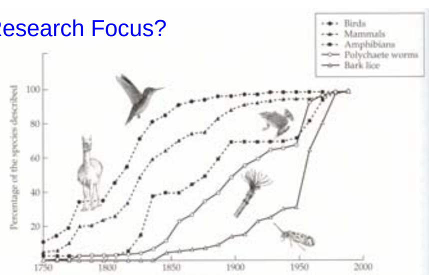


FIGURE 3.10 For five groups of Chilean animals, the cumulative percentage of the known species described from 1750 to 2000. Note that the majority of birds and mammals were largely described by 1900, and probably few new species remain to be discovered. In contrast, polychaete worms and bark lice were largely neglected by early taxonomists and are only now being investigated and described. Amphibians are intermediate in their intensity of study. (After Primack et al. 2001.)

Primack 2006

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Mother Nature's DNA

The Human Genome Project has not cured any diseases yet—but it's revolutionizing

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Biodiversity

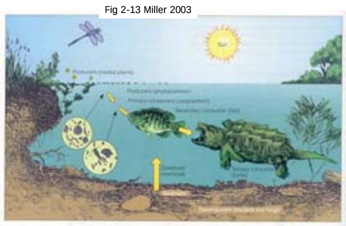
1. Genetic
   (nat. sel.)

2. Species

3. Ecological
   forests, deserts, lakes, wetlands, reefs etc.

4. Functional
   energy flow
   nutrient cycling
   etc.

Fig 2-13 Miller 2003



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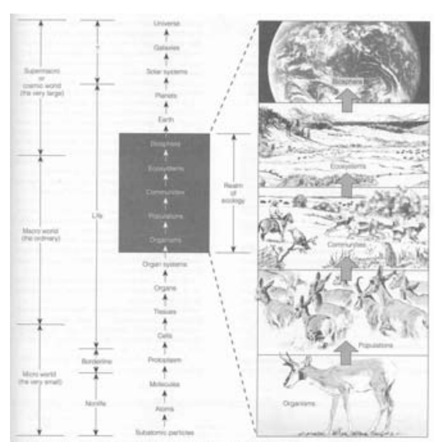
Levels of
Biological
Organization.

Scaling.



Miller, 2003

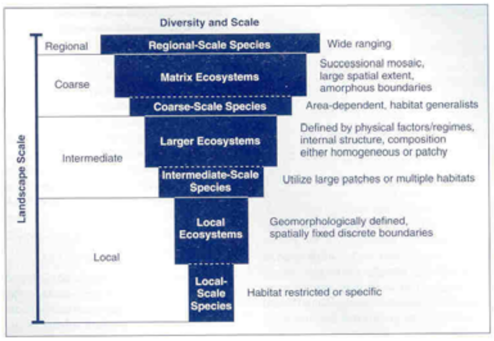
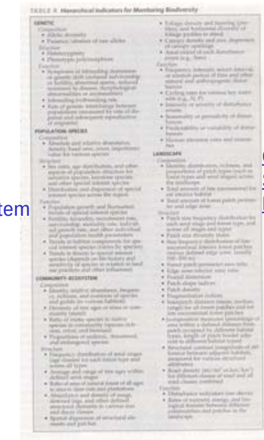


Figure 4.15 Van Dyke 2003
Biodiversity and scale. A method of categorizing biodiversity at regional, coarse, intermediate, and local geographic scales.
Modified from Poiani et al. (2000). © 2001 American Institute of Biological Sciences.

Biodiversity

1. Genetic
2. Population/Species
3. Community/Ecosystem
4. Landscape



Composition
Structure
Function

Groom et al. 2006

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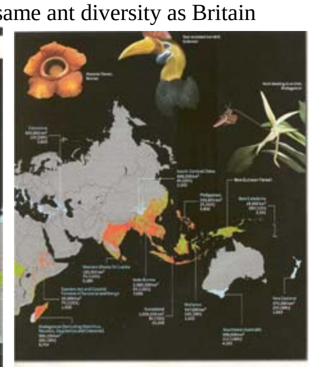
Where is biodiversity?

One tree in Peru with same ant diversity as Britain



Pimm and Jenkins 2005

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Species Richness and Latitude

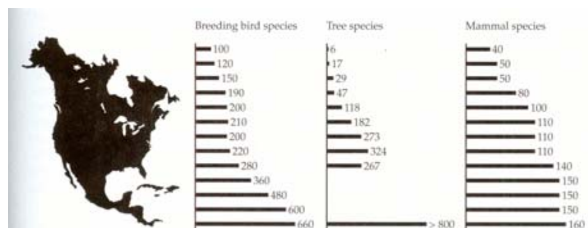

FIGURE 3.5 In North America, as in all the continents, the numbers of bird, tree, and mammal species increase toward the Tropics. The numbers of species indicated in the bar graphs correspond to latitude in the map at left. Tree species diversity is not available for some lower latitudes. (From Briggs 1995.)

Altitude?

Primack 2006

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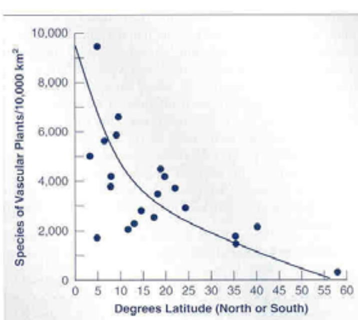

Figure 4.12
Latitudinal patterns in species richness from tropical to temperate regions. In most taxa the number of species increases from temperate to tropical regions. Van Dyke 2003
After Reid and Miller (1989). Reprinted from Huston (1994).

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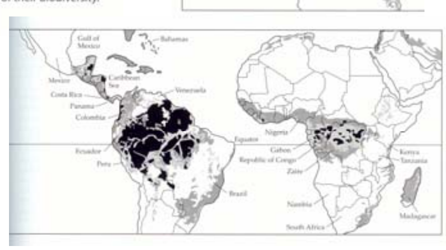
FIGURE 3.1 Tropical rain forests are found predominantly in wet, equatorial regions of America, Africa, and Asia. Eight thousand years ago, tropical forests covered the entire shaded area, but human activities have resulted in the loss of a great deal of forest cover, shown in the darkest shade. In the lighter shaded area forests remain, but they are no longer true tropical forests; instead they are (1) secondary forests that have grown back following cutting, (2) plantation forests such as rubber and teak, or (3) forests degraded by logging and fuelwood collection. Only in the regions shown in black are there still blocks of intact natural tropical forest large enough to support all of their biodiversity. (After Bryant et al. 1997.)

Tropical Rainforests



Primack 2006

Coral Reefs

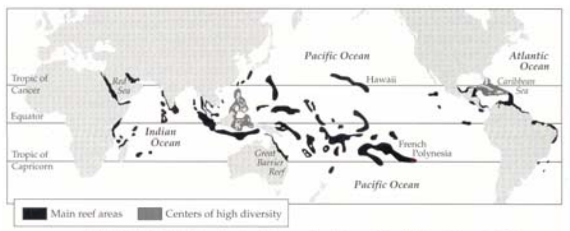


FIGURE 3.4 Global distribution of the coral reef biome. (After Wells and Hanna 1992.)

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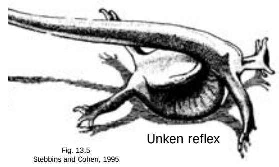
Primack 2006

Lissamphibia

Urodela
(salamanders)

10 families, 60 genera, 516 spp.

Ambystoma tigrinum



Unken reflex

Fig. 13.5
Stebbins and Cohen, 1995

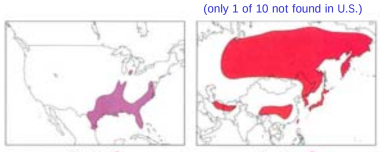
Ambystoma californiense

Urodela families

Figure 3–3 **Distribution of salamander families Sirenidae, Hynobiidae, and Salamandridae.**

Pough et al. 2004

(only 1 of 10 not found in U.S.)



Sirenidae

Hynobiidae

Salamandridae

Urodela families

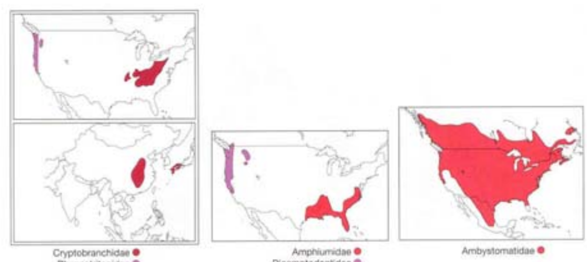


Figure 3–4 **Distribution of salamander families Cryptobranchidae, Rhyacotritonidae, Amphiumidae, Dicamptodontidae, and Ambystomatidae.**

Pough et al. 2004

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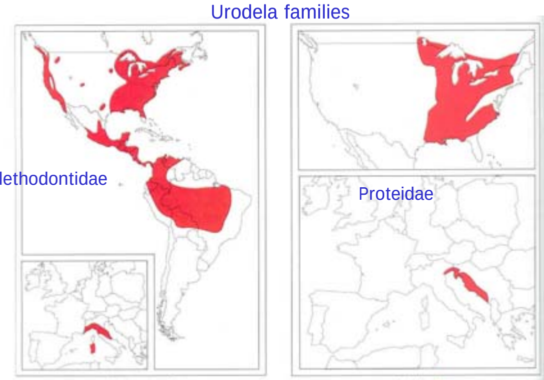
Urodela families

Plethodontidae

Proteidae



Pough et al. 2004

Figure 3–7 **Distribution of the salamander families Plethodontidae and Proteidae.**

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)

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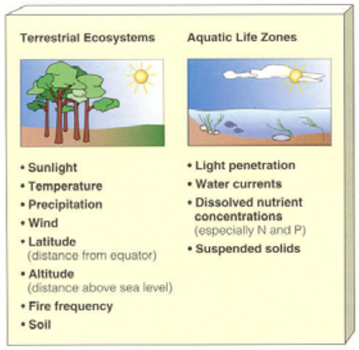
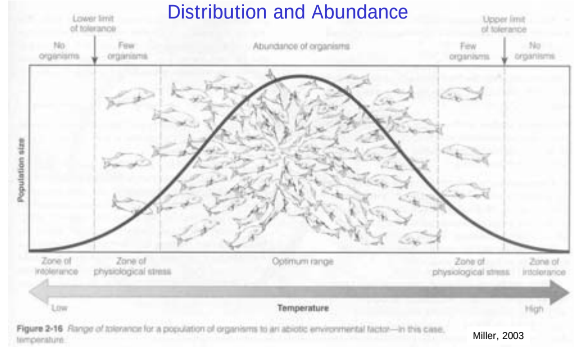
Distribution
and
Abundance



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



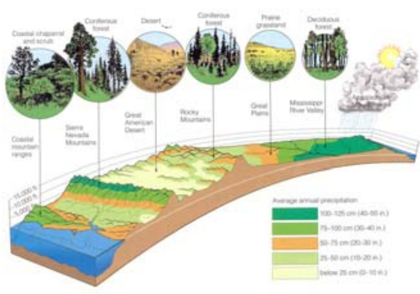
Range of tolerance of abiotic factor(s)

Terrestrial Biomes

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

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

- Latitude
- Altitude



Miller 2003 3-5

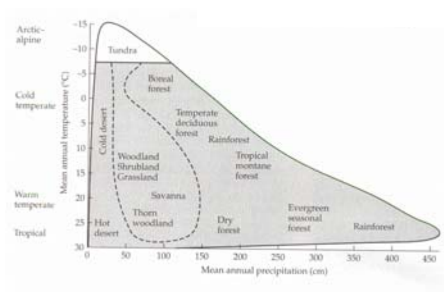
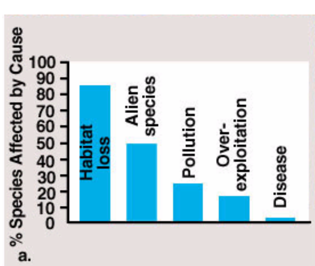


Figure 2.4 Biomes and climate. Distributions of the major biomes are plotted on axes of mean annual precipitation and temperature. Within the region bounded by the dashed line, factors such as seasonality of drought, fire, and grazing strongly affect which type of vegetation is present (Modified from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

Groom et al. 2006

Threats to biodiversity – habitat loss



Thanks to Chuck Price

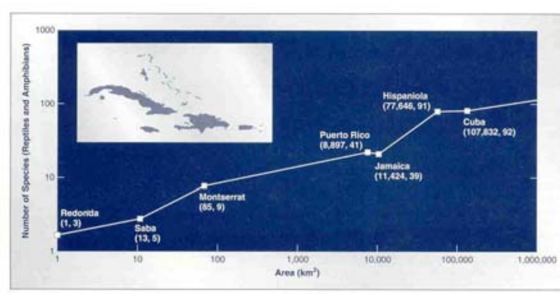


Figure 4.4
A general species-area relationship among some Caribbean islands. Note that species richness on islands increases with increasing area.
Based on data from Darlington (1957:483).

Species-Area Relationship

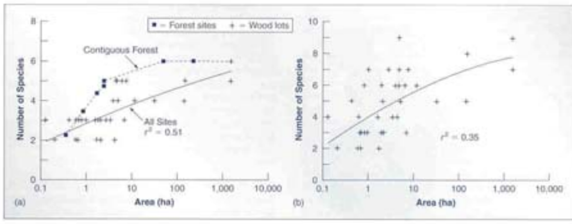


Figure 4.5

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.

After Napp and Swihart (2000).

Van Dyke 2003

Woodlots vs. contiguous forest

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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

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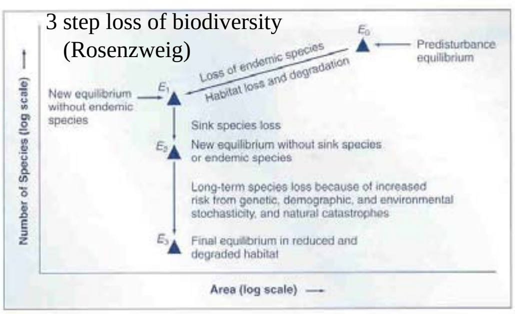

Figure 4.6

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).

Van Dyke 2003

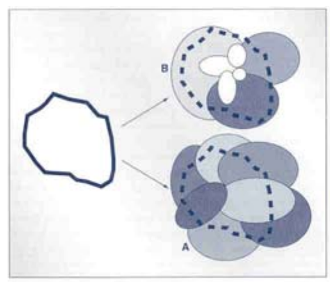

Figure 4.7

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

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

What being lost vs. why…

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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

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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

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

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

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)

Solomon et al. 1993

Aspidoscelis (*Cnemidophorus*)
Species vs. Parthenospecies…

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

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

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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?

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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**

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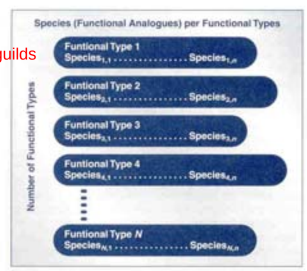

Figure 4.3
Total species diversity can be measured as the product of the number of functional types and the number of species per functional type. Two populations may have the same species diversity and still differ. For example, one may have many functional types and few functional analogues, and the 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.)

Groom et al. 2006

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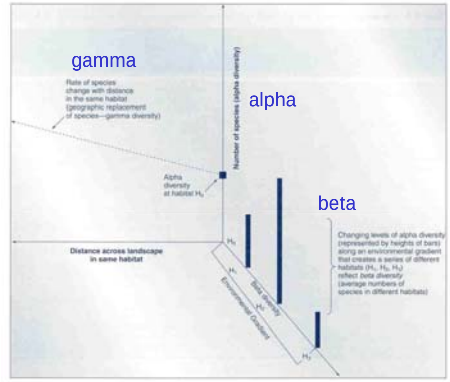

Van Dyke 2003

Figure 4.2

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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)

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

beta rarity with habitat specialists

gamma rarity if restricted to particular geographic areas

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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?)

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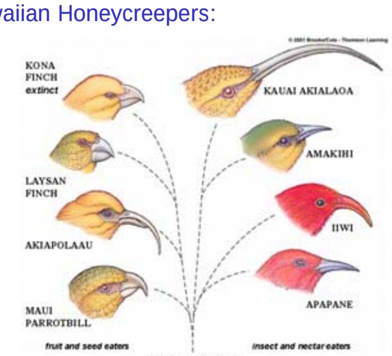
Endemism...

LIFE 8e, Figure 23.15

Hawaiian Honeycreepers:



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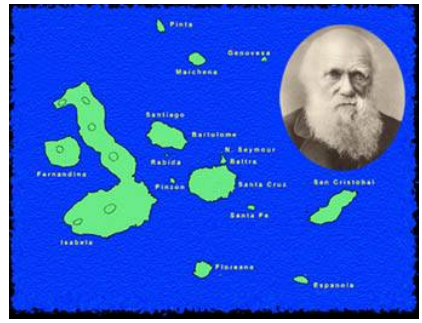
http://www.rit.edu/~rhrsbi/GalapagosPages/DarwinFinch.html

67



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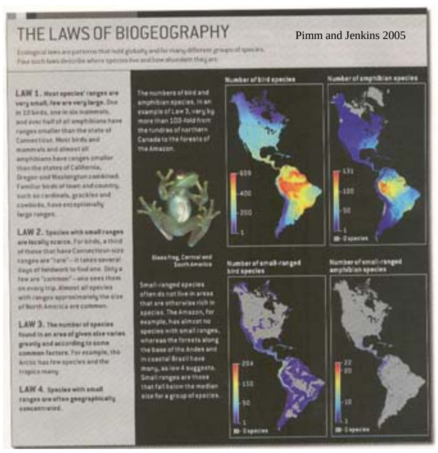

THE LAWS OF BIOGEOGRAPHY

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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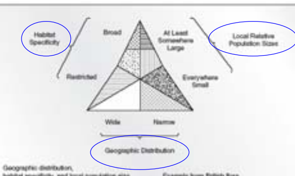

Symbol	Geographic distribution, habitat specificity, and local population size	Example from British flora
	Wide, broad, at least somewhere large	*Deschampsia cespitosa*, tufted hair-grass
	Wide, broad, everywhere small	*Hypochoeris maculata*, spotted gosmore
	Wide, restricted, at least somewhere large	*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 populations) 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

-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?

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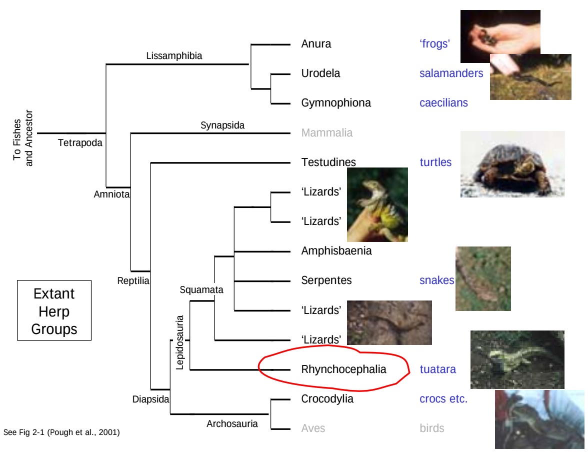

See Fig 2-1 (Pough et al., 2001)

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?

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