Lecture 06, 07 Sept 2006
Ch4, Leopold, Costanza, Driessen

Conservation Biology
ECOL 406R/506R
University of Arizona
Fall 2006

Kevin Bonine
Kathy Gerst

Biodiversity

Ch4, begin Ch2 for Tues
Lab this Friday (08 Sept 2006), meet S side BSE 1230
(see website for lab readings)

1

Housekeeping, 07 September 2006

Papers to turn in?

Upcoming Readings

today: Leopold, Text Ch.4, Costanza 1997, Driessen 2004

Tues 12 Sept: Textbook Ch. 4, begin Ch 2
Thurs 14 Sept: Text Ch. 2

Short oral presentations
12 Sept Gabe Wigtil and Kim Baker
14 Sept open
19 Sept Tara Luckau and Frank Emmert?
21 Sept Grant Rogers and Jeremy Daniel

2

Grading for Oral Presentations:

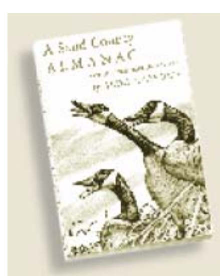
Content
(quality of content, relevance to conservation issues):
25 points

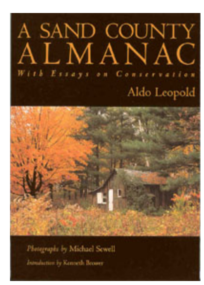
Presentation
(speaking, slide design, professionalism):
10 points

Response to questions:
5 points

3

1887-1948





http://www.aldoleopold.org/Biography/Biography.htm
Aldo Leopold Foundation

4

Leopold

Thinking like a mountain
" a mountain lives in mortal fear of its deer"

Escudilla
progress?
"It's only a mountain now."

The planet will survive, will we?

5

"a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise"

Aldo Leopold

6

Aldo Leopold Land Ethic

-land ethic enlarges the community
to include biota

-processes
-evolutionary/ecological biology

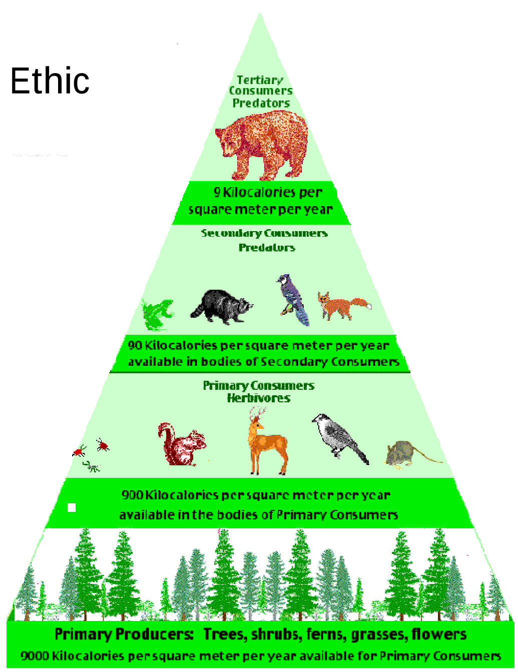
-scale of perturbation (temporal, spatial)

-What is “land-health?”

7

Aldo Leopold Land Ethic

-land pyramid



"In our attempt to make conservation easy we have made it trivial" (p.246)

-Leopold

9

"Whether you will or not

You are a King, Tristram, for you are one

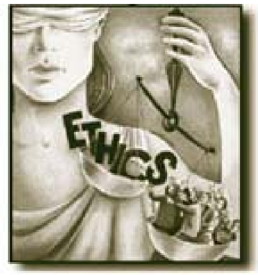
Of the time-tested few that leave the world,

When they are gone, not the same place it was.

Mark what you leave."

As quoted in Leopold, 1949
p. 261 (The Land Ethic)

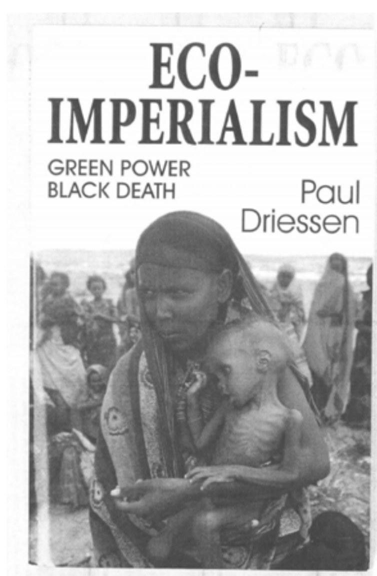
Role of scale... (context of disturbance and extinction)



Anthropogenic perturbations:

...fast rate and large spatial scale.
(Cited in Callicott 1997)

11



2004

5

Sustainable Mosquitoes – Expendable People

12

Chapter Five Footnotes

1. Fifi Kobusingye, personal conversation with Paul Driessen, May 6, 2003.
2. See www.FightingMalaria.org and extensive studies and articles cited and linked by that website, including "Malaria and the DDT Story," by Dr. Kelvin Kemm of Stratek Technology Strategy Consultants, in *Environment Health* (Lorraine Mooney and Roger Bate, editors). See also Walter Williams, "Killing people," *The Washington Times*, October 17, 2002; Deroy Murdock, "Nutritional Schizophrenia," NationalReviewOnline, June 25, 2002.
3. Barun Mitra and Richard Tren, *The Burden of Malaria*, Delhi, India: Liberty Institute, Occasional Paper 12, November 2002.
4. John Gallup and Jeffrey Sachs, *The Economic Burden of* Malaria, Harvard University Center for International Development, London School for Hygiene and Tropical Medicine, for the World Health Organization, 2000. For a detailed examination of the health, social and economic impacts of malaria – especially on African countries – see Richard Tren and Roger Bate, *When Politics Kills: Malaria and the DDT story*, Sandton, South Africa: Africa Fighting Malaria (2000). A more recent version of *Malaria and the DDT story* can be downloaded from the Institute of Economic Affairs website at http://www.iea.org.uk/record.php?type=publication&ID=11
5. Alexander Gourevitch, "Should the DDT ban be lifted?" *Washington Monthly*, April 9, 2003.
6. The chemical Alar was used to regulate the growth and ripening of apples, until it became the subject of an attack launched by Fenton Communications, the NRDC and CBS's "60 Minutes." In a later interview, David Fenton admitted that "the PR campaign was designed so that revenue would flow back to NRDC from the public." See Bonner Cohen, John Carlisle, *et al.*, *The Fear Profiteers: Do "socially responsible" businesses sow health scares to reap monetary rewards?* Arlington, VA: Lexington Institute (2000).
7. In so doing, Ruckelshaus ignored thousands of pages of scientific evidence attesting to the pesticide's safety and expert recommendations that its use be continued for malaria control.
8. Richard Tren, president, Africa Fighting Malaria, personal communication, December 20, 2002; Brian Sharp, P. van Wyk, et al., "Malaria control by residual insecticide spraying in Chingola and Chililabombwe, Copperbelt Province, Zambia," *Journal of Tropical Medicine and International Health*, pages 732-736, September 2002.
9. Alexander Gourevitch, "Should the DDT ban be lifted?" and Donald Roberts, personal communication to Paul Driessen, April 29, 2003..

10. Richard Tren, "DDT still saving lives," a UPI Outside View commentary, November 11, 2002. See also Bjorn Lomborg, *The Skeptical Environmentalist: Measuring the real state of the world*, Cambridge, UK: Cambridge University Press (2001), pages 233-235, 237, 243-244.
11. See Thomas R. DeGregori, *Bountiful Harvest: Technology, food safety and the environment*, Washington, DC: Cato Institute, 2002, page 132.
12. Fifi Kobusingye, personal conversation with Paul Driessen, May 6, 2003.
13. David Nabarro, director, Roll Back Malaria; quoted in "Malaria Meeting: Africans Discuss a Disease Biting Into Lives and Economies," ABCNews.com, April 2000.
14. Richard Tren, personal communication, December 17, 2002; Roger Bate, "Without DDT, malaria bites back," www.spiked-online.com, April 24, 2001.
15. Richard Tren and Roger Bate, *When Politics Kills: Malaria and the DDT story*, Sandton, South Africa: Africa Fighting Malaria (2000), page 24. All other countries combined contributed only $2.8 million, via the World Health Organization, they note.
16. Personal email to Paul Driessen, April 7, 2003.
17. Richard Tren and Roger Bate, *Malaria and the DDT Story*, London: Institute of Economic Affairs, 2001, page 58.
18. Richard Tren, president, Africa Fighting Malaria, personal communication, December 17, 2002.
19. DeGregori, page 147, citing Matt Crenson, "Thousands of Children Jeopardized by Pesticide Use," Associated Press, Nando.net online, December 18, 1997. Amazingly, the 1996 Food Quality Protection Act specifically forbids the USEPA from considering occupational exposures to pesticides on the part of the children and adults who grow and pick the produce Americans eat.
20. David Kaiza, "Uganda to use DDT despite ban," *The East African*, Nairobi, Kenya, December 2, 2002; Tom Carter, "Kenyan research center favors DDT use: Malaria toll trumps ecological threat," *Washington Times*, May 9, 2003.
21. *New York Times* editorial, December 23, 2002.
22. James Shikwati, "How Europe is killing Africans," *The Day* (New London, CT), February 3, 2003.
23. Niger Innis, "Jesse and Al: Missing in action," Congress of Racial Equality commentary, July 2003.

Costanza et al. 1997

The value of the world's ecosystem services and natural capital

Robert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farber‖, Monica Grasso†, Bruce Hannon¶, Karin Limburg#☆, Shahid Naeem, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Sutton‖‖ & Marjan van den Belt¶¶**

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‡ Economics Department (emeritus), University of Wyoming, Laramie, Wyoming 82070, USA
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‖ Graduate School of Public and International Affairs, University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA
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 # Institute of Ecosystem Studies, Millbrook, New York, USA
*** Department of Ecology, Evolution and Behavior, University of Minnesota, St Paul, Minnesota 55108, USA*
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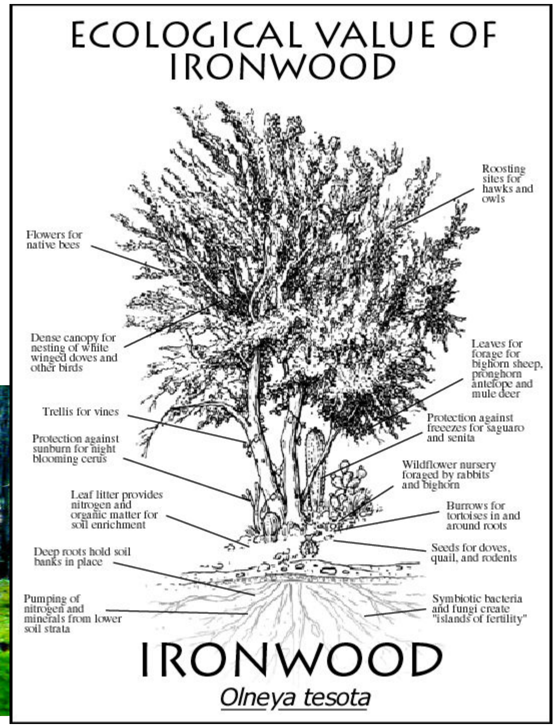
‡‡ Department of Ecology, Faculty of Agronomy, University of Buenos Aires, Av. San Martin 4453, 1417 Buenos Aires, Argentina
§§ Jet Propulsion Laboratory, Pasadena, California 91109, USA
‖‖ National Center for Geographic Information and Analysis, Department of Geography, University of California at Santa Barbara, Santa Barbara, California 93106, USA
¶¶ Ecological Economics Research and Applications Inc., PO Box 1589, Solomons, Maryland 20688, USA

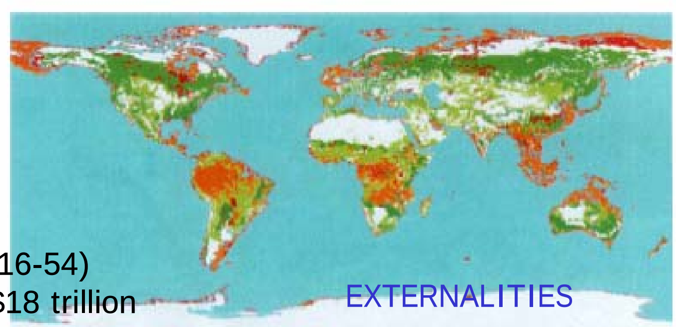
The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Lesser long-nosed bat (*Leptonycteris curasoae*) pollinating saguaro flower (*Carnegia gigantea*)



Costanza et al. 1997

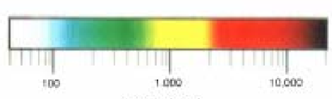
Figure 2 Global map of the value of ecosystem services. See Supplementary Information and Table 2 for details.



$33 trillion/yr (16-54)
Global GNP = $18 trillion

EXTERNALITIES

[excluded non-renewable]



Gas regulation $1.3 trillion
Disturbance reg. $1.8 trillion
Waste treatment $2.3 trillion
Nutrient cycling $17 trillion

Marine Services $20.9 trillion
(coastal $10.6 trillion)
Forests $4.7 trillion
Wetlands $4.9 trillion

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Costanza et al.
1997
Table 1

Table 1 Ecosystem services and functions used in this study

Number	Ecosystem service*	Ecosystem functions	Examples
1	Gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.
3	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	Water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.
5	Water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.
6	Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.
7	Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.
13	Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.
14	Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.
15	Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	Cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

* We include ecosystem 'goods' along with ecosystem services.

Table 2 Summary of average global value of annual ecosystem services

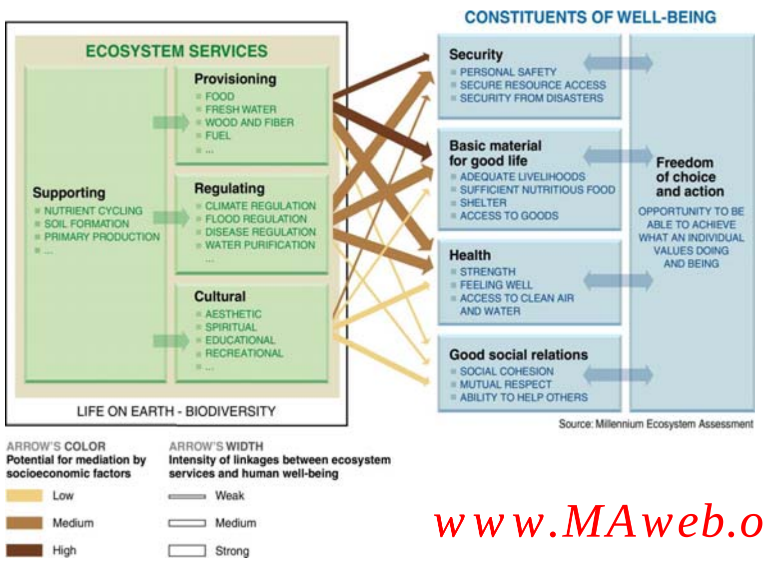
Biome	Area (ha × 10^6)	1 Gas regulation	2 Climate regulation	3 Disturbance regulation	4 Water regulation	5 Water supply	6 Erosion control	7 Soil formation	8 Nutrient cycling	9 Waste treatment	10 Pollination	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials	15 Genetic resources	16 Recreation	17 Cultural	Total value per ha ($ha^{-1} yr^{-1}$)	Total global flow value ($yr^{-1} × 10^9)
									Ecosystem services (1994 US$ $ha^{-1} yr^{-1}$)											
Marine	36,302																		577	20,949
Open ocean	33,200	38							118			5		15	0			76	252	8,381
Coastal	3,102			88					3,677			38	8	93	4		82	62	4,052	12,568
Estuaries	180			567					21,100			78	131	521	25		381	29	22,832	4,110
Seagrass/ algae beds	200								19,002						2				19,004	3,801
Coral reefs	62			2,750						58		5	7	220	27		3,008	1	6,075	375
Shelf	2,660								1,431			39		68	2			70	1,610	4,283
Terrestrial	15,323																		804	12,319
Forest	4,855		141	2	2	3	96	10	361	87		2		43	138	16	66	2	969	4,706
Tropical	1,900		223	5	6	8	245	10	922	87				32	315	41	112	2	2,007	3,813
Temperate/boreal	2,955		88		0			10		87		4		50	25		36	2	302	894
Grass/rangelands	3,898	7	0		3		29	1		87	25	23		67		0	2		232	906
Wetlands	330	133		4,539	15	3,800				4,177			304	256	106		574	881	14,785	4,879
Tidal marsh/ mangroves	165			1,839						6,696			169	466	162		658		9,990	1,648
Swamps/ floodplains	165	265		7,240	30	7,600				1,659			439	47	49		491	1,761	19,580	3,231
Lakes/rivers	200				5,445	2,117				665				41			230		8,498	1,700
Desert	1,925																			
Tundra	743																			
Ice/rock	1,640																			
Cropland	1,400										14	24		54					92	128
Urban	332																			
Total	51,625	1,341	684	1,779	1,115	1,692	576	53	17,075	2,277	117	417	124	1,386	721	79	815	3,015		33,268

Numbers in the body of the table are in $ $ha^{-1} yr^{-1}$. Row and column totals are in $ $yr^{-1} × 10^9$, column totals are the sum of the products of the per ha services in the table and the area of each biome, not the sum of the per ha services themselves. Shaded cells indicate services that do not occur or are known to be negligible. Open cells indicate lack of available information.

Costanza et al. 1997 Table 2

Millenium Ecosystem Assessment

Focus: Consequences of Ecosystem Change for Human Well-being



www.MAweb.org

2) Should 'intrinsic' or 'instrumental' values be the basis for planning conservation efforts? Why? (due 07 Sep)

20

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

THEODOSIUS DOBZHANSKY

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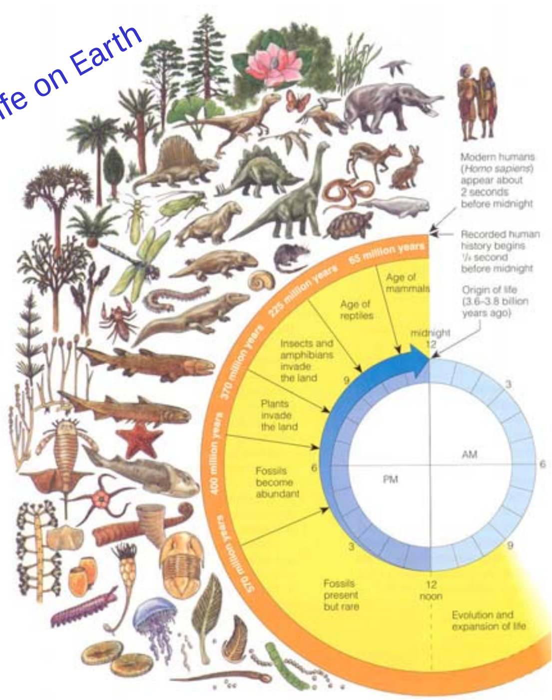
Evolution of Life on Earth



Miller 2003

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

22

Major Extinction Events

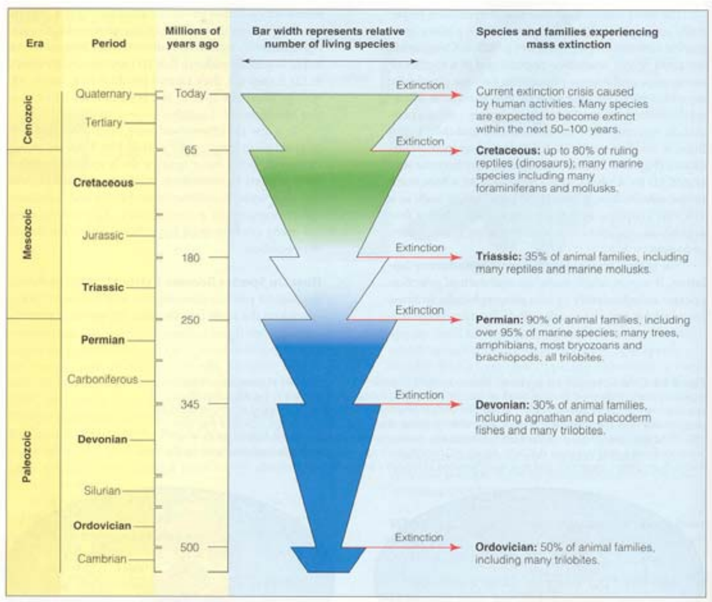


Figure 5-9 Fossils and radioactive dating indicate that five major *mass extinctions* (indicated by arrows) have taken place over the past 500 million years. Mass extinctions leave large numbers of organism roles (niches) unoccupied and create new ones. As a result, each mass extinction has been followed 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

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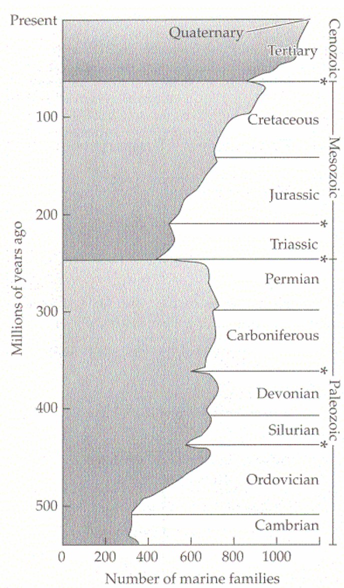


Figure 2.5 Diversity of marine families from the Cambrian to the present. The asterisks mark the five major mass extinction events.

Groom et al. 2006

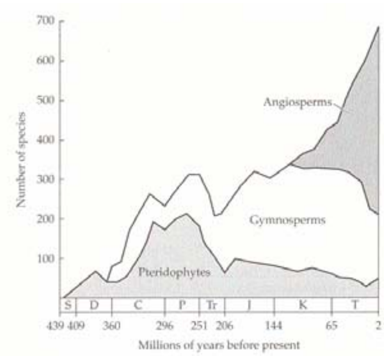


Figure 2.6 Terrestrial plant species richness. Ferns, gymnosperms, and angiosperms have, in turn, dominated the world's flora. (Modified from Signor 1990.)

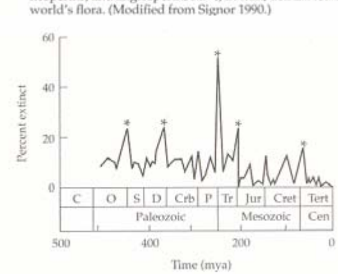
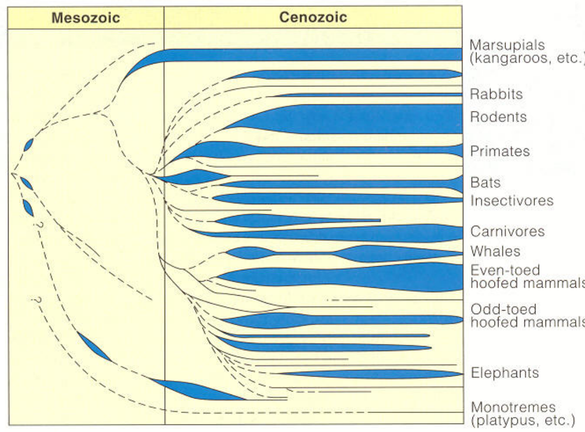


Figure 2.7 Extinctions of families through geologic time. The five hisrtorical mass extinction events are marked with an asterisk.

Adaptive Radiation

Figure 5-10 Adaptive radiation of mammals began in the first 10–12 million years of the Cenozoic era (which began about 65 million years ago) and continues today. This evolution of a large number of new species is thought to have resulted when huge numbers of new and vacated ecological niches became available after the mass extinction of dinosaurs near the end of the Mesozoic era. (Used by permission from Cecie Starr and Ralph Taggart, *Biology: The Unity and Diversity of Life*, 8th ed., Belmont, Calif.: Wadsworth, 1998)

Miller 2003



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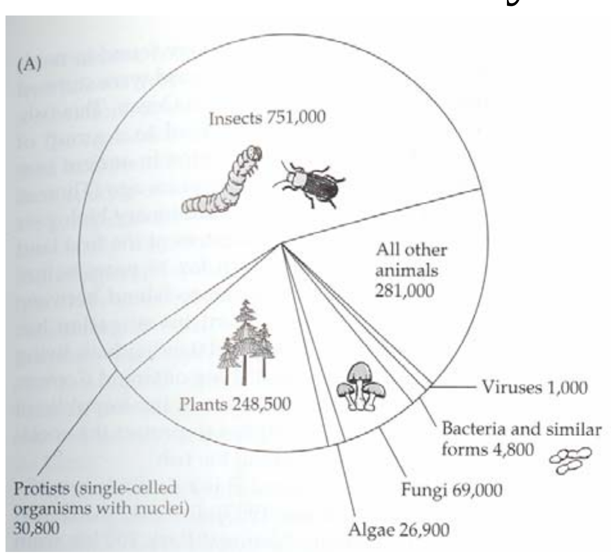
What is biodiversity?



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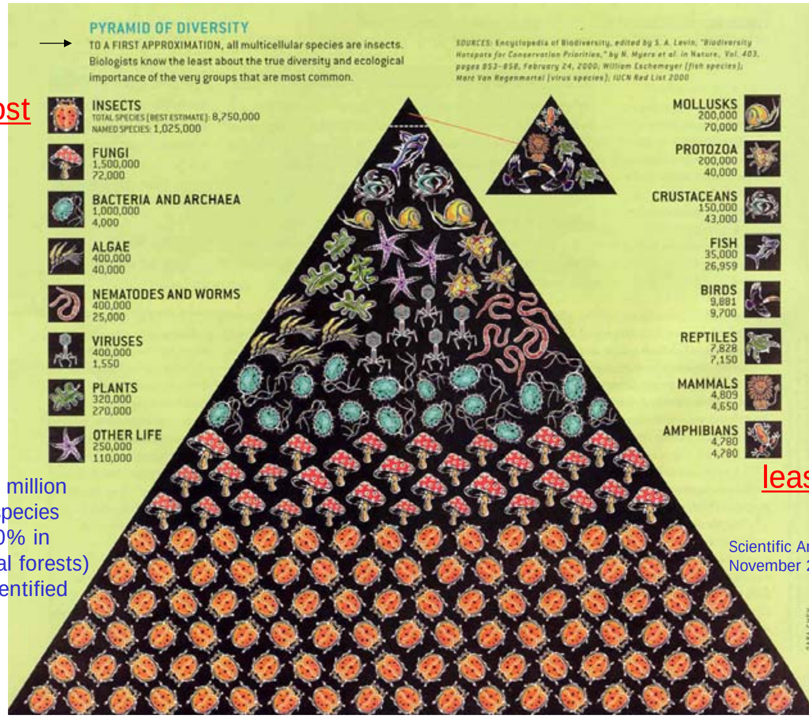
Primack 2006, Fig 3.6

most

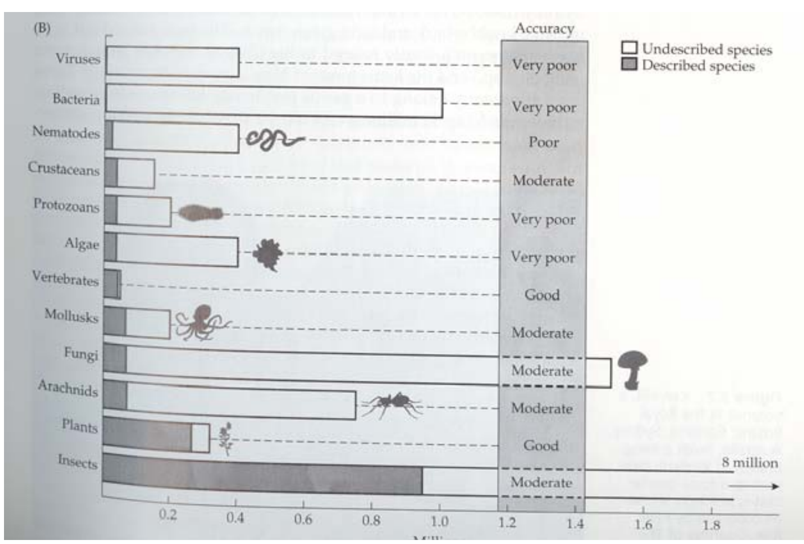


least

~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?

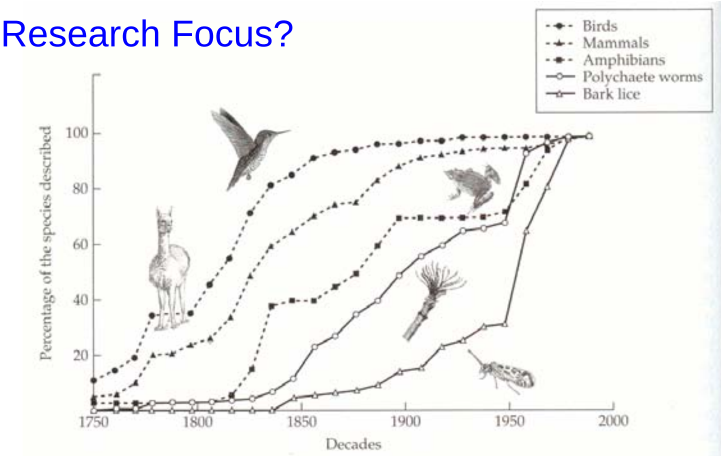


FIGURE 3.10 For five groups of Chilean animals, the cumulative percentage of the known species described from 1750 to 2000. Note that the majority of birds and mammals were largely described by 1900, and probably few new species remain to be discovered. In contrast, polychaete worms and bark lice were 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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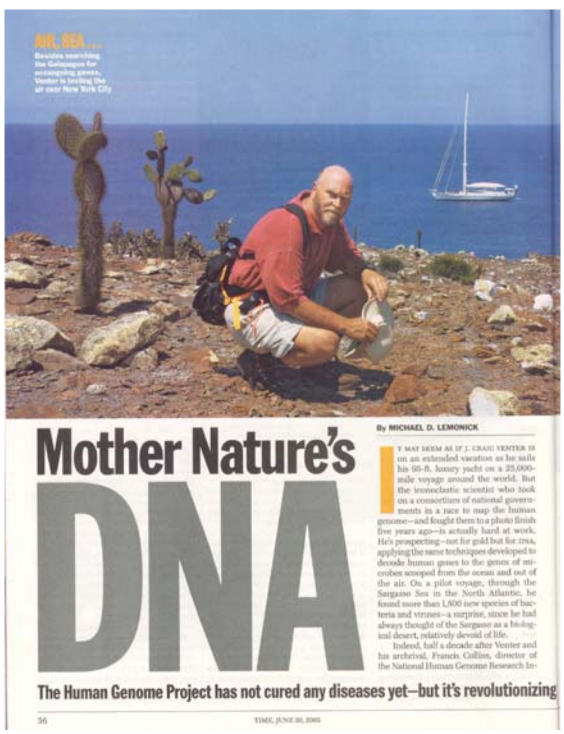

AIR, SEA . . .

Besides searching the Galapagos for oceangoing genes, Venter is testing the air over New York City

Mother Nature's DNA

By MICHAEL D. LEMONICK

IT MAY SEEM AS IF J. CRAIG VENTER IS on an extended vacation as he sails his 95-ft. luxury yacht on a 25,000-mile voyage around the world. But the iconoclastic scientist who took on a consortium of national governments in a race to map the human genome—and fought them to a photo finish five years ago—is actually hard at work. He's prospecting—not for gold but for DNA, applying the same techniques developed to decode human genes to the genes of microbes scooped from the ocean and out of the air. On a pilot voyage, through the Sargasso Sea in the North Atlantic, he found more than 1,800 new species of bacteria and viruses—a surprise, since he had always thought of the Sargasso as a biological desert, relatively devoid of life.

Indeed, half a decade after Venter and his archrival, Francis Collins, director of the National Human Genome Research In-

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

30

See 2-13 Miller 2003

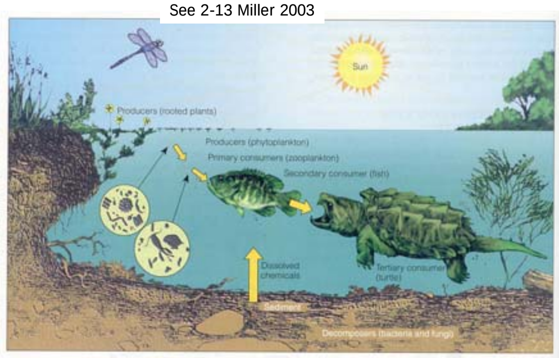

Figure 4-10 Major components of a freshwater ecosystem.

Biodiversity

1. Genetic
   (nat. sel.)

2. Species

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

4. Functional
   energy flow
   nutrient cycling
   etc.

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Levels of Biological Organization.

Scaling.

Miller, 2003

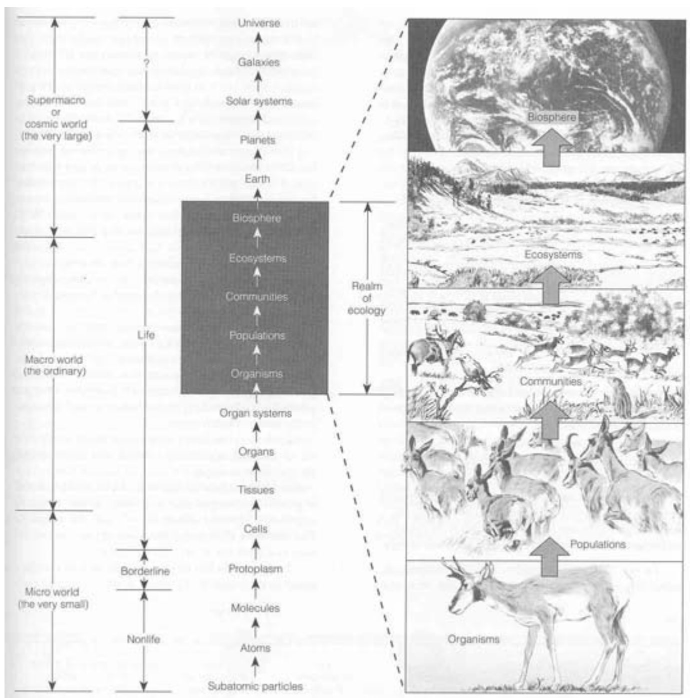

Figure 2-2 Levels of organization of matter in nature. Notice the five levels that ecology focuses on.

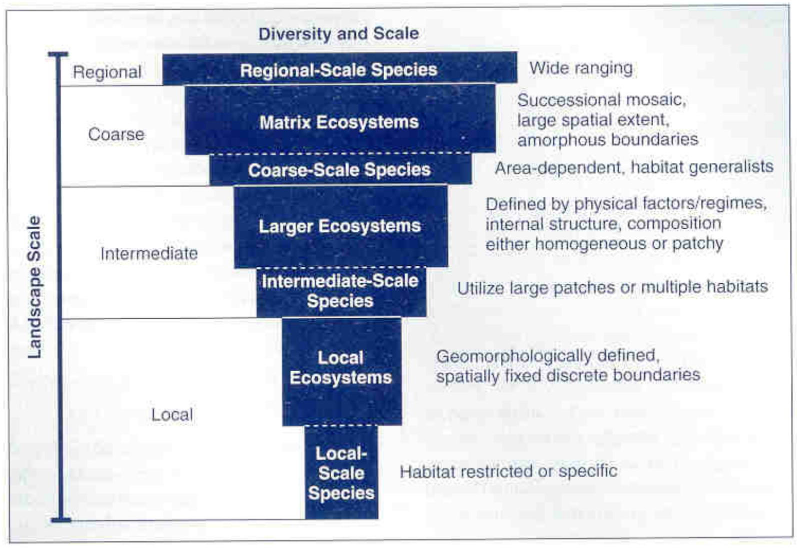

Figure 4.15 Van Dyke 2003

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.

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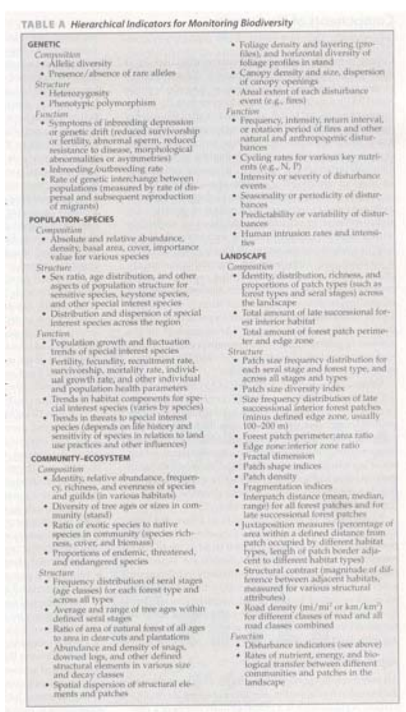

TABLE A ***Hierarchical Indicators for Monitoring Biodiversity***

GENETIC

Composition
- Allelic diversity
- Presence/absence of rare alleles

Structure
- Heterozygosity
- Phenotypic polymorphism

Function
- Symptoms of inbreeding depression or genetic drift (reduced survivorship or fertility, abnormal sperm, reduced resistance to disease, morphological abnormalities or asymmetries)
- Inbreeding/outbreeding rate
- Rate of genetic interchange between populations (measured by rate of dispersal and subsequent reproduction of migrants)

POPULATION–SPECIES

Composition
- Absolute and relative abundance, density, basal area, cover, importance value for various species

Structure
- Sex ratio, age distribution, and other aspects of population structure for sensitive species, keystone species, and other special interest species
- Distribution and dispersion of special interest species across the region

Function
- Population growth and fluctuation trends of special interest species
- Fertility, fecundity, recruitment rate, survivorship, mortality rate, individual growth rate, and other individual and population health parameters
- Trends in habitat components for special interest species (varies by species)
- Trends in threats to special interest species (depends on life history and sensitivity of species in relation to land use practices and other influences)

COMMUNITY–ECOSYSTEM

Composition
- Identity, relative abundance, frequency, richness, and evenness of species and guilds (in various habitats)
- Diversity of tree ages or sizes in community (stand)
- Ratio of exotic species to native species in community (species richness, cover, and biomass)
- Proportions of endemic, threatened, and endangered species

Structure
- Frequency distribution of seral stages (age classes) for each forest type and across all types
- Average and range of tree ages within defined seral stages
- Ratio of area of natural forest of all ages to area in clear-cuts and plantations
- Abundance and density of snags, downed logs, and other defined structural elements in various size and decay classes
- Spatial dispersion of structural elements and patches
- Foliage density and layering (profiles), and horizontal diversity of foliage profiles in stand
- Canopy density and size, dispersion of canopy openings
- Areal extent of each disturbance event (e.g., fires)

Function
- Frequency, intensity, return interval, or rotation period of fires and other natural and anthropogenic disturbances
- Cycling rates for various key nutrients (e.g., N, P)
- Intensity or severity of disturbance events
- Seasonality or periodicity of disturbances
- Predictability or variability of disturbances
- Human intrusion rates and intensities

LANDSCAPE

Composition
- Identity, distribution, richness, and proportions of patch types (such as forest types and seral stages) across the landscape
- Total amount of late successional forest interior habitat
- Total amount of forest patch perimeter and edge zone

Structure
- Patch size frequency distribution for each seral stage and forest type, and across all stages and types
- Patch size diversity index
- Size frequency distribution of late successional interior forest patches (minus defined edge zone, usually 100–200 m)
- Forest patch perimeter:area ratio
- Edge zone:interior zone ratio
- Fractal dimension
- Patch shape indices
- Patch density
- Fragmentation indices
- Interpatch distance (mean, median, range) for all forest patches and for late successional forest patches
- Juxtaposition measures (percentage of area within a defined distance from patch occupied by different habitat types, length of patch border adjacent to different habitat types)
- Structural contrast (magnitude of difference between adjacent habitats, measured for various structural attributes)
- Road density (mi/mi^2 or km/km^2) for different classes of road and all road classes combined

Function
- Disturbance indicators (see above)
- Rates of nutrient, energy, and biological transfer between different communities and patches in the landscape

Groom et al. 2006

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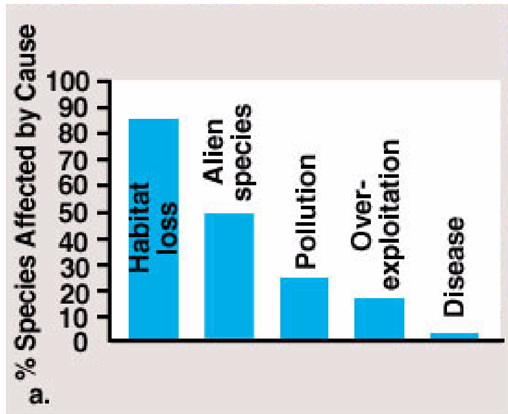
Threats to biodiversity – habitat loss



Thanks to Chuck Price

35

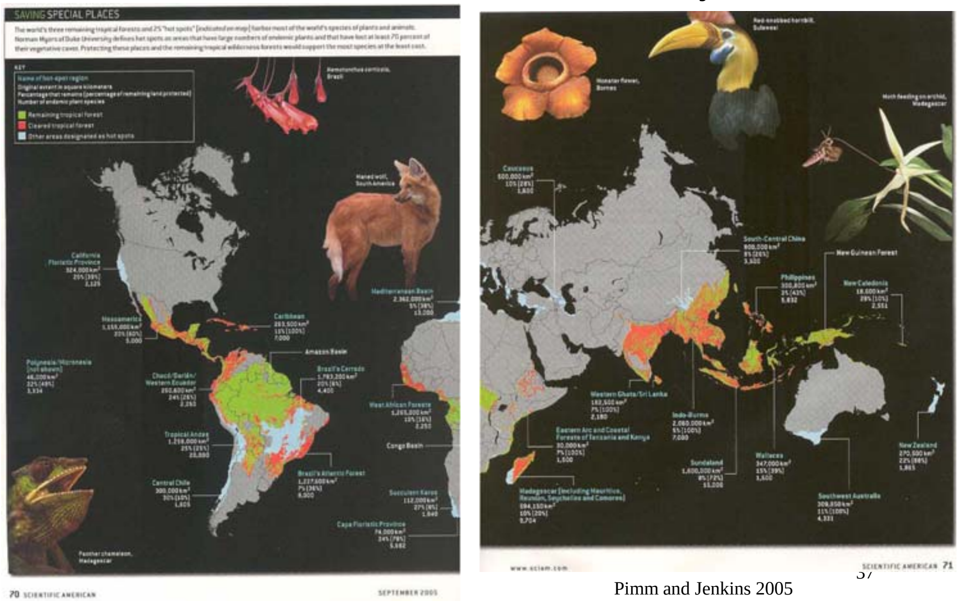
Biodiversity (Biological Diversity)

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

36

Where is biodiversity?

One tree in Peru with same ant diversity as Britain



Pimm and Jenkins 2005

37

Species Richness and Latitude

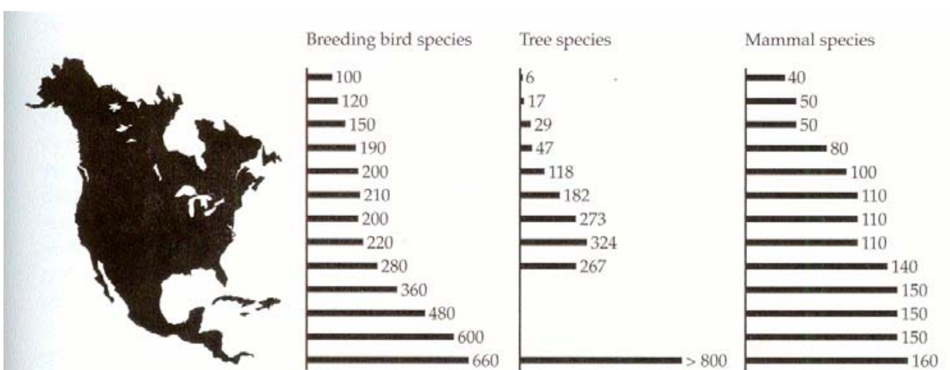


FIGURE 3.5 In North America, as in all the continents, the numbers of bird, tree, and mammal species increase toward the Tropics. The numbers of species indicated in the bar graphs correspond to latitude in the map at left. Tree species diversity is not available for some lower latitudes. (From Briggs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

Altitude?

Primack 2006

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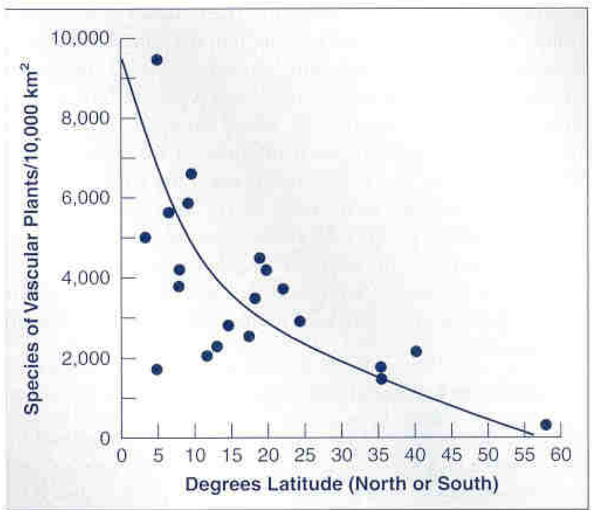


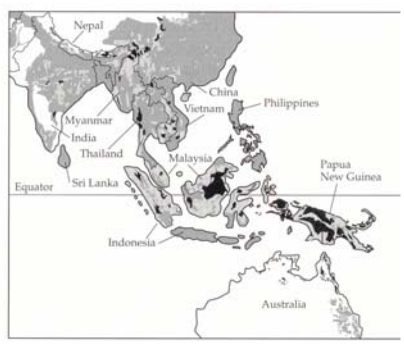
Figure 4.12
Latitudinal patterns in species richness from tropical to temperate regions. In most taxa the number of species increases from temperate to tropical regions.

Van Dyke 2003

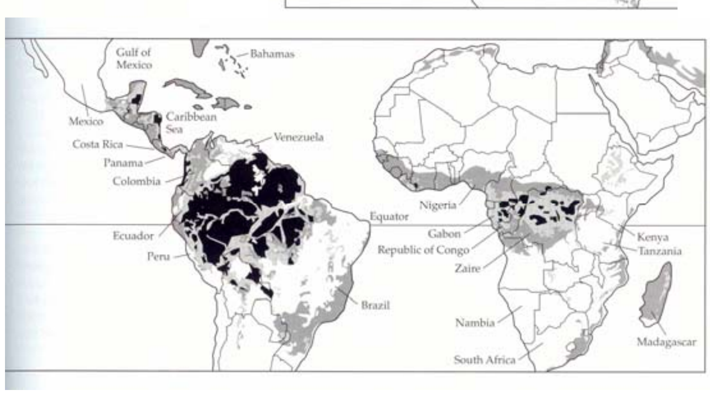
39

After Reid and Miller (1989). Reprinted from Huston (1994).

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

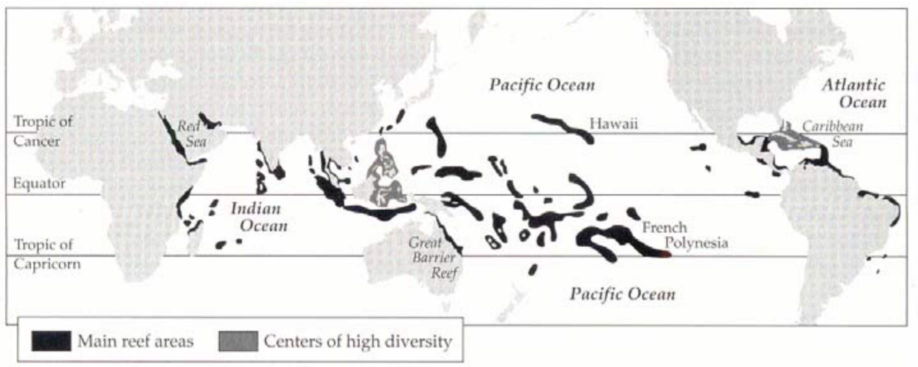


FIGURE 3.4 Global distribution of the coral reef biome. (After Wells and Hanna 1992.)

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Primack 2006

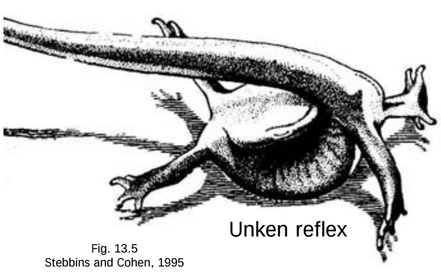
Lissamphibia

Ambystoma tigrinum

Urodela
(salamanders)

10 families, 60 genera, 516 spp.

Ambystoma californiense



Unken reflex

Fig. 13.5
Stebbins and Cohen, 1995

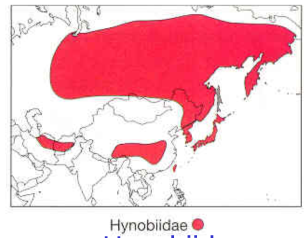
Urodela families

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

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

Pough et al. 2004

Sirenidae



Hynobiidae

Salamandridae

Urodela families

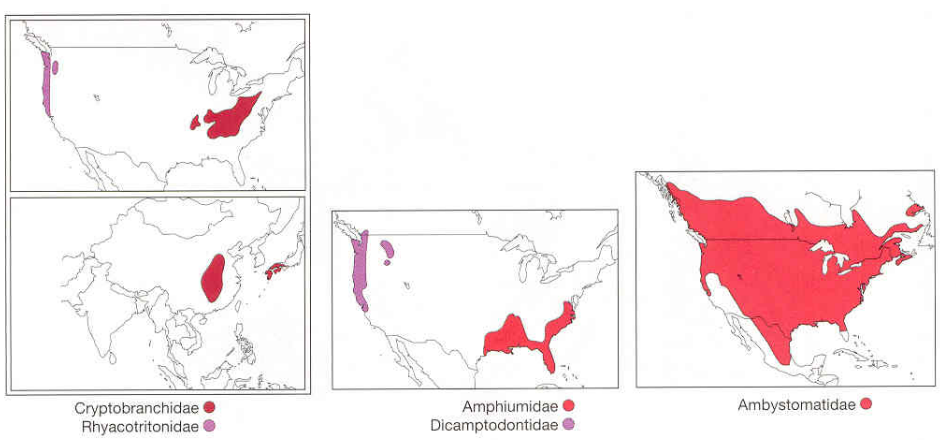


Figure 3–4 **Distribution of salamander families Cryptobranchidae, Rhyacotritonidae, Amphiumidae, Dicamptodontidae, and Ambystomatidae.**

Pough et al. 2004

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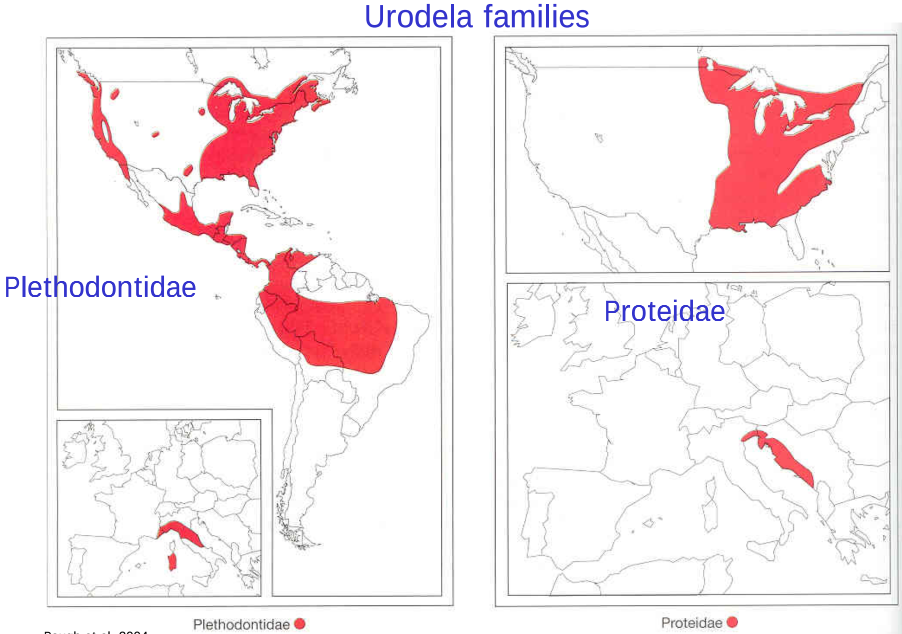
Urodela families



Pough et al. 2004

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