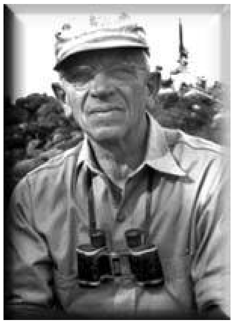
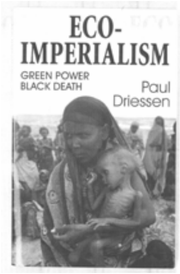
Lecture 05, 04 Sept 2007
Leopold, Biodiversity

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

Kevin Bonine
Cathy Hulshof





Upcoming Readings
today: Leopold readings, Text Ch. 4, Costanza et al. 1997, Driessen 2004
Thurs 06 Sept: Walther et al. 2002, Peak Oil Link, (optional: National Geographic)
Tues 11 Sept: Text Ch. 4, and pp. 207-213

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## Conservation Biology Lab 406L/506L

Next Lab Friday 07 September
1230 S or W side BSE
(4th and Highland)
Hat, water, sunscreen, close-toed shoes
Readings on Course Website

07 September - Sabino Canyon
VAN
Flooding, Wilderness, Forest Management, Nuisance Wildlife

Especially relevant for 506 students:

## Conservation Seminar

If you are interested in participating in the Conservation Seminar (RNR696a – but you don't need to enroll) please attend Wednesday at 3:30 in BSE 218.

Chris McDonald
cmcdon@email.arizona.edu
(contact for readings)

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**Public Water Lecture with Peter Gleick**

Fresh water availability is a growing issue of concern across the world, butno where more than in arid lands. Tucson is no exception.

Will projections of our water supply in the distant future - even in the next decade or two - be accurate? How will prolonged drought affect both water quantity and quality? What impacts will water supply have on the region's economic viability?

Sustainable Tucson is co-host of a public lecture by international water expert, Peter Gleick, along with the Water Resources Research Center (WRRC) and Institute for the Study of Planet Earth (ISPE) at the University of Arizona, and the Southern Arizona Leadership Council (SALC).

A **MacArthur Fellow** and widely published in leading scientific journals, Dr. Peter Gleick is one of the world's top experts on the impacts of climate change on water supply. His work with communities and governments across the Southwest and the world brings a broad perspective to the local discussion.

How can we define **sustainable water policies**, based on sound laws and science? To what extent will water transfers and markets - the economics of shifting water - help us reconcile growth and supplies which are limited, keeping in mind that global warming, as well as land-use changes, will likely affect both surface and groundwater systems?

Sustainable Tucson believes Dr. Gleick's vision can help inform local planning by bringing the experience of many communities to bear on Tucson's creative solutions to long-term water security.

Dr. Gleick will address water experts and other leaders at the Arizona Hydrologic Society's regional conference, "Sustainable Water, Unlimited Growth, and Quality of Life: Can We Have It All?" to be held August 27 – 30 in Tucson.

The joint planning of this public lecture amongst university departments, civic, business, and community groups, points to exciting new dialogue over water and sustainability taking place in our community.

The lecture will take place in **Tucson on August 30, at 7:30 p.m. at Temple Emanu-El - 225 N. Country Club Rd.**

**Contact Madeline Kiser ( mkiser@dakotacom.net)**
**or Susan Williams (susanleewilliams@cox.net) for more information.**

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.

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

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

AZDStar 03 Sept 2007

'And God created humankind in God's image ... having dominion* over the earth.'

Genesis 1

# Faith goes green

By Stephanie Innes
ARIZONA DAILY STAR

With a belief that they must speak out for the silent, some people of faith in Tucson are giving a voice to Mother Nature.

Fueled by heightened media attention to global warming, worshippers and congregations are turning their attentions to the environment. They view protecting the Earth as a justice issue, infusing it with a passion that many historically devoted to ending racial, gender and economic inequality.

Nationally, the Sierra Club

See CHURCHES, A4

On StarNet: Read StarNet's "Desert Beliefs" blog for more coverage of faith and values at go.azstarnet.com/desertbeliefs.

* Some theologians and religious leaders say the word 'dominion' should not be understood as a license to dominate and exploit nature, but rather as a vocation of stewardship of the Earth.

AZDStar 03 Sept 2007

# Student gov't goals: ecology, book costs

## UA leader hopes ASUA will be seen as more relevant

**By Eric Swedlund**
ARIZONA DAILY STAR

Finding ways to make the campus more environmentally sustainable and continuing work to reduce the cost of textbooks highlight this year's student government agenda at the University of Arizona.

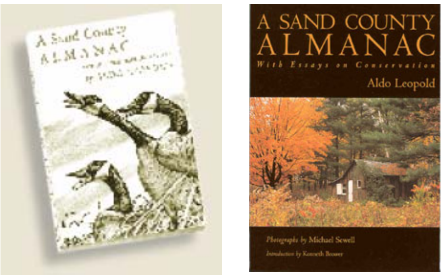
Building on past student government work on solar energy, one major goal is to establish a university committee on sustainability to review what can be done in the areas of improved recycling, "green" roofs, solar energy and water runoff, said

**Tommy Bruce,**
UA student body president

"Objectivity is only possible in matters too small to be important, or in matters too large to do anything about." (p. 226)

-Leopold

1887-1948



http://www.aldoleopold.org/Biography/Biography.htm

Aldo Leopold Foundation

Aldo Leopold:

Thinking Like a Mountain
Escudilla

The Land Ethic

The Outlook for Farm Wildlife
The Land-Health Concept and Conservation

## Aldo Leopold

"An ethic, ecologically, is a limitation on freedom of action in the struggle for existence.

An ethic, philosophically, is a differentiation of social from anti-social conduct."

(p. 238)

## Aldo Leopold Land Ethic

-social evolution (social disapproval for wrong actions)
-land ethic enlarges the community
to include biota

-human as plain member and citizen,
not ruler

-Conquerer self defeating because falsely thinks
s/he understands how the system works
and can control it

## Leopold Land Ethic

- -Property vs. propriety

- -Role of land [biology] in human history
  (Diamond, <u>Guns Germs and Steel</u>)

- -Sacrifice
- -Obligation of private landowner
- -Livestock, Violence

- -Economics?
  Farm as Factory or Place to Live?

## Aldo Leopold Land Ethic

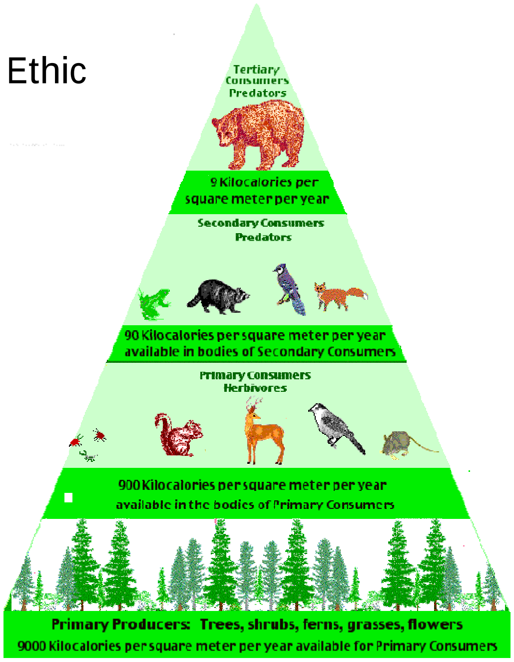
-What is “land-health?”

- -processes
- -evolutionary/ecological biology

- -complexity & quality
- -invasives

## Aldo Leopold Land Ethic

-land pyramid



“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

Leopold

*Thinking like a mountain*
“ a mountain lives in mortal fear of its deer”

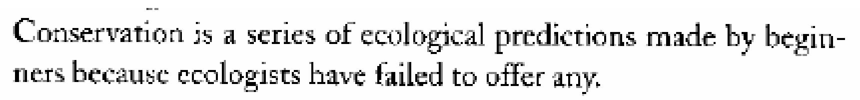
*Escudilla*
progress?
“It’s only a mountain now.”

The planet will survive, will we?

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

-Leopold

# The Land-Health Concept and Conservation



Conservation is a series of ecological predictions made by beginners because ecologists have failed to offer any.

Leopold, p. 220

"Whether you will or not

You are a King, Tristram, for you are one

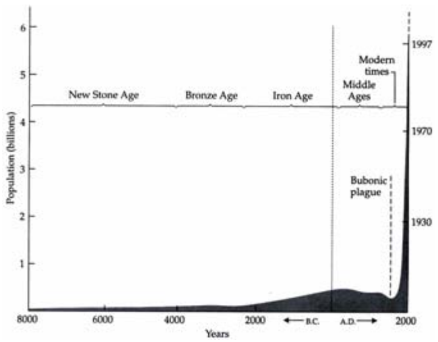
Of the time-tested few that leave the world,

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

Mark what you leave."

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

# Human Population?



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Discussion:

1. How do conservationists respond to the question, “What good is it?”

2. How do we verify that humans, or anything, has intrinsic value?

3. “Enclosed/Private” Goods, or “Common” Goods - Which of these is a better approach for conservation? Why?

4. What is the conservation role of the world’s religions?

Costanza et al. 1997

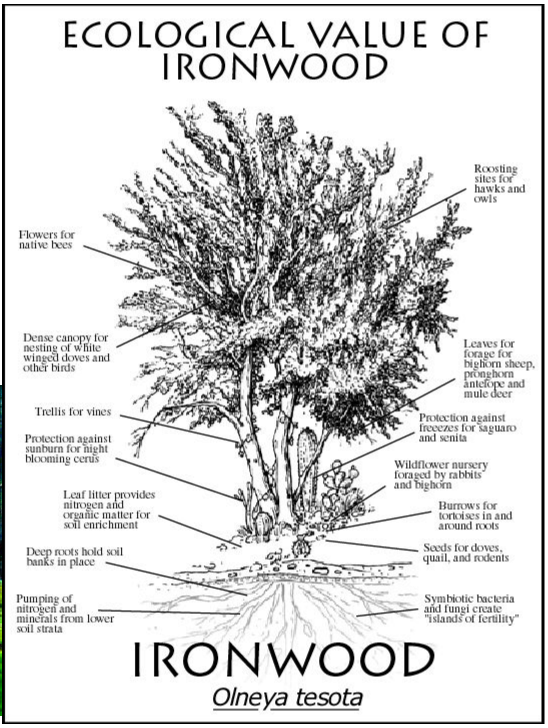
# The value of the world’s ecosystem services and natural capital

**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¶¶**

** Center for Environmental and Estuarine Studies, Zoology Department, and † Insitute for Ecological Economics, University of Maryland, Box 38, Solomons, Maryland 20688, USA*
*‡ Economics Department (emeritus), University of Wyoming, Laramie, Wyoming 82070, USA*
*§ Center for Environment and Climate Studies, Wageningen Agricultural University, PO Box 9101, 6700 HB Wageninengen, The Netherlands*
*‖ Graduate School of Public and International Affairs, University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA*
*¶ Geography Department and NCSA, University of Illinois, Urbana, Illinois 61801, USA*
*# Institute of Ecosystem Studies, Millbrook, New York, USA*
*** Department of Ecology, Evolution and Behavior, University of Minnesota, St Paul, Minnesota 55108, USA*
*†† Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
*‡‡ 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*

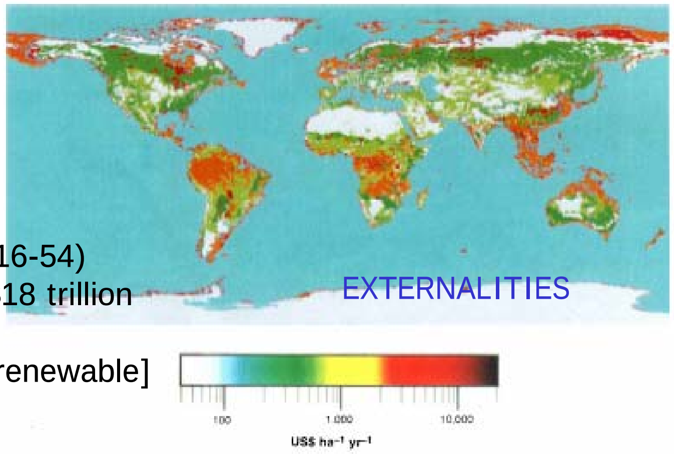
**The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth’s life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated 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 gigant*ea)



## 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

[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

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.

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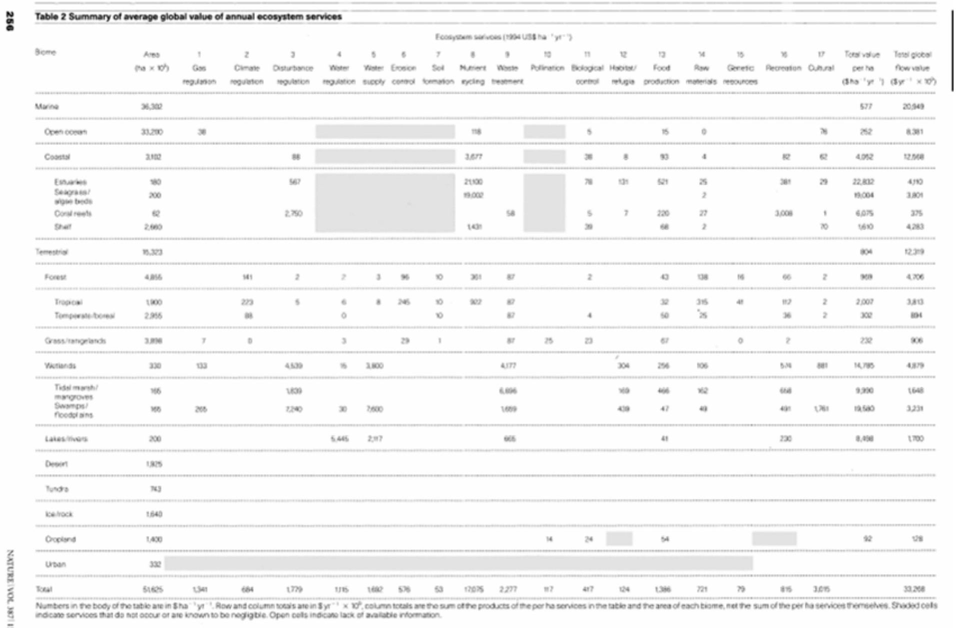

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**Table 2 Summary of average global value of annual ecosystem services**

| Biome | Area (ha × 10⁶) | 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 × 10⁹) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 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 × 10⁹, 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.

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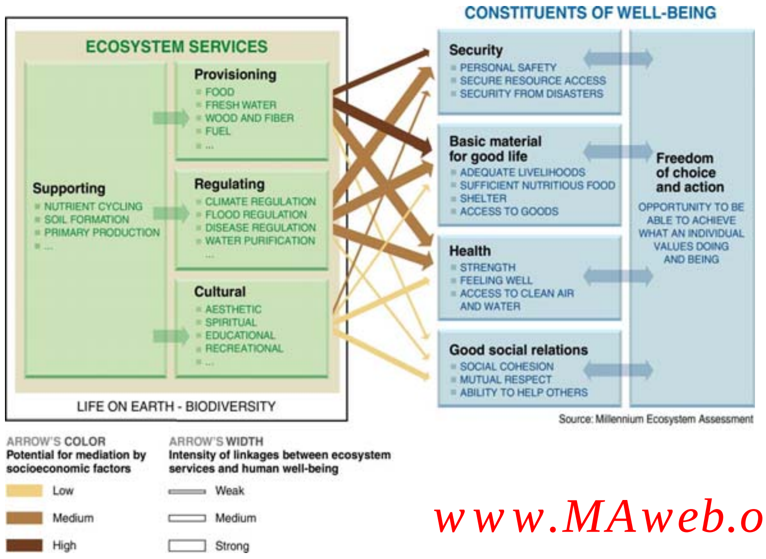
Costanza et al. 1997  Table 2

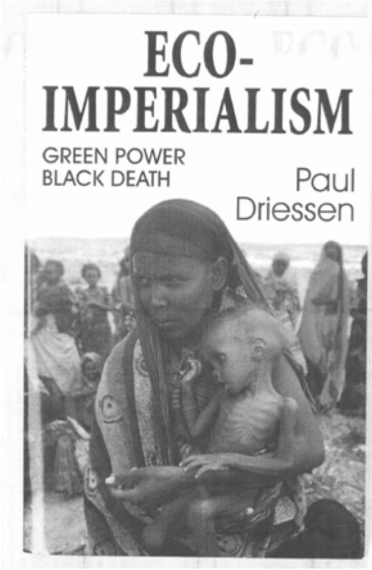
# Focus: Consequences of Ecosystem Change for Human Well-being

**Millenium Ecosystem Assessment**

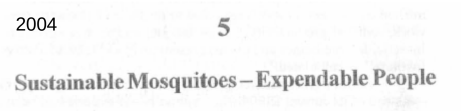


Source: Millennium Ecosystem Assessment

*www.MAweb.org*



2004



## 5

## Sustainable Mosquitoes – Expendable People

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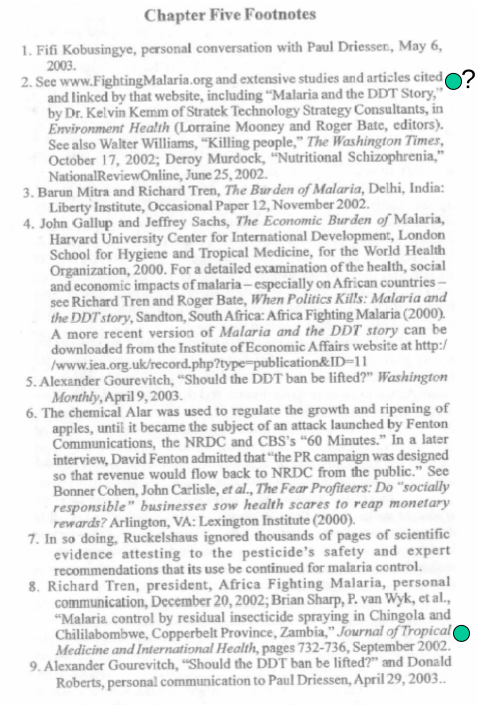
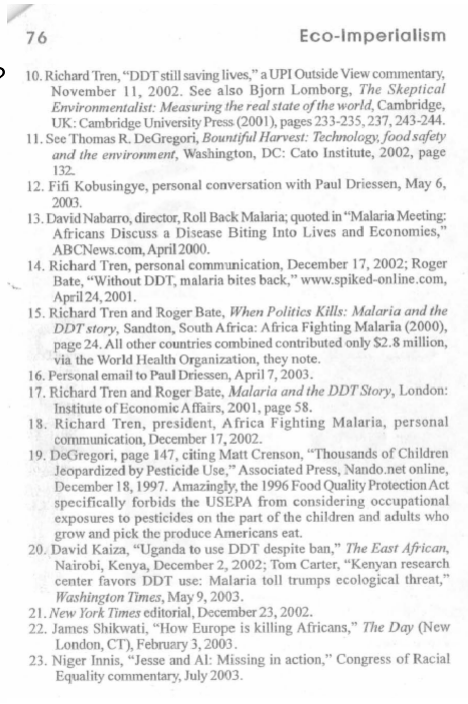


### Chapter Five Footnotes

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..



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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.

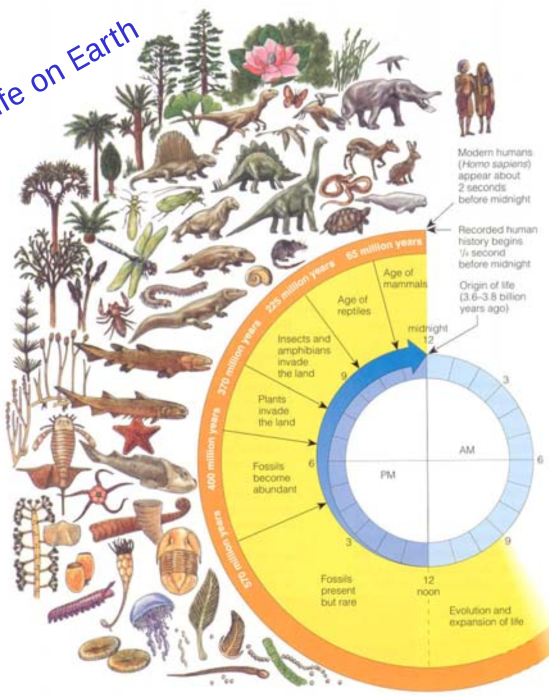
## Biodiversity (Biological Diversity)

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

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

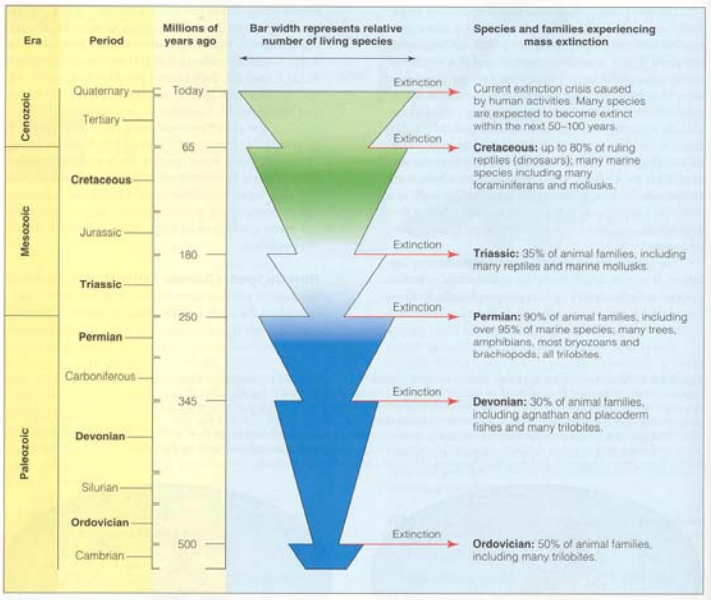
THEODOSIUS DOBZHANSKY

# 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



**Species and families experiencing mass extinction**

Current extinction crisis caused by human activities. Many species are expected to become extinct within the next 50–100 years.

**Cretaceous:** up to 80% of ruling reptiles (dinosaurs); many marine species including many foraminiferans and mollusks.

**Triassic:** 35% of animal families, including many reptiles and marine mollusks.

**Permian:** 90% of animal families, including over 95% of marine species; many trees, amphibians, most bryozoans and brachiopods, all trilobites.

**Devonian:** 30% of animal families, including agnathan and placoderm fishes and many trilobites.

**Ordovician:** 50% of animal families, including many trilobites.

**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

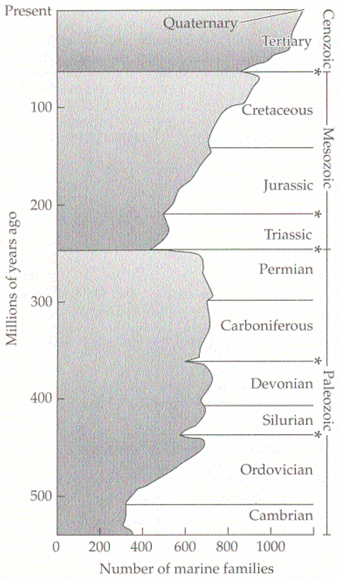


**Figure 2.5** Diversity of marine families from the Cambrian to the present. The asterisks mark the five major mass extinction events.

Groom et al. 2006

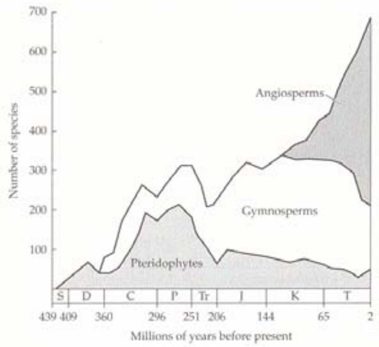


**Figure 2.6** Terrestrial plant species richness. Ferns, gymnosperms, and angiosperms have, in turn, dominated the world's flora. (Modified from Signor 1990.)

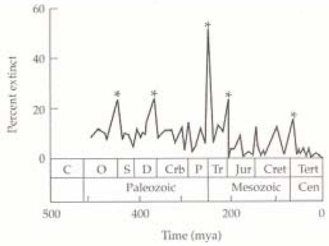
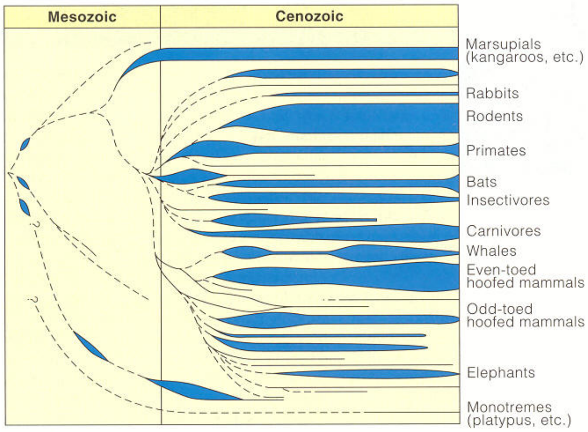


**Figure 2.7** Extinctions of families through geologic time. The five hisrtorical mass extinction events are marked with an asterisk.

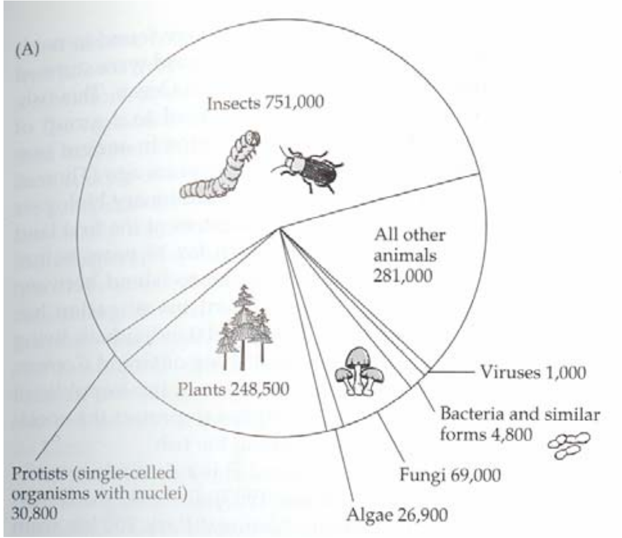
## Adaptive Radiation

**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)

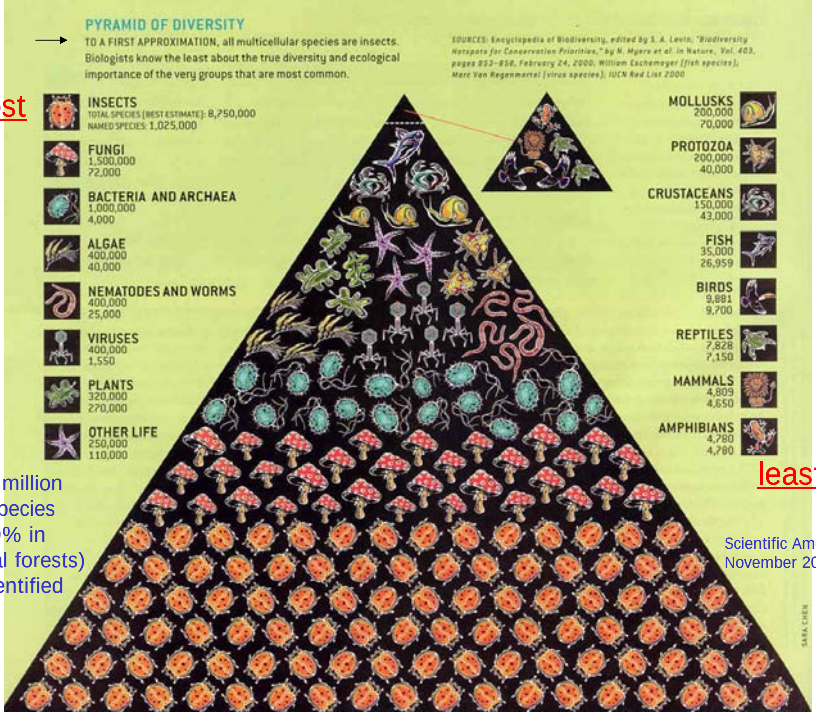
Miller 2003



# What is biodiversity?



Primack 2006, Fig 3.6



**PYRAMID OF DIVERSITY**

→ TO A FIRST APPROXIMATION, all multicellular species are insects. Biologists know the least about the true diversity and ecological importance of the very groups that are most common.

*SOURCES: Encyclopedia of Biodiversity, edited by S. A. Levin; "Biodiversity Hotspots for Conservation Priorities," by N. Myers et al. in Nature, Vol. 403, pages 853–858, February 24, 2000; William Eschemeyer (fish species); Marc Van Regenmortel (virus species); IUCN Red List 2000*

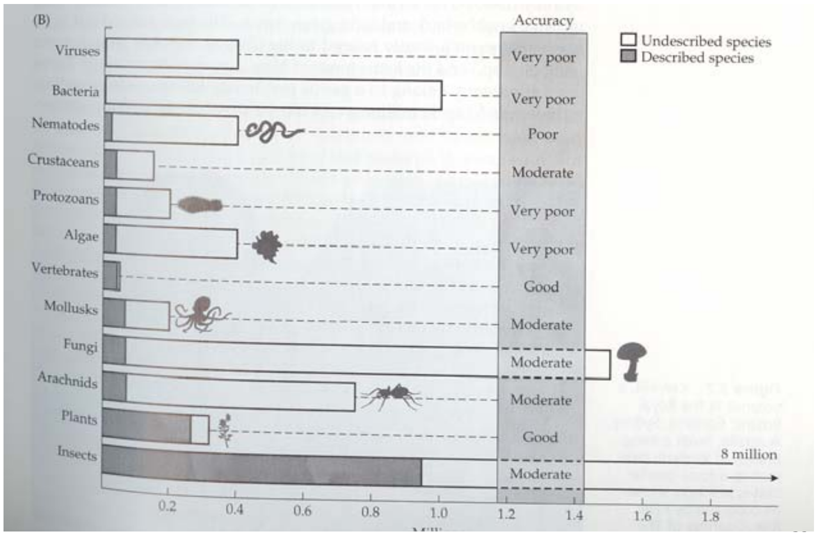
most

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?

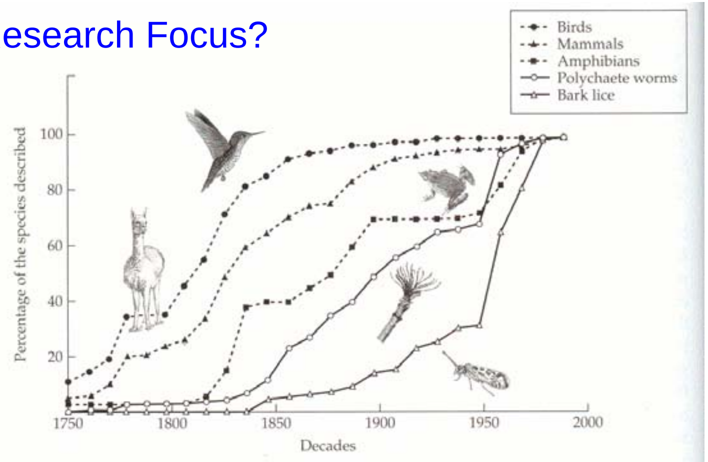
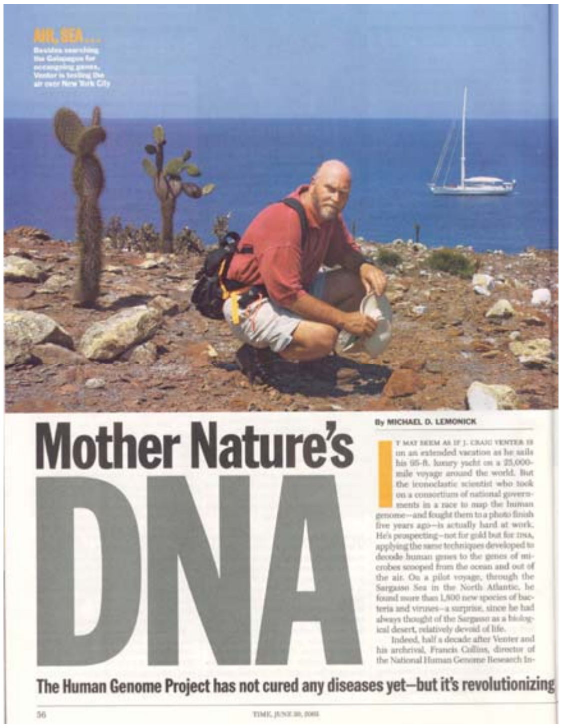


**FIGURE 3.10** For five groups of Chilean animals, the cumulative percentage of the known species described from 1750 to 2000. Note that the majority of birds and mammals were largely described by 1900, and probably few new species remain to be discovered. In contrast, polychaete worms and bark lice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



AIR, SEA...
Besides searching the Galápagos 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

36 TIME, JUNE 30, 2003

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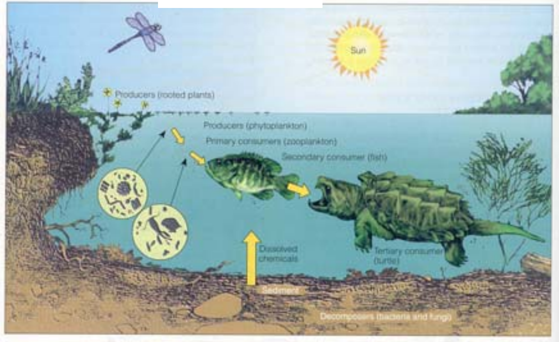


See 2-13 Miller 2003

**Figure 4-10** Major components of a freshwater ecosystem

## Biodiversity

1. Genetic
   (nat. sel.)

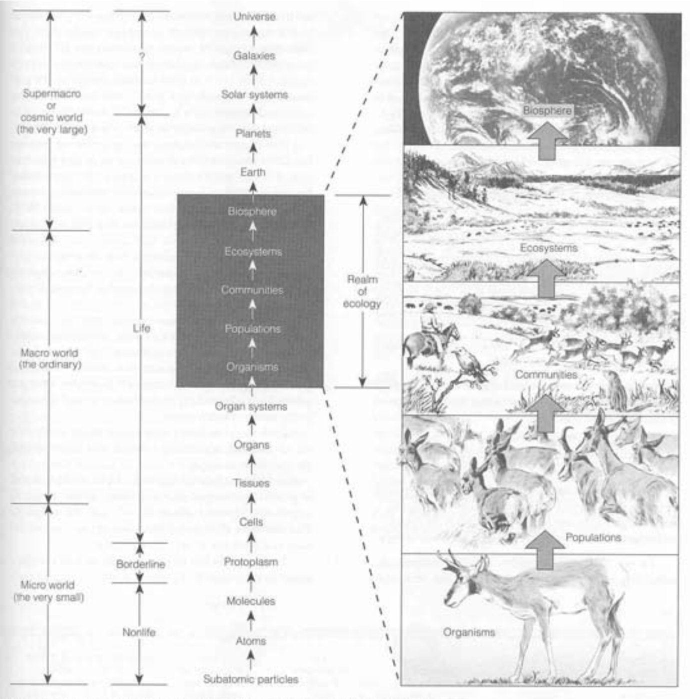
2. Species

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

4. Functional
   energy flow
   nutrient cycling
   etc.

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.

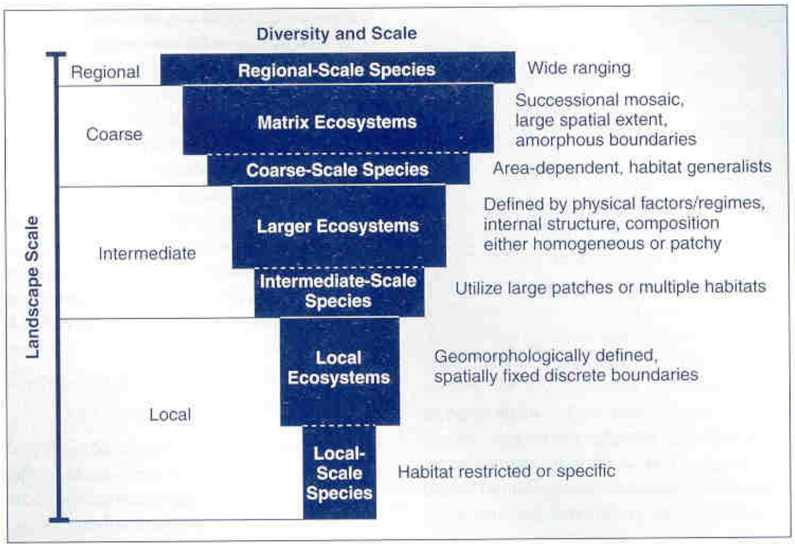


**Figure 4.15** Van Dyke 2003

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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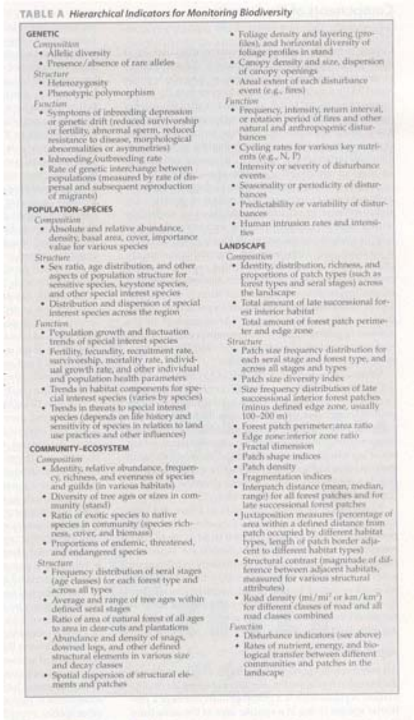


**TABLE A** *Hierarchical Indicators for Monitoring Biodiversity*

**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

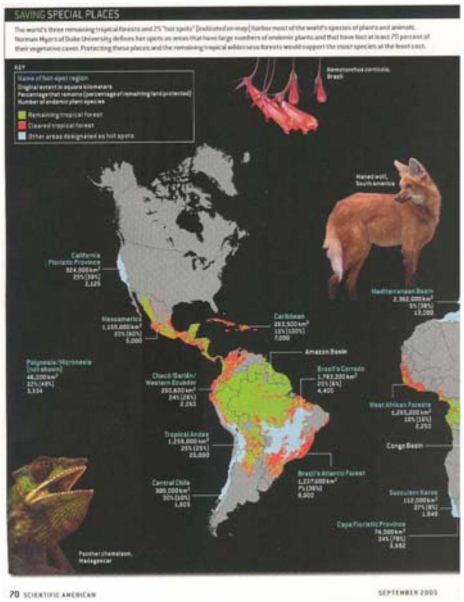
*Structure*
- Patch size frequency distribution for each seral stage and forest type, and across all stages and types
- Patch size diversity index
- Size frequency distribution of late successional interior forest patches (minus defined edge zone, usually 100–200 m)
- Forest patch perimeter:area ratio
- 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

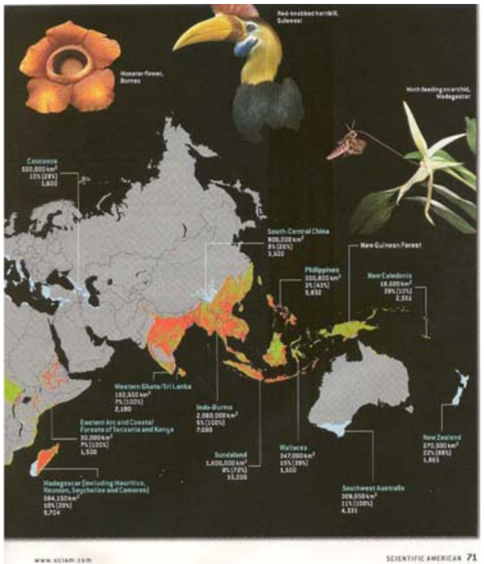
## Where is biodiversity?

One tree in Peru with same ant diversity as Britain



SAVING SPECIAL PLACES

The world's three remaining tropical forests and 25 "hot spots" [indicated on map] harbor most of the world's species of plants and animals. Norman Myers of Duke University defines hot spots as areas that have large numbers of endemic plants and that have lost at least 70 percent of their vegetative cover. Protecting these places and the remaining tropical wilderness forests would support the most species at the least cost.



Pimm and Jenkins 2005

## Species Richness and Latitude

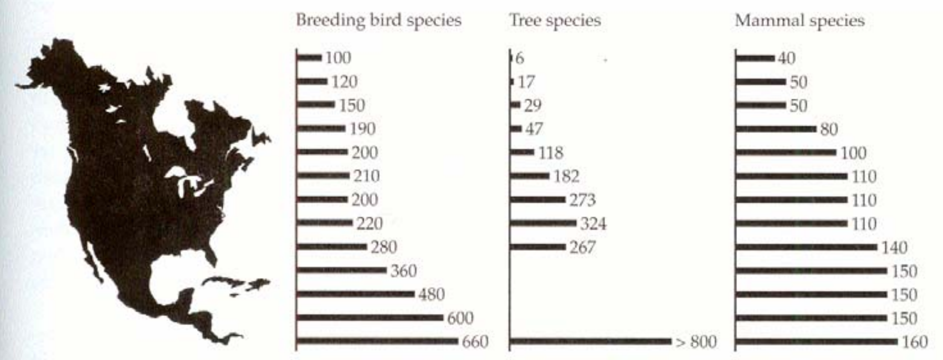


**FIGURE 3.5** In North America, as in all the continents, the numbers of bird, tree, and mammal species increase toward the Tropics. The numbers of species indicated in the bar graphs correspond to latitude in the map at left. Tree species diversity is not available for some lower latitudes. (From Briggs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

Altitude?

Primack 2006

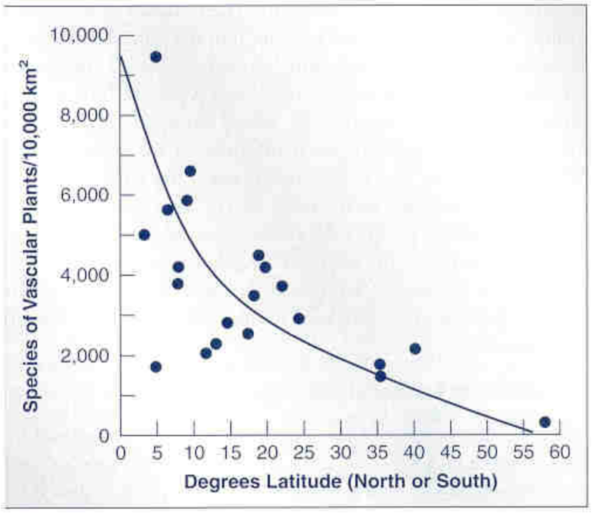


**Figure 4.12**

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).*