Biodiversity

Aquatic Ecology and Evolution

EAWAG

UNIVERSITÄT BERN

Biodiversity consists of the varied ecosystems in the biosphere, the species richness within those ecosystems, and the genetic variation within and among populations of each species.

The variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it.

We do know for certain that the rate of species extinction is high and that it largely results from an escalating rate of ecosystem degradation by a single species—*Homo sapiens*.

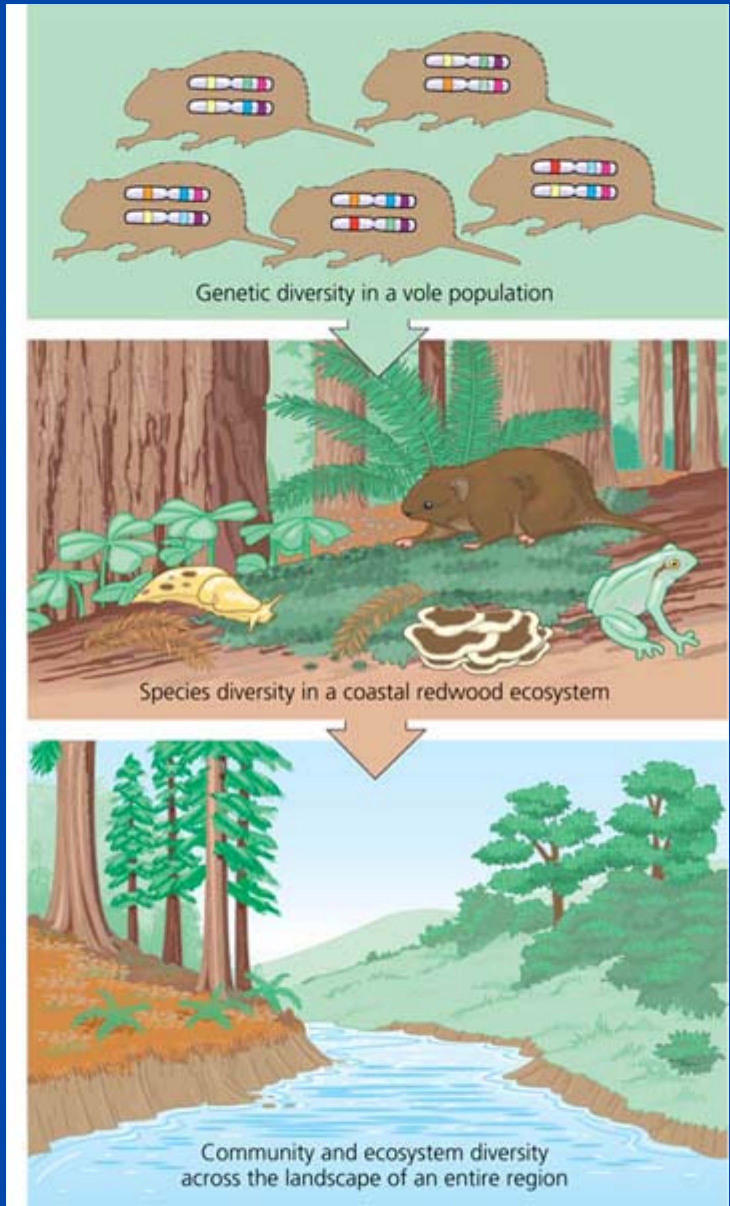
Human are threatening Earth’s biodiversity!!!!!!!

classical three levels of Biodiversity

iii) genetic variation within and among populations of each species

ii) species richness within those ecosystems

i) ecosystems



Levels of Biodiversity

genic diversity

adaptive diversity

species diversity

ecosystem diversity

Layers of information about biodiversity (numbers, relatedness, function)

• Individual genetic variation within a population

• genetic variation between populations that is often associated with adaptations to local conditions

individuals are selected
populations evolve

sources of genetic diversity

mutation (Point Mutations; Gene Number or Sequence; mutation rates)

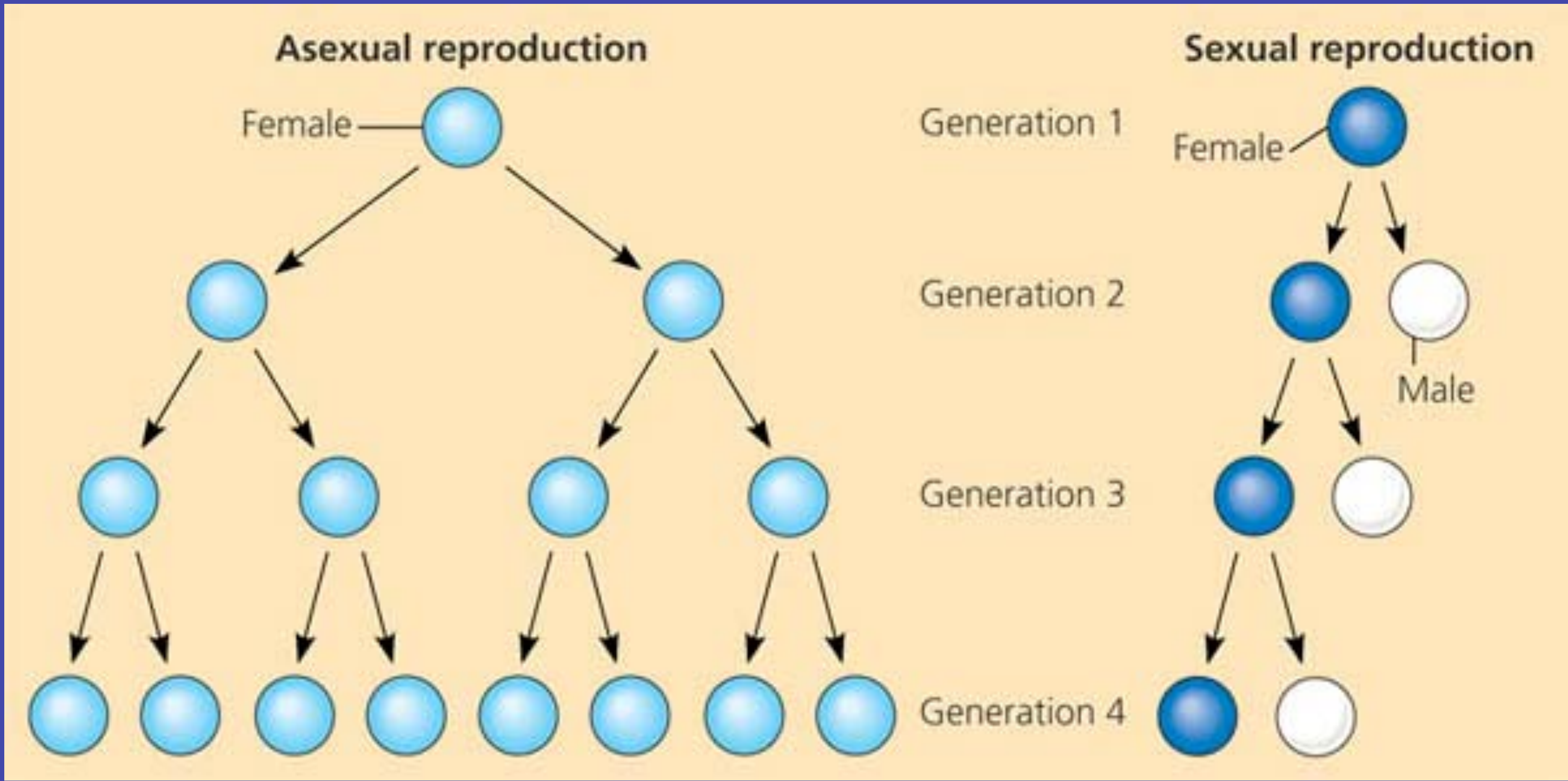
sexual recombination

one mutation in every 100,000 genes per generation in plants and animals

but much higher in microorganisms and viruses.

the most effective AIDS treatments at this time are drug "cocktails" combining several medications.

Reproductive Rates



A large number of genes is shared by all living organisms, whereas many others are unique to some specific lineages, indicating their different times of origin.

GENES

Where do new genes come from? Old genes!

Do all genes evolve at the same rate? No.

Where do new genes come from?

thehumangenome article

'New Domains'

23 of 94 InterPro families: Defense and Immunity
e.g. IL-1, interferons, defensins

17 of 94 InterPro families: Peripheral nervous system
e.g. Leptin, prion, ependymin

4 of 94 InterPro families: Bone and cartilage
GLA, LINK, Calcitonin, osteopontin

3 of 94 InterPro families: Lactation
Caseins (a, b, k), somatotropin

2 of 94 InterPro families: Vascular homeostasis
Natriuretic peptide, endothelin

5 of 94 InterPro families: Dietary homeostasis
Glucagon, bombesin, colipase, gastrin, IIGF-BP

18 of 94 InterPro families: Other plasma factors
Uteroglobin, FN2, RNase A, GM-CSF etc.

Loss of Olfactory Receptor Genes Coincides with the Acquisition of Full Trichromatic Vision in Primates.

PLoS Biol. 2004 Jan;2(1):E5. Epub 2004 Jan 20 Gilad et al.

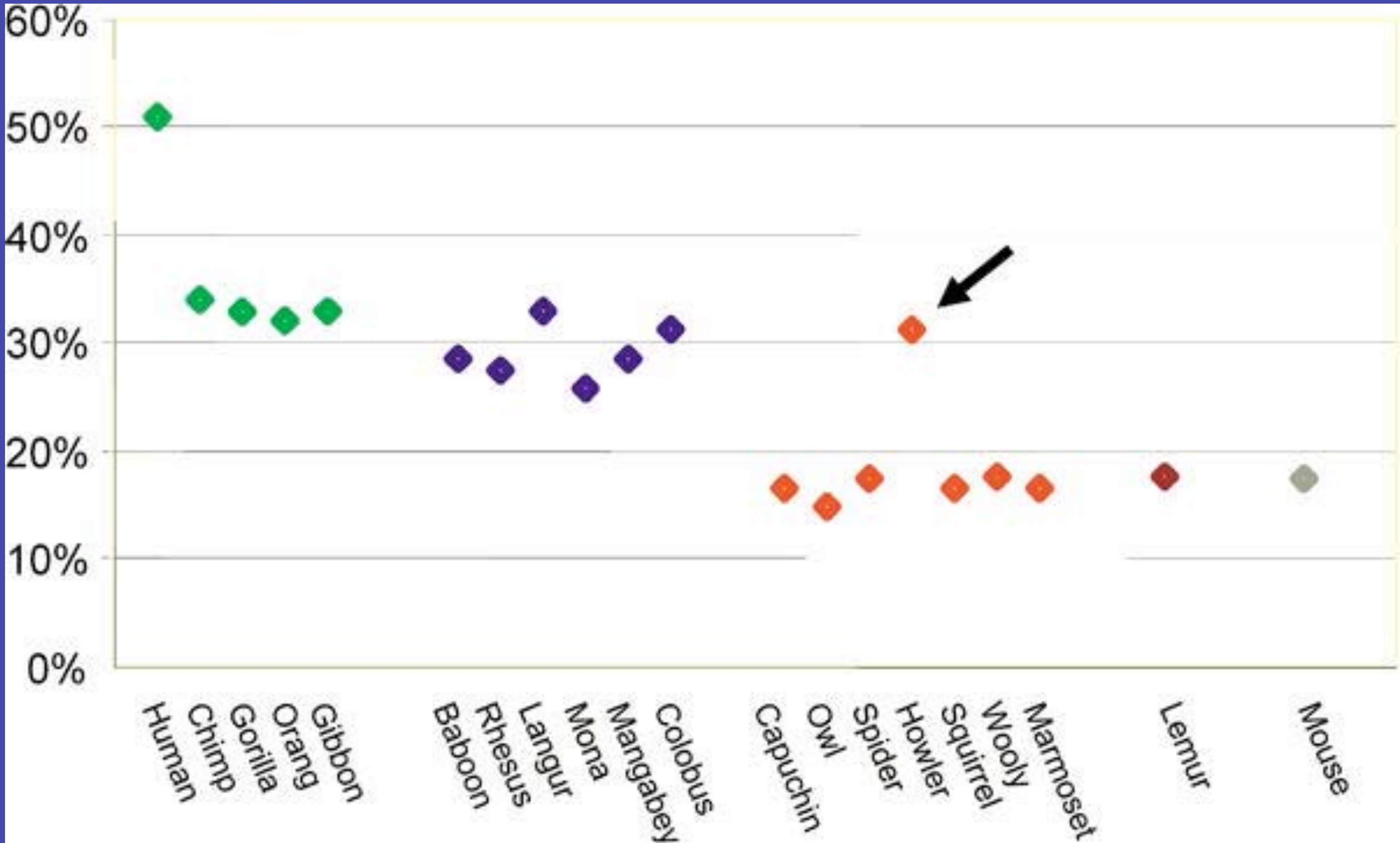


Figure 2. The Proportion of OR Pseudogenes in 20 Species

“Smell, Hearing Genes Differ between Chimps and Humans”

Genome News Network January 9 2004

“The 2.5Gb mouse genome sequence reveals about 30,000 genes, with 99% having direct counterparts in humans.”

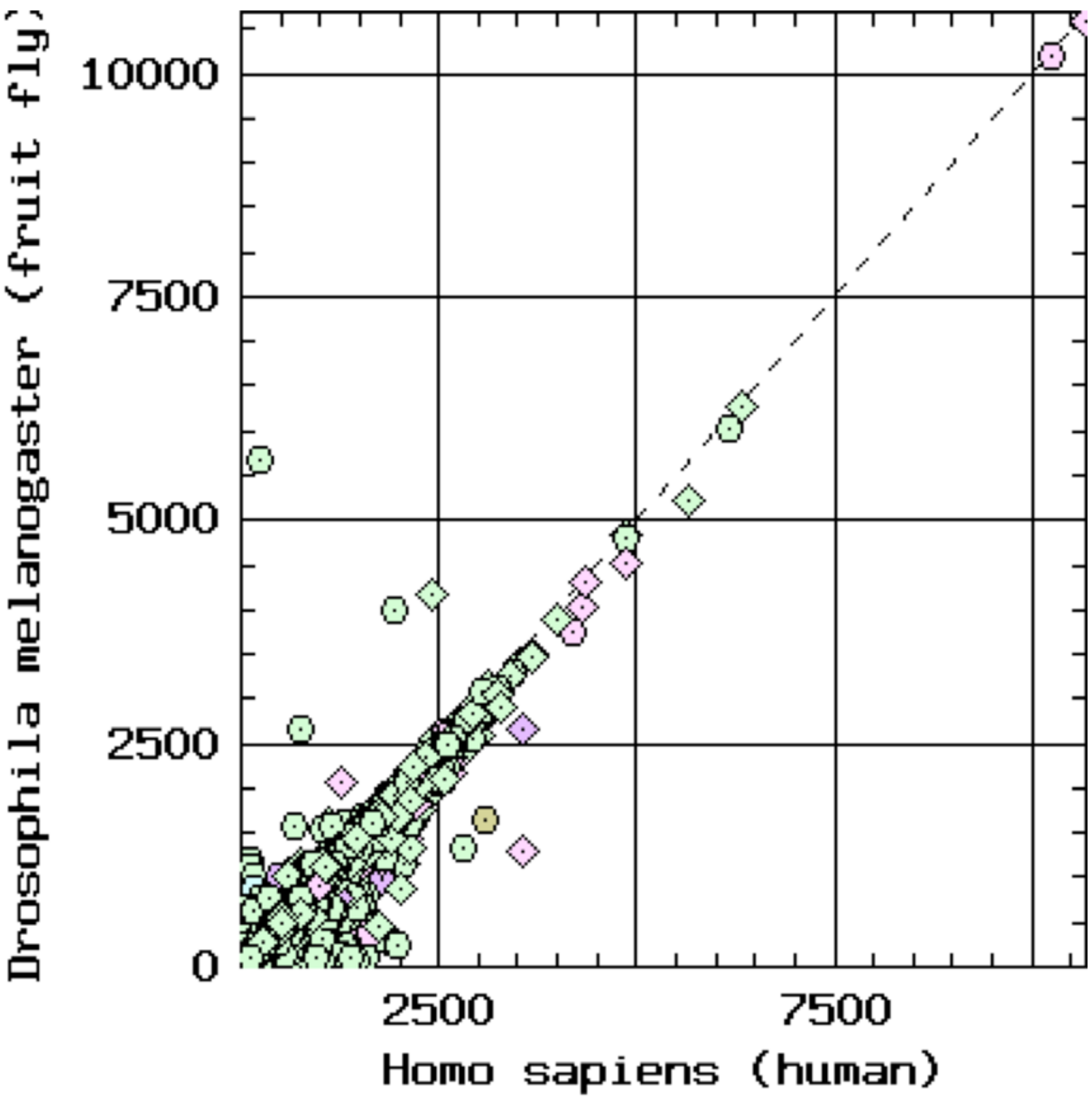
Nature editorial 5 December 2002.

Homologous genes identified by pair wise comparison are said **orthologs** when they belong to two different genomes and can be traced back to a common ancestor before the speciation event.

Homologs that diverged by gene duplication either before or after a speciation event are called **OUT paralogs** or IN paralogs (or co-orthologs) respectively

Sonnhammer Trends Genet. 18(12):619-20 (2002)

Distribution of *Arabidopsis thaliana* (thale cress) homologs



Each circle represents a single query genome protein, plotted by its BLAST scores to the highest scoring protein from each of the selected organisms. Symmetrical hits are shown as diamonds.

Initial numbers of genes from complete genomes

numbers of genes placed in a homology group

the numbers of groups for each species

HomoloGene Build 44.1 #build date Fri Oct 7 2005				
Species	**Number of Genes**	**HomoloGene**		
	Input	Grouped		groups
H.sapiens	23,144	19,315		18,786
P.troglodytes	21,526	13,408		13,344
C.familiaris	19,766*	16,737		16,302
M.musculus	25,242	20,149		18,845
R.norvegicus	22,694	18,646		17,245
G.gallus	18,029	12,134		11,301
D.melanogaste	13,780	7,956		7,861
A.gambiae	13,909	8,412		7,873
C.elegans	19,969*	5,171		4,923
S.pombe	5,043*	3,201		3,165
S.cerevisiae	5,863*	4,734		4,584
K.lactis	5,335	4,449		4,417
E.gossypii	4,726*	3,939		3,930
M.grisea	11,109	6,279		5,874
N.crassa	10,079	5,895		5,889
A.thaliana	26,324*	11,136		10,818
O.sativa	33,553	10,957		9,417
P.falciparum	5,222	938		917
				165,491
'*' indicates organisms where new genome annotation data is used in this build.				
Last updated on: Fri Oct 7 2005				

detection of homologs among the annotated genes of several completely sequenced eukaryotic genomes

Levels of Biodiversity

genic diversity

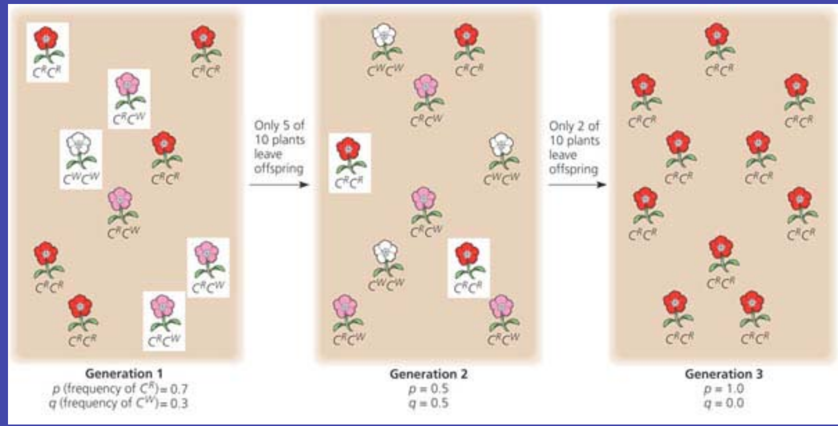
adaptive diversity

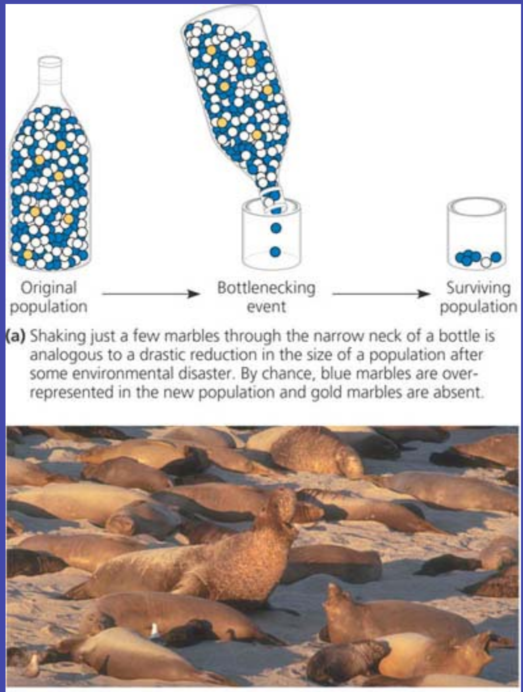
species diversity

ecosystem diversity

population's genetic composition

Genetic drift





(a) Shaking just a few marbles through the narrow neck of a bottle is analogous to a drastic reduction in the size of a population after some environmental disaster. By chance, blue marbles are over-represented in the new population and gold marbles are absent.

(b) Similarly, bottlenecking a population of organisms tends to reduce genetic variation, as in these northern elephant seals in California that were once hunted nearly to extinction.

Bottleneck effect

founder effect

Genetic drift that occurs when a few individuals become isolated from a larger population, with the result that the new population's gene pool is not reflective of the original population.

adaptive diversity

Preservation of Genetic Variation

Levels of Biodiversity

genic diversity

adaptive diversity

species diversity

ecosystem diversity

Species Diversity

Endangered species

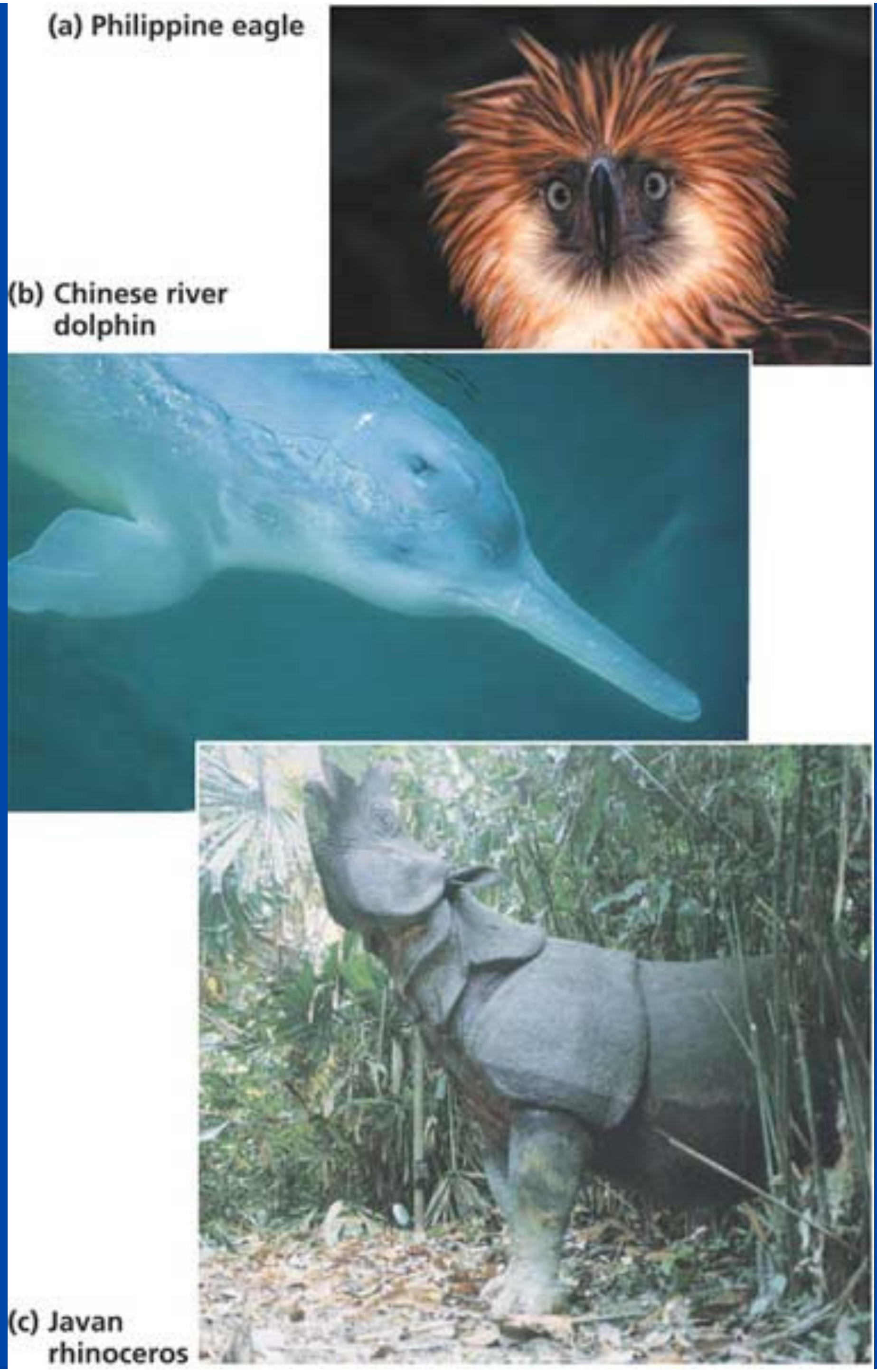
A species that is in danger of extinction throughout all or a significant portion of its range.

Threatened species

A species that is considered likely to become endangered in the foreseeable future.

A hundred heartbeats from extinction.

These are just three of the members of what Harvard biologist E. O. Wilson grimly calls the Hundred Heartbeat Club, species with fewer than 100 individuals remaining on Earth.



(a) Philippine eagle

(b) Chinese river dolphin

(c) Javan rhinoceros

Levels of Biodiversity

genic diversity

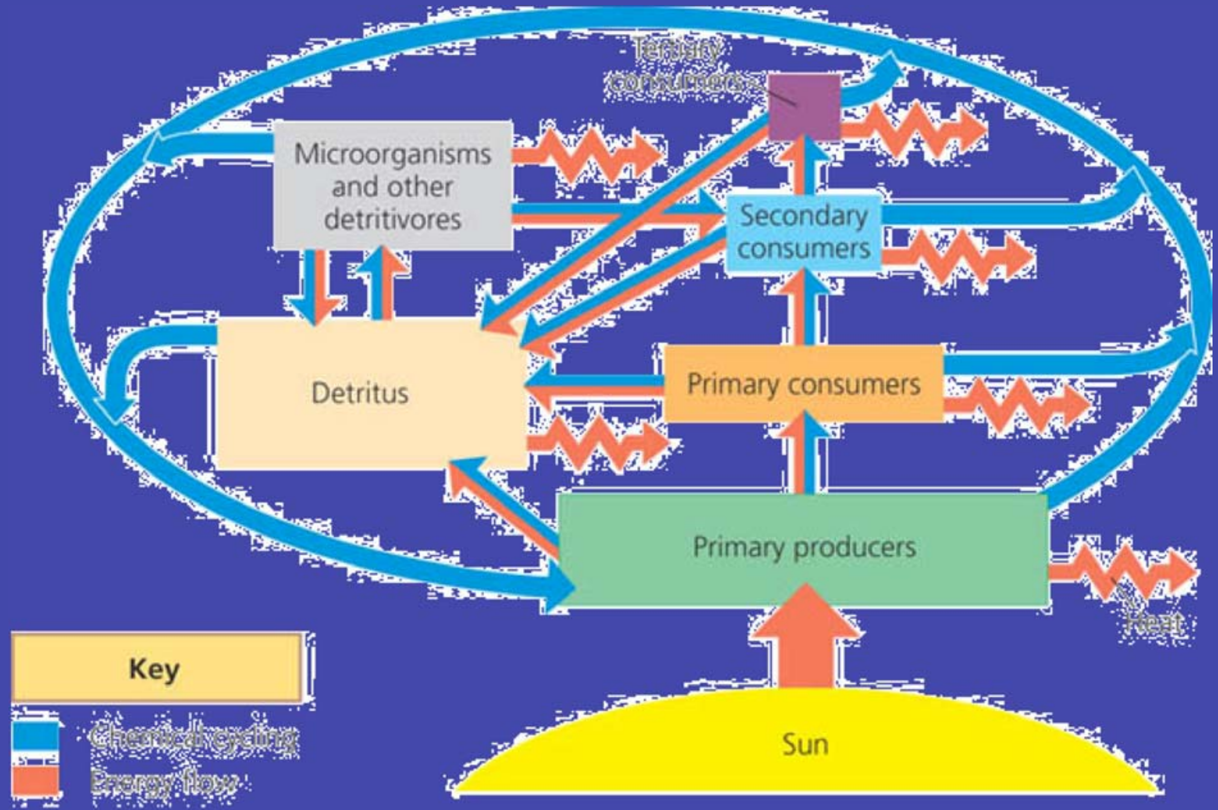
adaptive diversity

species diversity

ecosystem diversity

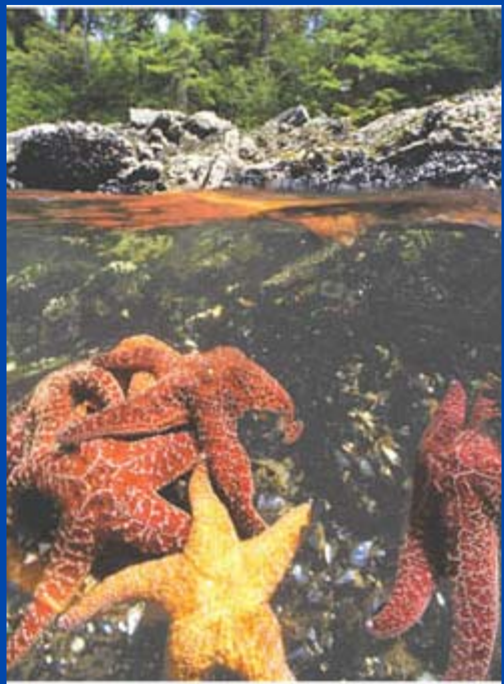
ecosystem consists of all the organisms living in a community as well as all the abiotic factors with which they interact.

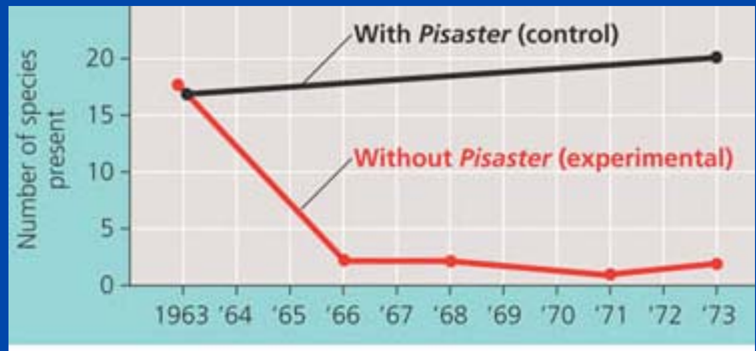
energy and nutrient dynamics in an ecosystem.



Ecosystem Diversity

The local extinction of one species—say, a keystone predator—can have a negative impact on the overall species richness of the community





Less biodiversity means...

Genetic Diversity

Genetic diversity is the "fundamental currency of diversity" (Williams and Humphires, 1996) that is responsible for variation between individuals, populations and species.

i) individual genetic variation within a population,
ii) the genetic variation between populations that is often associated with adaptations to local conditions

The loss of species also means the loss of genes.

Each species has certain unique genes, and biodiversity represents the sum of all the genomes of all organisms on Earth.

Such enormous genetic diversity has the potential for great human benefit.

In the 1970s, researchers discovered that the rosy periwinkle, which grows on Madagascar, an island off the coast of Africa, contains alkaloids that inhibit cancer cell growth.

Madagascar is also home to five other species of periwinkles, one of which is approaching extinction. The loss of these species would mean the loss of any possible medicinal benefits they might offer.

Functions performed by natural ecosystems that directly or indirectly benefit humans.

Ecosystem services

Purification of air and water

Reduction of the severity of droughts and floods

Generation and preservation of fertile soils

Detoxification and decomposition of wastes

Pollination of crops and natural vegetation

Dispersal of seeds

Cycling of nutrients

Control of many agricultural pests by natural enemies

Protection of shorelines from erosion

Protection from ultraviolet rays

Moderation of weather extremes

Provision of beauty and recreational opportunities

Four Major Threats to Biodiversity

Habitat Destruction

Introduced Species

Overexploitation

Disruption of Interaction Networks

Habitat Destruction

In almost all cases, habitat fragmentation leads to species loss, since the smaller populations in habitat fragments have a higher probability of local extinction.

Though most studies have focused on terrestrial ecosystems, habitat loss is also a major threat to marine biodiversity, especially along continental coasts and around coral reefs.

(a) Brown tree snake, introduced to Guam in cargo

(b) Introduced kudzu thriving in South Carolina

Introduced Species

also called invasive, nonnative, or exotic species, are those that humans move, either intentionally or accidentally, from the species' native locations to new geographic regions.

The European starling, brought intentionally into New York's Central Park in 1890 by a citizens' group intent on introducing all the plants and animals mentioned in Shakespeare's plays, quickly spread across North America, increasing to a population of more than 100 million and displacing many native songbirds

Overexploitation

Disruption of Interaction Networks

Species and ecosystem diversity is also known to vary with altitude *Walter (1985)* and *Gaston and Williams (1996: 214-215)*.

Mountainous environments, also called orobiomes, are subdivided vertically into altitudinal belts, such as montane, alpine and nival, that have quite different ecosystems.

Climatic conditions at higher elevations (e.g., low temperatures, high aridity) can create environments where relatively few species can survive.

Similarly, in oceans and freshwaters there are usually fewer species as one moves to increasing depths below the surface. However, in the oceans there may be a rise in species richness close to the seabed, which is associated with an increase in ecosystem heterogeneity

By mapping **spatial gradients in biodiversity** we can also identify areas of special conservation interest

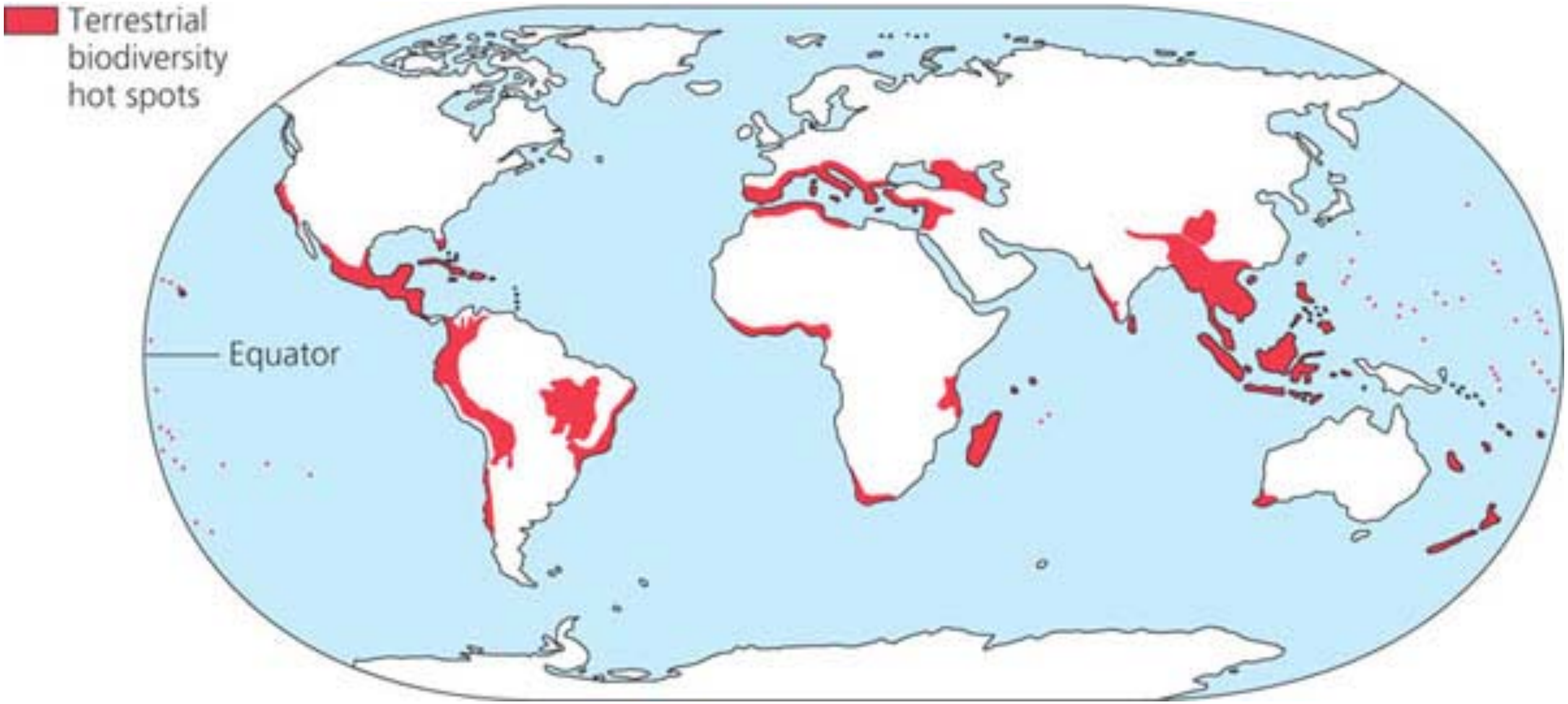
Endemic species those species whose distributions are naturally restricted to a defined region

Areas of high endemism are also often associated with high species richness (see Gaston and Spicer, 1998 areas that have high levels of endemism (and hence diversity) but which are also experiencing a high rate of loss of habitat

Biodiversity hotspots

areas that have relatively low biological diversity but also include threatened ecosystems (*Kareiva and Marvier, 2003*)

Biodiversity coldspots


Terrestrial biodiversity hot spots
Equator

Traditional Methods to Measure Biodiversity

Species Richness

Species Evenness

Disparity

Species Rarity

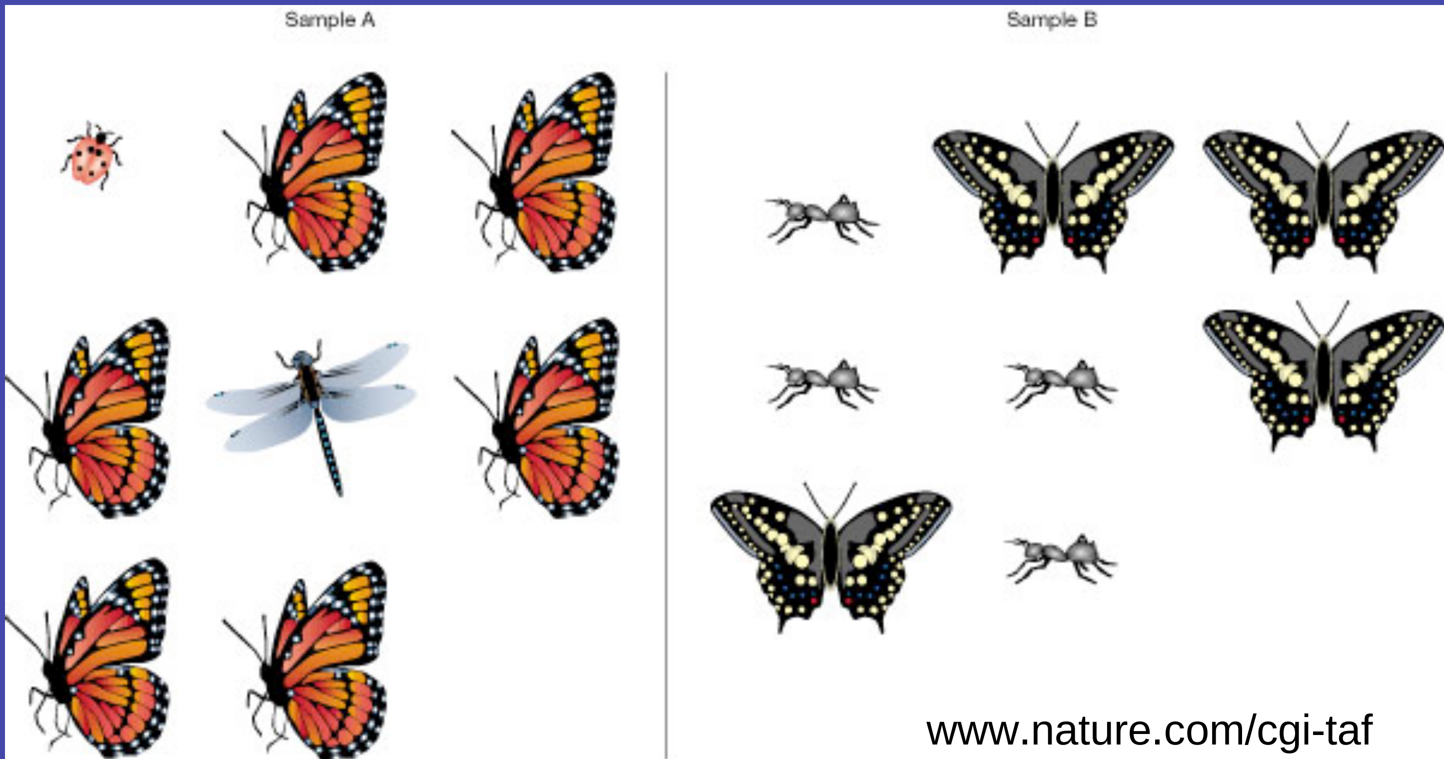
Genetic Variability

Species Richness

the total number of given species in a quantified area.

Species Evenness

the degree to which the number of individual organisms are evenly divided between different species of the community.



www.nature.com/cgi-taf

Disparity

measures the phenotypic differences among species resulting from the differences genes within a population.

Species Rarity

the rarity of individual organisms within a quantified area.

Genetic Variability

each population of a species contributes to additional biodiversity due to variations between genes.

Increase of productivity in an area corresponds with an increase in biodiversity.

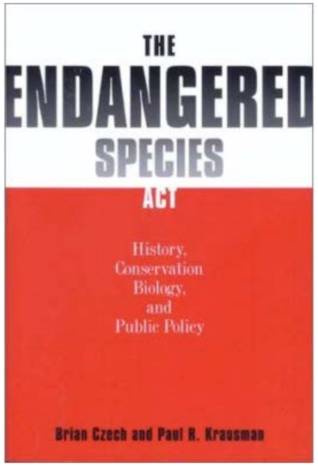
ex: tropical rain forest compared to semi-desert or tundra

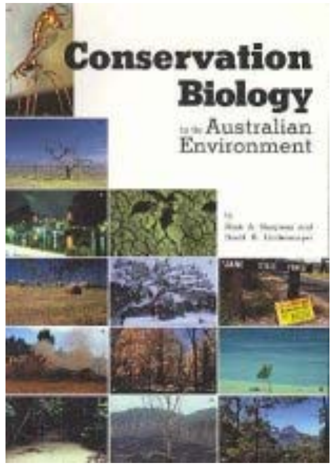
Ecosystems with high measures of biodiversity are more resistant to invader species.

ex Cheatgrass & Tamarisk

break!

Conservation **B**iology and **R**estoration





Conservation Ecology

Synthetic field that applies principles of ecology, biogeography, population genetics, economics, sociology, amnd other fields to the mantainace of biological diversity

Population conservation focuses on

population size,

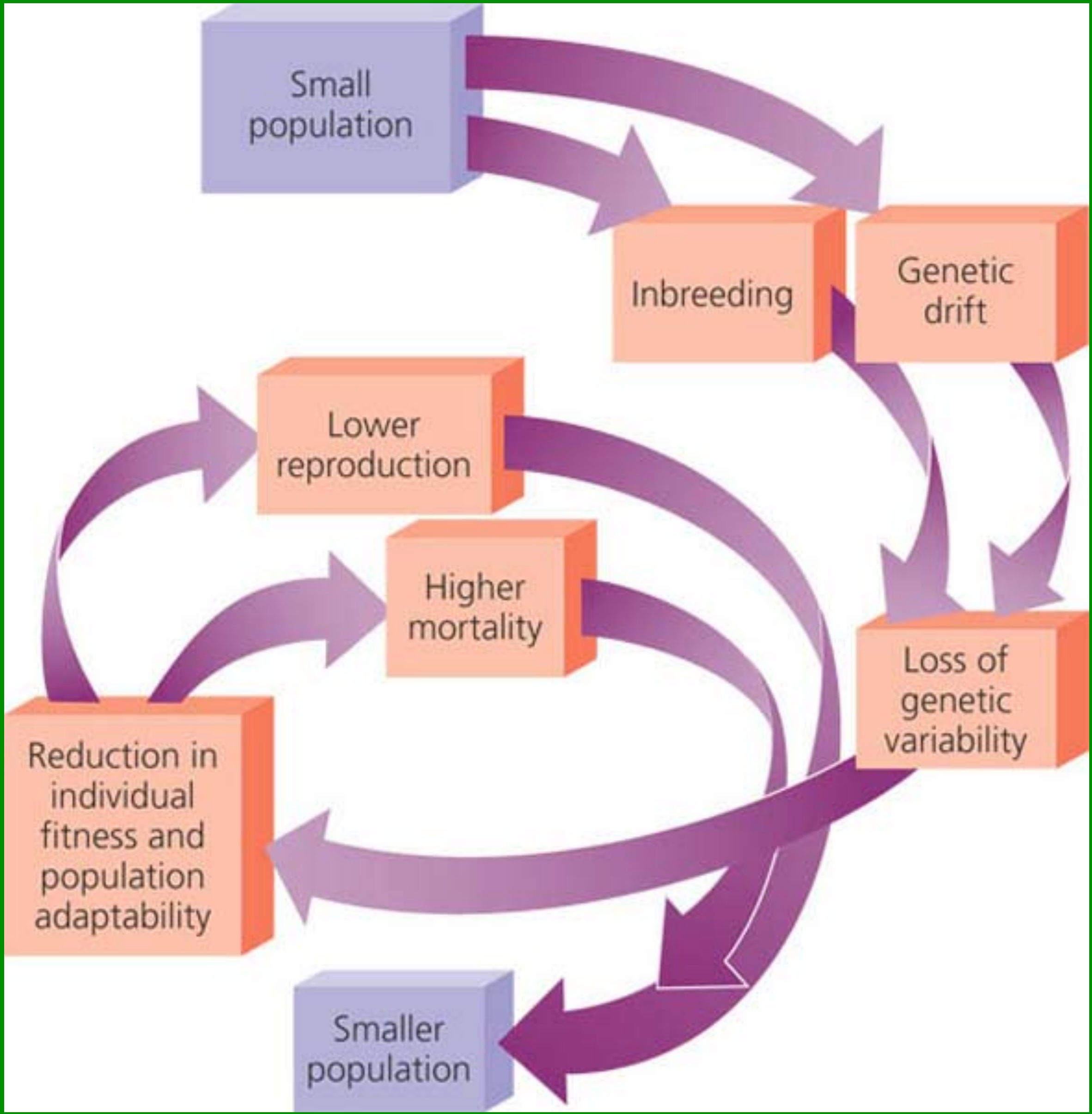
genetic diversity,

critical habitat

two main approaches:
the small–population approach: A species is designated as endangered when its populations are very small

the declining–population approach.

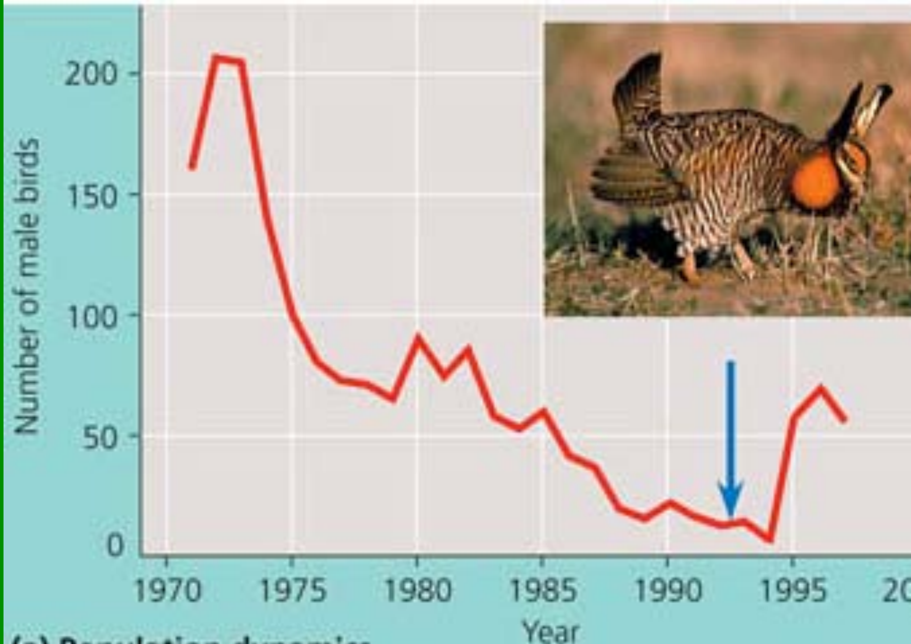
Processes culminating in an extinction vortex.



Inquiry What caused the drastic decline of the Illinois greater prairie chicken population?

EXPERIMENT Researchers observed that the population collapse of the greater prairie chicken was mirrored in a reduction in fertility, as measured by the hatching rate of eggs. Comparison of DNA samples from the Jasper County, Illinois, population with DNA from feathers in museum specimens showed that genetic variation had declined in the study population. In 1992, researchers began experimental translocations of prairie chickens from Minnesota, Kansas, and Nebraska in an attempt to increase genetic variation.

RESULTS After translocation (blue arrow), the viability of eggs rapidly improved, and the population rebounded.



(a) Population dynamics

(b) Hatching rate

CONCLUSION The researchers concluded that lack of genetic variation had started the Jasper County population of prairie chickens down the extinction vortex.

minimum viable population(MVP)

The smallest population size at which a species is able to sustain its numbers and survive.

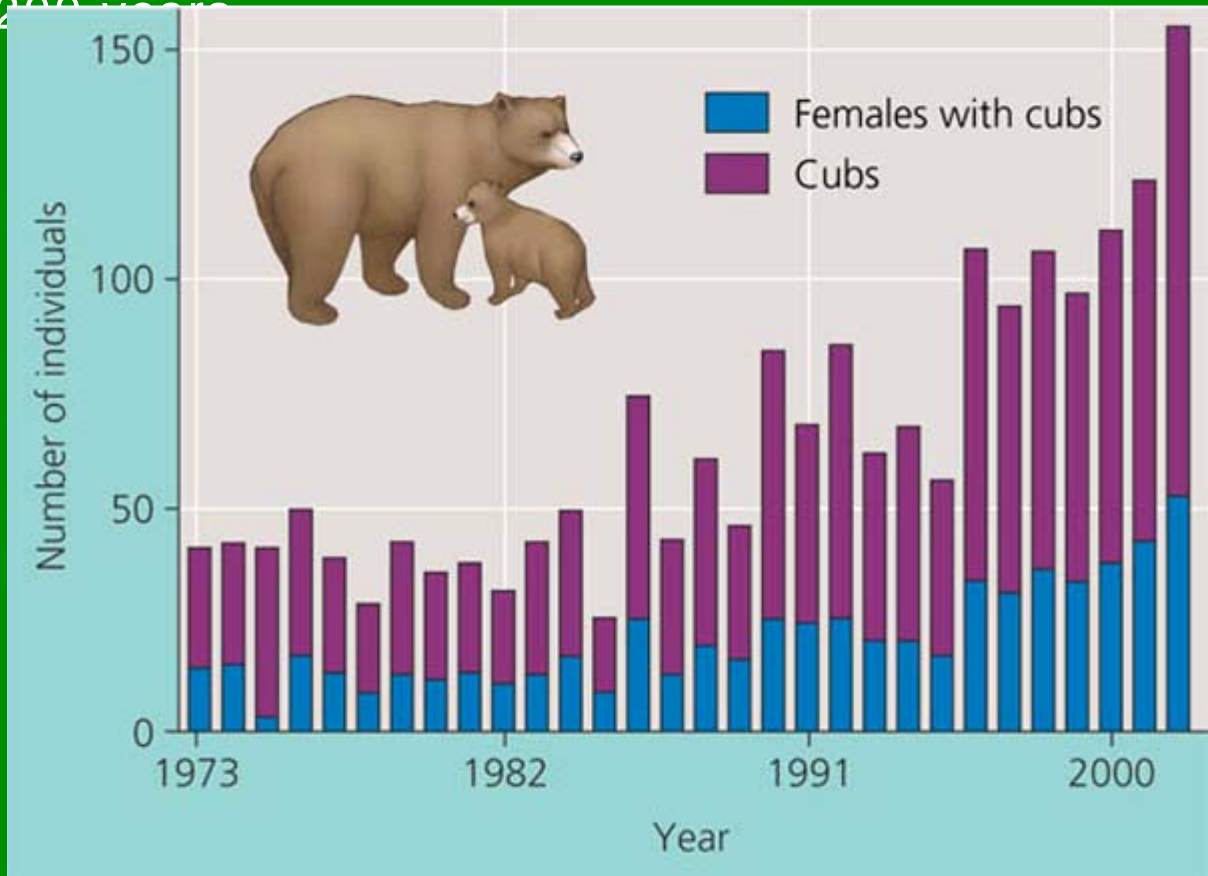
population viability analysis(PVA)

A method of predicting whether or not a population will persist.

Long–term (1978) monitoring of a grizzly bear population (by John and Frank Craighead)

the **grizzly bear** (*Ursus arctos horribilis*) is currently found in only 4 of the 48 contiguous states.

Shaffer, using life history data obtained for individual Yellowstone bears over a 12–year period, predicted that, given a suitable habitat, a total grizzly bear population of 70 to 90 individuals would have about a 95% chance of surviving for 100 years, whereas a population of 100 bears would have a 95% chance of surviving for 200 years.



small populations → loss of genetic variation over time,

- analyzed proteins, mitochondrial DNA, and nuclear microsatellite DNA to assess the **genetic variability** in the Yellowstone grizzly bear population.

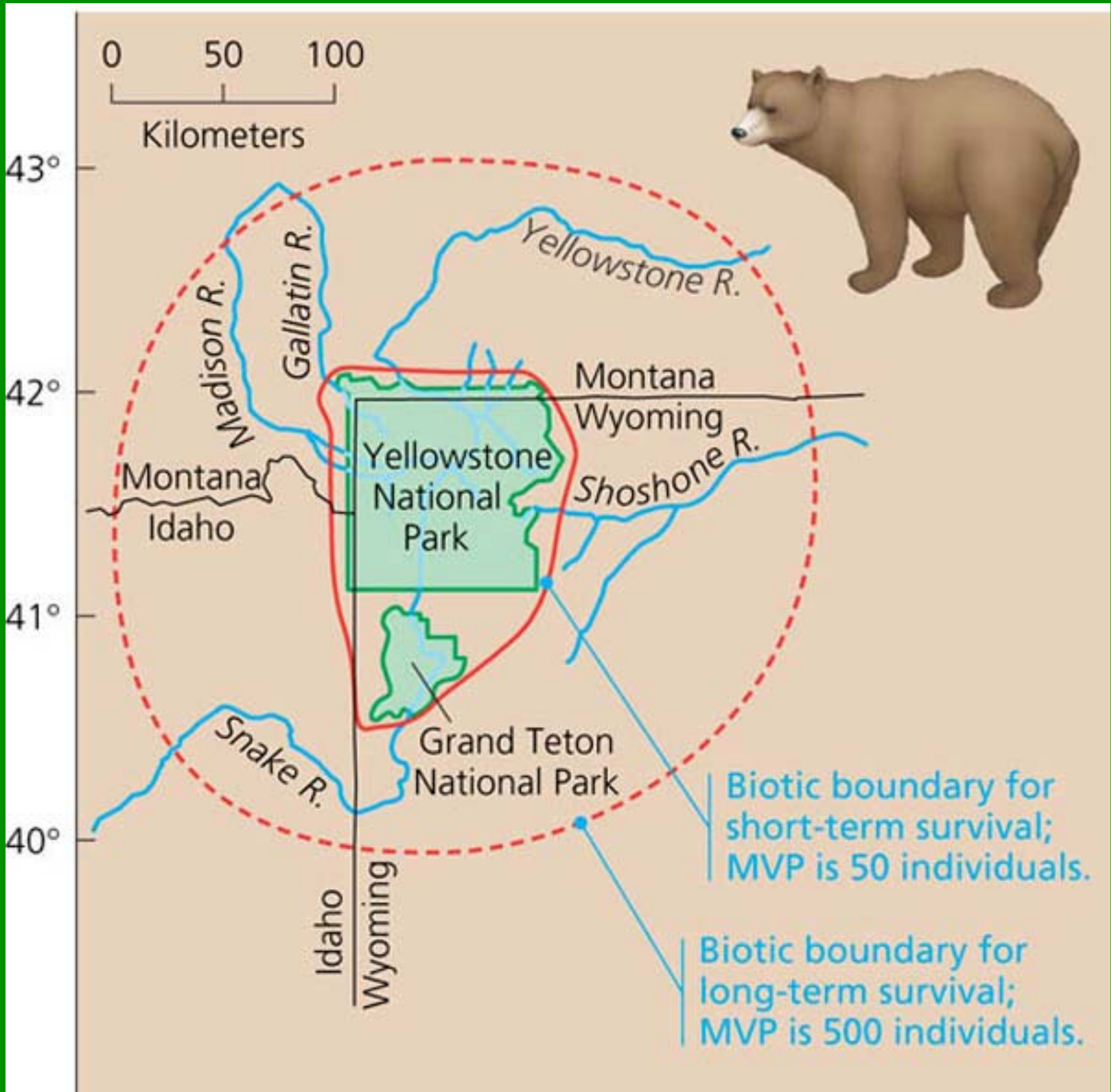
All results to date indicate that the Yellowstone population has **less genetic variability** than other grizzly bear populations in North America.

How might conservation biologists increase the effective size and genetic variation of the Yellowstone grizzly bear population?

Migration between isolated populations of grizzlies could increase both effective and total population sizes.

Corridors That Connect Habitat Fragments

A series of small clumps or a narrow strip of quality habitat (usable by organisms) that connects otherwise isolated patches of quality habitat.



The legal (green border) and biotic (red borders) boundaries for grizzly bears in Yellowstone and Grand Teton National Parks.

The **declining–population approach** focuses on threatened and endangered populations that show a downward trend, even if the population is far above minimum viable size.

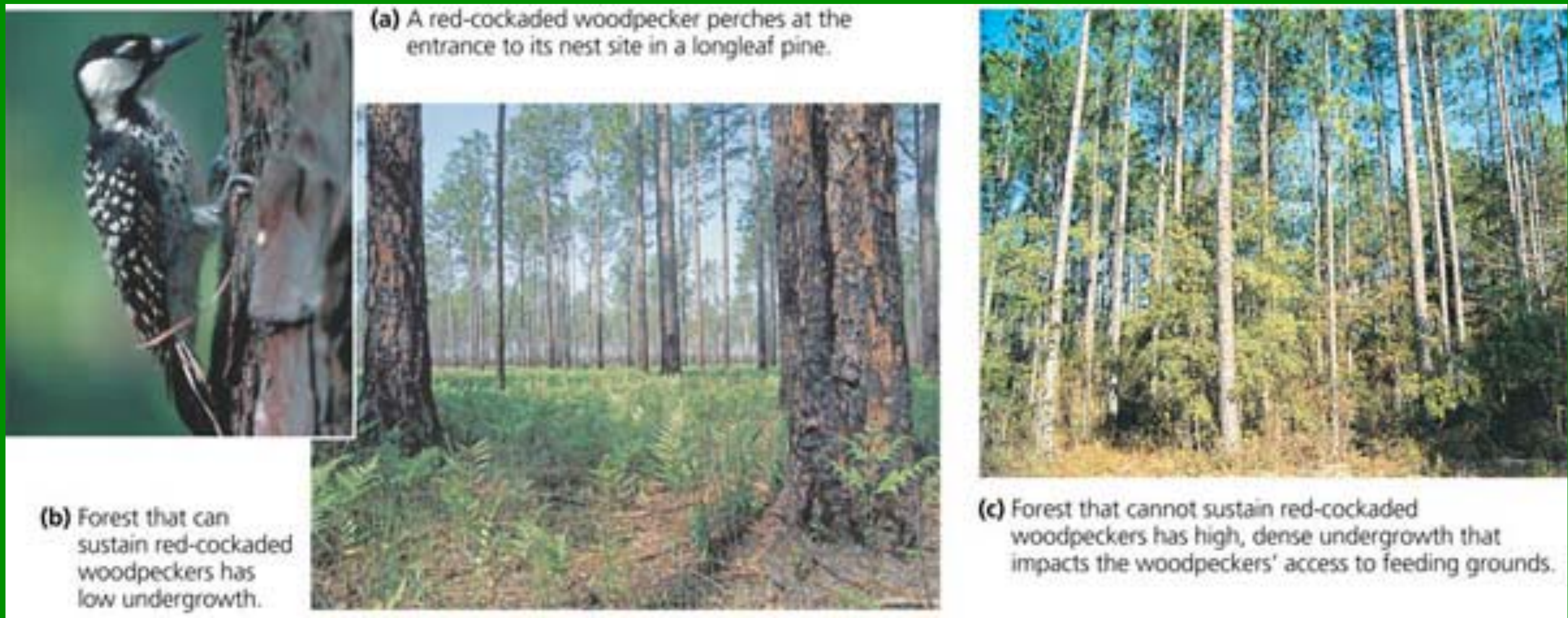
1. Assess population trends and distribution to confirm that the species is presently in decline or that it was formerly more widely distributed or more abundant.

2. Study the natural history of this and related species, including reviewing the research literature, to determine the species' environmental requirements.

3. Develop hypotheses for all possible causes of the decline, including human activities and natural events, and list the predictions of each hypothesis.

4. Because many factors may be correlated with the decline, test the most likely hypothesis first. For example, remove the suspected agent of decline to see if the experimental population rebounds relative to a control population.

5. Apply the results of the diagnosis to management of the threatened species and monitor recovery.



(a) A red-cockaded woodpecker perches at the entrance to its nest site in a longleaf pine.

(b) Forest that can sustain red-cockaded woodpeckers has low undergrowth.

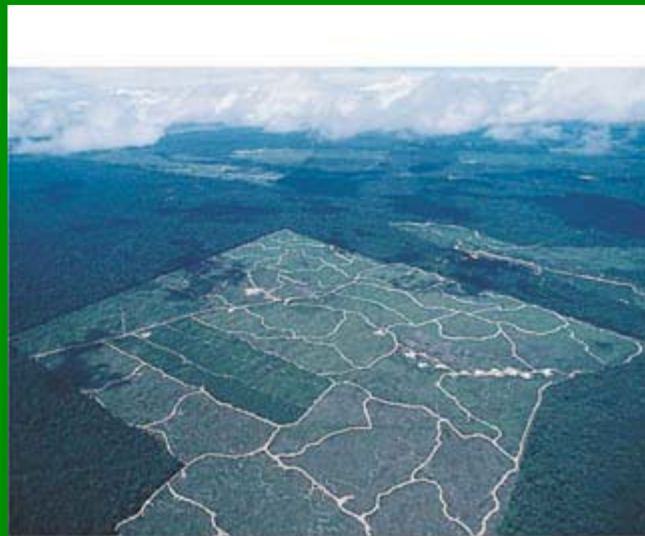
(c) Forest that cannot sustain red-cockaded woodpeckers has high, dense undergrowth that impacts the woodpeckers' access to feeding grounds.

landscape ecology

The study of past, present, and future patterns of landscape use, as well as ecosystem management and the biodiversity of interacting ecosystems

Landscape Structure and Biodiversity

(a) Natural edges. Grasslands give way to forest ecosystems in Yellowstone National Park.



(b) Edges created by human activity. Pronounced edges (roads) surround clear-cuts in this photograph of a heavily logged rain forest in Malaysia.

Long–term Biological Dynamics of Forest Fragments Project

Influence of fragmentation on the structure of communities in the heart of the Amazon River basin, a series of forest fragments

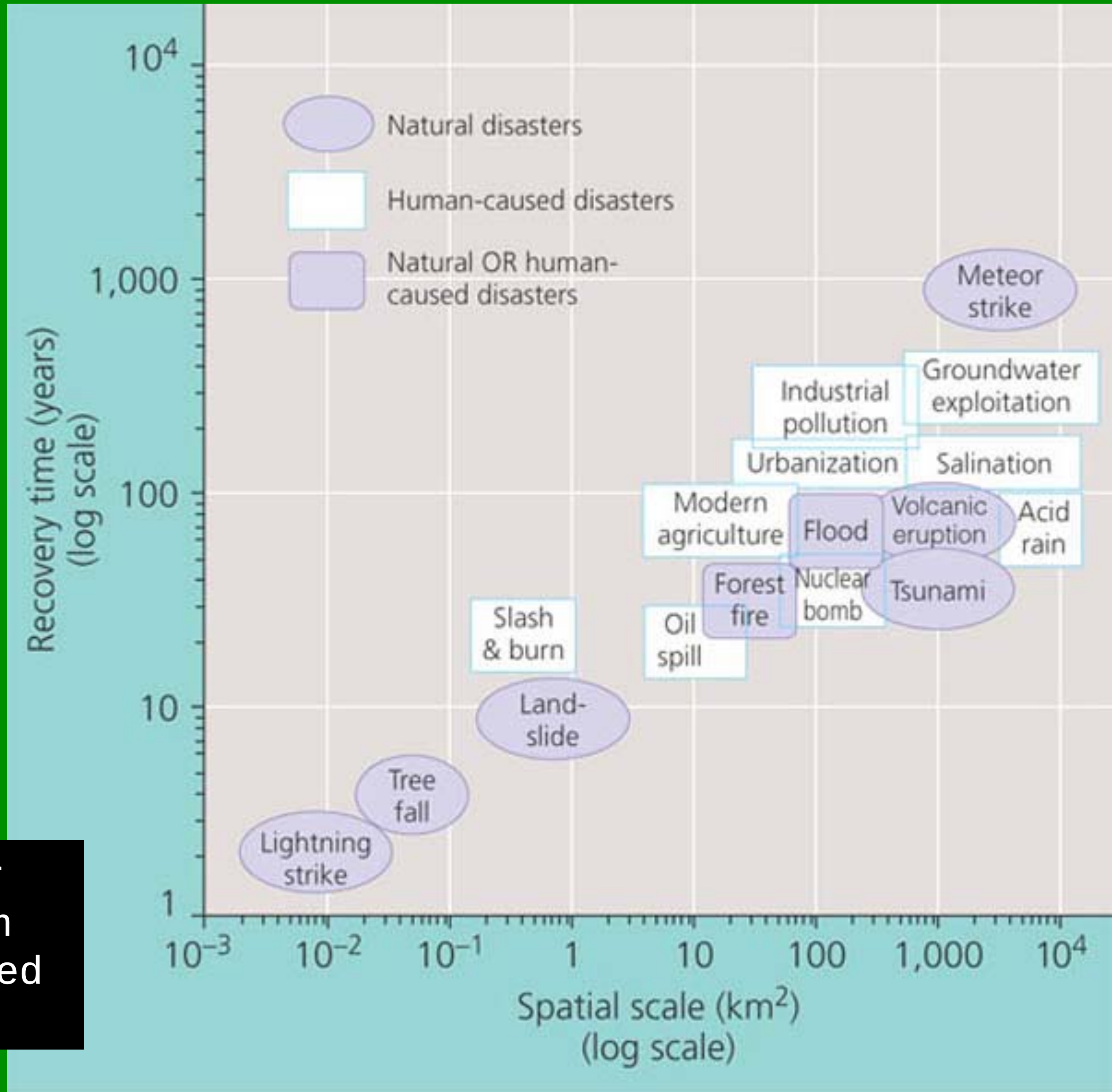
(a) Boundaries of the zoned reserves are indicated by black outlines.

(b) Local schoolchildren marvel at the diversity of life in one of Costa Rica's reserves.

An extensive region of land that includes one or more areas undisturbed by humans surrounded by lands that have been changed by human activity and are used for economic gain.

Zoned reserves

Restoration ecology attempts to restore degraded ecosystems to a more natural state



size–time relationship for community recovery from natural and human–caused disasters.

Bioremediation is the use of living organisms, usually prokaryotes, fungi, or plants, to detoxify polluted ecosystems

Biological augmentation uses organisms to add essential materials to a degraded ecosystem

Truckee River, Nevada. Damming and water diversions during

Kissimmee River, Florida. The Kissimmee River in south-

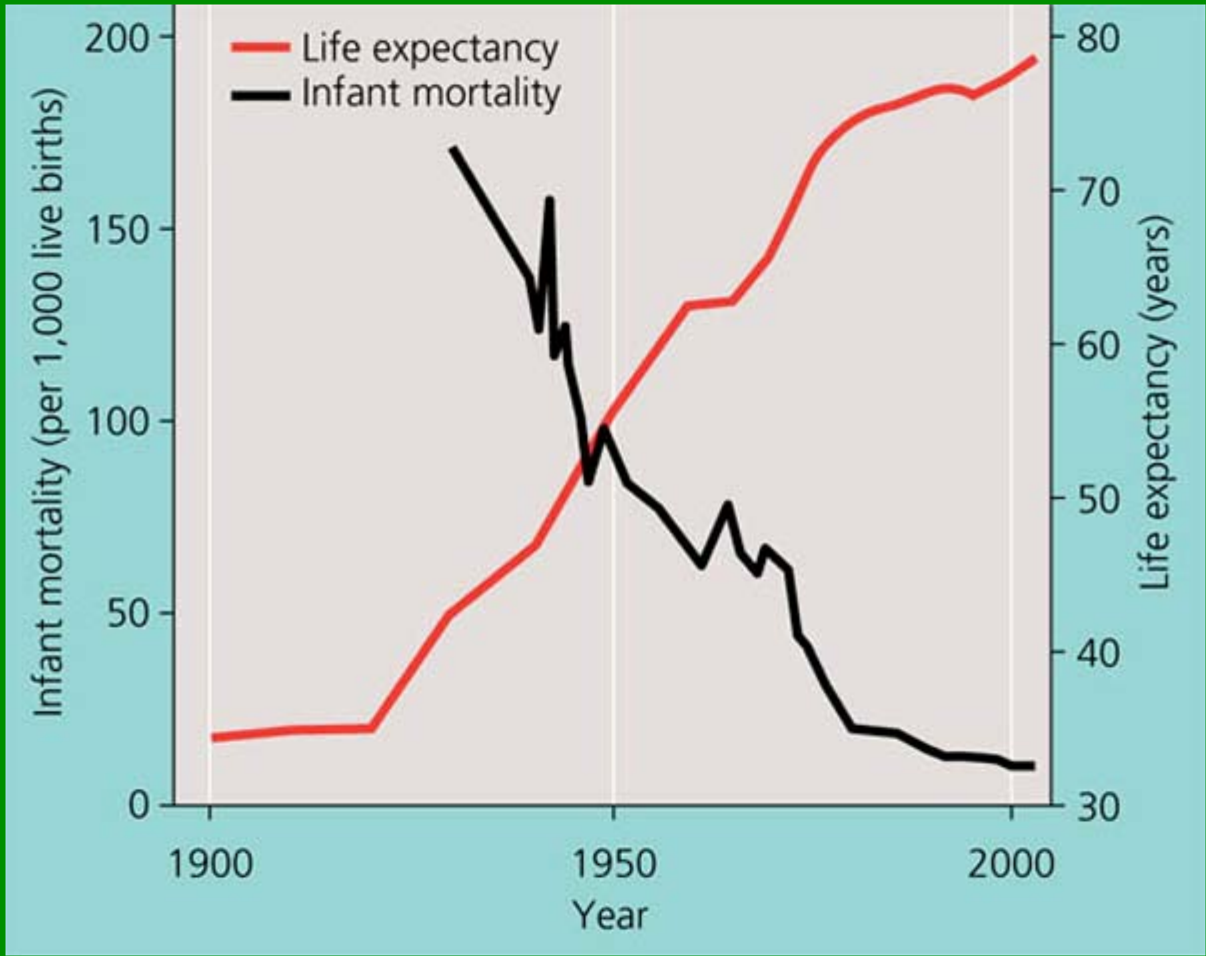
Rhine River, Europe. Centuries of dredging and channeling for

Coastal Japan. Seaweed and seagrass beds are important nurs-

Tropical dry forest, Costa Rica. Clearing for agriculture,

Succulent Karoo, South Africa. In this desert region of south-

Sustainable development seeks to improve the human condition while conserving biodiversity



E. O. Wilson makes the case that our biophilia is innate, an evolutionary product of natural selection acting on a brainy species whose survival depended on a close connection to the environment and a practical appreciation of plants and animals

(a) Detail of animals in a Paleolithic mural, Lascaux, France

(b) Biologist Carlos Rivera Gonzales examining a tiny tree frog in Peru