

Global Climate Change

Impacts on Biodiversity

Biodiversity

Biodiversity is the sum of all the different species of animals, plants, fungi, and microbial organisms living on Earth. Scientists estimate that upwards of 10 million—and some suggest more than 100 million—different species inhabit the Earth. Each species is adapted to its unique niche in the environment, for example, the peaks of mountains, the depths of deep-sea hydrothermal vents, polar ice caps, or tropical rain forests.

Biodiversity

The World Wildlife Fund defines biodiversity as “the millions of plants, animals, and microorganisms, the genes they contain, and the intricate ecosystems they help build into the living environment.”

Importance of Biodiversity

Biodiversity underlies everything from food production to medical research. Humans, the world over, use at least 40,000 species of plants and animals on a daily basis. Many people still depend on wild species for some or all of their food, shelter, and clothing. All of our domesticated plants and animals came from wild-living ancestral species. Over 70 percent of the pharmaceuticals used in the United States are either based on or synthesized from natural compounds found in plants, animals, or microorganisms.

Diversity Measures

Species

Genetic

Community (the species that occupy a particular locality and the interactions among those species)

Ecosystem (a community and its physical environment)

Ecosystem

The array of living organisms found in a particular environment together with the physical and environmental factors that affect them is called an ecosystem.

Healthy ecosystems are vital to life: They regulate many of the chemical and climatic systems that make available clean air and water and plentiful oxygen. Forests, for example, regulate the amount of carbon dioxide in the air, produce oxygen as a byproduct of photosynthesis, and control rainfall and soil erosion. Ecosystems, in turn, depend on the continued health and vitality of the individual organisms that compose them.

Loss of Species

Most biologists accept the estimate of E. O. Wilson that the Earth is losing approximately 27,000 species per year. This estimate is based primarily on the rate of disappearance of ecosystems, especially tropical forests and grasslands, and our knowledge of the species that live in such systems. We can measure the rate of loss of tropical rain forests, for example, by analyzing satellite photographs of continents from different periods that show rates and amounts of habitat destruction—and from these measurements calculate the approximate number of species being lost each year.

Extinctions Past & Present

This extraordinary rate of extinction has occurred only five times before in the history of life on Earth. Mass extinctions of the geological past were caused by catastrophic physical disasters, such as climate changes or meteorite impacts, which destroyed and disrupted ecosystems around the globe. In the fifth mass extinction, which occurred more than 65 million years ago, the Earth was shrouded in a cloud of atmospheric dust—the result of meteorite impact. The resulting environmental disruption caused the demise of 76 percent of all species alive at the time, including the dinosaurs. Today's sixth extinction is likewise primarily caused by ecosystem disturbance, but this time the destroying force is humankind.

Biodiversity Through Time

- Originations and extinctions have occurred throughout the fossil record, with the continual increase of global biodiversity indicating that the former have, on average been more common than the latter. The only major reversals to this trend have occurred during the mass extinctions, with the huge end-Permian mass extinction in particular resetting the diversity 'clock'.
- Extinctions were often not random.
- The global diversity of species reached an all-time high approximately 30,000 years ago.

Comparing Past & Present

- In the fossil record, an individual species lasts around 5 million years before it becomes extinct. Since our best estimate is that there are 10 million species on Earth today, we can predict that 2 species should be lost per year (0.00002%).
- The current observed extinction rate, for birds and mammals, is 0.01% per year. Or 500 times that of the background rate of extinction.
- At this rate, it would take only 8,000 years to equal the extinction event that killed the dinosaurs.
- Even conservative estimates (Regan et al. 2001. *Am. Nat.* 157: 1-10) are 50 times that background rate.
- Observation and Island Biogeography theory predicts that the rate may increase to 0.5% per year.

Human-Caused Extinctions

- ❖ The first noticeable effects of human activity on extinction rates can be seen in the elimination of large mammals from Australia, North America, and South America. (e.g., Miller et al. 1999. *Science* 283: 205-208).
- ❖ Approximately 80% of North American animals weighing more than 45 kg went extinct 'shortly' after the arrival of humans.

Ecosystem Services

- Biological communities are of vital importance in protecting watersheds, buffering ecosystems against extremes of flood and drought, and maintaining water quality.
- When vegetation is removed, the rates of soil erosion and the rates of landslides increases rapidly, decreasing the value of land for human activities.
- Silt (soil particles suspended in water from runoff) kills freshwater and marine animals.
- Erosion and flooding can make the water supplies along rivers undrinkable.
- The conversion of wetlands increases flooding rates drastically.

- Hydrologic cycles are disrupted by deforestation.
- Plant communities are important in moderating local, regional, and even global climate conditions.
- Waste treatment and nutrient retention.
- Pollinators, pest control, etc.
- Recreation & ecotourism
- Educational & scientific value

Total Value?

In a paper published in *Nature* in 1997, a group of 13 ecologists & economists estimated the value of environmental services at \$16-\$54 trillion per year. This estimate is based on the cost of artificially providing the same services. The services they evaluated included food production, raw materials, recreation and water supply, regulation of climate and atmospheric gases, water cycling, erosion control, soil formation, nutrient cycling and the purification of wastes.

Agriculture

Plants. Only a very small proportion of the world's plants are used for food on a large scale. About 30,000 are thought to be edible, but only about 150 are used as human food. 90% of the world's food comes from 15 species. Three of them - wheat, corn, and rice - supply two-thirds of this amount. Although there are over 10,000 species of cereals, no new ones have been brought into cultivation during the past 2000 years.

Loss of Genetic Variation

The dangers of relying on genetically homozygous crops are illustrated by the Great Irish Potato Famine. Potatoes were introduced into Ireland from the New World in about 1600 and eventually most of the Irish people became dependent on this one crop. But then in 1845-1847, the wind-borne potato blight fungus spread throughout the country and caused almost complete failure of the potato crop. It is estimated that 1 million people died of starvation.

Wild Plants Are Important Sources of Genetic Material

- A wild relative of the potato was found in Peru, and when it was hybridized with the standard crop plant a variety was obtained that was resistant to potato blight.
- A wild barley plant from Ethiopia provided a gene that protects the \$160 million California barley crop from lethal yellow dwarf virus.
- Rice grown in Asia is protected from the four main rice diseases by genes brought in from a wild species from India.

- In both India and Africa, yields of cassava (tapioca) - one of the most important root crops throughout the tropics - were increased 18-fold because of disease resistance brought in from wild Brazilian cassava.
- The sugar cane industry in the U.S. was saved from collapse by disease-resistance genes brought in from wild Asian species.
- A wild tomato discovered in the Andes has been used to increase the sugar content of cultivated varieties, increasing their commercial value by \$6.5 million per year.

Pesticides

- ❖ Calabar bean was traditionally used as a poison in West Africa. Chemical studies of this plant led to the development of methyl carbamate insecticides.
- ❖ Daisy plants (*Chrysanthemum cinerariaefolium*) were first used centuries ago as a lice remedy in the Middle East, and this led to the discovery of pyrethrum insecticides. The seeds contain a natural insecticide called pyrethrin, a generic name for six related active compounds. It is one of the safer insecticides for several reasons: it decomposes rapidly in sunlight; it has few known effects on mammals; and insects do not develop resistance to it.
- ❖ In South America, the natives use an extract of a forest vine to stun fish; this led to the discovery of rotenone, a biodegradable insecticide.
- ❖ The bacterium *Bacillus thuringiensis* produces toxic proteins that kill certain insects but are apparently harmless to humans. These are being produced and marketed as biopesticides. And Monsanto has engineered cotton plants that produce their own protein insecticide.
- ❖ The Neem tree, in India, has been found to be a source of the insecticide azadirachtin, as well as fungicides, spermicide, and agents potentially valuable in birth control such as materials that prevent implantation or cause abortion. The tree has been used in traditional agriculture, medicine and cosmetics for centuries.

Medicines

The pharmaceutical industry is much more dependent on natural products than is generally realized. About a quarter of all prescription drugs are taken directly from plants and more than 70% of them are modeled on natural compounds.

These include morphine, codeine, quinine, atropine, and digitalis. Yet, fewer than 1% of rainforest plants have been tested.

Anti-Cancer Drugs

The rosy periwinkle was used in Cuba, the Philippines, and South Africa for the treatment of inflammation, rheumatism, and diabetes. In the late 1950s, vincristine and vinblastine were isolated from the periwinkle plant by Eli Lilly scientists and these chemicals were shown to have anti-cancer effects. Treatment with these drugs has increased the chances of remission to 99% in childhood leukemia and to 70% in Hodgkin's disease. Global sales of vincristine and vinblastine earn the Eli Lilly Company about \$100 million each year.

Specific Example

The Pacific Yew tree, a rare and slow-growing tree in the Pacific Northwest, is the only source of a drug called taxol, which appears to be very effective in treating ovarian cancer and has great promise for treating breast cancer as well. Each year, about 20,500 women are diagnosed with ovarian cancer and about half die from it. But it takes six Pacific yew trees to extract enough taxol to treat one patient. The National Cancer Institute has enough available to treat about 300 patients - not even enough to complete clinical trials. The yew tree is found only in old-growth forests.

Specific Examples & Warning

- *Epipedobates tricolor*. Nonaddictive painkiller 200 times stronger than opium.
- *Callophylum lanigerum austrocoriaceum* (same genus as mangosteen). Collected from Malaysia in 1987. National Cancer Institute determined that extract provided “100 percent protection against the cytopathic effects of HIV-I replication.”

Utility is Unpredictable

Nobody could have predicted that bread mold would be the source of one of the most useful antibiotics; that armadillos would have been useful in medical research because they are the only experimental animal that can be infected with leprosy; or that the Madagascar periwinkle would be a source of an anti-leukemia drug, or that a heat-loving microbe living in a hot spring at Yellowstone National Park would provide a key ingredient in DNA fingerprinting.

Non-Utilitarian Value

- Wildlife is worth conserving because it is interesting, beautiful, spectacular. Wild animals and plants provide inspiration not only to biologists but also to millions of naturalists, explorers, painters, photographers, writers, poets and musicians.
- According to a survey conducted for the U.S. Fish and Wildlife Service, 77 million Americans participated in wildlife-related recreation in 1996. During that time, they spent \$108 billion compared to only \$81 billion on cars.

Global Climate Change

- ❖ 1700 species shifted their ranges an average of 6.1 kilometers per decade towards the poles.
- ❖ Increased frequency of 'heat waves'. 30,000 people died in France alone in 2001.
- ❖ Melting of glaciers and polar ice.
- ❖ Rising sea levels.

- ❖ Spread of diseases to higher elevations and more northerly latitudes
- ❖ Earlier spring arrival (Mean of 2.3 days per decade)
- ❖ Population declines of polar bears and penguins
- ❖ Extensive reviews support the conclusion that global surface temperatures have increased by 0.6° C during the last century.

Past Changes

- During the past 2 million years, there have been at least 10 cycles of warming and cooling.
- These events are often accompanied by increases in extinctions. Smaller warming and cooling trends during the past 1,000 years are tightly correlated with agricultural output.
- Following the last glaciation of North America, trees species migrated southward at a rate of ~25 km per century.

Predictions

- Predictions for the next century range from increases in average temperature of anywhere to 1.4° C to 5.8° C.
- Increases will be greatest at high latitudes and over large continents.
- Rainfall will increase globally, but will vary by region.
- Increase in extreme weather events.

Extinction

- ❖ Global warming has already been implicated in numerous population extinctions and at least two species extinctions (Pounds et al. 2007)
- ❖ 10-20% of all species on Earth are expected to go extinct by 2050.

Why This Change is Different

- Species habitat are smaller than in the past.
- Species habitats are more fragmented than in the past.