The Science of Biodiversity

Our planet's biodiversity --its immense variety of animals and plants -- is threatened. Scientists need to be able to teach the public about biodiversity, why it's endangered, and why even the smallest organism can make a difference.

The Present State of the Earth's Biodiversity

Biodiversity is short for biological diversity. It describes the variety of living organisms of all kinds -- animals, plants, fungi, and microorganisms -- that inhabit a particular area. Most commonly, biodiversity is measured by the number of species present in an ecosystem, but genetic diversity within those species and the diversity of different ecosystems across the landscape are also important. The diversity of subdivisions of species, such as subspecies and populations, is important as well, since it is the raw material for the evolution of new species in the future.

The Enormous Variety of Species

Scientists have identified and described about 1.4 million species. Only a small proportion of these are the organisms we're commonly acquainted with: of the 1.4 million known species, only about 4,000 are mammals and 9,500 are birds. Over half of all known species are insects. Far more species in the world remain unknown to science. Estimates of just how many vary, but there are probably between two and twenty times as many unknown species as known ones.

Most of the planet's biodiversity is in the tropics. Tropical forests, which take up only about 7 percent of the Earth's land area, house about half its species. The canopies of tropical trees are especially diverse. In a single tree in Peru, for example, 43 species of ants were found -- about the same number as live in the entire British Isles.

The great majority of species are rare. In most ecosystems, there are just a few common species (e.g., white oak in eastern US forests) and a much larger number of rare species (e.g., bitternut hickory, hackberry, slippery elm, Kentucky coffee tree, shingle oak). This rarity is one of the reasons why so many species remain unknown and also why so many are vulnerable to extinction.

The Massive Extinction of Modern Times

Massive extinctions have occurred five times during the earth's history -- most notably about 65 million years ago, when about 15 percent of living species, including the dinosaurs, died out; and about 245 million years ago when over 60 percent of all living species disappeared. There is strong scientific evidence that we are now in the opening phase of a sixth massive extinction. This extinction is unprecedented in both its breadth and speed. In the past 10,000 years, and especially the past 500, the rate of extinction of species has increased to somewhere between 100 and 1,000 times what it was before human history began.

Scientists' conservative estimates suggest that a significant percentage of the world's species are likely to become extinct within the next several decades. Unlike all previous episodes of mass extinction, the one now under way is human-caused and can be stopped by timely action.

The most common reason for the loss of biodiversity is loss of habitat. Species become extinct when the places they live are destroyed: when forests are cut down, wetlands are polluted, or prairies are plowed up. Two other causes are also significant: overexploitation such as hunting and collecting and the introduction of foreign species such as predators and diseases.

Islands are especially vulnerable to species extinction. Because of their isolation, many unique species have evolved on islands. When predators are introduced or habitat is destroyed, these species have nowhere to escape. As many as 2,000 species of birds have become extinct in the Pacific since human settlement: nearly 20 percent of the number of bird species that exist worldwide today. This is why ecologists are so concerned about the fragmentation of terrestrial ecosystems into "habitat islands."

The concentration of many endangered species in small areas also makes them especially vulnerable to climate change. Species on mountaintops or islands, for example, cannot easily migrate to new areas if global warming makes their environment too hot or too dry for them. In some areas, the ranges of endangered species are extremely small, and the dangers correspondingly great.

The Benefits of Biodiversity to Humans

Humans benefit from biodiversity in many ways. Besides the animals and plants that we use for food, shelter, raw materials, and companionship, there are thousands of species whose natural products are literally life-saving. Indeed, many ecosystems provide invaluable services to humanity without most of us even realizing it.

Useful Products from the Wild

Nearly 25 percent of the drugs used in the United States originally came from plants. The total economic value provided by plant-based anticancer drugs in the United States is over $250 billion a year. One of the best-known examples of the medical value of a species previously considered worthless is the anticancer drug taxol. This drug was originally extracted from the Pacific yew, Taxus brevifolia, a small tree of the old growth forests of the Pacific Northwest. Taxol has become the standard treatment for advanced cases of ovarian cancer, which strikes 24,000 women every year. Until the discovery of taxol's effectiveness, the Pacific yew was considered a "weed tree" of no economic value.

Another plant whose economic value was recently discovered is the Lake Placid mint, a rare herb of the scrublands of central Florida. This species occurs in only 300 acres on a protected biological station. It has been found to contain a natural insect repellent that deters ants, as well as a powerful antifungal compound with potential medical uses.

Two compounds derived from African plants are now being used as sugar substitutes. Thaumatin, derived from the katemfe bush of West African rain forests, is 100,000 times sweeter than table sugar. Brazzein, a protein derived from the fruit of an African vine,

was discovered as a spin-off from studies of the eating habits of monkeys. It is 2,000 times sweeter than sugar and, unlike substitutes such as saccharin and aspartame, it retains its flavor over time, is nontoxic, and remains stable when heated.

Such recently discovered examples -- as well as long-known ones such as quinine, penicillin, and aspirin -- demonstrate that conserving even apparently "useless" organisms can produce enormous benefits. Since only about 5 percent of the 250,000 known plant species have been analyzed for their medicinal properties, thousands more such compounds may be waiting to be discovered.

Genetic Diversity

Beyond the number of species that exist, it's also important to conserve genetic diversity within individual species. Populations that fall below 1,000 breeding adults may suffer severe genetic problems that can threaten their long-term viability. Called "inbreeding depression," this phenomenon can lower the fitness of offspring to the point that the population's survival is threatened.

Genetic diversity is particularly important in domesticated plants and animals and their wild relatives. The breeding of new strains of pest-resistant crops and livestock is critically dependent on the supply of new genetic variability. This variability has been provided to scientists by wild relatives of domestic plants and animals, and by the thousands of cultivated varieties grown by peasant farmers around the world. The importance of such genetic diversity was proved by the southern corn leaf blight outbreak of 1970, which destroyed 15 percent of the crop -- the greatest economic loss in a single crop in a single year in the entire history of agriculture. This devastating blight spread rapidly across the United States because of the lack of genetic diversity in US corn varieties.

Biodiversity in Ecosystems

Individual species within ecosystems, as well as ecosystems as a whole, are vital to human society.

The Role of Even the Smallest Organism

Many of the benefits of biodiversity conservation come from "ecosystem services," whose very existence may go unrealized. Even species that appear unimportant may actually play a critical role in maintaining ecosystem health and productivity.

Songbirds in Missouri were recently found to increase the productivity of white oak forests by controlling the populations of leaf-damaging insects that feed on white oak saplings. Without the birds, the saplings had twice as many insects feeding on them and lost twice as much of their leaf area.

Soil nitrogen -- a key element for agricultural productivity -- depends on bacteria such as Rhizobium, which live in the roots of leguminous plants. Although three-fourths of our atmosphere is nitrogen, crop plants cannot absorb the gas directly. It must first be converted to the nitrate form by a process known as fixation. The legume-Rhizobium

symbiosis is responsible for the fixation of 80 million tons of nitrogen each year -- twice as much as the total industrial production of nitrogen fertilizer.

Microorganisms often prove to have unexpected values to science because of their ability to carry out chemical reactions. A major breakthrough in genetic engineering -- the polymerase chain reaction technique used to make copies of DNA -- was only possible because of the discovery of a heat-stable enzyme in bacteria living in the hot springs of Yellowstone National Park.

The lesson of these examples is simple: even the most obscure organisms in an ecosystem are worth conserving.

The Value of Diverse Ecosystems

The quality of the water we drink, the air we breathe, and the soil in which we grow our food depends on the integrity of natural ecosystems. People have long recognized the role of healthy forests in reducing erosion, preventing flooding, maintaining the purity of the water, and tempering climatic fluctuations. In recent years we've come to see that other ecosystems have similar values.

Wetlands such as swamps, marshes, and mangroves filter large quantities of pollutants from the water. They also serve as breeding grounds for thousands of species of wildfowl, fish, and shellfish, and thus are vital to the productivity of our lakes and oceans.

Air quality, too, depends on healthy natural ecosystems. By absorbing the pollutants produced by our industries and vehicles -- sulfur and nitrogen compounds, ozone, and heavy metals -- healthy forests and grasslands help to keep the air breathable and reduce damage caused by acid rain. But this pollution can eventually overwhelm the resistance of ecosystems, lowering their absorptive capacities, damaging the trees and grasses, and causing their more sensitive species (e.g., lichens) to disappear.

The productivity of the soil also depends on maintaining a diverse, healthy community of organisms. Plants need a variety of microorganisms to grow: bacteria and algae for nitrogen and fungi for phosphorus. Livestock need a diversity of microbes in their stomachs in order to digest the grasses they eat. Equally important to ecosystem productivity are the insects, fungi, and microorganisms that decompose manure and dead animals and plants, returning their minerals to the soil.

According to recent data, many US ecosystems are already highly endangered. The Department of the Interior has identified 30 different ecosystem types as having been reduced in area by 98 percent or more, including the longleaf pine forests of the deep South, the tall-grass prairie of the Great Plains, and many kinds of wetlands.

Since the most common threat to species' survival is the loss of habitat, preserving endangered ecosystems is an important way to protect the endangered species within them, as well as preventing other species from becoming endangered. The reverse is also true: by protecting endangered species, we prevent the breakdown of the ecosystems in which they live.