

Biodiversity encompasses the diversity of life – the varying and different species, genes and ecosystems of the Earth. The ongoing loss of biodiversity threatens human well-being and makes the need for conservation ever more pressing.

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Introduction

Biodiversity encompasses the diversity of life – the varying and different species, genes and ecosystems of the Earth. Given the myriad interconnections amongst all the forms of life, the loss of a species or variation within a species, or the diminishment of an ecosystem has the potential to threaten the rest of life, including humans. The current global rate of species extinction is between 1,000 and 10,000 times the normal and 60% of ecosystem services worldwide are either degraded or being used unsustainably. Whether one values biodiversity for the services it provides to humans, or instead sees all species and ecosystem as having a right to exist, the accelerating loss of biodiversity, driven largely by the development of natural lands, makes the need for conservation ever more pressing.

Background

The last word in ignorance is the man who says of an animal or plant: What good is it? If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of aeons, has built something we like

but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering. – Aldo Leopold, A Sand County Almanac (1949) p. 190

Definition

Biodiversity is not simply another word for species diversity or a measurement of the number species occurring in a certain area. It encompasses the diversity of genes, species and ecosystems (Keesing et al., 2010). According to the International Union for Conservation of Nature (n.d.), biodiversity is:

the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

Biodiversity is the foundation of life on Earth. It is “extremely complex, dynamic and varied like no other feature of the Earth.” (IUCN, n.d.) It is

the totality of life on earth across all organizational levels, such as genes, populations, species, communities, ecosystems, and landscapes (ecoregions and biomes), as well as the interactions and processes that sustain each level, and the range of variability within all levels, across space and time. (Wilson, 2011, p. 15)

Biodiversity is “what makes it possible for millions of species, including people, to exist” (IUCN, nd.).

Loss of Biodiversity

We are losing biodiversity at an alarming rate. In terms of species richness, the global rate of species extinction is between 1,000 and 10,000 times the normal background rate. In the past 450 million years, there have been five mass extinctions. The last mass extinction, thought to be caused by an asteroid, resulted in the disappearance of dinosaurs. We are now experiencing a sixth mass extinction, with rates similar to the last five. This time, humans are the asteroid (Wilson, 2011).

Although concerns about threats to species diversity tend to focus on impressive species like whooping cranes and tigers, there are equal or greater threats to small organisms such as arthropods and microbes. Small organisms are often more specialized and adapted to certain plant species and habitats than are large animals, and therefore they are more susceptible to extinction through the loss of a specific plant species (Pimentel et al., 1992).

Keystone Species

The loss or range reduction in one species may substantially change the abundance of other species found in association with it, or there may be little impact beyond that one species. A keystone species is one whose impact on its environment is both strong and disproportionate to its relative abundance, as measured by biomass or productivity. If the keystone species is removed, the remaining ecosystem may experience a dramatic shift, even though that species was only a small part of its physical presence. Keystone species can impact ecosystems in several ways:

- **Through the types and amounts of food they eat:** A commonly cited example is the sea otter in the northeastern Pacific Ocean, which have a voracious appetite for sea urchins. Sea urchins feed upon kelp, and without the otters, the sea urchin population would explode and kelp forests, which offer abundant food and habitat for fish and other animals, would be decimated.
- **As engineers or earth movers who change the physical structure of the ecosystem:** The American beaver is an example of an engineer. See the section below for more information.
- **As pathogens and parasites which regulate the overall species abundance in an ecosystem:** Parasites and pathogens can reduce the numbers of more successful competitors, leading to numerical dominance by an otherwise weaker competitor.
- **As system processors that affect the rate of nutrient transfer** (Schulze, & Mooney 1994): Grizzly bears are examples of system processors, as they leave about half of the salmon carcasses they harvest on the forest floor, which then provide food for bacteria and other animals (Reimchen, 2011).

Keystone Species in Pennsylvania

In Pennsylvania, the American beaver (*Castor canadensis*) is an example of a keystone species because

of the dams it builds and the wood it cuts to build them. These activities alter stream morphology and hydrology, significantly impacting the riparian ecosystem. A vast number of other species rely on the altered habitat beavers create. According to Naiman (1988), the dams

retain sediment and organic matter in the channel, create and maintain wetlands, modify nutrient cycling and decomposition dynamics, modify the structure and dynamics of the riparian zone, influence the character of water and materials transported downstream, and ultimately influence plant and animal community composition and diversity.

Causes of Loss of Biodiversity

Habitat Loss and Fragmentation

The main cause of biodiversity loss is the development of natural lands and loss of natural habitat. Natural habitat has been lost from 58% of the United States' land and more than half of the country's original wetlands have been filled. Each year, 1.6 million acres of open space are lost to development and the remaining natural lands are increasingly fragmented, isolated, and lacking in natural ecological processes, which limits their ability to provide necessary habitat (Wilson, 2011). Habitat destruction and degradation are the largest threat to species, contribute to the endangerment of 85% of imperiled species (species especially vulnerable to extinction) (Wilcove, Rothstein, Dubow, Phillips, & Losos, 1998).

Invasive Species

Competition with, or predation by, invasive species is the second largest threat to species, impacting 49% of imperiled species (Wilcove et al., 1998). Habitat loss and fragmentation play an important role in increasing the presence of invasive species. Fragmentation is the process by which large expanses of habitat are divided into smaller, isolated patches by development or resource extraction such as roads, buildings, drilling or timbering. The new forest edges created by fragmentation provide points of entry for nonnative species. On roads, automobiles carry seeds of invasive plants on their undercarriages and tires and spread them miles away. The cars create air turbulence, which further spreads seeds along roads. Residential development often brings with it plantings of exotic plants, whose seeds can escape into nearby natural areas. And the new edges give a competitive advantage to predatory animals, such as brown-

headed cowbirds, foxes and skunks, which are well adapted to edge habitat.

For more information on forest fragmentation, see the guide *The Environmental Impacts of Forest Loss and Fragmentation*. (forest loss and fragmentation guide coming soon.)

Pollution

Pollution is the third largest threat to species, contributing to the endangerment of 24% of all imperiled species. For aquatic animals, it is the second leading cause of endangerment. Aquatic pollution, including siltation, is drastically increased when natural lands, especially riparian buffers, are lost. Riparian buffers – the lands and complex assemblage of plants bordering rivers, streams, bays and other waterways – naturally filter pollutants and nutrients from water. Rainwater and snowmelt can soak into natural lands and be slowly released into waterways. In contrast, water flows over nonporous surfaces such as roads, parking lots, turf grass, rooftops and construction sites, picking up dirt and pollutants and carrying them into water bodies. For more information on the impacts of habitat loss on water quality and aquatic species, see the guide [Natural Lands, Water Quality and Aquatic Species](#).

The Importance of Conserving Biodiversity

The importance of biodiversity is often looked at in two ways: intrinsic value and the value of the services it provides to humans. In the intrinsic view, biodiversity is worth protecting, regardless of its value to humans. All species and ecosystems have intrinsic value and have a right to exist simply because they already exist. In the services view, biodiversity is important because it provides a number of ecological services to people.

Ecosystem Services

Biodiversity provides multiple services to humans, many of them essential for continued life. These include the production of clean air and water, wild animals for hunting and food crop pollination, carbon sequestration, forestry and fisheries products, fertile soils, plant species for medicine, gene pools for agricultural breeding, aesthetic beauty, and open spaces for outdoor recreation. Studies in recent years have suggested that the conservation of biodiversity improves the ability of an ecosystem to retain nutrients and remain productive (Cardinale, 2011).

However, according to the Millennium Ecosystem Assessment (2005), 60% of ecosystem services worldwide are either degraded or being used unsustainably. Ecosystem services that have been degraded over the past 50 years include fisheries, water supply, waste treatment and detoxification, water purification, natural hazard protection, regulation of air quality, regulation of regional and local climate, regulation of erosion, spiritual fulfillment, and aesthetic enjoyment.

Species Contributions Vary Over Time

Research has found that many species are needed to maintain a functioning ecosystem in the long-term, at different places and under varying environmental conditions (Isbell et al., 2011). Researchers reviewed 17 studies of the importance of biodiversity in grasslands (which included studies of 147 grassland plants). They found that, although a small number of species could provide an ecosystem service in one year, under one set of conditions, most of the 147 plant species were important at least once for the maintenance of that service because different sets of species provided services at different years under different environmental conditions and at different places.

This research supports the precautionary principle for biodiversity preservation, according to which all species should be conserved because we cannot be certain which species actually provide ecosystem services. According to researcher Forest Isbell,

This means that biodiversity is even more important for maintaining ecosystem services than was previously thought.... Our results indicate that many species are needed to maintain ecosystem services at multiple times and places in a changing world, and that species are less redundant than was previously thought. (McGill University, 2011).

Examples of Ecosystem Services

The following subsections elaborate on some of the ecosystem service reasons for protecting biodiversity.

Disease Prevention

A loss of biodiversity has been shown to cause an increase in the spread of disease. Researchers speculate this is because some species are better at buffering disease transmission. Species that have low rates of reproduction or invest heavily in immunity (and so would be less likely to be disease hosts) tend to be more strongly impacted by biodiversity loss than those with high reproductive rates or those that invest less in immunity (and would consequently be more likely disease hosts) (Keesing et al., 2010). This tie

between biodiversity and the spread of disease is seen in eastern North America in the spread of Lyme disease. The white-footed mouse is simultaneously the most abundant and competent host species for the Lyme bacterium and the highest-quality host for immature tick vectors. Virginia opossums are poor hosts for the pathogen and kill the vast majority of ticks that attempt to feed on them. Virginia opossums however are absent from many low-diversity forest fragments and degraded forests, places where the mice are abundant. The decline in opossum population leads to an increase in the transmission of Lyme disease (Keesing et al., 2010).

Another example is the West Nile virus, a disease transmitted by mosquitoes, with birds as hosts. Three studies found strong correlations between low bird diversity and increased risk of people contracting the disease. Birds that are good hosts for the West Nile virus tend to dominate areas where avian diversity is low. When avian diversity is high, there are many species of birds that are less competent hosts, thus lessening the prevalence of the virus (Keesing et al., 2010).

Improved Water Quality

Over the past century, humans have more than doubled the rate of nitrogen input onto land, mostly through burning fossil fuels and application of agricultural fertilizers. Excess nitrogen flows into streams and rivers, where it contributes to an excessive supply of nutrients, one of the leading causes of degraded water quality worldwide (Cardinale, 2011).

Research has shown that the more biologically diverse a stream is, the better it will be able to remove these nutrients. One of these research studies looked at the removal of nitrogen by different kinds of algae. When nitrogen removal in water containing between one and eight different kinds of algae was studied, (all with the same total amount of algae), there was a linear increase in the nitrogen uptake as the number of different kinds of algae increased. Together, the eight species of algae removed an average of 4.5 times more nitrogen than a single species alone (Cardinale, 2011).

This has led to the conclusion that the conservation of biodiversity could be a useful tool in managing the uptake and storage of excess nutrients. According to researcher Bradley Cardinale,

...naturally diverse habitats are pretty good at cleaning up the pollutants we dump into the environment, and loss of biodiversity through species extinctions could be compromising the

ability of the planet to clean up after us.

(University of Michigan, 2011)

(For more information on the problems with excess nutrients, see the guide [Natural Lands, Water Quality and Aquatic Species](#).)

Forestry Products

Mixed forests have a higher rate of biomass production than do homogeneous stands of trees. Because each tree has specific nutrient requirements, mixed stands make more effective use of the complex nutrients in soil (Pimentel et al., 1992). Homogeneous stands are also more susceptible to disease and animal pests, as harmful microbes, insects and other pests tend to be associated with specific tree species. Monoculture tree stands are at greatly increased risk for destruction by insect pests and disease as compared to a diverse tree stand.

Genetic Diversity and Buffer from Change

Although individuals of a species appear uniform, there is often a great deal of genetic variability within the species. Large, genetically diverse populations maintain a wide range of variations. Some of these are advantageous or disadvantageous in the present environment and many are neutral. Some variations may be advantageous in adapting to future conditions, but it cannot be predicted which ones will be beneficial (Loo, 2009). Genetic diversity is necessary to allow evolutionary processes over the long term, whether the changes are gradual or catastrophic, natural or human-induced.

In the face of rapid and catastrophic environmental change, resulting from high CO₂ levels, the importing of exotic diseases, parasites, herbivores or predators, the widespread loss of forests, desertification, or changing temperatures, the survival of species may depend upon the existence of particular pre-adapted variants in existing populations. (Loo, 2009, p. 4)

Unknown Values

Nature is extremely complex, interdependent, and interconnected, in ways we do not often understand. This argument suggests that the best way to protect the parts we do value and understand may be to keep all of the parts.

Biodiversity in Freshwater Ecosystems

Loss of Biodiversity

Globally, freshwater ecosystems cover just 0.8% of the Earth's surface yet contain almost 9.5% of the Earth's known species (Nobles & Zhang, 2011), including 25% of all vertebrates and 40% of all fish (Dudgeon et al., 2006). Freshwater ecosystems may well be the most endangered ecosystems in the world. Declines in biodiversity are far greater in fresh waters than in most terrestrial ecosystems, matching the extinction rate of tropical rainforests (Nobles & Zhang, 2011). In North America, extinction rates of freshwater animals, based on combined data sets for unionid mussels, crayfishes, fishes and amphibians, is five times higher than species losses calculated from any terrestrial habitat (Ricciardi & Rasmussen, 1999).

Habitat Loss and Degradation

The threats to global freshwater biodiversity can be grouped into five interacting categories: overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasive species. Environmental changes such as climate change and shifts in precipitation are superimposed upon all of these threat categories (Dudgeon et al., 2006). Two of these threats are highlighted below.

Pollution problems are pandemic and are closely linked to terrestrial habitat destruction. Their position in the landscape (almost always in valley bottoms) makes lakes and rivers 'receivers' of the wastes, sediments and pollutants in storm runoff. Although considerable progress has been made in reducing water pollution from domestic and industrial [point sources](#), threats from excessive nutrient enrichment and other [nonpoint source](#) chemicals such as endocrine disrupters are growing, which lends especial importance to the preservation and restoration of riparian buffers and the pairing of farmland preservation programs with programs to teach and implement best management practices.

Aquatic habitat degradation is brought about by an array of interacting factors. It may involve direct impacts of human activities (such as excavation of river sand) or indirect impacts that result from changes within the drainage basin that are carried downstream. Loss of natural terrestrial lands especially impact freshwater habitats. For example, when a forest is cut down, increased surface runoff brings greater sediment loads that smother river bottom habitats both near the cleared area, and further downstream. Because animals use different parts of

the river, and sometimes live on both land and water, they are at risk from different environmental stresses throughout the various parts of their habitat.

(See [Environmental Benefits of Conservation: Water Quality and Aquatic Species](#) for more information on habitat preservation and the prevention of water pollution.)

Case Study: Freshwater Mussels

Importance in the Ecosystem

Unionids (freshwater mussels) provide several essential ecosystem services, including water filtration and habitat provision. They are filter feeders; as water moves through their cilia, fingerlike structures on their gills, they catch and remove particles, eating some and spitting out others. Large unionid populations can filter an amount of water equal to, or greater than that of the average daily stream discharge (the volume of water which flows through a stream each day) (Nobles & Zhang, 2011). Unionids remove large amounts of phytoplankton, bacteria and inorganic nutrients. *E. coli* and the blue-green algae that cause taste and odor problems in water are favored foods. Their shells create habitat, stabilize sediment and provide habitat for bottom dwelling animals. Large populations correlate to higher overall levels of freshwater biodiversity.

Threats to Unionid Populations

Scientists regard unionids as the most imperiled of all organisms in North America (Nobles & Zhang, 2011) and the rate of their decline has been described as catastrophic (Vaughn & Hakenkamp, 2001). Nearly 75 percent of North America's 300 freshwater mussel species are in decline or heading toward extinction (ANS, 2012), half are classified as threatened with extinction and a further 37 species are already presumed extinct (Cambridge, 2011).

Freshwater mussels possess a suite of traits that make them especially vulnerable to habitat destruction and alteration. The persistent influx of excess organic nutrients and pollutants, increased stormwater runoff, increased sediment, loss of steady year round water flow and loss of temperature moderation caused by the loss of natural lands are widespread problems for unionid populations. (For information on how the loss of natural lands cause these problems, see the guide [Impacts of Natural Land Loss on Water Quality](#))

The loss of these functions impacts unionids in several ways, all of which are compounded by the fact that they are sedentary animals, and unable to move away from highly impacted areas. Unionids typically live buried in fine substrate in streams and rivers.

Increased stormwater runoff scours river bottoms and destroys their habitat while increases in fine sediments can smother unionids by overwhelming their filtering capacity (Machtinger, 2007). Increased pollutant levels impact unionids because have high toxin accumulation rates (Machtinger, 2007). Increased nutrients in the water can lead to a [rapid depletion of the oxygen](#) they rely on. Large swings in water temperature threaten breeding, which requires specific water temperatures. Increased nutrients, pollutants and sediment also impact the host species of fish required by the unionids for the first stage in their life cycle (Machtinger, 2007).

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The Pennsylvania Land Trust Association would like to know your thoughts about this guide: Do any subjects need clarification or expansion? Other concerns? Please contact Andy Loza at 717-230-8560 or aloza@conserveland.org with your thoughts. Thank you.

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