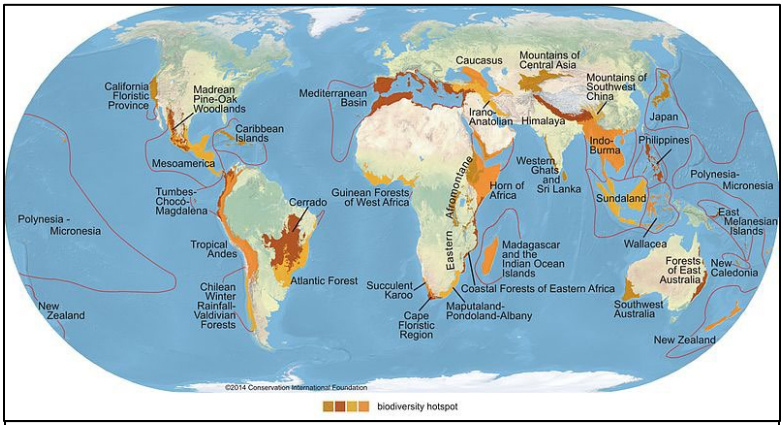
A Guide to Extinction and Conservation

Understanding Biodiversity

Simply defined, **biodiversity** is the variety of life on Earth, including all its forms, levels, and combinations. Biodiversity is often explored at three levels: ecosystem, species, and genetic diversity. The highest level of biodiversity is **ecosystem diversity**. This level includes the variety of physical settings and communities where organisms live and evolve. Examples include rain forests, wetland, tropical reefs, and grasslands. A **species** is a group of individual organisms that have many of the same characteristics, and are different from all other organisms in some distinct and important way (see "What is a Species?" on page xx for more information). **Species diversity** includes the variety of plants, microorganisms, and animals on Earth. The most basic units of all life on Earth are **genes**. **Genetic diversity** is the variety of hereditary characters found in a breeding population. In general, the more unrelated organisms are in a breeding group, the greater genetic diversity that group has, resulting in a greater viability of the population as a whole. The loss of genetic variation reduces a population's or species ability to survive environmental changes or disease outbreaks.

Biodiversity Hotspots

In equatorial (tropical) ecosystems, biodiversity is the highest, and it gets progressively less moving up into polar ecosystems. Island ecosystems, such as the Hawaiian islands, Madagascar, and Indonesia also have high levels of biodiversity. Around the world, 36 areas are deemed **biodiversity hotspots**. These hotspots contain high levels of **endemism** (species that are found nowhere else) and are severely threatened. Despite representing only about 2.4% of Earth's land surface, biodiversity hotspots support more than half of the world's plant species and nearly 43% of the world's bird, mammal, reptile, and amphibian species. High levels of diversity in these areas makes them more vulnerable to losing species.



Biodiversity hotspots around the world.

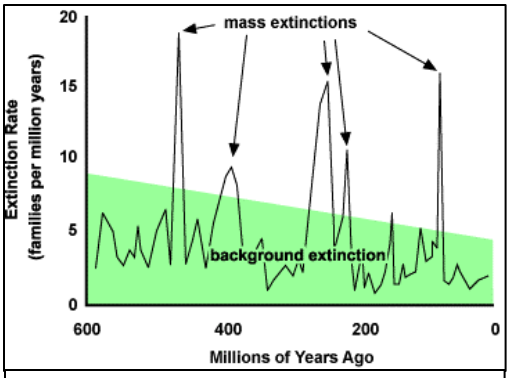
Image Credit: Conservation International
https://commons.wikimedia.org/wiki/File:Biodiversity_Hotspots_Map.jpg

The Importance of Biodiversity

The contributions of biodiversity to the quality of life on Earth are immeasurable. Biodiverse ecosystems and organisms are Earth's life support system; they maintain important ecological functions that provide oxygen, fresh water, fertile soil, protection from storms, climate stability, and many other critical services that support life. The IUCN (International Union for the Conservation of Nature) estimates the monetary value of goods and services provided by ecosystems is roughly $33 trillion per year! The economic benefits provided by biodiverse ecosystems is estimated to be 10-100 times the cost of maintaining them.

Extinction through Time

When a species is considered **extinct**, it no longer exists. Extinction can occur for a variety of reasons, and has historically occurred as a natural process throughout Earth's history. Earth has been in a state of geological flux for hundreds of millions of years. Geological change and biological change go hand-in-hand, as species adapt to survive ever-changing conditions. Should a species be unable to adapt fast enough to these changes, it may go extinct. Populations and even whole species lineages may disappear, leaving opportunities for new and better-adapted organisms to emerge.

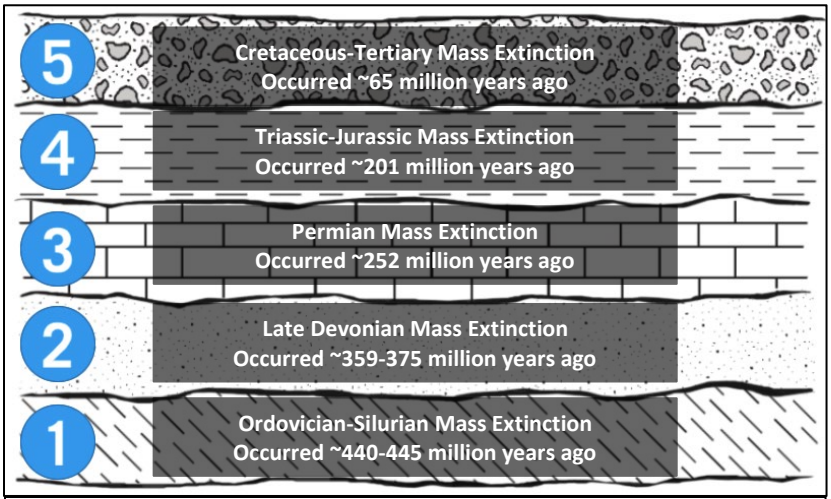


There always exists a low-level extinction rate, known as the background extinction rate. On average one to five species goes extinct each year. Occasionally, species will go extinct at higher rates, resulting in a mass extinction event.

Image credit: Extinction rate graph, Berkeley

Mass Extinctions

According to the fossil record, as few as 2-4% of all species that have ever lived are believed to survive today. As such, throughout Earth's history, many species have gone extinct. If you spread all extinctions out over Earth's 4.5 billion year history, the natural extinction rate (**background extinction rate**) is about one to five species per year, according to the fossil record. A **mass extinction** occurs when the extinction rate greatly exceeds the background extinction rate. Throughout Earth's history, there have been five such extinction events, though scientists agree we are in the midst of a sixth mass extinction caused by human activities. The first extinction to occur was the Ordovician-Silurian Mass Extinction. Most of the life was in the sea during this time period, thus it was mostly marine species affected. It is estimated 85% of species went extinct. The second mass extinction event was the Late Devonian Mass Extinction, which occurred as a series of extinctions over several millions of years. It is estimated that 79-87% of land vertebrates and 22% of marine families went extinct. The Permian Mass Extinction was the third mass extinction event. This event is also known as "The Great Dying" as it is estimated 96% of species went extinct. All life today originates from the 4% of species that survived this extinction event. The Triassic-Jurassic Mass Extinction is the fourth event, during which 22% of marine families, 53% of genera, and 76-84% of species went extinct. The



The Earth is approximately 4.56 billion years old. To put that in perspective, if you wrote a book about Earth's history, devoting on a single page to each year, the book would be about 145 miles from cover to cover (about the distance from Madison to Chicago)! Rock layers contain the story of Earth's history and the fossil record the story of life on Earth. The image above shows Earth's Five Mass Extinctions, in terms of geologic history (i.e. where in the rock layers they would have occurred).

Image adapted from San Diego Zoo Global Ending Extinction: The Basics Module 1

fifth mass extinction event, the Cretaceous-Tertiary (also known as the K/T extinction), is most famous for the extinction of the dinosaurs. However, it is estimated that nearly 50% of the world's species went extinct. This mass extinction made way for mammals to become the dominant species.

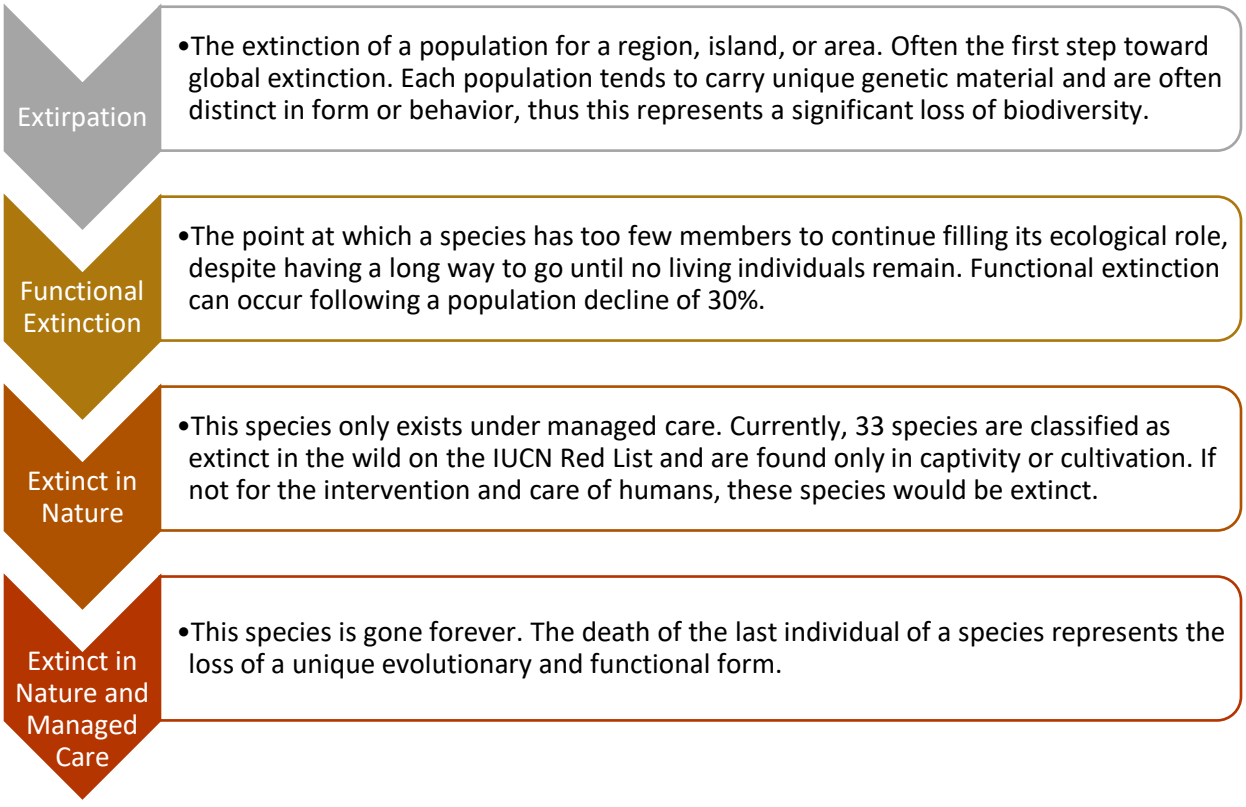
Fossil evidence reveals there is no single cause responsible for the past mass extinctions. However, they share four important commonalities with each other, as well as today's extinction crisis:

- The event caused a catastrophic loss of global biodiversity.
- The result rapidly unfolded (in the context of evolutionary and geological time).
- The extinctions were somewhat systematic, taxonomically speaking. That is, whole groups of related species were lost while other groups survived and remained largely unaffected.
- The event or cause often led to the rise of species that were not previously dominant, due to vacant ecological niches.

Mass extinctions are often followed by **adaptive radiation** events in which a lineage rapidly diversifies to exploit open niches and available resources. However, the term "rapid" is relative. This diversification may take tens of millions of years. After the Permian Mass Extinction, it look 10-20 million years for biodiversity to recover to its previous levels.

Extinction as a Process

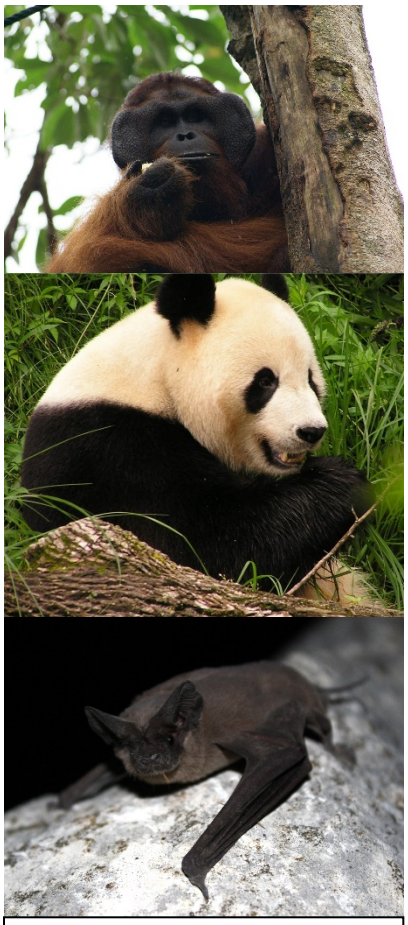
By examining past extinctions, we know that extinction is a process, not a single event. The global extinction of a species typically represents an end point in a long series of population extinctions. Each step of the process represents a loss of unique evolutionary history and genetic diversity. The steps in the process of extinction are **extirpation, functional extinction, extinct in nature,** and **extinct both in nature and in managed care.**



Prone to Extinction

While human activities are the primary cause for the current extinction crisis, some species have natural traits that make them more vulnerable to extinction than others. Species that possess more than one of these characteristics are particularly at risk. These traits include:

- **Large Species**: These species require more space, and as such are more likely to face exploitation or conflict with humans as they compete for resources.
- **Species with a naturally small population or range:** The smaller the population, the lower its genetic diversity tends to be. These species can have a harder time adapting to environmental changes due to the low genetic diversity. Species with a small range or population are also particularly vulnerable to extinction from habitat loss, exploitation, or the introduction of invasive species.
- **Slow reproducers:** Species with a naturally low birth rate have a limited ability to recover from population losses. Contrarily, fast-reproducing species have shorter generation times and tend to be more resilient to population losses, recovering more quickly.
- **Species with specialized food requirements**: Animals with special dietary needs need to forage over large areas to find their food, making them more vulnerable to habitat loss.
- **Species with specialized habitat requirements**: These species are more easily affected by local catastrophic events, particularly if their habitats are small or widely dispersed.
- **Species that are very sensitive to environmental change**: Some species have a very difficult time adapting to changes in their environment. Birds of prey are particularly sensitive to chemical changes; some species have a hard time competing with introduced species that occupy a similar niche; amphibians and corals are sensitive to water quality changes.
- **Species that have economic value or interfere with human activities**: Some species have a commercial value for their meat, fur, oil, horns, or tusks. Other species may interfere with economic activities, such as agricultural pests or animals that prey on livestock. The fishing industry and increasing demand for seafood have led to dramatic declines in some fish populations.
- **Species that migrate**: Migratory species generally depend on several different habitats, making them more vulnerable to habitat destruction.



Orangutans are naturally slow reproducers. Females only have one offspring at a time, which usually stays with the mother for six to seven years.

Giant pandas are specialized feeders; their primary diet consists of bamboo.

Many species of bats rely on caves with specific temperature and humidity levels to roost and hibernate. When hibernating, these bats are essentially helpless to mass mortality from various environmental disturbances.

Modern Causes of Extinction

Past mass extinctions have been the result of such catastrophic events as asteroid impacts, volcanic eruptions, drastic climate change, ocean acidification, or some combination thereof. However, the current mass extinction is largely caused by human activity. Discussed below are some major causes of extinction species face today.

- **Habitat Loss:** It has been estimated that more than 80% of the Earth's surface and 40% of the world's original forest cover has been modified by human activity. Thus, habitat loss is considered the greatest threat to plant and animal species. Habitat loss occurs in three major forms:
    - **Habitat Destruction:** The direct destruction of habitats where they can no longer provide the food, water, or shelter species need to survive. Examples include filling in wetlands, cutting down forests, and dredging rivers.
    - **Habitat Fragmentation:** Fragmentation occurs when wildlife habitat is broken up into fragments by roads, agriculture, and/or development. It isolates species from one another, reducing genetic diversity. Fragmentation makes it more difficult and dangerous for individuals or populations to find food, whether it's the threat of vehicles or collisions with buildings.
    - **Habitat Degradation:** Pollution, introduction of invasive species, and disruption of natural processes (such as hydrology) are some ways habitats can become too degraded to support wildlife.
- **Invasive Species:** An invasive species is a plant or animal that does not belong where humans have brought them, either intentionally or accidentally. Without natural controls, such as predators, these species often thrive, out-competing native species in the habitat. Other threats posed by invasive species include predation on native species, introducing diseases, or destroying/degrading the habitat.
- **Exploitation:** Many plant and animal species are being harvested or killed at an unsustainable rate. Hundreds of millions of plants and animals are caught or harvested from the wild each year for food, pets, ornamental plants, leather, tourist curios, or medicines.
- **Diseases:** Introduced diseases can cause dramatic population declines, die-offs, or reductions in reproductive success. The Global Amphibian Crisis is caused by a chytrid fungus; canine distemper and rabies have had major impacts on large carnivores; white-nose syndrome began plaguing bats of North American in 2006, which has led to 100% mortality rates in some areas.
- **Pollution:** Many products and activities that make modern human life possible are polluting the planet. Even places that are relatively untouched by 21st century developments experience the effects of pollution. Pollution comes in a variety of forms, such as untreated sewage, mining waste, pesticides,

White-nose syndrome is a disease caused by an invasive fungus known as *Pseudogymnoascus destructans*, or *Pd*. Since its discovery in a single cave in New York, WNS has killed 5.7 million bats and now threatens 7 bat species in 25 states and 5 Canadian provinces. WNS causes bats to wake up more often during hibernation, using up stored fat reserves needed to get them through the winter.

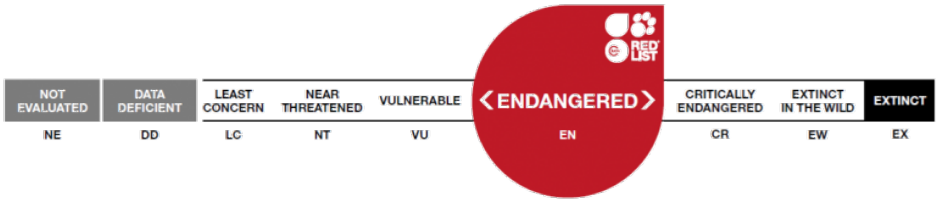
noxious gases, sound, and light pollution. These all can have dramatic effects on food webs, breeding, and other life processes.

- **Climate Change:** This topic is complex and has its own section. See "An Introduction to Climate Change" on pages xx-xx for more information.

Monitoring Endangered Species

The **International Union for the Conservation of Nature (IUCN)** is the largest overseer of work related to conservation of biodiversity. It is a large network consisting of scientists, governments, non-governmental organizations (NGOs) working to support the conservation of nature through research and restoration, development of laws and policies, and providing supportive resources. In 1964, the **IUCN Red List** was established as has become the most authoritative and comprehensive status assessment of global biodiversity, guiding conservation efforts at all levels around the world. The Red List defines the severity and specific causes of a species' threat of extinction. Classification as endangered has to do with the extent and severity of threat a species faces, taking into account habitat and range, in addition to population size. The Red List classifies species into nine categories. Three of the categories are considered threatened categories and to be placed in one of these categories, a species must meet at least one of the following criteria, though as many criteria as data permit should be assessed. Each criteria has a numerical threshold that designate should the species be classified as **vulnerable, endangered,** or **critically endangered**. The criteria are as follows:

A. Declining population (past, present, and/or projected)
B. Geographic range size, and fragmentation, decline, or fluctuations
C. Small population size and fragmentation, decline, or fluctuations
D. Very small population or very restricted distribution
E. Quantitative analysis of extinction risk (e.g. population viability analysis)



The nine categories listed by the IUCN Red List are:

- **Extinct (EX):** There is no reasonable doubt that the last individual of a taxon has died. Exhaustive surveys are conducted in known and/or expected habitat, at appropriate times (e.g. diurnal, seasonal, annual), and throughout historic ranges. When these surveys fail to record an individual, the taxon is considered extinct.
    - Example: Thylacine (Tasmanian tiger)
- **Extinct in the Wild (EW):** A taxon is known only to survive in cultivation, captivity, or as a naturalized population well outside the past range. Exhaustive surveys as described for extinct are also conducted to classify a taxon as extinct in the wild.
    - Example: Scimitar-horned oryx

- **Critically Endangered (CR):** The best available evidence indicates a taxon meets any of the criteria A to E thresholds for critically endangered. This taxon is considered to be facing an extremely high risk of extinction in the wild.
    - Example: Bornean orangutan
- **Endangered (EN):** The best available evidence indicates a taxon meets any of the criteria A to E thresholds for endangered. This taxon is considered to be facing a very high risk of extinction in the wild.
    - Example: Red panda
- **Vulnerable (VU):** The best available data indicates a taxon meets any of the criteria A to E thresholds for endangered. This taxon is considered to be facing a high risk of extinction in the wild.
    - Example: African lion
- **Near Threatened (NT):** A taxon is considered near threatened when it has been evaluated against the criteria but does not meet the thresholds for critically endangered, endangered, or vulnerable at the time of assessment, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
    - Example: White rhinoceros
- **Least Concern (LC):** A taxon is considered to be of least concern when it has been evaluated against the criteria and does not qualify for a threatened category. Widespread and abundant taxa are included in this category.
    - Example: Rock hyrax
- **Data Deficient (DD):** Data deficient is not a category of threat. A taxon is listed in the data deficient category when there is inadequate information to make an assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category is done with great care and indicates that more information is required and acknowledges the possibility that future research will indicate a threatened classification is appropriate.
    - Example: Killer whale
- **Not Evaluated (NE):** A taxon has not yet been evaluated against the criteria.

For more information, the Guidelines for Using the IUCN Red List Categories and Criteria can be found on the website for the IUCN Red List.