# A4.2 Conservation of biodiversity

Unity and diversity—Ecosystems

**Standard level and higher level: 3 hours**

## Guiding questions

• What factors are causing the sixth mass extinction of species?

• How can conservationists minimize the loss of biodiversity?

## SL and HL

### A4.2.1—Biodiversity as the variety of life in all its forms, levels and combinations

Include ecosystem diversity, species diversity and genetic diversity.

**Biodiversity** is the variety of life across all levels of biological organization in all its forms and combinations. It is of 3 main types:

1. **Genetic diversity**: the amount of genetic variation existing in the gene pool of a species. There are several ways to measure this, including (**HAS**):
   - **H**eterozygosity level via number of heterozygous individuals or genotype frequency
   - **A**verage number of nucleotide differences per site, for any randomly sampled pair of nucleotides
   - **S**ingle polynucleotide polymorphisms (SNPs)
2. **Species diversity**: abundance of species in a given location or on Earth.
   - The **Simpson reciprocal index** (***D***) is one method of measuring species diversity which calculates the probability that two individuals randomly selected from a sample will belong to the same species.

     $$D = \sum_{i=1}^{R} \frac{N(N-1)}{n_i(n_i-1)}$$

     $R$ = total number of species in the sample

     $N$ = total number of individuals in all species in the sample

     $n_i$ = number of individuals in species $i$

     The higher the calculated value of the *D* index, the greater the diversity. The *D* index takes into account both **species richness** (number of different species in a given sample) and **species evenness** (relative abundance of species in a sample; how equally abundant they are).
3. **Ecosystem diversity**: the number of different ecosystems in a given location or on Earth.

Biodiversity is constantly changing due to ecological and evolutionary factors, but there are patterns to it:

- Biodiversity is highest at the equator and decreases towards the poles. There are several hypotheses to explain this, including the existence of relatively many niches in them and the stability of their temperatures
- Biodiversity is higher on land than in the ocean because tropical forests promote more rapid speciation compared to marine ecosystems
- Biodiversity increases as the area containing a species increases; bigger islands are more diverse than smaller islands because they have the capacity to sustain more niches

## A4.2.2—Comparisons between current number of species on Earth and past levels of biodiversity

Millions of species have been discovered, named and described but there are many more species to be discovered. Evidence from fossils suggests that there are currently more species alive on Earth today than at any time in the past.

Millions of species have been discovered, named and described but there are many more species to be discovered. Evidence from fossils suggests that there are currently more species alive on Earth today than at any time in the past, but it is difficult to accurately estimate. Biodiversity increases when rates of speciation are greater than extinction rates, and decreases when the opposite is true.

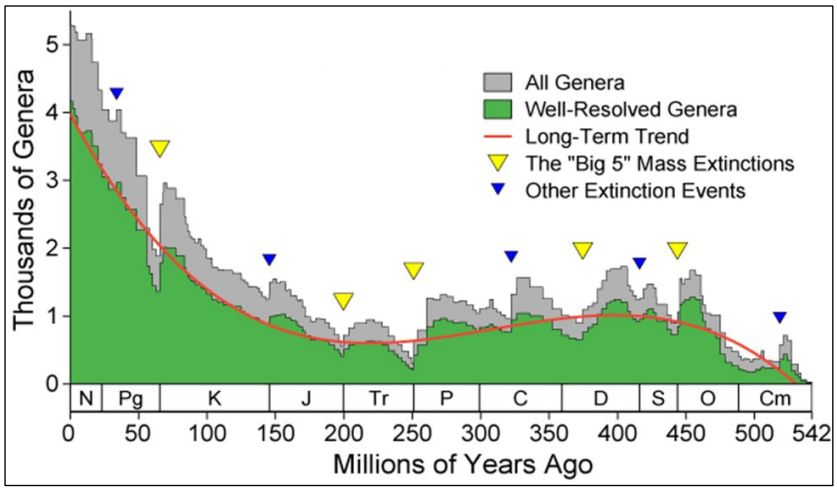


**Figure 1: the number of genera (in thousands), a measure of biodiversity, across the years.**

## A4.2.3—Causes of anthropogenic species extinction

This should be a study of the causes of the current sixth mass extinction, rather than of non-anthropogenic causes of previous mass extinctions.
To give a range of causes, carry out three or more brief case studies of species extinction: North Island giant moas (*Dinornis novaezealandiae*) as an example of the loss of terrestrial megafauna, Caribbean monk seals (*Neomonachus tropicalis*) as an example of the loss of a marine species, and one other species that has gone extinct from an area that is familiar to students.
*Note: When students are referring to organisms in an examination, either the common name or the scientific name is acceptable.*

Scientists believe humans are now causing or about to cause the sixth mass extinction, called the **Holocene (Anthropocene) Extinction**. There is worldwide scientific consensus that this extinction is driven and caused by anthropogenic factors, including (**CHOP**):

1. **Climate change**: greenhouse gases released from human activities are causing rapid changes in environmental variables like temperature, precipitation patterns, etc. Species that are unable to migrate, adapt, or acclimate (exhibit phenotypic plasticity) to such changes will go extinct.
2. **Habitat destruction**: agricultural uses of land to grow crops or care for livestock requires the clearing of forests and natural habitats.
3. **Overharvesting**: overfishing and overhunting for food or ornamentation have endangered many species.
    - For example, the North Island giant moas (*Dinornis novaezealandiae*) are large flightless birds native to New Zealand that have become extinct 600 years ago due to overhunting by human settlers.
    - For example, the Caribbean monk seals (*Neomonachus tropicalis*) is the only marine mammal extinction in the tropics due to overhunting by humans.
4. **Pollution** (air, land, water) releases toxins to the biospheres, causing global warming, eutrophication, soil erosion, etc.

## A4.2.4—Causes of ecosystem loss

Students should study only causes that are directly or indirectly anthropogenic. Include two case studies of ecosystem loss. One should be the loss of mixed dipterocarp forest in Southeast Asia, and the other should, if possible, be of a lost ecosystem from an area that is familiar to students.

Anthropogenic factors can directly or indirectly cause ecosystem loss, including (**WASP CODE**):

1. **Water drainage** is the removal of water from a wetland area for agricultural or land use, which destroys the habitats of many species.
2. **Agricultural expansion** is the deforestation and destruction of natural habitats to clear land for agriculture, which is the leading cause of ecosystem loss due to the growing human population.
3. **Subsurface extraction**: mining and oil drilling disrupt the natural operations of ecosystems and release toxic chemicals into the environment, polluting it.
4. **Population pressure**: the ever-increasing human population inevitably leads to greater consumption of natural resources in an unsustainable manner.
5. **Climate change**: the enhanced greenhouse effect is causing global changes in temperature, one of the most important environmental variables for all species. Any change will lead to major consequences.
6. **Overexploitation** of natural resources, including plants and terrestrial/marine animals, causes a **tragedy of the commons**.
7. **Dam construction** disturbs natural water flow, prevents fish migration, alters water temperature, and affects the nearby soil.
8. **Eutrophication** is a type of human pollution in which water systems are supplied with high concentrations of nitrogen, sulfur, and phosphorus (fertilizer) through sewage outflow or agricultural run-offs, leading to high fish and plant mortality. Algal blooms lead to algal death and eventually ecosystem death as conditions become intolerable for sustaining life.

For instance, deforestation due to logging and agricultural expansion, in addition to urbanization, have both caused the loss of mixed dipterocarp forest in Southeast Asia. This is important because these tropical forests harbor a huge diversity of plant and animal species, so they must be conserved to protect the local ecosystems. They also store a lot of carbon in peat, which is released through human activities into the atmosphere, further contributing to climate change.

## A4.2.5—Evidence for a biodiversity crisis

Evidence can be drawn from Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services reports and other sources. Results from reliable surveys of biodiversity in a wide range of habitats around the world are required. Students should understand that surveys need to be repeated to provide evidence of change in species richness and evenness. Note that there are opportunities for contributions from both expert scientists and citizen scientists.

The **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)** was founded by the United Nations to help assess issues regarding biodiversity and ecosystems. IPBES achieves this by:

1. Identifying and prioritizing important scientific information for governments and policymakers
2. Scientific peer-review of knowledge to ensure reliability and validity of biodiversity surveys
3. Develop methodologies and solutions for the implementation of scientific findings about ecosystems and biodiversity in government policies

IPBES encourages **citizen science** whereby the public aids scientists in data collection and analysis.

### A4.2.6—Causes of the current biodiversity crisis

Include human population growth as an overarching cause, together with these specific causes: hunting and other forms of over-exploitation; urbanization; deforestation and clearance of land for agriculture with consequent loss of natural habitat; pollution and spread of pests, diseases and invasive alien species due to global transport.

Anthropogenic (human-led) factors are the causes of the current biodiversity crisis, including:

1. **Urbanization** requires a large number of resources which are often sought unsustainably
2. **Overexploitation** of natural resources like trees and animals (overhunting) negatively affects interactions between species in ecosystems, increasing their vulnerability to extinction
3. **Deforestation** and clearance of land for **agriculture** both lead to the loss of natural habitats
4. **Pollution** of land and water disrupts ecosystems and kills organisms
5. **Invasive alien species** (like pests or diseases), because they are not native (**endemic**) to locations outside of their usual habitat, can compete with endemic species and predate on them, disturbing ecosystems. Humans exacerbate invasions of alien species by deliberate introduction and global transport.

None of these causes are new to ecosystems but they have been significantly increased in intensity in the last 200 years due to human population growth, which is the overarching cause of the current biodiversity crisis.

### A4.2.7—Need for several approaches to conservation of biodiversity

No single approach by itself is sufficient, and different species require different measures. Include in situ conservation of species in natural habitats, management of nature reserves, rewilding and reclamation of degraded ecosystems, ex situ conservation in zoos and botanic gardens and storage of germ plasm in seed or tissue banks.

Conservation of biodiversity can be done through several approaches (no single approach by itself is sufficient), depending on the requirements of each species and the nature of the crisis. This includes (**MISER**able):

1. **Management of natural reserves**: establishment and management of protected natural areas like national parks, wildlife sanctuaries, and biosphere reserves to protect species in their habitats.
2. **In situ conservation**: maintaining the wilderness of natural habitats by having as little human intervention as possible to preserve the integrity of the ecosystem.
3. **Storage of germ plasm in seed or tissue banks**: preserving genetic material (pollen, seeds, sperm, eggs) at low temperatures to aid in future restoration or breeding programs.
4. **Ex situ conservation**: moving animals or plants to zoos, botanical gardens, and aquaria if their natural habitats have become too harsh (many predators, strong competition, etc.).
5. **Rewilding and reclamation of degraded ecosystems**: reintroducing native species and rehabilitating habitats to reinstate ecological processes.

### A4.2.8—Selection of evolutionarily distinct and globally endangered species for conservation prioritization in the EDGE of Existence programme

Students should understand the rationale behind focusing conservation efforts on evolutionarily distinct and globally endangered species (EDGE).

The **EDGE of Existence programme** prioritizes conservation efforts on **evolutionary distinct (ED)** and **globally endangered (GE)** species to ensure that irreplaceable biodiversity is not lost. ED species are those with no close relatives or belong to a very small clade that, if extinct, would cause the loss of entire phylogenetic branches and macroevolutionary history. GE species are those listed as critically endangered on the International Union for Conservation of Nature (IUCN) Red List.

**NOS**: Classification is an example of pattern recognition but the same observations can be classified in different ways. For example, “splitters” recognize more species than “lumpers” in a taxonomic group.

Taxonomists classifying entities (species, diseases, etc.) must decide whether to lump together entities in one category or split them apart:

- **Lumpers** are individuals who classify broadly and generally allow for ranges of characteristics to be classified into fewer entities.
- **Splitters** classify based on specific defining characteristics and/or nuances and thus create multiple classifications to reflect these distinctions.

**NOS**: To be verifiable, evidence usually has to come from a published source, which has been peer-reviewed and allows methodology to be checked. Data recorded by citizens rather than scientists brings not only benefits but also unique methodological concerns.

To be verifiable, evidence usually has to come from a published source, which has been peer-reviewed and allows methodology to be checked. Data recorded by citizens rather than scientists brings not only benefits but also unique methodological concerns.

| Advantages | Disadvantages |
|---|---|
| • Public engagement in environmental issues<br>• Raising awareness about environmental issues<br>• Democratization of science<br>• Increased scientific literacy by the public<br>• Incorporation of local, traditional, or indigenous knowledge | • Health and safety concerns due to improper training<br>• Data quality concerns due to variability between volunteer data<br>• Lack of standardization protocols<br>• Verification issues |

**NOS**: Issues such as which species should be prioritized for conservation efforts have complex ethical, environmental, political, social, cultural and economic implications and therefore need to be debated.

Determining which species should be prioritized for conservation efforts is difficult because it carries complex ethical, environmental, political, social, cultural and economic implications.

- **Ethical**: should species be conserved for their intrinsic worth or for the benefits they provide to humans?
- **Environmental**: to what extent can negative cascading effects, due to the interconnectedness of ecosystem relationships, be avoided?
- **Political**: how much of conservation efforts are influenced by political agendas and policies?
- **Sociocultural**: what are the impacts of conservation efforts on local and indigenous communities?
- **Economical**: should species that provide the most economic benefit receive the most funding for their conservation?

## Linking questions

• In what ways is diversity a property of life at all levels of biological organization?

• How does variation contribute to the stability of ecological communities?

## Review questions

- Define biodiversity. [1]
- Define the Simpson reciprocal index. [1]
- Outline the **two** perspectives scientists can hold when classifying organisms. [2]
- Distinguish between in-situ conservation and management of natural reserves. [2]
- Outline how biodiversity changed across the millennia. [3]
- Given the limited number of resources that can be dedicated to conservation, outline how these efforts are prioritized. [3]
- Outline the characteristics of species that make them high priority for conservation. [3]
- Outline the significance of the EDGE of Existence programme in conserving biodiversity. [3]
- Outline the role of societal collaboration in conservation of biodiversity. [4]
- Outline the issues that arise when prioritizing conservation efforts. [4]
- Describe the different approaches to conservation of biodiversity. [7]
- Describe the causes of the current biodiversity crisis. [7]
- Describe the advantages and disadvantages of citizen science. [8]
- Discuss how diversity manifests in all levels of biological organization. [8]
- Describe causes of ecosystem loss. [8]
- Discuss the relative advantages and disadvantages of different types of biodiversity in measuring variation across levels of biological organization. [8]

## References


“Biodiversity Part 2: The Long View.” *Old Rag Master Naturalists*, www.oldragmasternaturalists.org/ormn-blog/biodiversity-part-2-the-long-view.

Ann Clark, Mary, et al. *Biology 2e*. E-book, OpenStax, 2018, https://openstax.org/books/biology-2e/pages/1-introduction. OpenStax.

Hochschild J. Lumpers and Splitters, Individuals and Structures. In: Racialized Politics: The Debate about Racism in America. edited by David Sears, Jim Sidanius, and Lawrence Bobo. Chicago IL: University of Chicago Press; 2000. pp. 324–343

Scheel, Dirk-Martin et al. “Biogeography and taxonomy of extinct and endangered monk seals illuminated by ancient DNA and skull morphology.” *ZooKeys* ,409 1-33. 14 May. 2014, doi:10.3897/zookeys.409.6244

Thaxton, Courtney et al. “Lumping versus splitting: How to approach defining a disease to enable accurate genomic curation.” *Cell genomics* vol. 2,5 (2022): 100131. doi:10.1016/j.xgen.2022.100131

Walker DW, Smigaj M, Tani M. The benefits and negative impacts of citizen science applications to water as experienced by participants and communities. *WIREs Water*. 2021; 8:e1488. https://doi.org/10.1002/wat2.1488