The big picture

? Guiding question(s)

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

How can conservationists minimise the loss of biodiversity?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

In the midst of a mass extinction

For nearly 175 million years, dinosaurs ruled the Earth. Ranging from giant horned herbivores to ferocious predators, dinosaurs showed an amazing diversity of forms and occupied different habitats. Yet, 66 million years ago, within a relatively short period of time, dinosaurs became extinct (**Figure 1**) with only lineages that led to modern birds (derived from dinosaurs) and crocodiles (existing prior to most dinosaurs) surviving. Along with the dinosaurs, more than 60% of the other species perished! This was the fifth mass extinction.

Overview (/study/ap 422- cid- 755105/o

Figure 1. The extinction of dinosaurs!

Mass extinctions are not new in the history of the Earth. A mass extinction happens when a significant proportion (at least 75%) of the Earth's species become extinct, within a short period of geological time (on average less than 2 million years), over a large geographic area. Although still debated, scientists believe that an asteroid crashing on the surface of the Earth precipitated changes that led to the extinction of dinosaurs. Similarly, the previous mass extinctions are believed to have been caused by catastrophic natural events. Look at the timeline in **Figure 2** to help you understand this better.

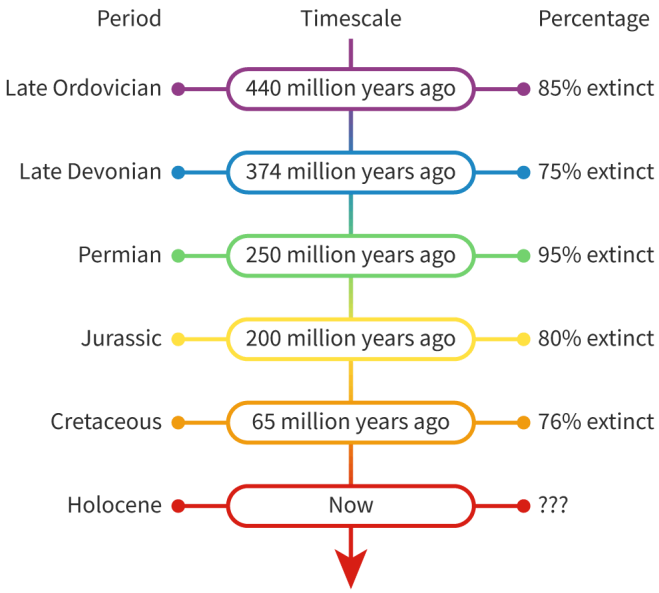


Figure 2. A timeline of mass extinctions.

More information for figure 2

We are in the midst of the sixth mass extinction. Like speciation (section A4.1.6–7 (/study/app/bio/sid-422-cid-755105/book/speciation-id-43794/)), extinction is a natural process. So, why is the extinction of species that we see today termed 'mass extinction'? What are the factors causing the sixth mass extinction of species? How is this different from the other mass extinctions?

Student view

Overview (/study/ap 422-cid-755105/o

Prior learning

Before you study this subtopic make sure that you understand the following:

- Fundamental concepts of ecology (previous courses).
- Using barcodes and environmental DNA to investigate biodiversity of habitats (see section A3.1.14—15 (/study/app/bio/sid-422-cid-755105/book/identifying-species-hl-id-43231/) HL Only)
- Speciation and evolution (see section A4.1.6—7 (/study/app/bio/sid-422-cid-755105/book/speciation-id-43794/))

Biodiversity

A4.2.1: Ecosystem, species and genetic diversity A4.2.2: Current and past levels of biodiversity

Learning outcomes

By the end of this section you should be able to:

- Identify the levels of biodiversity — ecosystem diversity, species diversity and genetic diversity.
- Compare the current number of species and past levels of biodiversity.

A natural wonder — the Great Barrier Reef

Snorkelling or diving through the waters of the Great Barrier Reef takes you to a world of amazing beauty. The reef is the world's largest coral reef ecosystem extending for nearly 2300 kilometres. Clownfish, sharks, manta rays, giant clams, turtles and whales are just some of the marine life found below the ocean surface. The reef teems with life, with hundreds of species of brilliantly coloured fish, hard and soft corals, molluscs, seaweeds, marine worms, sponges, anemones, crustaceans and many more.

The Great Barrier Reef is certainly one of the most diverse habitats on the planet. How is this diversity measured? Is it restricted only to the number of species seen in the ecosystem?

Biodiversity

Biodiversity or biological diversity is the variety of living organisms including plants, animals and microorganisms. Biodiversity exists at three levels:

- genetic diversity
- species diversity
- ecosystem diversity.

Student view

Overview (/study/ap 422-cid-755105/o

Levels of biodiversity

Genetic biodiversity

You will have noticed that although individuals of a species (see section A3.1.1–4 (/study/app/bio/sid-422-cid-755105/book/what-is-a-species-id-43227/)) are fundamentally similar, each individual is a little different from the others (**Figure 1**). In humans, for example, there could be variations in the colour of the eyes or the colour of the skin or the texture of the hair or the height of individuals...the list is endless! Dogs come in different breeds ranging from lap-sized chihuahuas to huskies that pull sledges. Apples vary in colour and taste. These variations are caused by variations in the genes.

Figure 1. Variation in humans.

Credit: Plume Creative, Getty Images (https://www.gettyimages.com/detail/photo/community-royalty-free-image/546206527)

Genes are the basic units of inheritance. Mutations (see subtopic D1.3 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43250/)) result in slightly different versions of the same genes. These versions are called alleles (see subtopic D3.2 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43244/)). Genetic diversity is the variation that exists in genes of a population.

Why is genetic diversity important? A higher genetic variation increases the probability of alleles in the gene pool that allow an organism to adapt to changing environmental conditions. For example, think of a scenario when a population with a high genetic variation is exposed to adverse climatic conditions. Due to the genetic variation, there are greater chances that the genes that enable organisms to adapt to the climatic conditions already exist in the population. Due to differential reproduction, these genes are transmitted from one generation to another making sure the species survives. Thus, genetic diversity acts as the raw material for evolution.

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43529/print/) Assign

Aspect: Patterns and Trends

Genetic diversity has been identified as an important factor that influences the long-term survival potential of a population. One of the predictions made by evolutionary theory is the increased risk of extinction due to low genetic variation. While there is no clear correlation between the two in endangered species, scientists continue to investigate this prediction, studying trends and discrepancies.

Student view

One such example is the evolution of DDT-resistant mosquitoes. DDT is an insecticide that is often used to kill mosquitoes. When DDT was first sprayed, there was a decrease in the local mosquito population. However, a small fraction of the population survived due to the presence of DDT-resistance genes – a result of genetic variation. These resistant mosquitoes reproduced, passing on the gene to their offspring and eventually resulting in a population of DDT-resistant mosquitoes.

On the contrary, if the genetic diversity is low – as often seen in endangered species, the chances of the species surviving is lower when environmental conditions change. Watch **Video 1** to help you understand this better.

Watch **Video 1** and answer the questions.

- Explain the statement 'Inbreeding is common in small, isolated populations and leads to genetic uniformity'.
- Through conservation efforts, the number of American Bison have increased. Would the genetic diversity of this population be similar to that of the original population? Explain.

Video 1. The importance of genetic diversity.

Species biodiversity

Species diversity in very simple terms, refers to the variety of species seen in a particular habitat. The species diversity differs according to habitat.

The species diversity depends on two factors:

- Species richness or the number of different species in the area. For example, the Great Barrier Reef or the Amazon Rainforest has a greater number of species compared with the Antarctic continent or salt pans.
- Species evenness or the relative abundance of different species in the given area. If the numbers of individuals of each species (species abundance) are similar across different species, the species evenness is high. Conversely, if the numbers of individuals of each species vary, the species evenness is low.

In other words, both the number of different species and their relative abundance across the community determine species diversity.

Ecosystem diversity

An ecosystem is defined as the community (see subtopic C4.1 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43544/)) of organisms and their interaction with the abiotic environment. Ecosystems vary in size.

Overview (/study/ap 422-cid-755105/o

Study skills

Let us take a moment to clarify the difference between biomes (see section B4.1.6—7 (/study/app/bio/sid-422-cid-755105/book/determinants-of-biome-distribution-id-44396/)) and ecosystems. Biomes are large regions of the world such as forests, coral reefs, grasslands and deserts. Each biome is characterised by distinct vegetation, wildlife, soil and climate. Within a biome, you will find different ecosystems.

Ecosystem diversity is the variety of ecosystems, both terrestrial and aquatic, found in a given geographical area. For example, a rainforest has many ecosystems within it, including:

- the canopy, formed of overlapping branches and leaves of tall trees
- the understory that lies several metres below the canopy
- the forest floor.

Ecosystem diversity is a function of community and habitat diversity. It is important for determining total biodiversity, but ecosystem diversity is harder to measure. This is because boundaries of many ecosystems are not fixed and tend to gradually change from one type to another.

Interactive 1 shows the interplay between genetic, species and ecosystem diversity.

Interactive 1. Biodiversity in a Rainforest.

More information for interactive 1

The illustration highlights biodiversity, which refers to the variety of life at different levels, from genes to entire ecosystems. It showcases how life on Earth is diverse and interconnected, emphasizing three key types of biodiversity. Each slide represents a different level of biodiversity.

Slide 1: Genetic Diversity

The first panel displays five macaws, each with unique color patterns—red, blue, green, and yellow—highlighting genetic variation within the same species.

At the bottom of the slide, the following text is given. If you look closely, you will notice the variations in the population of macaws indicating genetic diversity.

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

Slide 2: Species Diversity

The second slide shows a diverse group of animal species, including a frog, macaw, monkey, seal, donkey, sloth, and toucan, symbolizing the variety of species found in ecosystems like rainforests.

At the bottom of the slide, the following text is given. Rainforests show an amazing diversity in species.

Slide 3: Ecosystem Diversity

The third panel features a richly detailed landscape with a river, trees, birds, fish, and forest animals, representing the variety of ecosystems coexisting in a single geographical area.

At the bottom of the slide, the following text is given. The diverse ecosystems that exist in a geographical area contribute to the ecosystem's diversity.

Diversity at all levels is important. In fact, these levels cannot be separated. For example, a high diversity in the types of ecosystems would indicate a high diversity in the types of species seen. Changes in one level often cause changes in the other levels.

Making connections

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

While this topic focuses on biodiversity, diversity in itself is an essential feature of life. Biodiversity is the diversity that exists in genes, in species and in ecosystems; however, diversity is seen at other levels too. Take the example of cells. Cells are the basic structural and functional unit of life. Yet cells differ in shape, size, structure and function.

Comparing biodiversity

Different organisms have lived on Earth during different periods of time. Strong evidence for this comes from fossils; for example, the preserved remains of organisms such as bones, teeth or leaves. Yet, a very small percentage of animals that lived on the Earth became fossils – probably due to the fact that the conditions necessary for fossils to form rarely occur. Even though fossil records are incomplete and often patchy, they are indicators of the diversity of species that existed in the past and are used to understand the changes in biodiversity over geological timelines.

These studies in turn have led to the current view that the number of species seen on Earth today is more varied in number and complexity than at any point in the past.

Making connections

Rising temperatures, an outcome of climate change (see subtopic D4.3 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43218/)), are causing environmental changes with impacts on natural habitats and the species to which they provide home. Identifying patterns seen both in the decline and extinction of species and in the adaptation and survival of other species will help scientists take steps to prevent further decline and extinction.

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

Scientists estimate that there are approximately 8.7 million species of plants and animals in existence, of which only 1.2 million species have been identified and categorised. This means that a huge 86% of the species still remain to be discovered! This estimate does not take into account prokaryotes.

There are many reasons why it is taking time to catalogue species. Part of the problem is that many living organisms live in inaccessible places or even inside other organisms. However, the lack of knowledge of the true biodiversity has consequences as each species not only has its own intrinsic value but could also be an answer to problems. The current rate of biodiversity loss means that we are losing species faster than we are identifying them!

Aspect: Patterns and Trends

Taxonomists (see subtopic A3.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43528/)) are scientists who categorise organisms into groups. They are often divided into two groups: the lumpers and the splitters. The lumpers 'lump' or place organisms in fewer, larger groups. Splitters on the other hand, 'split' organisms based on differences and place them in several smaller groups. While lumpers and splitters may make the same observations, the way they classify or group organisms is different.

It is evident that the science of classification, although an exercise of recognition of patterns, may vary as the same observations could be classified in different ways.

Try the following activity to help with your understanding of genetic diversity.

Activity

- **IB learner profile attribute**: Thinker
- **Approaches to learning**: Thinking skills — Providing a reasoned argument to support conclusions
- **Time required to complete activity:** 30 minutes
- **Activity type:** Pair activity

Instructions

- Read the Overview given below.
- Read the articles — (1) (https://evolution.berkeley.edu/evo-news/cheating-cheetahs-prosper/), (2) (http://news.bbc.co.uk/1/hi/sci/tech/6701515.stm) (necessary) and (3) (https://cheetah.org/learn/about-cheetahs/) (optional) for a deeper understanding.
- Use the strategy of 'Think-Pair-Share' to answer the questions and discuss with the class.

Overview

Cheetahs (*Acinonyx jubatus*), the world's fastest mammals, are on the brink of extinction again. Hunting and habitat destruction have reduced the size of their population. Mating with relatives (like siblings) is common, which in turn reduces variability in the genes and allows the persistence of recessive genes.

In May 2007, biologists discovered that female cheetahs mate with multiple males when fertile. In other words, the cubs in a litter have different biological fathers. This is important from an evolutionary viewpoint.

- Explain the crisis faced by cheetahs. Use terms like genetic diversity, genetic variation, etc., in your answer.

Student view

- Why might 'cheating' in cheetahs provide part of the solution to this crisis?

A4. Unity and diversity: Ecosystems / A4.2 Conservation of biodiversity

Causes of anthropogenic species extinction

A4.2.3: Causes of anthropogenic species extinction

Learning outcomes

By the end of this section you should be able to:

- Describe the causes of anthropogenic species extinction.
- Analyse case studies to understand the range of causes of extinction.

Dodos (*Raphus cucullatus*) (**Figure 1**) were flightless birds that once thrived on the island of Mauritius. These large birds had no natural predators and were unfortunately not afraid of humans. Within 200 years of discovery, the dodos disappeared from the face of the Earth. What could have led to the rapid extinction of these species?

Figure 1. Gone forever — the dodo!

Credit: Aunt_Spray, Getty Images (https://www.gettyimages.com/detail/photo/male-dodo-bird-illustration-royalty-free-image/511944190)

Causes for anthropogenic species extinction

As mentioned, we are currently experiencing the sixth mass extinction. There has been an alarming decline in plant and animal species. Extinction rates are historically higher than ever, with predictions of 10% to 50% species loss within the next century, a relatively small amount of time on evolutionary timelines. Many species, like the dodos, have become extinct, while many others are on the brink of extinction.

Overview (/study/ap 422-cid-755105/o

However, unlike the previous mass extinctions, the sixth mass extinction is a result of human activity. When human activity leads to extinction of species it is called anthropogenic species extinction.

Let us take the example of the dodo. The sailors who came to the island of Mauritius found the dodos easy to hunt. The birds were slow, could not fly and had no natural predators. Overexploitation along with destruction of their natural habitat caused the dodos to become extinct in a relatively short period of time.

Anthropogenic species extinction is caused by

- overexploitation due to overhunting or overharvesting
- habitat loss due to human activity
- introduction of invasive or alien species outcompeting native species
- habitat degradation due to pollution
- climate change.

Case study: the extinction of moas

Megafauna literally means large animals. Moas, mammoths and giant kangaroos are examples of extinct megafauna. There has been a lot of debate around what led to the extinction of these megafauna, with causes ranging from volcanic eruptions to diseases to climate change. The case of the North Island moas is particularly compelling with reference to anthropogenic extinction as their extinction was clearly caused by humans.

The moas were flightless birds (**Figure 2**) endemic to the islands of New Zealand. One of the nine species that became extinct, the North Island giant moas (*Dinornis novaezealandiae*) were tall, slender birds with long, shaggy, hair-like feathers. These herbivorous birds thrived for millions of years, yet about 600 years ago, they became extinct.

International Mindedness

In the case of the moas, the oral traditions or *whakataukī* of the early Māoris provide interesting clues about these species and their decline. A large number of these describe the moas and their habitat, the best way to eat them and then their disappearance.

A particularly compelling line translates to ‘The people will disappear like the moas’. The arrival of the early Europeans was associated with the introduction of new diseases and habitat loss, sparking an intense fear in the Māoris about their own existence.

Recent fossil studies with the analysis of bone DNA indicate that the extinction of these birds was caused by human activity. For millions of years the islands of New Zealand surrounded by water remained isolated. When the island was colonised by Polynesians in the 13th century, the large birds became a source of food for the newly arrived humans. The birds who had never seen terrestrial mammals before people arrived, stood no chance. Birds of all ages and the eggs were eaten. Within a short span of 100 years, the birds were hunted to extinction by a relatively small population of approximately 2,500 individuals.

Apart from overexploitation, rats which ate the eggs and chicks, and diseases brought by humans could also have been factors that contributed to the extinction of the moas.

If you looked back, you would notice striking similarities in the extinction of both moas and dodos.

Student view

Overview (/study/ap 422-cid-755105/o

Figure 2. The lost moas.

Credit: ZU_09, Getty Images (https://www.gettyimages.com/detail/illustration/moa-extinct-giant-bird-in-new-zealand-royalty-free-illustration/1409766603)

Aspect: Evidence

Moas were driven to extinction by humans. How do we know this? Recent studies of the gene pools indicate that the populations of different species of moas were large and thriving until the arrival of the first humans. This contradicts the earlier suggestion that populations of the moas were already on the decline before the arrival of the early humans. Scientific knowledge and claims need to be supported by evidence (https://www.nature.com/articles/ncomms6436#Sec9).

Case study: extinction of the Caribbean monk seal

The Caribbean monk seals (*Neomonachus tropicalis*) (**Figure 3**) were marine mammals found in the warm waters of the Caribbean Sea and the western Atlantic Ocean.

The first sighting of these mammals is recorded in the accounts of Christopher Columbus in 1494. The record goes on to state how the sailors killed eight seals resting on the beach. An account from the 17th century describes how fishermen killed hundreds of seals every night to fuel oil lamps and grease machinery. In less than 600 years, the Caribbean monk seals had become extinct.

The Caribbean monk seals were relentlessly hunted in the 18th and 19th centuries for their blubber and other products. The docile and non-aggressive nature of these mammals whose only natural predators were sharks, made hunting easy. In addition, overfishing in the waters where they lived, meant that these animals fell short of food sources like fish and molluscs. Deprived of their natural food, many individuals in an already declining population starved to death. The last sighting of the animal was in 1952.

Student view

Overview (/study/ap 422-cid-755105/o

Figure 3. One of the last Caribbean monk seals, in the New York Aquarium in 1910.

Source: "Cms-newyorkzoologicalsociety1910 (https://commons.wikimedia.org/wiki/File:Cms-newyorkzoologicalsociety1910.jpg)" by New York Zoological Society is in the public domain

International Mindedness

In 2015, the United Nations General Assembly consisting of 193 nations developed and adopted 17 Sustainable Development Goals. One of these goals is SDG 14-Life below water (https://sdgs.un.org/goals/goal14). Oceans and seas form 70% of the planet. These important ecosystems provide water and food, help in nutrient cycling, regulate climate and even provide jobs. Conserving oceans, seas and all marine resources becomes essential for life on Earth. However, the reverse is seen more often with human activity harming these ecosystems.

Case study: a recent extinction, the splendid poison frogs

The splendid poison frogs (*Oophaga speciosa*) (**Figure 4**), last spotted in the wild in 1992, were declared extinct in 2020. With their bright colours serving as a warning to predators of their toxicity, these small frogs were once widespread in the humid forests of Panama.

What led to the decline of this once abundant species? One of the reasons attributed is a reduction in their geographic range due to activities such as logging, conversion of forests for agriculture and expansion of urban areas. The degradation and loss of their natural habitats led to a decline in the population of the frogs. In addition, these frogs were trafficked as part of the 'pet' trade. The death knell for the already declining population was the outbreak of a fungal disease that had been ravaging amphibian populations in the tropics.

Student view

Overview (/study/ap 422-cid-755105/o

Figure 4. Splendid poison frog, a recent extinction.

Study skills

When you refer to an organism, you may use either the common name or the scientific name.

Case study: extinction of the Tasmanian wolf

The thylacine or Tasmanian wolf or Tasmanian tiger (*Thylacinus cynocephalus*) (**Figure 5**) was a dog-headed marsupial with 15–20 stripes across its back. The thylacine were large carnivores feeding on smaller marsupials, rodents and birds. Historically, these animals lived across Australia; however, at the time of their extinction, they were found only in Tasmania.

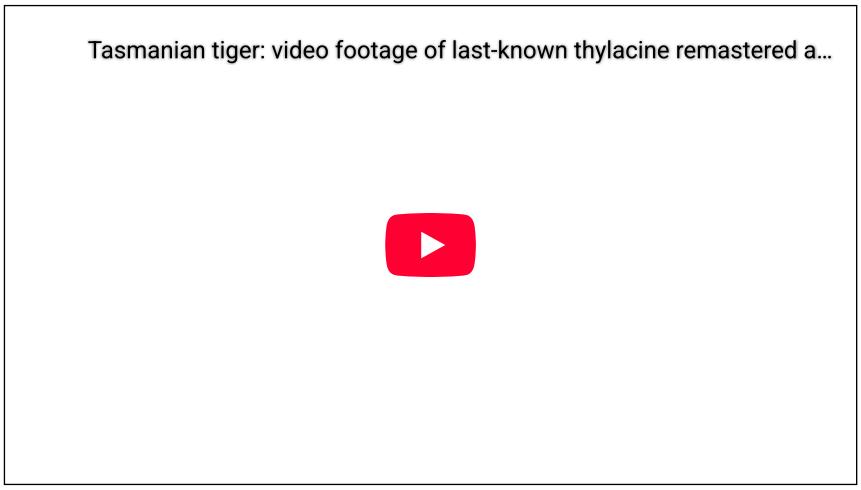
Figure 5. Thylacine, a memory.

Student view

Overview (/study/ap 422-cid-755105/o

Colonisation by the Europeans led to the decrease of an already low population. There are multiple causes attributed to the decline of thylacine. The thylacine fed on sheep and were therefore considered pests by the European settlers who hunted them down. Between 1888 and 1909, rewards were offered for killing thylacine.

In addition, the dingoes often outcompeted them with respect to food. Since the mid-2000s, technological advances have supported new research into the origin of dingoes. A 2011 study utilising DNA testing and sequencing shows that the Australian dingo is closely related to East Asian domestic dogs, and arrived via South-East Asia between 5,000 and 10,000 years ago. They would have exerted a constant competition pressure on the thylacine which were even kept as pets or exported to zoos. Together, these eventually led to the extinction of the thylacine with the last individual dying in a zoo in 1936 (**Video 1**).



Video 1. Footage of the last-known thylacine.

More information for video 1

The beginning of the video shows a solitary Tasmanian tiger pacing in a cage, now enhanced with lifelike colours based on museum specimens. The onscreen text reads “Film colourisation remastered footage of the last-known Tasmanian tiger.”
The video switches to the original black and white scene and onscreen text reads “The footage was originally filmed in 1933 in black and white” and “NFSA scanned the original 35 mm black-and-white negative into 4K.”
The video later switches back to coloured mode and carries on. The text reads “Colourisation experts in France matched the colour through drawings, sketches and paintings... as well as pelts from museum collections.”

Theory of Knowledge

Denialism is often a way to avoid a truth that is psychologically uncomfortable.

Despite overwhelming evidence to the contrary, many individuals are of the view that the effects of human activity in biodiversity loss are exaggerated. Many reject evidence and believe that human activity does not really have a damaging effect on biodiversity or the planet.

Why and how do we decide to act upon (or ignore) evidence? What should you look for when vetting scientific sources of information? What leads to denialism? Can you think of other scientific concepts that are often denied?

Student view

Overview (/study/ap 422-cid-755105/o

To sum up, the sixth mass extinction is under way and characterised by an extinction rate far higher than before, unprecedented in the Earth's history. The case studies point to humans as the primary drivers of the sixth mass extinction. We need to act quickly and with intensity to slow or stop extinctions.

International Mindedness

The sixth mass extinction is a result of human activity. Yet, there are conservationists, organisations (see section A4.2.7—8 (/study/app/bio/sid-422-cid-755105/book/8-conservation-of-biodiversity-id-44392/)) and even lay people who are tireless in their efforts to conserve species and save them from extinction. One such group is the 'Hargila army (https://www.theguardian.com/global-development/2023/feb/09/assam-hargila-army-women-saved-india-rarest-stork-greater-adjutant#:~:text=They%20are%20part%20of%20the,scavenger%20bird%20is%20known%20locally.)' of Assam, India, comprising local women who are involved in the conservation of the endangered Greater Adjutant Storks (called Hargila locally). This is just one example, there are many more.

Try the activity below to summarise your learning on extinction and ways to help reduce the rate of species extinction.

Activity

- **IB learner profile attribute:** Caring
- **Approaches to learning:** Self-management — Breaking down major tasks into a sequence of steps
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

Instructions

- Watch **Video 2** on species extinction.
- Form groups of four and discuss. Some questions to get you started are:
  - If extinction is a natural process, why are scientists alarmed now?
  - What are the drivers of this extinction process?
  - Why would extinction of other species matter to humans?
  - Is it possible for humans to 'peacefully' coexist with other species?
- Think of how to work as a community to reduce the rate of species extinction.
- In your groups, prepare a poster on affirmative actions that you could take.
- Evaluate each other's posters.

Student view

Video 2. Why are thousands of species facing extinction?

Causes of ecosystem loss

A4.2.4: Causes of ecosystem loss

Learning outcomes

By the end of this section you should be able to:

- Describe the causes of ecosystem loss.
- Analyse case studies to understand the range of causes of ecosystem loss.

Ecosystem loss

Interactive 1 shows different ecosystems across the world. How is human activity affecting these ecosystems? What happens to the inhabitants of these ecosystems? Would this impact us?

Interactive 1. Logging in the Amazon Rainforest.

More information for interactive 1

An interactive slideshow with four slides displays before and after views of damaged scenes in different ecosystems, along with a descriptive text.

Users can navigate between the slides using the arrows at the bottom.

Slide 1: Tropical rainforest ecosystem

Before: An aerial view of a dense forest filled with trees, partially covered with fog.

After: An aerial view displays the left side of the forest cleared of trees, with several logs scattered on the ground. The right side still has dense tree cover.

Overview (/study/ap 422- cid- 755105/o

Description: Logging in the Amazon rainforest.

Slide 2: Grassland ecosystem

Before: Elephants drinking water from a water body in a lush grassland.

After: Elephants, deer, and zebras stand in a dry grassland.

Description: Drying of water holes in Namibia due to global warming.

Slide 3: Aquatic ecosystem

Before: A boat rowing in a river with trees lining both the sides.

After: A polluted water body with broken buildings on the left and discarded boat parts on the right. The water is filled mostly with plastic waste.

Description: Polluted water bodies in the Philippines

Slide 4: Wetland ecosystem

Before: A water body with scattered small and tall plants growing in it.

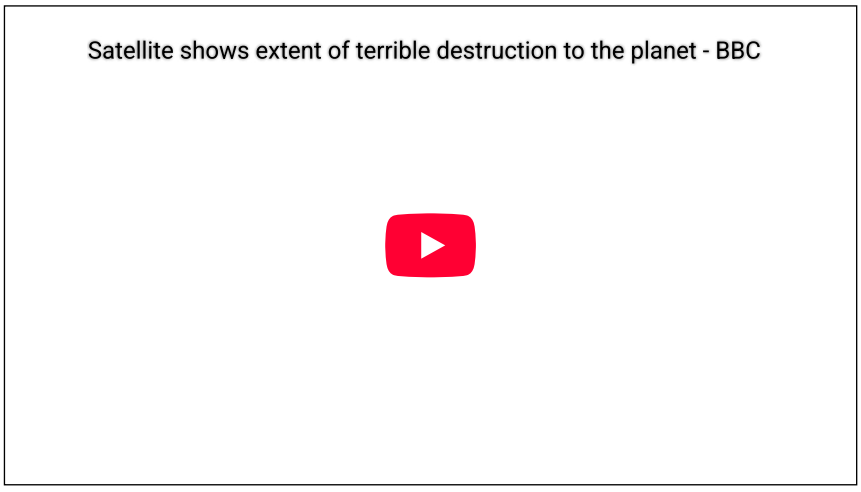
After: An excavator digs a small hole in the soil. In the background, multiple dug-up holes are visible.

Description: Wetland excavated to explore for oil

This slide helps users compare before-and-after scenes to recognize the visual impact of human activities on natural environments.

Human activity has led to the decline and destruction of ecosystems (**Video 1**). When entire ecosystems collapse, the species dependent on the ecosystem are driven to the brink of extinction. In addition, healthy ecosystems have many benefits often referred to as ecosystem services such as:

- supplying resources, including water, food, timber and medicines
- providing basic services essential for survival, for example decomposition of waste, flood control, prevention of erosion, storage of carbon, climate regulation, nutrient cycling, formation of soils, water cycle, etc.



Video 1. The devastation caused by human activity.

Student view

Overview (/study/ap 422-cid-755105/o

Case study: the fall of the dipterocarp forests

The mixed dipterocarp forests of southeast Asia are tropical rainforests (**Figure 1**). The dominant species of trees seen in these forests belong to the family Dipterocarpaceae. Deriving its name from its two-winged fruit, Dipterocarpaceae includes nearly 695 species of trees ranging in size from shrubs to towering trees that emerge from the canopy.

Dipterocarps are keystone species (see section D4.2.5 (/study/app/bio/sid-422-cid-755105/book/sustainability-id-44397/)), essential for ecosystem services and functions because

- they support a number of other forms of life
- their leaves, fruits and seeds are food sources for many herbivores
- decomposition of their falling leaves enriches the forest floor
- their roots hold the soil
- they provide a home to many forms of life including arboreal animals, birds and epiphytic plants
- their canopy forms a large portion of the total canopy, sheltering the underlying layers from the torrential rain
- they lock up large amounts of carbon, and so help in capturing and storing atmospheric carbon dioxide and hence, help fight climate change.

Source: "Dipterocarp Rainforest at Sepilok (https://commons.wikimedia.org/wiki/File:Dipterocarp_Rainforest_at_Sepilok_(14100164413).jpg)" by Mike Prince is licensed under CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/deed.en)

Source: "Dipterocarp Winged Seed (https://commons.wikimedia.org/wiki/File:Dipterocarp_Winged_Seed_(Shorea_sp.)_(15866621516).jpg)" by Bernard DUPONT is licensed under CC BY 2.0 (https://creativecommons.org/licenses/by-sa/2.0/deed.en)

Figure 1. A dipterocarp forest and the two-winged fruits that give the family its name.

Unfortunately, these forests are under threat. The trees are highly prized for their timber and are extensively felled. This has driven many dipterocarp species to the brink of extinction. Yet another threat is clearing of the forests for palm oil plantations. Palm oil trees (*Elaeis guineensis*) were brought to southeast Asia by the Europeans. Planting of palm oil trees has led to deforestation and clearing of massive tracts of the rainforests. Often, to clear the forests, stretches are burned down releasing carbon into the atmosphere.

Student view

Overview (/study/ap 422-cid-755105/o

The destruction of these forests means that already endangered animals such as elephants and orangutans are losing their homes. Thus, destruction of the dipterocarp forests has far-reaching consequences, not only for the life they support but also for humans.

Creativity, activity, service

Strand: Service
Learning outcome: Recognise and consider the ethics of choices and actions

Be a wise consumer — make sustainable choices!

In Indonesia and Malaysia many of the dipterocarp forests have been cleared for palm oil (*Elaeis guineensis*) plantations, leading to a significant reduction in the biodiversity of the area. Habitat loss further endangers a number of species including orangutans, already classified as critically endangered.

Palm oil is used to make a variety of products ranging from packaged food to soaps. By avoiding the use of palm oil, you can save the forests and the species they support.

- Visit a supermarket and examine labels. Check whether the items contain palm oil (look for terms such as palmate, palmitate, palmitic acid or palm oil kernels).
- Make a list. Write to the manufacturers asking them to use palm oil-free substitutes. Remember every voice counts.
- Think of other ways you can make your voice heard.

International Mindedness

Deforestation and the alarming loss of forest cover is a cause of concern. SDG 15-Life on land (http://sdgs.un.org/goals/goal15), aims to 'protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss' — UN 2015 addresses this concern. The goal recognises the importance of ecosystem services and has multiple targets to be achieved globally by 2030. Your contribution to SDG 15 is important — one way to contribute is by being an ethical consumer.

Case study: the dying reefs

Coral reefs found below the ocean surfaces, are one of the Earth's most diverse ecosystems and are often called the rainforests of the sea. The reefs are home to nearly 25% of the world's marine species, including fish, reptiles, crustaceans and seaweeds.

Coral reefs are colonies of coral polyps, with their exoskeletons forming the reefs. Symbiotic algae live in the tissues of these polyps and give the coral its colour.

Reefs provide a myriad of benefits:

- they sustain food webs
- provide food for people
- are sources for new medicines
- protect the coastline from erosion and storms.

Student view

Overview (/study/ap 422- cid- 755105/o

However, the coral reefs are under great stress and many species of corals are endangered. Threats to the reefs include:

- pollution, including nutrient-rich fertiliser runoff, hot water from power plants, rubbish, plastic, oil spills
- destructive fishing activities like overfishing and the use of explosives and cyanide
- loss of natural habitat due to coastal development
- unsustainable tourism where careless divers damage coral reefs
- climate change results in rising ocean temperatures and ocean acidification due to the increased absorption of carbon dioxide (see section D4.3.7 (:sectionlink:134576)). This in turn causes corals to expel their algae, leading to bleaching (or whitening) of the coral reefs (**Video 2**).

Video 2. The process of coral reef bleaching.

Bleaching of corals impacts their viability as it stunts their growth and leaves them vulnerable to disease (**Figure 2**). It also affects the other species that depend on the reefs. Although coral reefs can recover from bleaching, this takes at least 10–15 years provided environmental conditions improve.

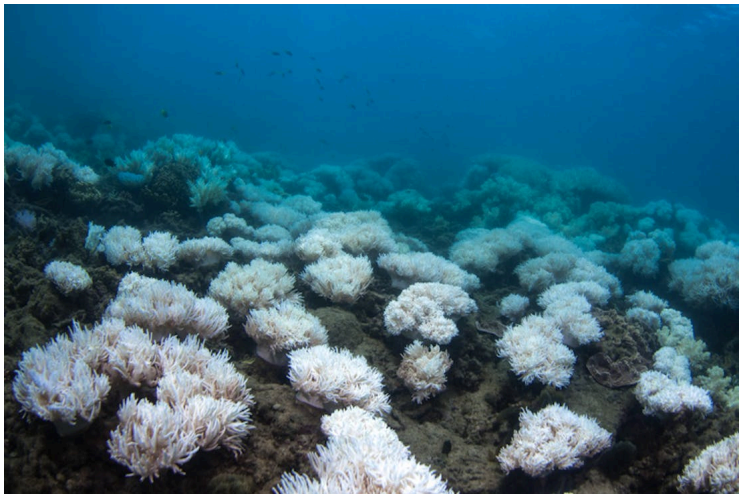


Figure 2. Widespread bleaching of the Great Barrier Reef, which has experienced three mass bleaching events in the last five years — 2016, 2017 and 2020 — caused by rising ocean temperatures.

Credit: Brett Monroe Garner, Getty Images (https://www.gettyimages.co.uk/detail/photo/coral-bleaching-on-the-great-barrier-reef-in-royalty-free-image/1214651237)

Student view

Try this group activity to discuss the pros and cons of clearing forest to build new housing.

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Activity

- **IB learner profile attribute:** Caring
- **Approaches to learning:** Social skills — Actively seeking and considering the perspective of others
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

A local newspaper carried the following headline: 'Clearing a forest to meet housing needs! Short-term gains or long-term losses?'.

Background information

A rapidly developing city is faced with a severe housing crisis. Land prices have sky-rocketed and many people are homeless. One of the options floated by the local authority is to clear a nearby forest. This proposal has met with severe resistance from one group of people and approval by another group. Due to this, the local authority has invited creative solutions from the general population.

What will you do?

- Form groups of four.
- Discuss and list both 'short-term gains' and the 'long-term losses' of the proposed housing plan.
- Try to keep in mind perspectives of different people, for example the people who require housing, the labourers for whom work is a necessity, the indigenous people living in the forest, environmentalists and so on.
- Once your list is ready, brainstorm and come up with a win—win situation for all. Remember your solution cannot be a change of location.
- Present the solution in class.
- Discuss merits/demerits of each proposal and select the best one.

5 section questions

A4. Unity and diversity: Ecosystems / A4.2 Conservation of biodiversity

Evidence and causes of the biodiversity crisis

A4.2.5: Evidence for a biodiversity crisis A4.2.6: Causes of the current biodiversity crisis

Learning outcomes

By the end of this section you should be able to:

- Analyse evidence for a biodiversity crisis from different sources.
- Describe the causes of the current biodiversity crisis.

Student view

Video 1 shows population growth through time. You will notice that in 1950, the estimated human population was 2.5 billion. In mid-November 2022, the world population reached 8 billion people. What sort of implications does this have for species who share the Earth with us?

Overview (/study/ap 422-cid-755105/o

Video 1. The exponential growth of the human population.

Evidence for a biodiversity crisis

The evidence for a biodiversity crisis comes from multiple sources.

IPBES

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) is an intergovernmental organisation established by the UN to assess and strengthen biodiversity and ecosystem services. The IPBES Global Assessment Report On Biodiversity and Ecosystem Services (https://knowledge4policy.ec.europa.eu/publication/global-assessment-report-biodiversity-ecosystem-services-intergovernmental-science-0_en#:~:text=The%20Global%20Assessment%20Report%20%282019%29%20produced%20by%20the,global%20level%20being) was released in 2019. The report has been compiled by 145 expert authors from 50 different countries over three years and states that over a million plant and animal species are threatened with extinction.

IUCN

The IUCN (International Union for Conservation of Nature) looks to address challenges in conserving nature and natural resources. The work of the IUCN is supported by NGOs (non-governmental organisations), indigenous peoples' organisations, volunteer scientists and experts. The IUCN Red List of Threatened Species (https://www.iucnredlist.org/) (**Figure 1**) and the IUCN Red List of Ecosystems (https://www.iucnrle.org/) are conservation tools as they seek to assess current status and inform conservation action and policy. The IUCN Red List of Ecosystems is a global standard for assessing the conservation status of ecosystems.

Based on assessments and reassessments of the species, the IUCN Red List of Threatened Species has nine categories: Extinct (E), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE).

The IUCN Green Status of Species, a part of the IUCN Red List, measures the conservation success of species.

Student view

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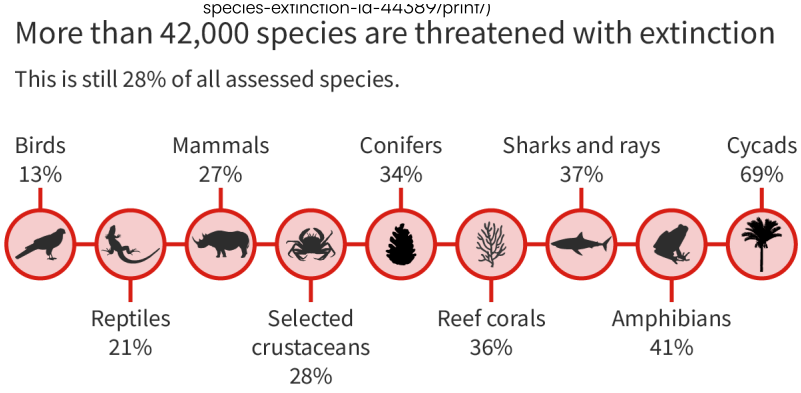

Figure 1. The IUCN Red List.

More information for figure 1

The image is an infographic illustrating the percentage of species threatened with extinction across various groups. Text at the top states: "More than 42,000 species are threatened with extinction. This is still 28% of all assessed species." Below this, a series of icons are connected in a horizontal line, each within a circle and labeled with a group name and percentage.

Starting from the left: - Birds: 13% - Reptiles: 21% - Mammals: 27% - Selected crustaceans: 28% - Conifers: 34% - Reef corals: 36% - Sharks and rays: 37% - Amphibians: 41% - Cycads: 69%

Each circle contains a silhouette representing the respective species group. The circles are linked with thin red lines.

[Generated by AI]

Contributions by expert scientists and citizen scientists

Besides scientists, contributions to science can also come from the general public. Citizen science refers to research conducted with the help of the general population who are not professional scientists. The research is often conceived and designed by expert scientists but executed with the involvement of interested citizens. Expert scientists provide the relevant information about the study and the methods for data collection. This is used by citizen scientists to gather data. Expert scientists then work with these data to answer their research questions. The example given below illustrates the process.

The Horseshoe Count

Every spring, millions of horseshoe crabs (*Limulus polyphemus*) migrate to Delaware Bay Shore for spawning. Fossil records indicate that this has been taking place for around 350 million years. The crab spawn is also an important food source for several migratory birds such as the red knot. The spawn is also used as bait by the fishing industry and for medical purposes. To prevent spawn overharvesting, it is vital to undertake a census to understand the number of crabs. This census data are then used to limit the number of horseshoe crabs harvested for human use. The annual survey is undertaken by volunteers (citizen scientists) who are specially trained to distinguish between male and female crabs and in data recording.

Biodiversity surveys

Biodiversity surveys provide valuable information to decision-makers regarding the use of resources and species conservation. These usually take place within a defined area and are repeated to get a better understanding of the biodiversity. Repeated surveys give information about species richness and evenness, which helps experts understand the changes taking place within a community.

Student view

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Aspect: Evidence

Claims are evaluated by scientists using evidence. 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 bring not only benefits but also unique methodological concerns.

In science, verifiable information comes from papers that have been peer reviewed and published. Peer review is an important aspect of scientific publishing wherein experts review articles submitted to a particular scientific journal to evaluate and assess the quality of the article. The reviewers often provide feedback and suggest changes to the authors. While this process is time-intensive, it ensures that scientific publications are reliable, coherent and useful.

Although the citizen science approach lends the 'eyes and ears' to the expert scientist, it has some unique challenges, depending on the project and its size. These include training constraints, the recruitment of volunteers and the costs associated with developing the resources required to gather and report data.

The population explosion and threats to biodiversity

The human population grew exponentially from 1 billion to 7 billion in just 200 years. In 2011, the human population was 7 billion and in November 2022, it reached 8 billion (**Figure 2**).

This rapid increase in the population has widespread implications. As the population grows, the demand increases for resources including food, water and space. This increasing pressure for resources leads to overexploitation of natural resources and habitat destruction. This, in turn, adversely impacts biodiversity. The current rate of extinction is 100 to 1000 times higher than the past, leading to a biodiversity crisis.

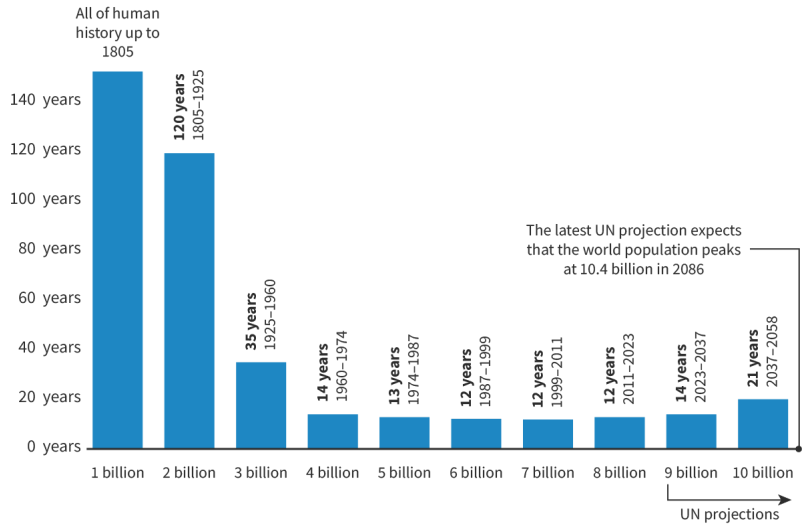


Figure 2. Population growth — the 1 billion hike.

Data source: Our World in Data (https://ourworldindata.org/world-population-growth#:~:text=The%20world%20population%20increased%20from,to%20under%201.0%25%20per%20year.): History Database of the Global Environment; UN World Population prospects (2015); UN Medium Projection (2015). Licensed under CC BY SA 4.0 (https://creativecommons.org/licenses/by/4.0/deed.en_US)

More information for figure 2

Student view

The bar chart illustrates the time taken to reach each billion of world population growth, starting from 1 billion up to a projected 10 billion. The X-axis denotes population in billions, starting from 1 billion to 10 billion. The Y-axis represents the number of years taken to reach each billion, with intervals marked at 0, 20, 40, 60, 80, 100, 120, and 140 years.

- The first bar indicates that it took all of human history up to 1805 to reach 1 billion.
- From 1 to 2 billion took 120 years (1805-1925).
- From 2 to 3 billion took 35 years (1925-1960).
- From 3 to 4 billion, it took 14 years (1960-1974).
- The next bars show a declining trend where each subsequent billion takes fewer years: 4 to 5 billion in 13 years (1974-1987), 5 to 6 billion in 12 years (1987-1999), 6 to 7 billion in 12 years (1999-2011), and 7 to 8 billion in 12 years (2011-2023).
- From 8 to 9 billion is projected to take 14 years (2023-2037), and from 9 to 10 billion is projected to take 21 years (2037-2058).
- The chart notes the latest UN projection that the world population is expected to peak at 10.4 billion in 2086.

[Generated by AI]

Some of the specific causes of biodiversity loss are outlined below.

Hunting and overexploitation

One of the major drivers of biodiversity loss is overexploitation, such as overhunting and overfishing. Overexploitation is the overuse of natural resources at rates faster than they can be replenished.

Overhunting has led to the decline and even extinction of many species. For example, hunting of the Bengal tiger for both sport and for their body parts has led to a drastic decline in their populations and the extinction of three subspecies. Although these animals are now a protected species, poaching and habitat destruction further dwindles their population. Other examples where hunting has led to species being declared threatened include the elephant, bison and black rhinoceros.

The case studies in the previous sections (A4.2.3 (/study/app/bio/sid-422-cid-755105/book/causes-of-anthropogenic-species-extinction-id-44389/) and A4.2.4 (/study/app/bio/sid-422-cid-755105/book/causes-of-ecosystem-loss-id-44390/)) include other examples of overexploitation including the felling of the dipterocarps in southeast Asia for timber.

Today, while many countries ban hunting and have stringent policies for protecting endangered species, illegal hunting (poaching) continues.

Destruction of habitats

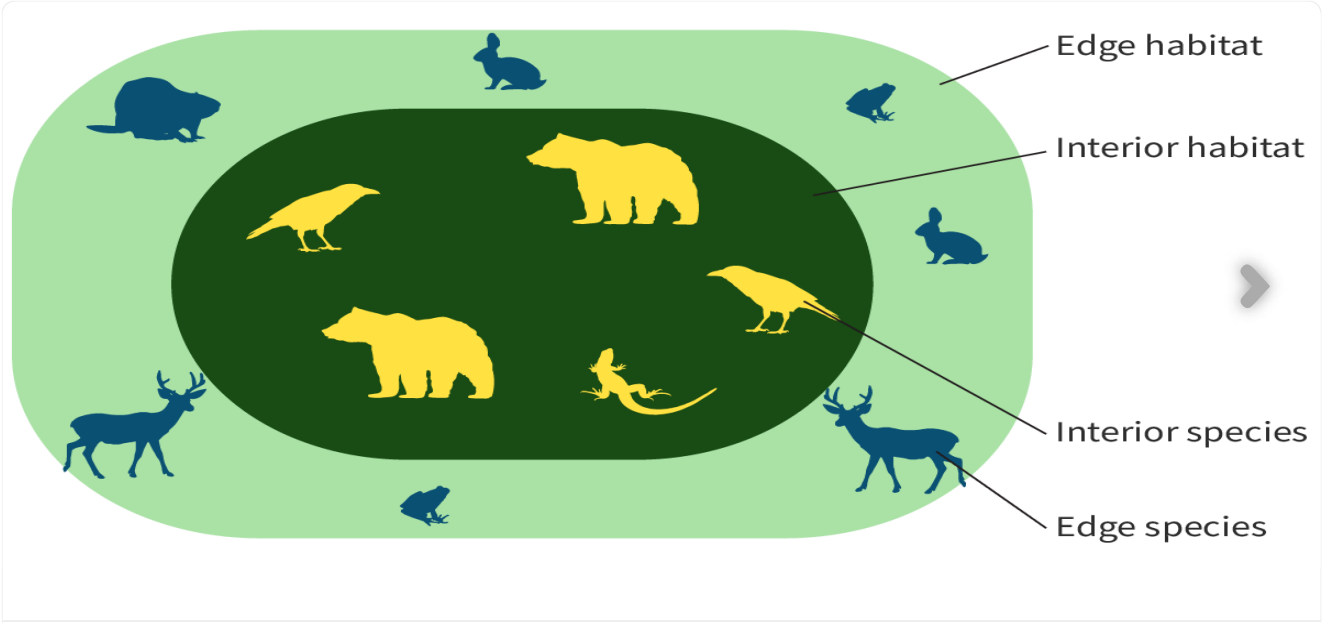
As the demand for space increases, more and more of the natural habitats are lost. When habitats change drastically, species adapted to life in these habitats can no longer survive there. For example, deforestation or the clearing of forests for agriculture, damming of rivers and filling of wetlands bring irrevocable changes in the habitat.

Habitat fragmentation

Urbanisation encroaches on existing natural habitats and can fragment them into smaller habitats. For example, the laying of railway lines through a natural habitat, fragments the area into smaller isolated patches. This, in turn, restricts animal mobility, reduces access to resources and increases the risk of extinction. One solution to this is building corridors for the safe passage of animals.

Overview (/study/ap 422- cid- 755105/o

Interactive 1 shows how habitat fragmentation can occur.



Interactive 1. Habitat Fragmentation.

More information for interactive 1

An interactive slideshow that demonstrates the effects of **habitat fragmentation** on biodiversity, highlighting changes in **edge habitats** and **interior habitats**. As large, continuous ecosystems are divided into smaller patches, the proportion of edge habitat increases, while interior habitat decreases. The interactive allows users to observe how these changes impact species distribution and biodiversity, illustrating the decline of interior-dependent species and the rise of edge-adapted species.

The three dots below the illustration on each slide allow the user to navigate between slides. The “Fullscreen” icon at the top right can be used to see each slide in the zoomed-in version.

Read below to understand the illustrations provided in each slide.

Slide 1: An illustration that depicts a contrast between the edge habitat and interior habitat in an environment. The edge habitat is highlighted in light blue and has species such as rabbits, frogs, mice, and reindeer. The interior habitat is highlighted in dark green and has species such as lizards, wolves, and bird species. On the right, from top to bottom, the text reads: Edge habitat, Interior habitat, Interior species, and Edge species.

Slide 2: An illustration shows a solid purple line dividing the edge habitat and interior habitat of an environment in half. The purple line is labeled with “Fragmentation.” On the right, the text from top to bottom reads: Edge habitat and Interior habitat.

Slide 3: An illustration depicting the broken environment with both containing edge and interior habitats. In the edge habitat, the species count has increased while in the interior habitat, the species count has decreased. The text on the right, from top to bottom reads: Edge habitat and species increase, and Interior habitat and species decrease.

International Mindedness

One solution to habitat fragmentation that is practised across the world is the creation of corridors. Corridors allow animals to move from one habitat patch to another safely and freely, which is critical for their survival. These green corridors have been built by humans to maintain biodiversity so that animals can move and complete their

Student view

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life cycles. While many initiatives have been taken by governments, the European Green Belt (http://www.europeangreenbelt.org/european-green-belt/) connects national parks, biosphere reserves and other areas across borders resulting in a continuity of natural habitats.

Invasive species

As humans colonised different regions of the Earth, they introduced new species either accidentally or deliberately to these environments. These introduced species become invasive alien species (see section C4.1.13 (/study/app/bio/sid-422-cid-755105/book/invasive-species-id-44398/)) when they disrupt existing food chains, reproduce quickly, spread aggressively and outcompete endemic species.

For example, the Japanese knotweed, *Reynoutria japonica* (**Figure 3**) (see section A4.1.11 (/study/app/bio/sid-422-cid-755105/book/hybridisation-and-polyploidy-in-speciation-hl-id-43797/)) was introduced into the ponds of Europe as an ornamental plant.

Figure 3. The highly invasive knotweed (*Reynoutria japonica*). The plant reproduces and spreads easily, smothering native species and taking over gardens and national parks. Removing the weed is difficult and expensive.

Pet Burmese pythons (**Figure 4**) were introduced into the Everglades of Florida. At the top of the food chain, the pythons feed on local species, ill-equipped to handle these new predators. This has led to a reduction in the populations of the local species.

Student view

Overview (/study/ap 422- cid- 755105/o

Figure 4. The Burmese python (*Python bivittatus*) takes over the Everglades.

Source: "Burmese python (6887388927) (https://commons.wikimedia.org/wiki/File:Burmese_python_(6887388927).jpg)" by U.S. Fish and Wildlife Service Headquarters is licensed under CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/deed.en)

Pests and diseases

Global transport has also introduced pests as well as diseases to native species. As consumer demand increases, live animals including goats, sheep, pigs and cows or refrigerated products are transported across the world. However, this increases the risk of disease transmission.

In another example, the global trade in amphibians has led to the spreading of a fungus native to southern Asia. This in turn has caused a decline in the amphibian population across the world. The spread of diseases is not restricted to animals. The chestnut blight in chestnut trees is caused by a fungus that was present in nursery stock exported to the USA from Asia.

Common pests that have been transported across the globe include cockroaches and rats. While regulatory mechanisms may be in place, the chances of transporting pests or their eggs and disease-causing pathogens remain high.

Pollution

Pollution is one of the leading causes of biodiversity loss. Pollution is the introduction of substances into the environment that adversely affect the environment. Pollution can take the form of air, water and land pollution. Some causes of pollution are outlined below.

The release of sulfur dioxide and nitrogen oxides (a combination of NO and NO_2) from industries into the air results in acid rain, which has a detrimental effect on plant and animal lives.

There is more information about how pollutants released into water often enter the food chain resulting in biomagnification and affecting consumers in section D4.2.9 (/study/app/bio/sid-422-cid-755105/book/pollution-and-restoration-id-44399/).

Accumulation of plastic across habitats is one of the biggest threats to biodiversity. Plastic in the oceans is often ingested by seabirds and marine turtles (**Figure 5**). For threatened species like the Hawaiian monk seals, plastic pollution (see section D4.2.10 (/study/app/bio/sid-422-cid-755105/book/ecological-succession-hl-id-44400/)) pushes them further down the path of extinction.

Student view

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Dumping of rubbish not only pollutes the environment, but also can be a breeding ground for pests like flies, cockroaches, rats and mice.

Figure 5. Marine turtles often feed on plastic bags mistaking them for jellyfish, a source of food. The plastic blocks the intestine and leads to the slow death of animals.

Credit: richcarey, Getty Images (https://www.gettyimages.com/detail/photo/sea-turtle-and-plastic-polution-royalty-free-image/1251409754)

Creativity, activity, service

Strand: Service
Learning outcome: Demonstrate engagement with issues of global significance

One of the major causes of the current biodiversity crisis is pollution. You could play a role in cleaning up a polluted area by picking up rubbish in areas such as local parks/beaches/walking trails/tourist spots, etc. Alternatively, your school could adopt a section of the beach/park, etc.

Make sure that you gather a team of volunteers and carry the necessary equipment before you start.

Identify the causes of the biodiversity crisis. Drag and drop the words in the box to the correct pictures in **Interactive 2**.

Student view

Habitat fragmentation | Habitat loss

Invasive species | Pollution | Poaching

Check

Rights of use

Interactive 2. Threats to Biodiversity.

More information for interactive 2

The image is a grid of five distinct photographs, arranged with three images on the top row and two on the bottom row.

Top Row:

Top Left: This image shows a collection of dense green leafy plants and bushes. Some lighter-colored flowers or leaves are visible within the greenery. The scene appears to be a natural outdoor environment, possibly near a body of water, as a blurry light area at the top might suggest water or sky reflecting off a surface.

Top Center: This photograph captures a scene on a paved road. An adult elephant is walking from right to left across the road, followed by a smaller, younger elephant walking behind it. Lush green vegetation and trees line both sides of the road. The sky is overcast or pale white.

Top Right: This is a close-up shot of a bird's head and upper body. The bird has dark feathers and a long, pointed beak that is slightly open. Its head is turned towards the viewer. The bird appears to be entangled or surrounded by clear plastic netting or debris, which is visible in the foreground and around its head and beak. The background is blurry but suggests more of the same plastic material.

Bottom Row:

Bottom Left: This image displays a large collection of shark fins laid out on a light-colored surface, possibly snow or a light-colored ground. The fins are of various sizes and shades of grey, and they are densely packed together, overlapping in some areas. The sheer number of fins suggests a large-scale harvesting or trade.

Bottom Right: This image shows a deforested landscape. In the foreground, there is a chaotic scene of tree stumps, fallen logs, and scattered debris on bare earth. In the background, a line of remaining green trees is visible on the horizon. The sky is a pale blue or overcast. The image conveys the impact of logging or deforestation on a forest ecosystem.

Five causes of the biodiversity crisis are given as drag-and-drop below the images and they should be dragged and placed in the correct images: Habitat fragmentation, Habitat loss, Invasive species, Pollution, and Poaching.

Overview (/study/ap 422-cid-755105/o

Read below for the solution:

Top row, from left-to-right are: Invasive species, Habitat Fragmentation, Pollution

Bottom row, from left-to-right are: Poaching, and Habitat Loss

Try this activity to learn about a local species that is endangered or under threat of extinction.

Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Communication skills — Applying interpretive techniques to different forms of media
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

Your task

Build public awareness on the biodiversity crisis through a comic strip.

Prior research

- Enquire: Is there a local plant or animal species that is endangered? What policies are in place for its protection?

Instructions

- In class, form groups of four. Discuss your ideas.
- Create a series of cartoons to depict the threats to biodiversity. You can learn more about the elements of a comic strip here. (https://prezi.com/wxnzhrcy4sun/elements-of-a-comic-strip/)
- Self-evaluate your work, bearing in mind the criteria in **Table 1.**
- Display at various places in the school.

Table 1. Self-evaluation criteria.

Criteria	How will I rate myself on a scale from 1 to 5 (1 being the least)	Reason
Creativity		
Accuracy of the content		
Dialogues		
Organisation		
Overall ('Does my work convey a powerful message?')		

Student view

Conservation of biodiversity

A4.2.7: Approaches to conservation of biodiversity A4.2.8: Selection of species for conservation prioritisation

Learning outcomes

By the end of this section you should be able to:

- Describe different ways to conserve biodiversity.
- Know the mechanism of conservation prioritisation.

A visit to Kenya is incomplete without going for a safari at Masai Mara National Park (**Figure 1**). Often cited as the inspiration for the movie, 'The Lion King', the national park has extensive savannahs, rivers, water holes and of course, animals including the big cats, wildebeest, zebra and the black rhino. In addition, there are opportunities to volunteer and make your mark. The Masai Mara is thus a curious blend of tourism, community development and wildlife conservation. How do parks like the Masai Mara help in conservation? Are parks the only way to conserve our biodiversity?

Figure 1. Masai Mara.

More information for figure 1

The image is a map showing the African continent with a highlighted section zooming into Kenya. Within this zoomed-in section, the Masai Mara region is marked. Kenya is prominently labeled, and the map outlines the country's borders as well as its surrounding geography. The Masai Mara is indicated in a different color to distinguish it from other regions. This highlights its location within Kenya, giving a geographic context to the national park's position on the continent.

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Conservation: a multi-pronged approach

Conservation is the protection and the sustainable use of the resources we have. Conservation biology looks at maintenance of biodiversity by protecting species and their ecosystems.

The conservation of biodiversity requires a multi-pronged approach. The diversity in species necessitates that different measures be taken to conserve different species.

In situ conservation

On-site or in situ conservation is a way of conserving animals and plants in their natural habitats while maintaining the original biodiversity of the area. In situ conservation involves designating, managing and maintaining areas for the protection of plant and animal species.

National parks and wildlife sanctuaries are protected terrestrial areas, while marine reserves conserve marine species and habitats (**Figure 2**). Nature reserves are areas smaller than national parks and protect a particular habitat and/or plants and animals, often declared as endangered. Human activity in these areas is strictly regulated. Responsible tourism, such as conservation safaris, in these areas helps to generate funds that contribute to their maintenance as well as increasing public awareness.

In situ conservation conserves the plant or animal species and their habitat. It allows the species to continue living in the habitat to which they are adapted, preserves their normal behaviour (in the case of animal species) and prevents disruptions of the food chains. Thus, in situ conservation is less disruptive and more cost-efficient.

Credit: Sebastian Condrea,

Getty Images (https://www.gettyimages.com/detail/photo/group-of-zebras-in-tsavo-national-park-kenya-royalty-free-image/1316669738)

Credit: sourabh,

Getty Images (https://www.gettyimages.com/detail/photo/royal-bengal-tiger-royalty-free-image/1130059968)

Credit: LFPuntel,

Getty Images (https://www.gettyimages.com/detail/photo/turtle-and-tons-of-fish-royalty-free-image/599749232)

Student view

Overview (/study/ap 422-cid-755105/o

Figure 2. Safe havens in the Tsavo National Park, Kenya (left), the Jim Corbett National Park, India (middle) and the Galápagos Marine Reserve, Galápagos Islands (right).

Ex situ conservation

On the other hand, in off-site or ex situ conservation, plants and animals are conserved outside their natural habitats. Ex situ conservation techniques vary and include zoos, botanical gardens and aquariums.

In some species the numbers are too small to sustain the species or risk of poaching is high. In these cases, scientists establish gene banks to store 'biodiversity', which involve the storage of germplasm (or genetic resources). These collections of living material include animals in zoos, plants in botanical gardens, seeds, sperms, eggs, pollen, DNA collections and so on.

Seed banks dehydrate and cool seeds prior to storage (**Figure 3**). One such example are seed banks created to store the original wild strains of food crops such as rice in an effort to conserve their genetic information.

Figure 3. The Millennium Seed Bank at Kew Gardens, England, has an underground collection of over 2.4 billion seeds representing over 39 000 species from across the world.

Tissue banks, for example the DNA and Tissue Bank at Kew, England, store tissue samples from plants.

Zoos maintain multiple species of mammals, birds, reptiles and amphibians while botanical gardens conserve plants.

Captive breeding

Captive breeding is a conservation technique for preventing the extinction of species whose populations are small, often fragmented and on the verge of extinction. Animals in zoos or other places are encouraged to breed and then reintroduced into the wild. However, one of the major drawbacks of the technique is that small populations inherently have a lower genetic diversity (see section A4.2.1–2 (/study/app/bio/sid-422-cid-755105/book/title-to-come-id-43810/)) and thereby the chances increase of passing on unfit genes.

One successful example of this is the Arabian oryx (*Oryx leucoryx*) (**Figure 4**). The oryx, a type of antelope, became extinct in the wild in 1972; however, the antelopes existed in zoos. Captive breeding followed by 'training' the animals for release ensured that the species could be released back into the wild.

Student view

Overview (/study/ap 422-cid-755105/o

Source: "Arabian oryx (oryx leucoryx) (https://commons.wikimedia.org/wiki/File:Arabian_oryx_(oryx_leucoryx).jpg)" by Charles J Sharp is licensed under CC BY 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)

Source "AC—4 California condor (https://commons.wikimedia.org/wiki/File:AC%E2%80%934_California_condor.jpg)" by USFWS Pacific Southwest Region is in the public domain

Figure 4. The Arabian oryx (*Oryx leucoryx*) and California condor (*Gymnogyps californianus*) have been brought back from near extinction by captive breeding.

Rewilding

Rewilding is a conservation technique by which wildlife and natural processes are allowed to reclaim areas, bringing back biodiversity. In other words, the habitat is restored to what it would have been if human disturbance had not happened. Rewilding happens with human intervention as plant and animal species that have disappeared from the habitat are reintroduced. This, in turn, helps to rebuild ecosystems. The Rewilding Institute (https://rewilding.org/)run rewilding programmes and initiatives in this area.

Reclamation of degraded ecosystems

Unsustainable human activity often causes a degradation of the land and water. The loss could be due to erosion of the soil, deforestation, salination and so on. Land restoration strategies look at recovering and reclaiming degraded ecosystems. Studies have shown that land restoration and management with support from local communities and indigenous people yields higher results as they have a deep knowledge of the land. Forests are being restored across the world through programmes that engage local communities.

In **Interactive 1**, drag and drop to match the conservation strategy with its description.

Student view

Drag the conservation strategies into the correct boxes based on the descriptions.

1. The population of the black-foot ferret was near extinction in the wild. The species was successfully bred in captivity.

2. The lone wolves were reintroduced into Yellowstone National Park in 1995.

3. The Jim Corbett National Park is home to many endangered species including the Bengal tigers.

4. The San Diego Zoo houses many animals including giant pandas and koalas.

5. The support of the indigenous people and local communities is essential for land restoration.

In situ | Rewilding | Reclamation | Ex situ | Captive breeding

Check

Interactive 1. Conservation Strategies.

So, we have the conservation strategies but can these be used to save and protect all species on Earth? If decisions have to be made on which species to conserve, which species do you think scientists would select and why? Who determines the significance of the species to be protected? What rules or procedures would they have to follow?

EDGE

The answer lies with EDGE – Evolutionarily Distinct and Globally Endangered. The EDGE of Existence was launched by the Zoological Society of London in 2007 as a conservation programme to prioritise conservation of evolutionarily distinct and endangered species. The most poorly known or neglected EDGE species are often selected to prevent them from silently disappearing from the face of the Earth.

The EDGE species:

- are often the only surviving members of their genus or even higher taxa
- are unique in their appearance, behaviour and genetic makeup
- have a unique evolutionary history
- are globally endangered.

Interactive 2. EDGE Species.

More information for interactive 2

An interactive slideshow with five slides presents photographs of EDGE species. Users can switch between slides using the arrows present at the bottom of each slide.

Slide 1: A Aye-aye (Daubentonia madagascariensis), a member of the lemur family, sits between tree branches. It has shaggy black fur, bright eyes, long thin fingers, and bat-like ears.

Slide 2: A Sunda pangolin (Manis javanica) rests on a tree branch. It has overlapping brown scales, a small head, and a long muscular tail.

Slide 3: A Sumatran rhinoceros (Dicerorhinus sumatrensis) stands in a forest environment. It has a thick, grayish-brown body with a wrinkled texture and a small horn.

Slide 4: An Indri (Indri indri), a tall lemur, holds a tree branch. It has black and white fur, long hind legs, and shorter arms.

Slide 5: A Green turtle (Chelonia mydas) swims underwater. It has an olive-green and dark brown shell, with scales on its face and flippers.

This slideshow helps users identify five EDGE species and describe their features.

The species are selected according to their:

- Evolutionary Distinctiveness (ED) score. The ED score is determined by the position of the animal on the phylogenetic tree (see subtopic A3.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43528/)). ED scores are higher for species that are evolutionarily more distinct or have fewer closer relatives.
- Globally Endangered (GE) score. This is calculated based on the IUCN Red List. The more endangered the species, the higher the GE score. For example, critically endangered species have a higher score than endangered species or vulnerable species.

The two scores are then combined to produce the EDGE score for a species (**Figure 5**). Higher than average EDGE values indicate that the species is threatened with extinction (**Video 1**).

Overview (/study/ap 422-cid-755105/o

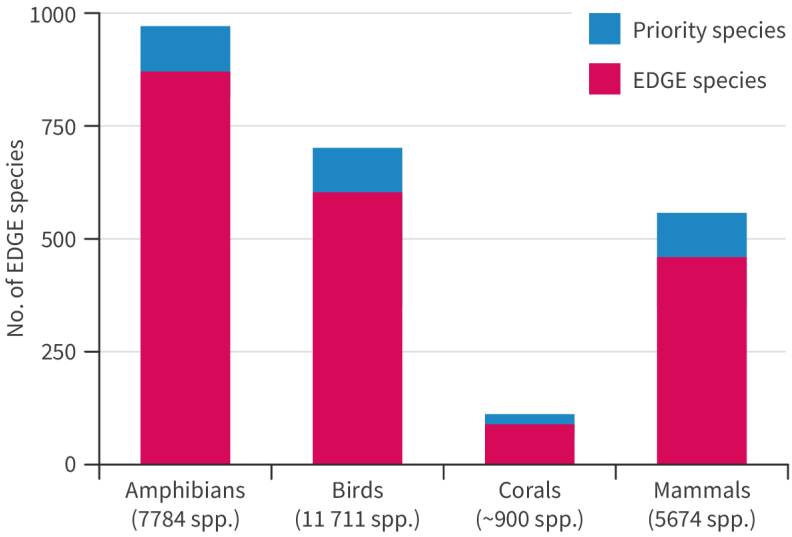

Figure 5. Number of EDGE species in each group. The priority species are the top 25 EDGE corals and the top 100 of the other groups.

Data source: Data used with kind permission of EDGE of Existence (https://www.edgeofexistence.org/) and ZSL (https://www.zsl.org/)

More information for figure 5

This bar chart shows the distribution of EDGE species across four groups: Amphibians, Birds, Corals, and Mammals. The Y-axis represents the number of EDGE species, ranging from 0 to 1000. Each group is represented by a bar which is divided into two segments. The blue segment at the top of each bar indicates the number of priority species. The larger pink segment at the bottom shows the number of EDGE species.\n\n- Amphibians: Total approximately 778 species, with the majority being EDGE species and a small fraction as priority species.\n- Birds: Around 750 EDGE species with a small portion represented as priority species, out of 11,711 total species.\n- Corals: With a total of ~900 species, they have very few EDGE species and even fewer priority species.\n- Mammals: About 800 species in this category with a significant number as EDGE species, while a noticeable portion is priority species.

[Generated by AI]

Video 1. An overview of the work done by EDGE.

More information for video 1

The video starts with the logo EDGE, and text below it says: Evolutionarily Distinct and Globally Endangered.

The video shifts to two experts looking at a computer, the text below reads: The Zoological Society of London's EDGE of Existence program uses a prioritization scheme that combines the Evolutionary Distinctiveness of a species with its Global Endangerment, or extinction risk, to identify global priorities.

Student view

Overview (/study/ap 422-cid-755105/o

The video shifts to close-up footage of a Ring-tailed lemur, sitting on a branch of a tree, followed by a purple frog croaking at the camera. The text below says: These are species that are unique in the way they look, live, behave, and are often isolated in the long branches of the tree of life with few or no close relatives. The scene shifts to a long-eared Jerboa hopping around, a hippopotamus with its baby, and a pangolin grazing grass. The text says: Many of these species have been completely overlooked by conservationists and receive little or no conservation attention. These evolutionarily distinct species represent many millions of years of evolution, or evolutionary history, and there really is nothing else like them on Earth, from the purple frog of India which lives most of its life underground and emerges only during the monsoon to breed to the Secretary bird of Africa which stalks across the African savannah, stamping snakes to death.

The scene shifts to a phylogenetic tree that has a Toucan, which is a group of bird species, a polar bear, and a meerkat at the ends of it, with text saying: But how do we measure the Evolutionary Distinctiveness of a species? The diagram fades out and another phylogenetic tree diagram appears with a mouse on its leftmost end. The text says: Essentially, the longer a species has evolved in isolation and the fewer close relatives it has, the more evolutionarily distinct it is. This is our measure of value, or irreplaceability.

The video transitions to pictures of a western long-beaked Echidna, a spiny anteater. The text reads: The long-beaked echidnas of Papua New Guinea are the most evolutionarily distinct and threatened mammals, one of the only mammal species in the world to lay eggs. An animated Echidna is shown laying eggs. The video shifts to a white background with the IUCN Red List logo with a photo of a Sunda Pangolin, marking it as CRITICALLY ENDANGERED. The text reads: The Global Endangerment of a species is the threat category assigned by the IUCN Red List. The scene shifts to a category scale diagram. The text reads: Each category, from Least Concern to Critically Endangered, represents the increasing likelihood of a species becoming extinct and is our measure of the urgency of action needed. The word URGENT appears like a stamp on the diagram.

The video transitions to a photo of a Chinese Giant Salamander underwater. The text reads: The Chinese Giant salamander is the largest amphibian in the world, growing up to 1.8m long. An illustration accompanies the text - a salamander held in a pair of human hands, measuring its size under a scale that reads 1.8m. The text further reads: Critically endangered, it is the most threatened and evolutionarily distinct amphibian species.

The video shifts to a graph with xy axes, where the x-axis represents Global Endangerment and the y-axis represents Evolutionary Distinctiveness. The text reads: These two measures — evolutionary distinctiveness and global endangerment based on phylogeny and IUCN Red List assessments — are then combined using the EDGE metric to produce a score for every species. The video shifts to a list of the Top 100 EDGE birds with their names written, with an illustration of a Giant Ibis. The text reads: EDGE Lists highlight the top 100 species in each taxonomic group as conservation priorities due to their evolutionary uniqueness and level of threat. The video transitions to a photo of a Giant Ibis. Multiple lists are shown titled ‘EDGE LIST’. The text reads: Priority EDGE lists have been created for mammals, birds, amphibians, and corals.

The video shifts to a group of experts seated in a meeting room having a discussion, followed by a few experts handling an animal with care while examining it. The text reads: The EDGE of Existence program focuses conservation efforts on priority EDGE species, raising awareness of these little-known species and highlighting their importance and their plight. The video shifts to experts moving through a river on a boat, followed by attaching a device to a tree, and waving bye at the camera standing on a beach. The text reads: One of the best ways to put conservation action in place is through in-country capacity building to conserve their own biodiversity, and this is achieved through a comprehensive Fellowship program that trains early-career conservationists, called EDGE Fellows.

Worked example 1

Identify the species that would have the highest ED score on the hypothetical evolutionary tree. Each branch of the tree represents millions of years of evolution.

Student view

Overview (/study/ap 422-cid-755105/o

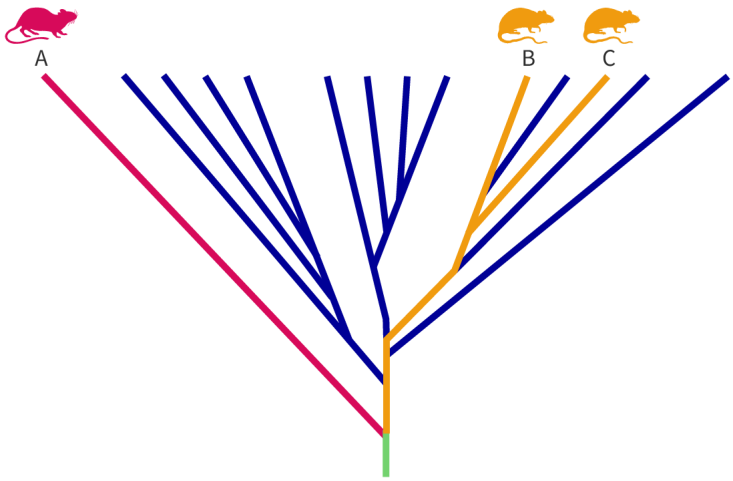

Figure 6. Hypothetical evolutionary tree.

More information for figure 6

The image illustrates a hypothetical evolutionary tree depicting the evolutionary relationships among species. The tree has a central root from which various branches diverge. Three key branches are highlighted: Branch A on the left is shown in pink and extends further back compared to others. Branch B is orange, diverging into multiple closely related lines, suggesting recent common ancestry. Branch C parallels Branch B, indicating a similar evolutionary path. Each branch represents millions of years of evolution. Animal silhouettes are present at the tips of branches A, B, and C, representing different species. The structure implies significant evolutionary differences, with species on Branch A likely having the highest Evolutionary Distinctiveness (ED) score, as it diverges earliest from the root.

[Generated by AI]

Species A has a higher score as it is alone on the branch of the evolutionary tree, whereas species B and C have other close relatives.

Extinction of A would mean that there would be no similar species left on Earth. In other words, a relatively larger amount of unique evolutionary history would be lost.

Creativity, activity, service

Strand: Service
Learning outcome: Demonstrate how to initiate and plan a CAS experience

There are many organisations like EDGE that work towards conservation of species. For example, the EDGE fellows help in conservation action. Think of ways you can help in the conservation of species. You could either volunteer or raise funds. You could even start an organisation that focuses on conservation of species in your locality that are endangered.

Student view

Overview (/study/ap 422- cid- 755105/o

Aspect: Global impact of science

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

In programmes like EDGE, is there international consensus for the process of selection of EDGE species?

Every species on Earth is important and contributes to productivity and sustainability of ecosystems. Each species has a right to exist. While deciding on the prioritisation of species for conservation efforts, scientists should be aware of the ethical, environmental, political, social, cultural and economic consequences of their decision. This prevents unintended consequences.

Try this activity to debate whether conservation prioritisation is needed.

Activity

- **IB learner profile attribute**: Balanced
- **Approaches to learning**: Social skills — Actively seeking and considering the perspective of others
- **Time required to complete activity:** 30—45 minutes
- **Activity type:** Group activity

Panel discussion: Is conservation prioritisation needed?

Instructions

- Research the topic of conservation prioritisation. You can check the work done by EDGE of Existence too.
- Nominate a group of four participants to be the panellists.
- Each of the participants should take one of four roles: politician, indigenous person, conservationist, EDGE fellow.
- Your teacher is the moderator, and the remaining students the audience.
- Have the audience prepare questions to ask the panellists.
- Conduct the session as given:
  - Each panellist takes 2 minutes to present their viewpoint.
  - The audience asks questions. The questions can be directed to a specific panellist.
  - Close the discussion within a predetermined time.
- Reflect on the activity and summarise understanding.

5 section questions

A4. Unity and diversity: Ecosystems / A4.2 Conservation of biodiversity

Summary and key terms

Student view

- The levels of biodiversity include genetic diversity, species diversity and ecosystem diversity.

- There are more species alive on Earth today than at any time in the past, with millions of species yet to be discovered.
- Unlike the other five mass extinctions, the sixth mass extinction is anthropogenic in nature.
- Examples of anthropogenic species extinction include the North Island moas, the Caribbean seal monks, the splendid poison frog, dodos and thylacine.
- Ecosystem losses could be caused due to anthropogenic factors, for example as has occurred in the mixed dipterocarp forests.
- Evidence for the biodiversity crisis can be drawn from intergovernmental agencies such as IPBES and IUCN as well as reliable surveys.
- Human population growth has placed a tremendous demand on natural resources.
- Specific causes for the current biodiversity crisis include overhunting and overexploitation, habitat loss and fragmentation, pollution, introduction of invasive species, pests and diseases.
- Conservation of biodiversity should be through both ex situ and in situ approaches. Captive breeding, rewilding and restoration of degraded ecosystems contribute to conservation.
- The EDGE of Existence programme prioritises evolutionarily distinct and globally endangered species for conservation.

Overview (/study/ap 422-cid-755105/o

Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. Unlike the other mass extinctions, the sixth mass extinction is in nature.
2. The variety of microorganisms, plants and animals seen in an area is known as .
3. The variations between individuals in a population arise due to .
4. The number and relative abundance of species in an ecosystem is known as .
5. Coral reefs, wetlands, deserts, alpine regions and rainforests indicate .
6. The of the moas, a type of , was due to overhunting.
7. In mixed dipterocarp forests, dipterocarps are the species.
8. approaches include national parks and sanctuaries.
9. Zoos and botanical gardens are examples of approaches.
10. Thriving ecosystems like the coral reefs or rainforests regulate climate, provide food and other .
11. Recreating an area's natural state to restore biodiversity is known as .
12. An example of a gene bank is a where seeds are stored to conserve biodiversity.
13. The programme is a strategy that looks at conservation prioritisation.

In situ | biodiversity | EDGE | ecosystem diversity | keystone | species diversity | extinction | rewilding | ecosystem services | anthropogenic | ex situ | megafauna | seed bank | genetic diversity

Check

Interactive 1. Diversity and Unity in Ecosystem

A4. Unity and diversity: Ecosystems / A4.2 Conservation of biodiversity

Checklist

Student view

Overview (/study/ap 422-cid-755105/o

What you should know

After studying this subtopic you should be able to:

- Identify the levels of biodiversity — ecosystem diversity, species diversity and genetic diversity.
- Compare the current number of species and past levels of biodiversity.
- Describe the causes of anthropogenic species extinction.
- Analyse case studies to understand the range of causes of extinction.
- Describe the causes of ecosystem loss.
- Analyse case studies to understand the range of causes of ecosystem loss.
- Analyse evidence for a biodiversity crisis from different sources.
- Describe the causes of the current biodiversity crisis.
- Describe different ways to conserve biodiversity.
- Know the mechanism of conservation prioritisation.

Investigation

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/investigation-id-44395/print/) Assign
Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/checklist-id-44394/print/) Assign

- **IB learner profile attribute:** Inquirers
- **Approaches to learning:** Research skills – Comparing, contrasting and validating information
- **Tool 2:** Technology – Applying technology to collect data, Identify and extract data from databases
- **Tool 3:** Mathematics – Graphing
- **Time required to complete activity:** 4–6 hours
- **Activity type:** Individual activity

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/summary-and-keywords-id-44393/print/) Assign

In the sixth mass extinction, conservationists are trying to minimise the loss of biodiversity. This is often a race against time; however, data show that there are patches of hope as efforts of conservations seem to yield results.

Your task

Research and find out:

- What does the Living Planet Index tell us about the biodiversity crisis?
- Can conservationists make a difference?

The Living Planet Index (LPI) is defined as a measure of the 'average decline in monitored wildlife populations'. You can find out more about this here (https://ourworldindata.org/biodiversity), and the 'sources' tab here (https://ourworldindata.org/grapher/global-living-planet-index?tab=table) provides some more information.

The LPI is often interpreted wrongly.

Student view

Overview (/study/ap 422- cid- 755105/o

- Begin by reading about and understanding the meaning of the term 'average decline (https://ourworldindata.org/living-planet-index-decline)'.
- Analyse the LPI (https://ourworldindata.org/biodiversity) across the different regions.
- Collate the average decline in the different regions as a bar graph.
- Prepare a report. Make sure that you include the methods, sources and limitations of the LPI.
- Present your report in class. Your presentation should include:
  - Introduction
  - Key data (three to four findings)
  - Discussion
  - Limitation(s)
  - Future direction (if applicable)
- Invite the audience to ask questions.

A4. Unity and diversity: Ecosystems / A4.2 Conservation of biodiversity

Reflection

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/reflection-id-46870/print/) Assign

Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Reflection

Now that you've completed this subtopic, let's come back to the guiding questions introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43529/).

- What factors are causing the sixth mass extinction of species?
- How can conservationists minimise the loss of biodiversity?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

Student view

Overview (/study/ap 422-cid-755105/o

0/2000

Submit

Rate subtopic A4.2 Conservation of biodiversity

Help us improve the content and user experience.

☆ ☆ ☆ ☆ ☆

Student view