Conservation of biodiversity

International Baccalaureate · IB Diploma · Biology · SL

Scope and prerequisites

A field contains thousands of plants, yet almost all belong to one crop variety. A nearby wetland has fewer large plants but many species and habitats. Which place has more biodiversity, and which evidence would justify spending a limited conservation budget there?

This unit covers A4.2 for both SL and HL, with no additional higher-level content: levels of biodiversity, comparisons through time, human-caused extinctions and ecosystem loss, evidence of a biodiversity crisis, its causes, complementary conservation methods and EDGE priorities. Prerequisites: species, variation, evolution and ecological sampling. All numerical survey datasets and maps below are invented teaching examples unless a named published source is identified. They are not observations from the school grounds.

Biodiversity exists at several levels

Biodiversity is the variety of life, including genetic variation within species, differences among species, and differences among ecosystems. A count of visible animals does not measure all three levels.

Level	What varies	A conservation question
Genetic	Alleles and inherited variation within a species	Does a breeding population retain enough variation for future change?
Species	Species present and their relative abundances	Are rare species disappearing even while common species increase?
Ecosystem	Communities, habitats and their physical environments	Are wetlands, forests and grasslands being replaced by one land use?

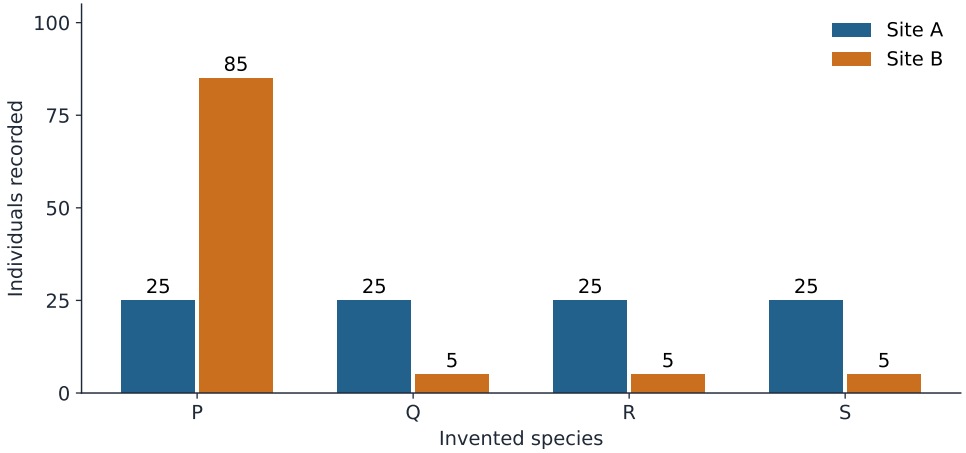
Losing several genetically distinct populations can reduce biodiversity even before their species becomes globally extinct. Conversely, adding many individuals of one already common species does not necessarily restore lost species or ecosystems. A useful conservation goal identifies the level being protected and how success will be measured.

Species richness is the number of species recorded. **Evenness** concerns how evenly individuals are distributed among those species. Total abundance counts individuals. These quantities answer different questions and must not be substituted for one another.

■ Worked example: equal richness is not equal composition

In invented standardized surveys, sites A and B each contain 100 individuals in four species. A has counts 25, 25, 25 and 25. B has 85, 5, 5 and 5.

- Both have total abundance 100 and recorded richness 4.
- The dominant species represents $25/100 = 25\%$ at A but $85/100 = 85\%$ at B.
- A is more even. B's high total abundance does not remove the dominance of one species.



Both invented samples: total = 100; richness = 4.
Dominant species: A 25%; B 85%.

Use the same sampling effort and identification rules. The bars describe these samples, not a complete census of every organism at each site.

A diversity index can combine aspects of a community into one value, but its formula and convention must be stated. An index does not identify the cause of a change. Counts, uncertainty and species composition remain useful even when a summary index is calculated.

Compare the present with the past carefully

Many species have been described, while many others remain undiscovered or undescribed. Fossils record past organisms and show diversification interrupted by major losses. Evidence supports long-term increases in diversity in many groups and very high present richness, but the fossil record is not an equally complete census of every period and habitat.

Hard parts preserve more readily than many soft tissues; accessible rocks and extensively studied regions supply more records. Changes in sampling and classification also affect apparent counts. "More recorded species" can reflect a better survey or a

revised species boundary rather than a sudden ecological increase. Define whether a comparison concerns described species, estimated total richness, a particular group or a local sample.

High present diversity and a current biodiversity crisis are compatible. A large total can be declining rapidly. A population can fall sharply before global extinction occurs, and habitats can lose ecological functions before every species disappears. We therefore need repeated measurements, not just one impressive count of living species.

Three human-caused extinction cases

Extinction is the loss of a species everywhere. Local disappearance is extirpation: a species may still survive elsewhere. "Extinct in the wild" differs from global extinction because individuals remain in captivity or cultivation. A date of official assessment is not necessarily the date when the last individual died.

North Island giant moa: loss of terrestrial megafauna

The North Island giant moa, *Dinornis novaezealandiae*, was a large flightless bird of New Zealand. Its remains occur widely in archaeological sites. Human hunting for food was the main cause of its extinction. Sustained removal can prevent a population from replacing its losses. This is an example of over-exploitation of terrestrial megafauna, not evidence that a large body automatically prevents extinction. The Te Papa/Birds New Zealand species account identifies overhunting as the main cause.

Caribbean monk seal: loss of a marine species

The Caribbean monk seal, *Neomonachus tropicalis* (called *Monachus tropicalis* in older records), was hunted heavily, including for oil and meat, and suffered human disturbance. A marine habitat did not protect it from sustained exploitation. The last confirmed sighting was in 1952; later searches and the absence of convincing records supported an extinction conclusion. NOAA's 2008 status review concluded that the species was extinct. Do not report 2008 as a directly observed death date.

Chinese paddlefish: a Yangtze example

The Chinese paddlefish, *Psephurus gladius*, inhabited the Yangtze system. Its decline involved overfishing and fragmentation of its river habitat; dams could obstruct movement between feeding and spawning areas. A 2020 study combined historical records with basin surveys and inferred extinction by the early twenty-first century. The study explains the evidence; the species was treated as extinct in the 2022 sturgeon-group assessment announcement.

This case is relevant to the river basin near the Yangtze delta region. A river population needs connected habitats and successful reproduction, not simply water remaining in its channel. Do not confuse the extinct paddlefish with other Yangtze fishes that have different conservation statuses.

Across the three cases, human pressures reduced survival or reproduction faster than populations could replace losses. Several pressures can interact. Explaining the causal chain is more useful than memorizing a list of species names without their habitats, threats or evidence.

Ecosystem loss removes relationships as well as area

An ecosystem includes organisms interacting with one another and with the physical environment. Replacing a diverse forest with a single-species plantation can leave many trees while removing much of the original community and its processes. Loss of area, degradation of quality and fragmentation are related but different changes.

Mixed dipterocarp forest in Southeast Asia

Lowland forests in parts of Southeast Asia contain diverse trees, including many dipterocarps. Timber extraction changes forest structure; roads can increase access and divide habitats. Subsequent clearance for oil-palm or other plantations replaces the forest ecosystem rather than merely removing selected trunks.

Distinguish logged forest from cleared land. Logged forests can retain substantial biodiversity and deserve protection; calling them "degraded" does not mean they are empty or worthless. Research in Sabah, Borneo compared unlogged, once-logged and repeatedly logged forests, showing the conservation value of forests that had already been logged. The primary study supports this distinction. Conservation must address both further clearance and the quality and connectivity of remaining habitat.

Yangtze estuary tidal flats

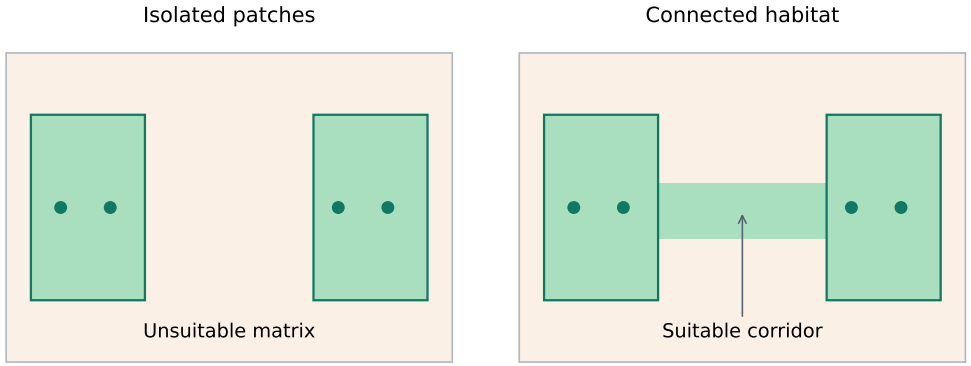
Intertidal flats are exposed and covered by the tides. They contain feeding habitats for waterbirds and communities adapted to changing water and sediment conditions. Coastal land reclamation can replace these habitats with enclosed land. Reduced river sediment supply can also change the balance between deposition and erosion.

Studies of the Yangtze estuary and delta identify reclamation and altered sediment supply as important causes of tidal-flat loss. See the estuary study and the delta analysis. A protected label alone cannot maintain the ecosystem if sediment processes and connected feeding areas are lost. Local gains in one place also need not offset losses elsewhere for the same organisms.

> ### Worked example: area is only one indicator
>
> An invented wetland map records 1,000 ha of suitable habitat initially and 760 ha later, using the same definition and mapping method. The loss is $1000 - 760 = 240$ ha, or $240/1000 \times 100 = 24\%$. The remaining fraction is 76%.
>
> This does not establish that 24% of species became extinct. Some can persist temporarily, others may disappear disproportionately, and the remaining habitat may be fragmented or degraded. Species surveys and measures of habitat quality are needed alongside area.

Fragmentation can reduce movement and gene flow

When roads, farms or buildings divide habitat, individuals may have fewer opportunities to find mates, migrate or recolonize empty patches. Smaller isolated populations may be more vulnerable to chance losses and loss of genetic variation. Edge conditions can differ from the interior in light, temperature, disturbance or predation.



Invented plan: green = habitat; tan = surrounding land use.
Test movement and breeding; a drawn connection is not proof.

The corridor represents a management hypothesis to test. It does not guarantee movement or successful reproduction for every species.

A corridor can improve connection when it contains suitable habitat and crosses barriers effectively. Width, vegetation, roads and the species' movement requirements matter. A strip useful to one organism may fail for another or spread unwanted organisms. Compare actual movement, survival and breeding before and after management rather than assuming a line on a map solves isolation.

Evidence for a biodiversity crisis needs repeated surveys

The IPBES 2019 global assessment estimated that around one million species were threatened with extinction. This is an estimate of risk, not a count of one million already extinct species. The assessment's summary combines evidence across many groups and habitats; a single local survey cannot establish a global rate of extinction.

A strong local comparison uses repeated surveys with similar area, duration, season, weather constraints, sampling method and identification rules. Record uncertain identifications and keep a consistent taxonomic basis. Use independent sites or sampling units and report variation, not only one total.

Invented comparable surveys of species P, Q, R and S give counts 40, 30, 20, 10 initially and 65, 25, 10, 0 later. Both totals are 100. Recorded richness falls from 4 to 3, while dominance of P rises from 40% to 65%. Equal total abundance therefore hides a change in composition and reduced evenness. Failure to record S is evidence of possible local loss, not proof that S is globally extinct.

Citizen scientists can expand coverage and supply long time series. Training, photographs, expert checks and consistent protocols strengthen those records. Uneven observer effort, changes in skill, difficult species and preferential reporting can bias trends. Published methods and accessible evidence allow other researchers to check the inference. Citizen data are valuable when their limits are handled, rather than rejected or accepted automatically.

Human pressures act through specific mechanisms

Human population growth can increase demands for food, water, energy and land. Its effects depend on consumption, technology and management, so population size alone does not fully predict a site's damage. Link each pressure to a mechanism and evidence.

Pressure	How biodiversity can decline
Over-exploitation	Hunting, harvesting or fishing removes organisms faster than replacement
Land-use change	Urbanization, agriculture and clearance replace or divide habitats
Pollution	Toxic materials or excess nutrients change survival and ecosystem conditions
Transport of organisms	Introduced pests, diseases or invasive species can disrupt communities
Climate change	Altered temperature, rainfall and sea conditions can shift suitable habitat

Not every introduced species becomes invasive, and not every species responds identically to warming or pollution. Interactions matter: a small fragmented population may be less able to move when climate changes. Identify the scale and affected species before making a management claim.

Combine conservation methods around the actual threat

In situ conservation protects species within their natural habitats. Nature reserves can protect communities and ecological processes, but they need suitable boundaries, management, enforcement and connections. A reserve that excludes important breeding or seasonal feeding areas may protect only part of a species' needs.

Restoration repairs degraded ecosystems by addressing causes and rebuilding suitable conditions. Rewilding aims to restore ecological processes and, where appropriate, native organisms. Removing a pressure, restoring water flow or recovering native

vegetation may be more important than simply planting a large number of trees. Set a baseline, choose suitable reference conditions and monitor outcomes. Reintroduction needs appropriate habitat and ecological assessment; release alone is not evidence of success.

Ex situ conservation maintains organisms outside their natural habitats, for example in zoos, botanic gardens or managed breeding collections. It can protect a population during an immediate threat and support later recovery. Small populations still need management of breeding, genetic diversity, health and suitable behaviour. Captive survival does not replace a functioning habitat or guarantee a self-sustaining wild population.

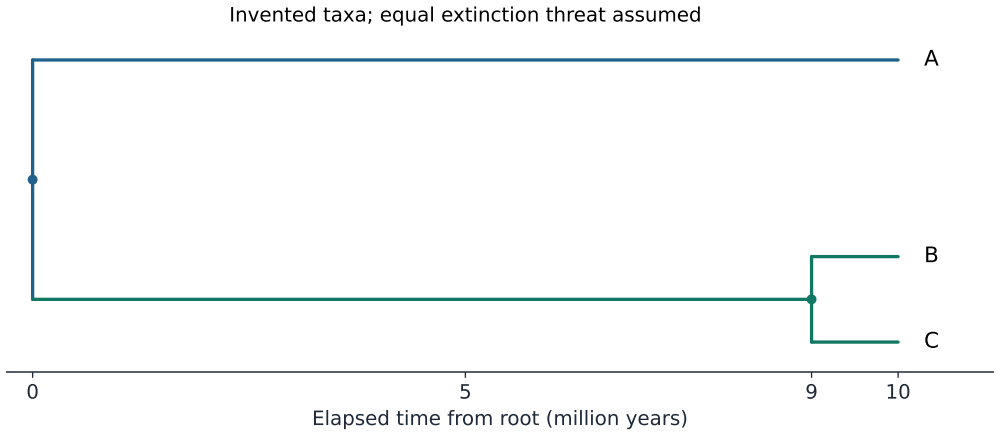
Germplasm is inherited biological material that can be conserved for future reproduction. Seed banks and tissue collections can preserve genetic resources. Seeds of many species can be dried and stored, but some cannot tolerate this treatment and require other approaches. A collection must maintain viability, identify its material correctly and retain suitable genetic representation. A freezer is not a substitute for every ecosystem interaction.

No single method is sufficient for every species. For an invented plant threatened by drainage and habitat clearance, a sensible package might protect and restore the wetland in situ, retain seed or tissue material ex situ as appropriate, and monitor establishment and reproduction. Banking seeds while allowing the last suitable habitat to disappear leaves the main cause unresolved.

Prioritize threatened evolutionary history with EDGE

The EDGE of Existence programme combines Evolutionary Distinctiveness with Global Endangerment. Evolutionary distinctiveness concerns how much relatively unique evolutionary history a species represents, using relationships on a dated phylogeny. Global endangerment concerns its extinction risk. A species with few close relatives can represent a large branch of history that would be lost if it disappeared.

Consider three invented equally threatened species in the figure. A has no close relative among these taxa, while B and C share a recent common ancestor. If threat and other conditions are comparable, conserving A may protect more unique evolutionary history. This explains a rationale, not a complete real EDGE score: do not invent a score from appearance or simply count individuals. The programme's explanation describes how phylogeny and threat are combined.



A has a long independent lineage; B and C are close relatives.
This illustrates priority, not a real EDGE score.

With equal threats in this simplified example, losing A removes more uniquely represented history. This is not a real EDGE ranking or a complete calculation.

Priorities also involve feasibility, ecological roles, cost, local knowledge, cultural values and effects on people. An evolutionary argument contributes evidence but does not remove ethical choices. State the goal, compare options transparently, involve affected communities and explain the trade-offs. Success requires a reduction in the actual threat, not merely a high position on a list.

Practice

All numerical datasets and management scenarios below are invented. Explain limits as well as calculations.

1. Distinguish genetic, species and ecosystem biodiversity. Give one loss that could occur at each level, and explain why a field with many crop plants need not be highly diverse at all three levels.
2. Sites A and B have counts 25, 25, 25, 25 and 85, 5, 5, 5. Calculate total abundance, richness and dominant-species percentage for both. Which is more even, and why does abundance not settle the comparison?
3. Explain two limits of comparing present and past recorded species counts. Why can high present richness coexist with a biodiversity crisis?
4. For each of the North Island giant moa, Caribbean monk seal and Chinese paddlefish, identify the habitat, an important human pressure and a causal route to extinction. Distinguish a last sighting from an assessment date.

5. Compare the loss of mixed dipterocarp forest with the loss of Yangtze tidal flats. Explain why many plantation trees do not necessarily replace a forest ecosystem, and why logged forest may still deserve protection.
6. Suitable habitat falls from 1,000 to 760 ha. Calculate area lost, percentage lost and percentage remaining. Why is it invalid to conclude that the same percentage of species became globally extinct?
7. For a fragmented habitat, propose one corridor benefit and two conditions needed for success. Give a possible limitation and one measurement that would test the proposal.
8. Comparable surveys change from counts 40, 30, 20, 10 to 65, 25, 10, 0. Compare total abundance, recorded richness and dominance. Does the zero prove global extinction? Explain.
9. Design a repeated biodiversity survey using citizen scientists. Give four features to standardize and two ways to check identification or observer bias. Explain what a published method adds.
10. Explain how human population growth can increase biodiversity pressures while not being a complete explanation by itself. Link over-exploitation, habitat change, pollution and invasive organisms to distinct mechanisms.
11. A threatened wetland plant loses habitat through drainage. Propose an in situ measure, a restoration measure and an appropriate ex situ backup. Give one limit of each and a measure of recovery beyond counting planted individuals.
12. Explain germplasm conservation. Why cannot all plant species be conserved in the same dry-seed storage conditions, and why does stored genetic material not preserve an entire ecosystem?
13. Two equally threatened species differ in evolutionary distinctiveness. Explain the EDGE rationale for prioritizing the more distinct species, why appearance alone is insufficient, and two other considerations that could affect the final decision.

■ Worked answers

1. Genetic biodiversity: variation within a species, reduced when distinct populations or alleles are lost. Species biodiversity: variety and relative abundance of species, reduced by species losses or increased dominance. Ecosystem biodiversity: variety of ecological systems, reduced when different habitats are converted to one land use. Many individuals can belong to one species or cultivar and occupy one simplified ecosystem.
2. A: total 100, richness 4, dominance $25/100 \times 100 = 25\%$. B: total 100, richness 4, dominance $85/100 \times 100 = 85\%$. A is more even because its individuals are equally distributed. Both totals are identical, but their composition differs greatly.
3. Preservation and discovery differ among periods, habitats and organisms; survey effort and taxonomic boundaries also change. Recorded counts are not complete equal-quality censuses. A large present total can still be declining, with population and habitat losses occurring before global extinctions are confirmed.
4. Moa: terrestrial New Zealand, overhunting removed individuals faster than replacement. Monk seal: Caribbean marine/coastal habitats, heavy hunting and disturbance reduced survival and reproduction. Paddlefish: Yangtze river system, overfishing and barriers to movement/spawning fragmented the population. A last confirmed sighting records detection; an assessment later evaluates all evidence. Neither is automatically a directly observed date of the final death.
5. Forest clearance replaces diverse communities and structure with another land use; plantation tree abundance does not reproduce the original species and processes. Logged forest can retain important biodiversity. Tidal-flat loss involves replacement by reclaimed land and changes in sediment supply and erosion. Both require attention to habitat quality and ecological processes, not area alone.
6. Loss $= 1000 - 760 = 240$ ha. Percentage lost $= 240/1000 \times 100 = 24\%$; remaining $= 760/1000 \times 100 = 76\%$. Species respond differently, some persist temporarily, and local habitat loss is not a census of global extinctions. Survey composition, population trends and remaining habitat quality too.
7. A suitable corridor may improve movement, mating or recolonization. It needs appropriate habitat and effective continuity across barriers; width and species-specific behaviour matter. It may fail for a species or spread undesirable organisms. Compare movement, survival or breeding using consistent before-and-after or managed-and-comparison surveys.
8. Both totals are 100. Recorded richness falls $4 \rightarrow 3$; dominant P rises $40/100 = 40\%$ $\rightarrow 65/100 = 65\%$, a 25-percentage-point rise. The later sample is less even and S is not detected. Detection failure or local loss is possible; there is no evidence here that S disappeared everywhere.
9. Standardize area, effort/duration, season and method, with comparable identification rules and suitable conditions. Train observers, use photographs or vouchers where appropriate without harmful collection, request expert verification and record uncertain identifications. Track observer effort and repeat independent units. Published methods allow other people to examine and repeat the comparison rather than relying on an unexplained total.
10. More people can increase demand for land, food, water and energy, but consumption, technology and management alter impacts. Exploitation exceeds replacement; habitat conversion removes or fragments suitable places; pollution changes biological conditions; an invasive organism may outcompete, consume or infect native organisms. Introduction does not automatically imply invasiveness.
11. Protect remaining habitat: reserve management can reduce clearance but may miss water flows beyond its boundary. Restore hydrology and native conditions: recovery takes time and may be incomplete. Preserve appropriately stored seeds or tissue and manage a backup population: viability and genetic representation need maintenance, and this does not replace habitat. Measure natural recruitment, survival, reproduction and continuing threat reduction.
12. Germplasm stores inherited material for future reproduction. Many seeds tolerate

drying and storage, while others require different methods such as suitable living or tissue collections. Storage needs viability tests and representative material. Genes in a collection do not recreate food webs, habitats, water flows or species interactions.

13. A more distinct lineage may carry more unique evolutionary history that would vanish with extinction. EDGE combines phylogenetic information with extinction risk; unusual appearance or low abundance alone is not a score. Feasibility and cost, ecological roles, local priorities and effects on people can also alter the decision. State the goal and trade-offs and address the actual threat.

Exam tips

Name the level of biodiversity and distinguish individuals, species, populations and ecosystems. Compare consistent repeated surveys before attributing a trend. Connect threats to mechanisms and measures to those threats. Distinguish assessment dates, detection dates and extinction itself. For a conservation decision, combine evidence, limits and an explicit goal.

References: IB Biology guide, A4.2. Named assessments, case studies and the EDGE method are linked in the relevant sections.